HACKING STEREOSCOPIC VISION: THE NINETEENTH-CENTURY CULTURE OF CRITICAL INQUIRY IN STEREOSCOPE USE

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Abstract:

While recent scholarship has emphasised the narratives of immersive realism that surrounded the parlour stereoscope, my aim in this paper is to better understand the counter-currents of nineteenth century stereoscopic culture – the artefacts, practices and discourses that powerfully undermined realist assumptions about spatial perception and the “truth” of stereoscopic representation. Wheatstone’s original stereoscopes were designed to “hack” spatial perception and subject each of its component principles to artificial manipulation. What Wheatstone uncovered were glaring anomalies in the prevailing theories of veridical sight, which had relied upon the principle of binocular convergence (understood as a precise trigonometric measure of depth). Following a popular tradition of critical inquiry known as “rational recreation,” amateurs too used their stereoscopes to reflect on the perplexities of binocular spatial perception. Analytic line drawings highlighted the inexplicable binocular suture of strikingly disparate images. Stereoviews with their images transposed revealed the capacity of the mind to constitute volumetric objects irrespective of binocular cues. Hyper-stereo images (taken from a wide separation and therefore at an increased angle of binocular convergence) sparked debate and perceptual uncertainty as to whether their 3D effects, or indeed all stereoviews, were distorted – elongated along the z axis and/or miniaturised. Realists, including some astronomers hoping to use hyper-stereo photographs as visual evidence of the shape of the moon’s surface, sought unsuccessfully to solve the problem of elongation by ensuring that the angles at which stereo photographs were taken were reproduced in the angles at which the eyes viewed them in the stereoscope. Astronomers were forced to quietly abandon the stereoscope as a reliable witness of spatial form. Others, artists in particular, revelled in the anti-realist implications of a spatial imagination which constructed the perceptual world in a sometimes capricious fashion.

Keywords: *stereoscopes; rational recreation; anti-realism; spatial perception; stereoscope design*

Introduction: Rational Recreation and the Stereoscope

In the 1850s the stereoscope was the most recent of a growing number of optical devices that promised to extend human visual abilities, to allow people to transcend local, physical limits and "see" distant worlds. Optical media were part of a technological sensorium, extending spatial human reach over the natural world (telescopes, microscopes, sighting and measuring devices) as well as over networks of governance, allowing trade and social power to operate at new spatial scales (visualised through magic lanterns, peepshows, panoramas and other technologies of virtual travel). Such mediations have attracted and continue to attract epistemological anxiety – do they reveal the truth of these worlds or distort that truth and deceive the observer? The Enlightenment answer to that anxiety was to produce theories, preferably with diagrams or working models, of all the elements of the mediation – including the eye itself conceived as an organic apparatus (Shapin, and Schaffer, 1985; Schickore, 2006). It was always hoped to prove the accuracy and reliability of the eye and its mediations.

The democratic extension of this project to prove mediation was "rational recreation." The idea was that citizens should become critical users of optical media in order to better navigate the social and political spaces that new media represented and helped to define. Accordingly, people were encouraged to investigate the workings of these devices and learn the lessons embodied in them about the principles of visual perception and illusion (Bellion, 2011). Sir David Brewster, one of the great popularisers of the stereoscope, hoped that it would play this dual role – as a medium of dazzling illusions and as an apparatus in amateur science demonstrations (Wade, 2004). He was committed to the idea that binocular vision produced visual truth, and that the stereoscope could accurately represent that truth. This was a contested position, however, and scholars have recently begun to situate Brewster within a longstanding scientific and philosophical debate about the reliability of human spatial perception, initiated in the early eighteenth century by George Berkeley (Berkeley, 1709; Bantjes, 2015; Plunkett, 2013).

In the spirit of rational recreation, I want to examine the artefacts – the Wheatstone stereoscope, the popular lenticular stereoscope and some of the curious stereograms made for them – to see what can be learned from them as philosophical toys. By taking a closer look at Charles Wheatstone's experiments with his stereoscope and pseudoscope I hope to clarify the extent to which they undermined confidence in veridical sight and helped to revive Berkeleyan scepticism about vision. I am also interested in the extent to which Brewster and other proponents of rational recreation unwittingly set amateur users of the parlour stereoscope on the path not to greater confidence in the medium, but to greater scepticism about both the stereoscope and the reliability of binocular vision, whose principles it revealed.

The pseudoscope and the stereoscope were scientific apparatuses designed by Charles Wheatstone to demonstrate that retinal disparity and preconceptions imposed by the mind influence spatial perception independently of all other known mechanisms (Wheatstone, 1838; 1852).

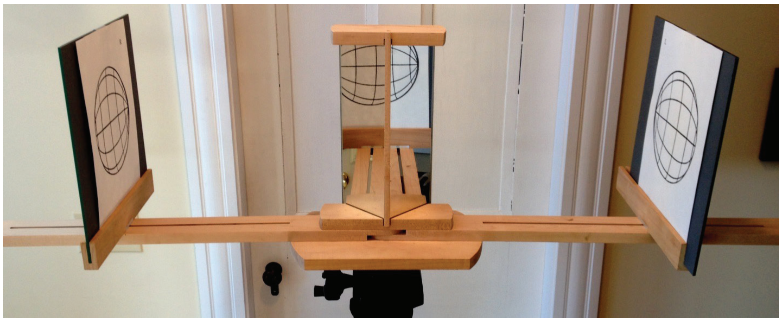

Figure 1 – *Wheatstone Stereoscope*. This is a replica of Wheatstone's 1852 design with adjustable image plates (to change the size of the retinal images projected) and moveable arms that allowed adjustments to the (base) angle of convergence of the eyes.

Both these principles turned out to be intractable mediations. Wheatstone was not able to offer a sufficient account of how either worked to assure critics like Brewster that they did not result in the distortion of perception. Defenders of veridical sight, like Brewster, downplayed or ignored retinal disparity and the constructive role of the mind, and turned instead to the principle of binocular convergence that had been used since the late seventeenth century to explain binocular space perception. This approach had the virtue of geometrical precision – I will call it the trigonometry of the eye.

Defenders of the stereoscope as a medium of visual truth, notably Thomas Sutton, the photographer and editor of the journal *Photographic Notes*, and the astronomer Warren de la Rue, also appealed to the trigonometry of the eye to understand the stereoscope and to make claims for its scientific precision. While binocular convergence *is* at play in the parlour stereoscope, the more that nineteenth century commentators examined those principles at work the more confused they became, and the more the recalcitrant instrument threw up the kinds of anomalies that Wheatstone's apparatuses had exposed. These anomalies cast doubt on the idea that the stereoscope could reproduce visual truth. They also, just as they had done in Wheatstone's careful investigations, cast doubt upon the ineluctable certainty of natural spatial perception. The stereoscope did produce a powerful immersive experience, but what it immersed observers in was not the reality, but an invocation of their own flawed perceptual space-making.

Wheatstone: Deconstructing Binocular Space Perception

I want to begin by looking again at the deconstructive work that Wheatstone's original stereoscope was meant to accomplish. We never *see* retinal images; they are components in our construction of a perceptual world that we apprehend as though it existed external to our bodies. Consequently we are never in a position to *compare* two retinal images. As late as 1838, no-one had noted or described the fact that volumetric objects project different shapes on the retinae. Wheatstone's first aim was to abstract the retinal images from embodied perception, externalise them, and place them side by side for our "leisurely inspection" (Lynch, 1991, p.214).

Any object that presents a flat face to the viewer, such as the staircase Wheatstone represented in schematic outline, will project identically on the two retinae and we have no difficulty understanding how their images can be fused into a coherent whole, however, any part of the object that visibly extends into the depth of the scene will, as Wheatstone demonstrated, project differently to each eye. Prevailing theories of vision had relied on the assumption that when two eyes are fixed on an object, the two retinal images projected must be the same shape and in the same position (Brewster, 1844). More importantly, there was no way of explaining, using geometric optics or indeed any known principles, how the mind could fashion the illusion of a coherent volume from two incompatible elements.[1]

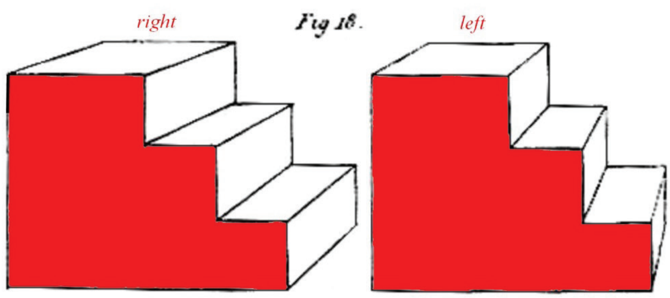

Figure 2 – *Wheatstone's Fig. 18 (1838): Abstracted Staircase* (highlights added). He produced the two projections from viewpoints 64 mm apart using Monge's descriptive geometry. The surfaces highlighted in red are all the same distance from the eyes, or, more accurately, they are within the same horopter – a surface defined by a given angle of convergence of the eyes.

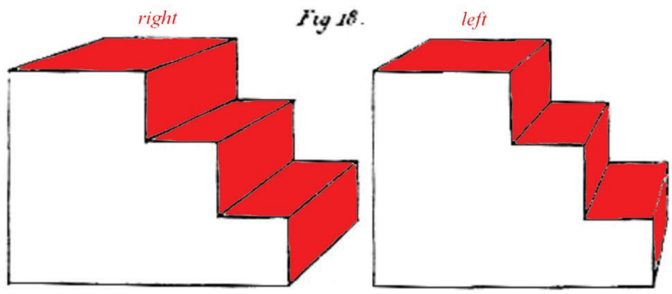

Figure 3 – *Wheatstone's Fig. 18 with retinal disparity highlighted*.

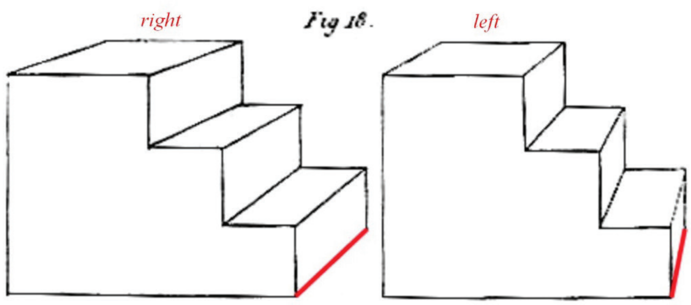

Figure 4 – *Abstraction of the Wheatstone Line*. Step One.

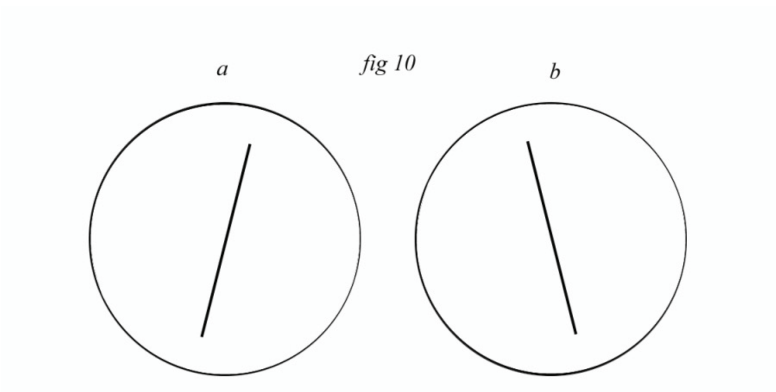

Figure 5 – *Wheatstone Line Fully Abstracted*. Wheatstone's (1838) Figure 10 is a pure abstraction of a receding line. We are viewing it as though it were centred equidistant from each eye. Note that in a Wheatstone stereoscope, for which this stereogram was designed, each image is reversed by the mirrors.

Wheatstone could not explain how the mind did it, but he was able to demonstrate *that* the mind could do it. This was one of the main functions of the stereoscope, to re-project dissimilar images onto the retinas by means of mirrors (to demonstrate that disparate images could be fused into a coherent spatial volume). This experiment revealed a further paradox: impossible fusion which should have produced incoherent volumes, instead produced spatial illusions of striking, unprecedented power. For example, Wheatstone's line drawing of a staircase can be seen on the page as volume, but in the stereoscope it lifts off the paper surface and appears to inhabit real space.

Wheatstone further abstracts the receding form of the object by stripping it of object-identity and perspectival foreshortening. He produces what I will call a "Wheatstone line", which is an example of pure retinal disparity. The figures intersect at one point only. They are abstractions of how any linear receding form will project on the retinae. While Wheatstone demonstrates that the mind can fuse the two component parts into a spatial construct, the effort to do so, as anyone who has tried it can attest, also exposes the action of the mind struggling with binocular space-making. The two lines never fully cohere in a stable form.[2] They do however, liberate a space from the paper surface – the lower tip of the line struggles to cohere decidedly on this side of the circle, as does the upper tip on the far side of the circle.

The mind succeeds in producing an ineluctable space in which an object, straining to assert its objectness, splits and doubles. As the eyes run along it, its region of stable coherence slides forward and back. This is an experience of dynamic spatial constructivism in a non-Euclidean medium. This is not an experience of realism – that is, not the direct apprehension of a stable spatial world that obeys the laws of Euclidean geometry.

Wheatstone's Anomalies for the Parlour Stereoscope

Figure 6 – *Wheatstone's Anomalies for the Parlour Stereoscope.*

The first stereograms were linear abstractions. Several series of these were produced in the standard format for the parlour stereoscope (Figure 6). Brewster (1856) recommended them to amateur users, and many were reproduced to illustrate discussions in popular periodicals about the stereoscope and binocular vision. Some were taken from Wheatstone's original line drawings, and others, by their design, seem intended to highlight some of the anomalies of binocular space perception that Wheatstone had uncovered.

Figure 7 shows the abstracted Wheatstone line, ready to illustrate to the home viewer the struggle of the mind as it attempts to create coherence in non-Euclidean space. Figure 8 is a dramatic demonstration of retinal disparity, which produces spatial figures of stunning depth and coherence. This was a popular nineteenth century image, widely reproduced (Anon. 1852a, 1852b).

Retinal disparity was the key to appreciating the non-realism of spatial perception and stereoscopic exhibition. For Wheatstone, the stable coherence of an object like a staircase, or, in this next example, a wall, depends "in no small degree on previous knowledge of the form we are regarding" (Wheatstone, 1838, p.393; 1852, p.13). In other words, the mind imposes spatial form based on pre-conceptions of the object's identity. If the mind is imposing spatial order,

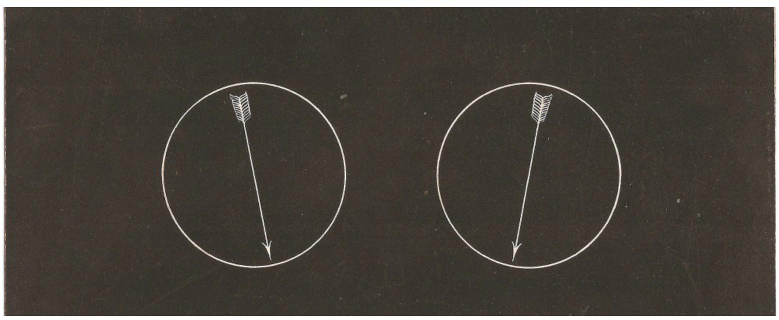

Figure 7 – *Wheatstone Line for the Lenticular Stereoscope*. (Unknown Lithographer, *Arrow and Circle*, lithograph, c.1852. Private collection.)

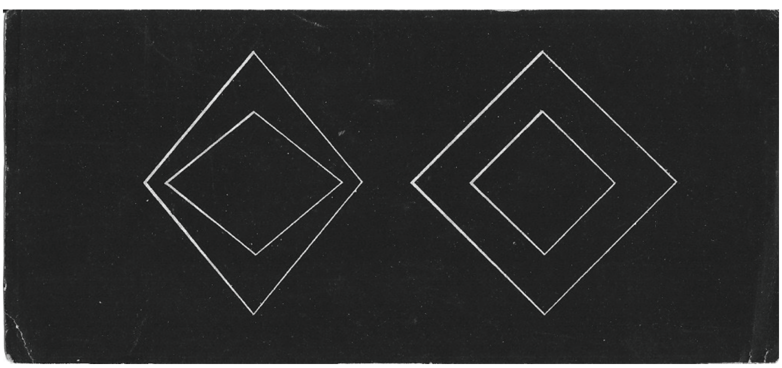

Figure 8 – Unknown Lithographer, *Lozenges and Squares*, lithograph, c.1852. Private collection.

then what guarantee is there that its preconceptions are not merely subjective? The realist ideal of objectivity – fidelity to the external object – was questioned in ways that many, notably Brewster, found both offensive and alarming (Brewster, 1856, p.151).

In order to rescue perceptual realism, Wheatstone's opponents denied that the mind ever sutured dissimilar images. They appealed instead to the eighteenth-century principle of binocular convergence. When the eyes fix on a close object they converge at a wide angle; when they fix on distant objects they converge at a lesser angle, to the point that, for objects in the far distance, the eyes are effectively parallel. The measure is tactile and calculative – we feel the muscular sensation of squinting and have a finely calibrated sensibility which allows us to associate tactile sensation with an idea of distance. For each angle of convergence there is a *determinate distance* that can be calculated trigonometrically. Eighteenth-century theorists imagined that we crudely position whole objects through this trigonometry of the eye.

In the nineteenth century, defenders of the theory, such as Ernst Brücke and Brewster, had to amend it in order to account for the complexity of volumetric objects that Wheatstone had exposed. They imagined that we must build up the surface of every object through thousands of sightings and trigonometric calculations, performed "with the rapidity of lightning" (Brewster, 1852, p.179; Anon., 1857, p.600). I will call this the "pointillist" theory of spatial perception. Wheatstone had considered this possibility and sought to rule it out in a number of ways. The first was to direct attention to the well-known phenomenon of the doubling of the binocular visual field, illustrated for home users in the following stereogram. If the pointillist theory were true, he reasoned, objects should never appear doubled.

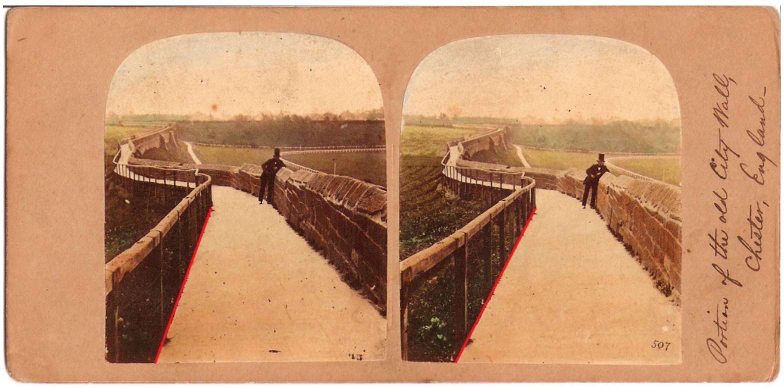

Figure 9 – Samuel Poulton, *Portion of Old Wall, Chester*, hand-tinted albumen prints, c.1858. Private collection. Here the re-embedded Wheatstone line coheres without a flicker of instability.

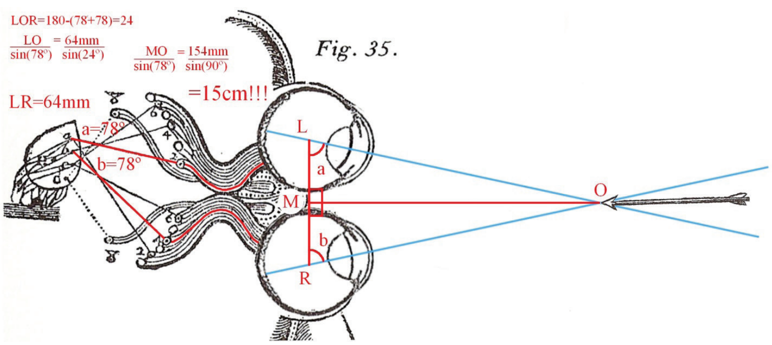

Figure 10 – *Binocular Convergence and the Trigonometry of the Eye*. The diagram of the optical apparatus is adapted (and repurposed) from Descartes's *La Dioptrique* (1637).

The visual construct, powerfully invoked when Figure 11 is viewed through the stereoscope, is of a receding truncated cone – it is as if one were looking into a deep, tapered bucket. The curved double line reads as the bucket handle arching up exactly over the centre of the bucket, however in the flat the handle clearly occupies two contradictory locations relative to the bottom of the bucket. In the stereoscope, it is not possible to suture the whole object. Either the handle coheres and the bottom of the bucket doubles; or the bottom coheres and the handle doubles. The stereogram is an ineluctable demonstration of binocular doubling in a single object and, as such, a visual refutation of the pointillist theory.

In the preceding figures I have modelled what the pointillist theory would look like applied to a Wheatstone line viewed through a Wheatstone stereoscope. The most notable anomaly for the theory is that the eyes must diverge to fix on the "furthest" point A. In other words A should be located, impossibly, beyond infinity.[3] Our eyes *do* adjust their angle of convergence as we scan objects, however the mind is able to generate a spatial construct even where trigonometric calculations would be contradictory or incoherent. It cannot be that the mind assembles every object through precise calculations of the location of each point on its surface.

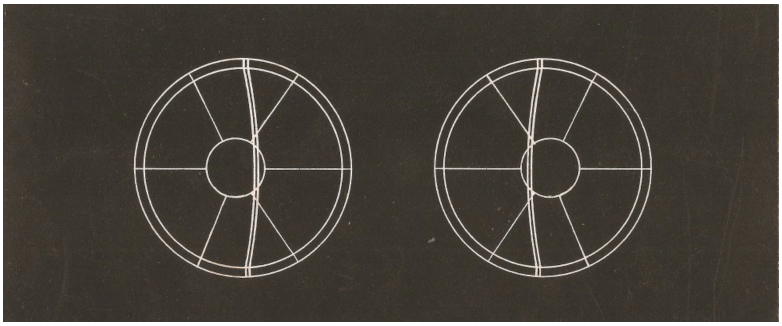

Figure 11 – Unknown Lithographer, *Doubled Bucket*, lithograph, c.1852. Private collection.

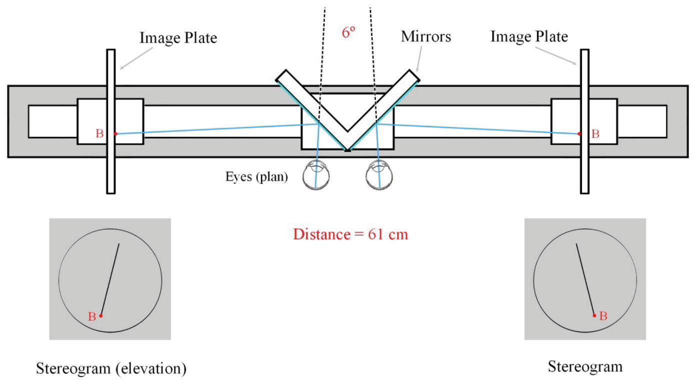

Figure 12b – *Pointillist Theory*. When the eyes fix on the paired points "B," they converge at an angle of 6º, and by trigonometric calculation this should locate the point 61 cm distant.

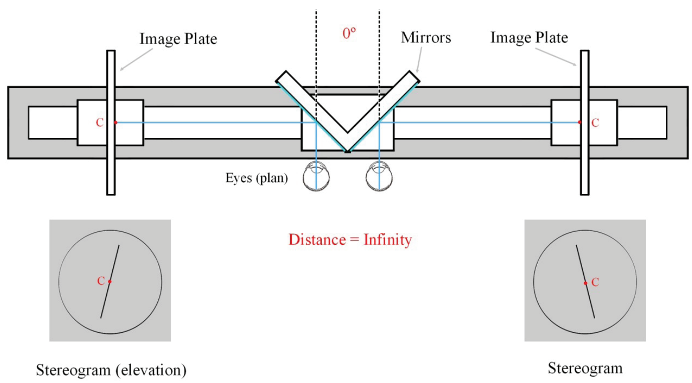

Figure 12c – *Pointillist Theory*. When the eyes fix on the paired points "C," the axes of the eyes are parallel (an angle of convergence of 0º) and the point should be located at infinity, however, perceptually the line does not appear to extend to infinity.

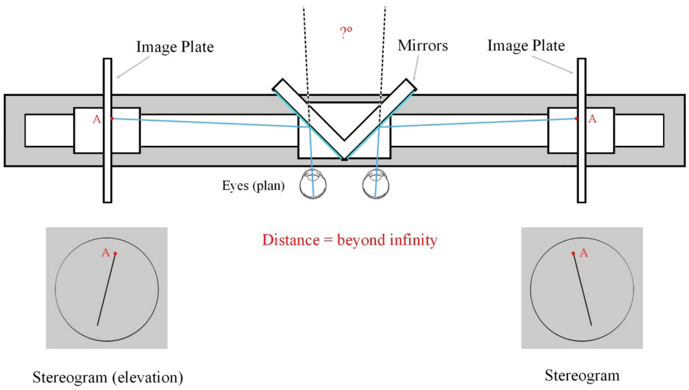

Figure 12a – *Pointillist Theory*. When the eyes fix on the paired points "A," the axes of the eyes *diverge*, suggesting two perceptually incoherent possible locations – 61 cm *behind* the head or *beyond* infinity.

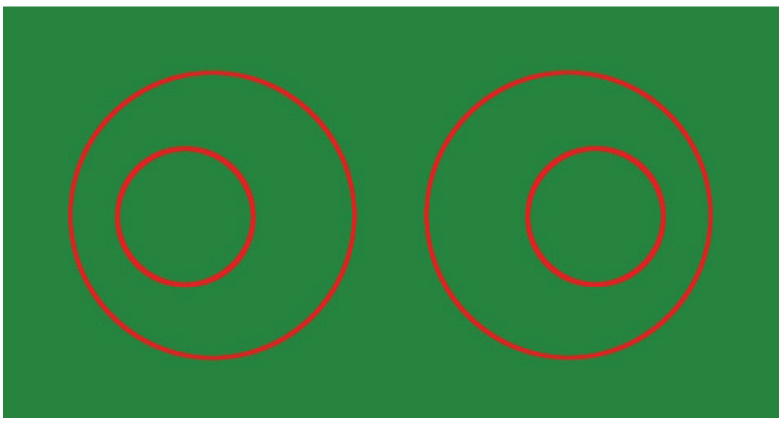

Figure 13 – *Wheatstone's Ocular Spectra*. This is a reconstruction based on one of Wheatstone's (1838) line drawings of the frustum of a cone.

Wheatstone may have assumed that in fixing the arms of his stereoscope in a parallel position, that is, at infinity, he was controlling for the effects of binocular convergence, however, clearly there is still room in this arrangement for the eyes to shift their point of fixation and thereby change the angle of convergence. Wheatstone sought first to discipline his gaze so that his eyes did not move, however, for even greater certainty he re-drew the stereogram with red lines on a green ground, viewed them under a bright light through the stereoscope with a fixed stare of long duration, and then closed his eyes to block out all light. He was able to fuse the resulting "ocular spectra" to form an object "in bold relief" (Wheatstone, 1838, pp.392-3). Experimentalists generally accepted this and similar "controls" as proof that binocular disparity somehow, against all geometric logic, produced a perception of volume independently from binocular convergence (Helmholtz, 1962 [1867], p. 397; Kreis, 1962 [1911], pp. 453-6; Wade, 2004, p. 121).

Stereoscopes Repurposed as Pseudoscopes

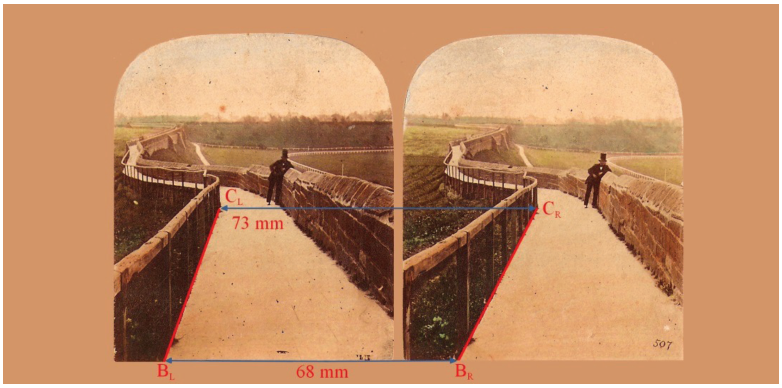

Figure – 14a *Normal*. The distance between paired points C is greater than that between paired points B. Therefore, viewed with a parlour stereoscope, the angle of convergence on C will be less, and C will appear further than B.

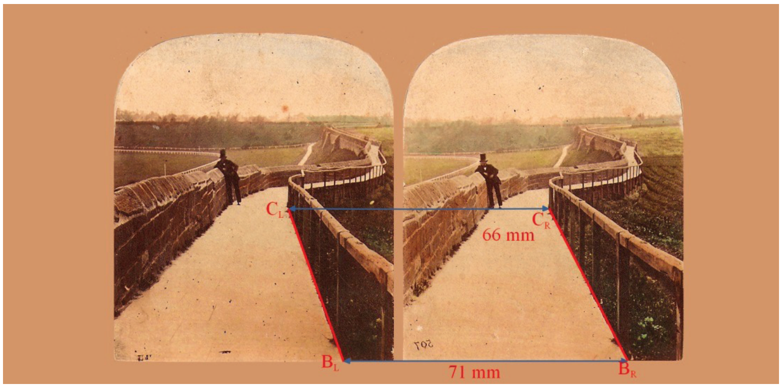

Figure – 14b *Stereoscope as Pseudoscope*. Here the images are flipped in the way that Wheatstone's pseudoscope would flip incoming images to the retinae. The distance between paired points C is *less than* that between paired points B. Therefore the angle of convergence is *greater* and C *should* appear *closer* than B. The middle ground should move forward and the foreground should move back.

In order to demonstrate the role of the mind in overriding binocular cues, Wheatstone constructed an additional instrument that he called a pseudoscope. Its purpose was to flip each retinal image (see Figure 14b), or in effect exchange the left image for the right and thereby reverse all binocular cues. His apparatus was designed in this way to "hack" actual perception, however the same effect can be produced with a stereoscope by simply switching the left and right images (see Figure 14c). Brewster (1856, p. 210) advised his popular audience to experiment with switching images in their stereoscopes – in effect repurposing them as pseudoscopes. "In general," he proposed, "what was formerly convex is now concave, what was round is hollow, and what was near is distant." This is what the pointillist theory predicts, however, many amateur observers were equally fascinated, just as Wheatstone had been, by the anomalies – instances where the mind dismisses the testimony of binocular convergence and refuses to invert volumes, or reposition objects.

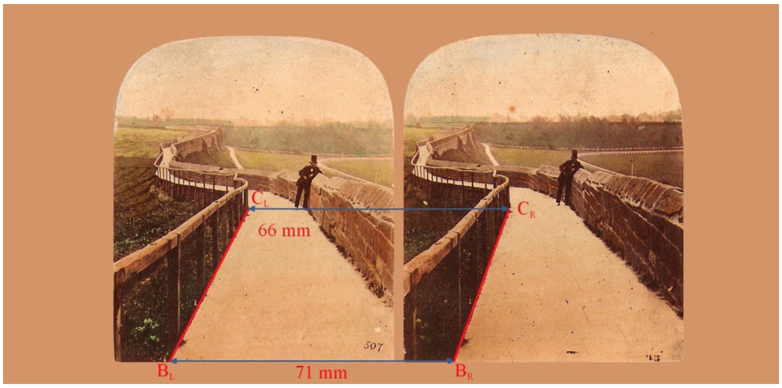

Figure – 14c *Stereoscope as Pseudoscope*. Here the left and right images are transposed in the way that Brewster recommended in order to produce pseudoscopic effects in the parlour stereoscope. The measures are identical to the flipped case. So, again, the middle ground should move forward, the foreground back and the whole space should turn "inside-out."

Figure 15a – Unknown Photographer, *Cove Rocks, Lizard Point*, albumen on translucent paper, backed by coloured tissue and paper (i.e. a "tissue view"). Private collection. The left and right images are transposed. Note that if you can "freeview" the image in a cross-eyed fashion the space will appear normal. Note also, as nineteenth century observers did, that when you freeview normal stereoviews this way, the space should, but typically does not turn itself inside out (Leconte, 1871 pp. 4-6).

People did follow Brewster's advice and transpose stereoscopic images (Anon., 1859; Leconte, 1871), but they did not always have to, as many stereoviews were manufactured with the images mistakenly glued to the backing in the wrong positions. Consider two examples (Figures 15 and 16). In the case of *Lizard Point*, the mind imposes "objectness" on the far rock outcrop and does not turn the convex form concave, but lifts it out and positions it forward, this side of the seated figure. *The Laundry*, like Wheatstone's Figure 10, exposes the action of the mind as it wrestles with contradictions. The background boards struggle to loom in front of the women while being repelled by the principle of overlap. The mind identifies each woman as a discrete and coherent form and reverses their depth-positions, but refuses to read their familiar convex forms as concave. Binocular convergence suggests that the kneeling woman and small boy should be placed in the background. They would then read as giants relative to the other figures. Preconceptions of human scale demand that they stay in the foreground.

Figure 15b – *Lizard Point*. The Photoshopped intervention here is meant to convey what the image looks like when viewed through the stereoscope – with the background rock formation lifted out of its former position and moved to the foreground.

Figure 16 – Marc-Antoine Gaudin, *The Laundry*, hand-tinted albumen prints, c. 1858. Private collection.

Experimenters, both expert and amateur, recognised that the mind refuses to invert volumes of recognisable objects for which we have preconceived notions of spatial form (Anon., 1859). The human face was particularly resistant to being transformed into a hollow mask (Carpenter, 1858, p. 460). Pseudoscopic effects exposed the action of the mind in ways that undermined not only the pointillist theory, but the very notion of visual realism in perception and stereoscopic exhibition. Spatial perception was shown not to be mimetic, but rather constructive – the mind is *making* space. In these bizarre stereoscopic transpositions the mind can be seen to wrestle uncertainly with its constructive task.

Amateurs using their stereoscopes and stereograms for critical inquiry in the tradition of rational recreation would have been exposed to the constructive role of the mind in spatial perception and the difficult problem of explaining how retinal disparity produces coherent volumes. Popular explanations of these artefacts pointed readers in this direction. "The eye does not see," cautioned Charles A. Long (1856, p. 47) in the most widely republished account of what the stereoscope demonstrated about binocular vision, "but is merely the instrument by means of which the mind perceives external objects while the judgment derived from experience determines their shapes and distances."[4] Some took decidedly anti-realist positions, concluding that "the objects of vision are but a mere phantasmagoria of the organ of sight" (Ingelby, 1853 cited in Schiavo, 2003, p. 113) or that "our seeing things as they really are" was merely an "illusion" (Anon., 1858, p. 209).

The Perplexing Theory of the Lenticular Stereoscope

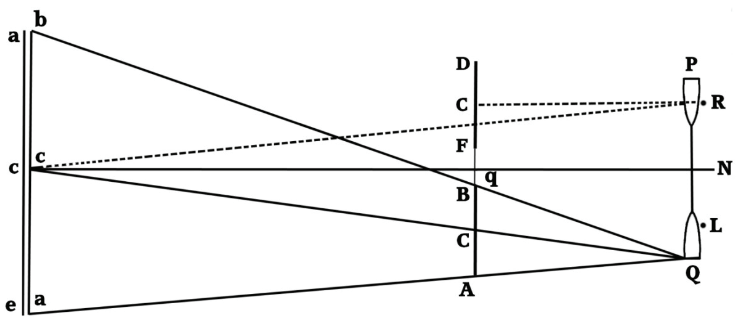

Figure 17 – *Diagram for Sutton's (1856b) Theory of the Stereoscope*. P and Q are semi-lenses. DCF and BCA are images on the stereogram. ace (mislabelled: it should be dcf) and bca are virtual images. Sutton makes the common mistake of assuming that all points on the stereogram will be "measured" at the same angle of convergence (RcQ).

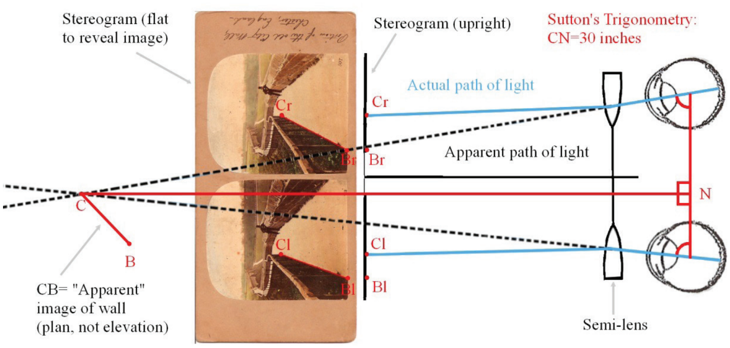

Figure 18 – *Reinterpretation of Sutton's Diagram*. (I have indicated that Point B can be located following the same geometric logic as for C. It and other points would be located in such a way as to produce a 3D virtual image, however, I think it is fatally misleading to imagine that we see a virtual image at that spot.)

Even those who tried to rescue veridical sight and the "truth" of stereoscopic representation encountered problems when they subjected their stereoscopes to serious scrutiny. There was ongoing debate about the "theory of the stereoscope" and much dissatisfaction about the ways in which the common parlour stereoscope distorted visual truth. Understanding the lenticular stereoscope turned out to be both complex and confusing. Realists got themselves into difficulties by appealing almost exclusively to geometric optics and the trigonometry of the eye. Consider the example of Thomas Sutton, whose diagram, reproduced in Figure 17, is meant to prove that the semi-lenses of a Brewster stereoscope distort the angles of binocular convergence.

Sutton is correct: the angles of convergence of the eyes when looking at a depiction of a scene in a lensed stereoscope are all considerably greater than they would be if one were gazing at the scene depicted. He assumes that the entire scene will appear closer, and calculates the perceived distance to be 30 inches (he should instead give a range of distances for the various objects represented). It is true that if we see by trigonometry, then the centre of the scene will appear 30 inches away rather than the 20 or 30 yards in the actual scene represented. The tiny retinal image of the man lounging against the wall could be projected as an object of man-height if that object is judged to be 30 yards away, however, if the object is judged to be only 30 inches away, the man must, reasons Sutton, appear to be tiny. He and many others convinced themselves on the strength of this theory that they actually saw only exquisite miniatures in the stereoscope (Sutton, 1857; Pietrobruno, 2011).

It should be clear by now that spatial perception cannot be reduced to trigonometric calculation. What Sutton fails to grasp is how readily the mind can dismiss the evidence of binocular convergence (whether calculated or estimated) when more plausible evidence is available. In this case, preconceptions about the size of human beings, walls and landscapes take precedence. The retinal images produced by the stereoview of these objects are about the same size as they would be if it was the objects themselves being viewed. Knowing the sizes, the mind can easily recalibrate all of the distances, but even the size of the retinal image can be overridden by preconceptions of object form, as anyone can determine for themselves by varying the position of the image plate of a Holmes viewer.

In constructing the spatial illusion, the mind makes selections from contradictory evidence in a way that is partially intentional. In some measure, we see what we expect to see. Nineteenth century theorists like Sutton saw miniaturisation because their theory primed them to see it. Interestingly, while we, even using period artefacts, might see the astonishing realism so often reported in the nineteenth century, Sutton and others saw an unacceptable distortion of reality. They thought that the problem of miniaturisation was caused by a design flaw affecting most lenticular stereoscopes, and that this flaw could be corrected.

Elongation of the Stereoscopic Moon

The final case I want to consider is another where the realists found themselves disappointed by unanticipated distortions of the stereoscope. The flaw, elongation along the z axis, turned out to be unfixable and potentially to affect any and all stereoscopes and perhaps natural vision itself. It was generally agreed that what we now call "hyperstereo" stereograms, when viewed in the stereoscope, made volumes appear, as Wheatstone put it, "exaggerated in depth" (Wheatstone, 1852, p. 8).[5] Hyperstereo is produced when the cameras taking the component photographs are positioned further apart than the normal inter-ocular distance of 64 mm.

The most discussed and debated hyperstereo image of the nineteenth century was the stereoview of the moon by astronomer Warren De la Rue. De la Rue photographed the moon at different moments of its "libration" (a side to side wobble on its axis) and the effect was as though the photographs were taken "some thousands of miles" apart (De la Rue, 1859, p. 143). The stereoscopic effect revealed the moon's volume in space to be something both expected and strange. De la Rue's colleague, Sir John Herschel, described the effect as "transcendent and wonderful" (quoted in Rothermel, 1993, p. 144). For astronomers the stereoview "brought to light details of dykes, and terraces, and furrows, and undulations on the lunar surface, of which no certain knowledge had previously existed" (Lee, 1862, p.91). Many were clearly willing to accept this, at least initially, as a stereoscopic enhancement of telescopic vision – a new technological mediation that could reveal hitherto undiscovered truths about the world.

A Russian astronomer, Gussew, believed that he saw a deformation of the moon's surface which, according to his calculations, rose "in its middle to a height of about seventy-nine English miles" (Herschel, 1862). Others discovered that, while the moon initially appeared spherical, the longer they gazed at it the more deformed it became, until, according to one observer, it seemed to "protrude in a most alarming manner, threatening to punch us in the eyes, the whole presenting the appearance of an unusually elongated turkey's egg" (Wister, 1874, p. 384). De la Rue attempted to demonstrate that there should be no hyperstereo distortion from his images. Citing Wheatstone's authority, he argued that what mattered was not the distance separating the cameras taking the image, but rather their angle of convergence. The angle of convergence for the stereoscopic moon was about 16º, the same as it would be if a person were viewing a small sphere from a distance of 10 inches (De la Rue, 1859).

As further proof, he drew two schematic diagrams of this sphere as it would be seen from the normal inter-ocular distance, and at an angle of convergence of 16º. The resulting stereoview would not be a hyperstereo and, he implied, should appear perfectly spherical when viewed in the stereoscope. Perhaps surprisingly,

Figure 19 – Warren De La Rue, *Lunar Photographs*, enlarged and published by Smith, Beck & Beck, collodion on glass. Private collection.

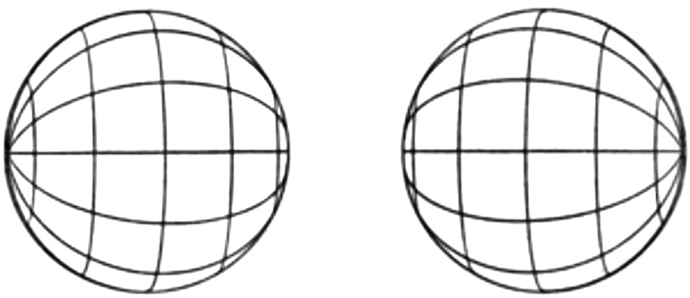

Figure 20 – *De la Rue's Perfect Globe*. (The originals are white on a black ground.)

it does not. Even if the viewing angle is set to 16º (Figure 21), the figure still becomes more egg-shaped the longer one looks at it. Increasing the angle of convergence tends to flatten the egg, and decreasing the angle tends to elongate it, however, at all angles, particularly if one fixes one's eyes on the "furthest" outer circle, the sphere can be made to look like a turkey's egg. No doubt for this reason, Herschel, who had initially championed the stereoscope and had been sympathetic to Gussew's strange hypothesis, had to admit that "the apparent egg-shaped form and lateral distortion [of the moon] may be either most extravagantly exaggerated, or made almost to disappear by different modes of viewing them" (Herschel, 1859). Astronomers quietly abandoned their hope that the stereoscope might be used to enhance human vision and take its place alongside the telescope as part of a reliable technological sensorium.

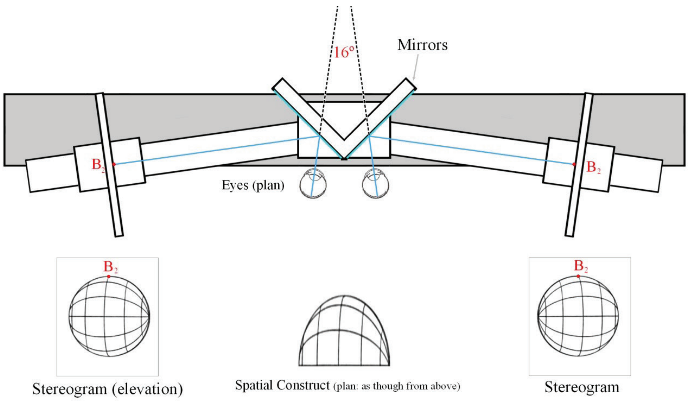

Figure 21b – *Perfect Globe at a 16º Viewing Angle.* While a base angle of 16º can be set for the Wheatstone stereoscope, all stereoviews of volumetric objects allow for slight variations in the angle of ocular convergence (see Figure 21c).

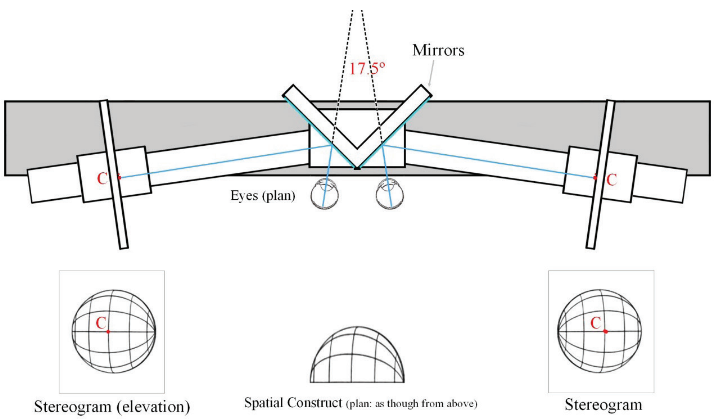

Figure 21c– *Perfect Globe in the Wheatstone Stereoscope.* The arms of the stereoscope are set at the same angle as in Figure 21b (16º), but the eyes have changed their angle of convergence as they scan the object. There is no determinate relationship between where the eyes fix on the globe and its capacity to elongate, however, fixing on the "closest" point "C" does help somehow to bind the figure into a spherical form.

Conclusion

Binocular visual space is non-Euclidean. The space itself and the objects within it split and double as the eyes probe its depth. Stripped-down geometric forms, such as De la Rue's sphere, Wheatstone's line or the schematic bucket with its impossible handle, help to expose, by means of the stereoscope, an instability and lack of coherence that is always covertly present within natural vision. It is as though binocular perception adds an *excess* of depth to near space which the mind must struggle to contain. We only see a stable spatial world that obeys the laws of Euclidean geometry by overriding binocular cues with other visual evidence and by imposing subjective preconceptions of spatial form onto our construction of an "objective" visual world. Pseudoscopes, and stereoscopes repurposed as pseudoscopes, made this constructive work of the mind, along with its hesitancies and reversals, visible in a way that was difficult to dismiss.

Nineteenth century scientists, photographers and ordinary citizens all shared an interest in understanding the way in which stereoscopes mediated perception in order to assess their reliability as witnesses of truth about the world. The evidence of public interest includes texts such as Brewster's *The Stereoscope* which encouraged people to critically examine their stereoscopes in the tradition of rational recreation,[6] the sets of stereoviews for the parlour stereoscope that highlighted the anomalous geometry of stereoscopic vision, and the critical discussions of stereoscopic principles within the popular press. Photographers became critical of the design and construction of stereoscopes, and the procedures for producing stereoviews for them. Indeed, most of the stereoview-stereoscope combinations that recent writers take as the epitome of nineteenth century realism were thought by many in the nineteenth century to produce egregious distortions of the real.

Even the best efforts to construct non-distorting stereoscopes led inevitably back to the anomalies that Wheatstone had uncovered. The problem of distortion, the failure to produce objective truth, was not merely within the apparatus, but within natural vision itself. Despite their flirtation with the idea of enhanced binocular vision, astronomers, like scientists in other disciplines, had long been seeking ways to eliminate fallible observations "by eye" in favour of mechanical means of measuring and recording – that is, in favour of a reliable technological sensorium (Rothermel, 1993), however thinkers like Brewster, who were interested in the social and political implications of access to knowledge, wanted to preserve the liberal-democratic promise of an unaided vision that all individuals could access. The extent to which ordinary users of the parlour stereoscope were troubled by these epistemological questions is difficult to assess. There is evidence, which I have not been able to consider here, that some artists, who took up the stereoscope as their medium, revelled in the anti-realist implications of a spatial imagination that constructs the perceptual world in sometimes capricious fashion.

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Endnotes

1 According to a more recent text, there still "exists at present no adequate neurophysiologic theory of how the brain actually achieves perceptual fusion of the two retinal images" (McIlwain, 1996, p.165).
2 They may have cohered for Wheatstone, but they do so for very few others – a variation in the spatial imagination that Helmholtz was aware of (1962 [1867], pp.452-3).
3 Helmholtz (1962 [1867], pp. 317-18) explicitly recognised this problem.
4 See also Bakewell (1859), Allan (1885), Burn (1858), Townsend (1861), Chambers (n.d. 1880s?), and the 1850s catalogue of the London Stereoscopic Co. (cited in Burn, 1858, pp. 30-2).
5 See, for example, the discussion of "stereoscopic angles" in Volume 8 (1863) of the journal *Notes and Queries*.
6 See also Anon., 1857, pp. 595-6.

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