

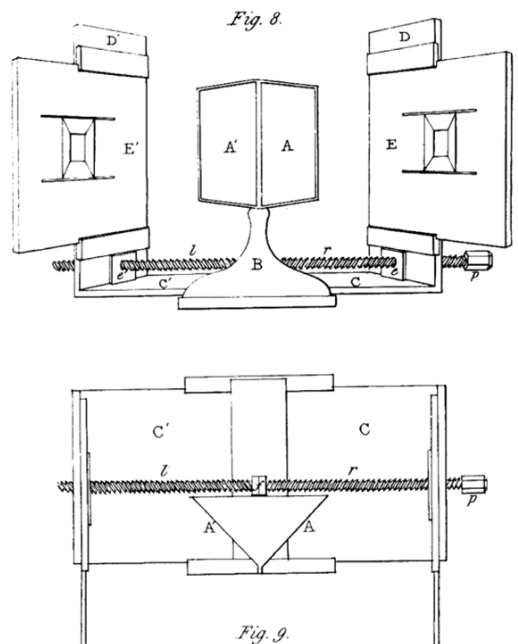
## Guest editorial

### Charles Wheatstone (1802–1875)

Charles Wheatstone was born two centuries ago, but one instrument he invented continues to influence the scientific lives of many researchers in vision. The stereoscope (figure 1) was invented in the early 1830s, and it opened a new world for the study of binocular vision. That world was the laboratory, and with the aid of the stereoscope the methods of physics could be applied to the investigation of spatial vision. Wheatstone was able to manipulate the pictures presented to each eye and observe the depth that was produced. In so doing, he found that:

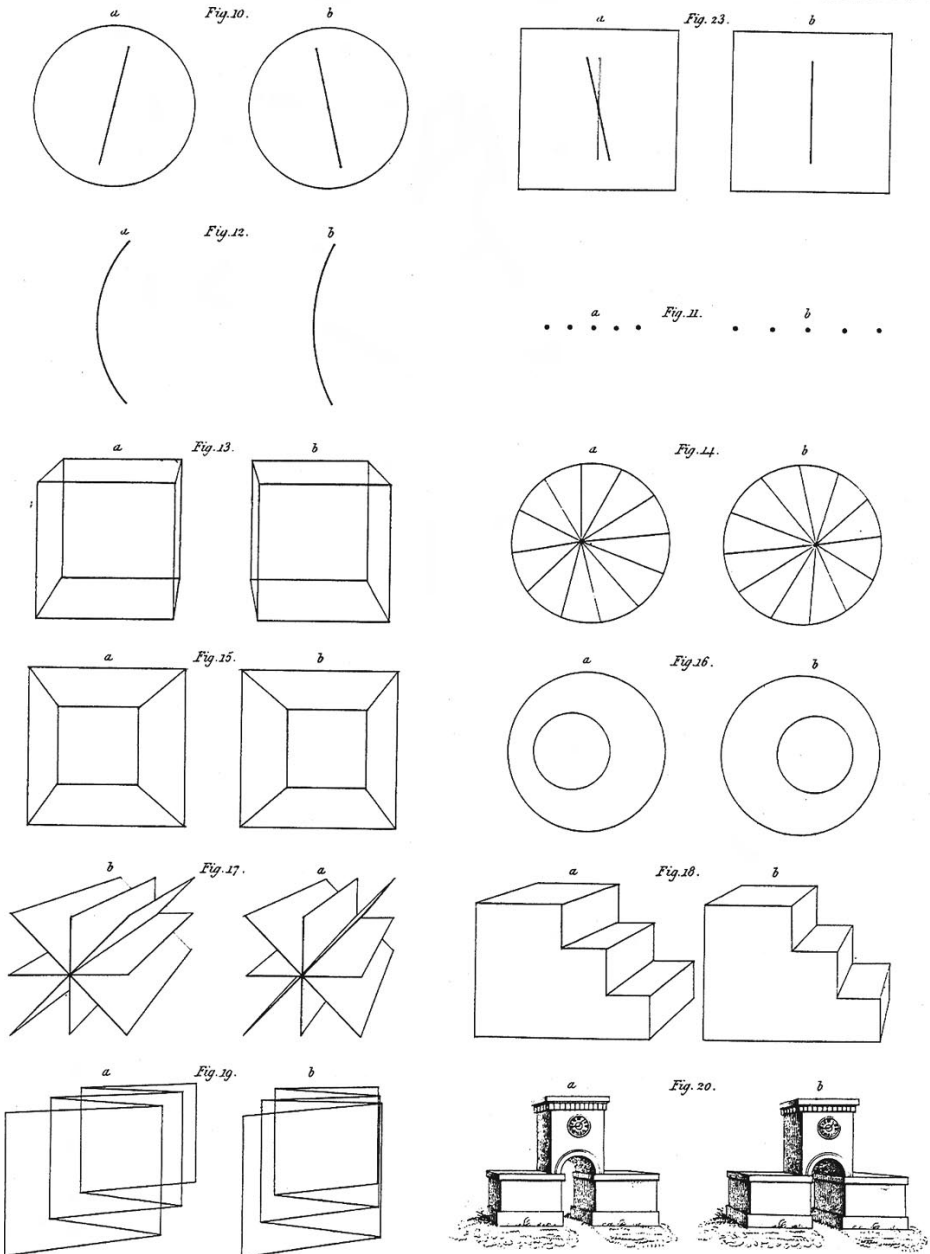
“the projection of two obviously dissimilar pictures on the two retinae when a single object is viewed, while the optic axes converge, must therefore be regarded as a new fact in the theory of vision. It being thus established that the mind perceives an object of three dimensions by means of the two dissimilar pictures projected by it on the two retinae, the following question occurs: What would be the visual effect of simultaneously presenting to each eye, instead of the object itself, its projection on a plane surface as it appears to that eye?... The stereoscope is represented by figs. 8. and 9.; the former being a front view, and the latter a plan of the instrument” (Wheatstone 1838, pages 372–373 and 375).

Binocular instruments were in existence long before the stereoscope was invented, as was knowledge of retinal disparities (see Crone 1992; Wade 1987, 1998). Indeed, Wheatstone (1838) described and illustrated the ways in which different stimuli could be viewed without a stereoscope—by under- and overconvergence, by using two viewing tubes, or by a combination of overconvergence and a septum between the eyes. He, himself, was able to dissociate accommodation from convergence, and so did not



**Figure 1.** Left, Charles Wheatstone (1802–1875), after a portrait in the *Illustrated London News* (1868) marking the award of his knighthood; and right, the mirror stereoscope viewed from the front and from above (from Wheatstone 1838).

*Phil. Trans. MDCCCXXXVIII. Plate XI. p. 372.*



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**Figure 2.** Wheatstone’s twelve paired drawings for the stereoscope; eleven produce depth from disparity, but the twelfth (*Fig. 23*) was designed to display diplopia from the stimulation of corresponding points. (Plate 2 from Wheatstone 1838.)

require the instrument he invented; the stereoscope was devised so that others could view dissimilar pictures with ease. Wheatstone’s original mirror stereoscope can be seen at the Science Museum, London. The “new fact in the theory of vision” was the systematic dissimilarities between the two pictures. Wheatstone realised this as a consequence of a fortuitous observation:

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“When a single candle flame is brought near such a [metal] plate, a line of light appears standing out from it, one half being above, and the other half below the surface; the position and inclination of this line changes with the situation of the light and of the observer, but it always passes through the centre of the plate. On closing the left eye the relief disappears, and the luminous line coincides with one of the diameters of the plate; on closing the right eye the line appears equally in the plane of the surface, but coincides with another diameter; on opening both eyes it instantly starts into relief. The case here is exactly analogous to the vision of two inclined lines when each is presented to a different eye in the stereoscope. It is curious, that an effect like this, which must have been seen thousands of times, should never have attracted sufficient attention to have been made the subject of philosophic observation. It was one of the earliest facts which drew my attention to the subject I am now treating” (Wheatstone 1838, page 379).

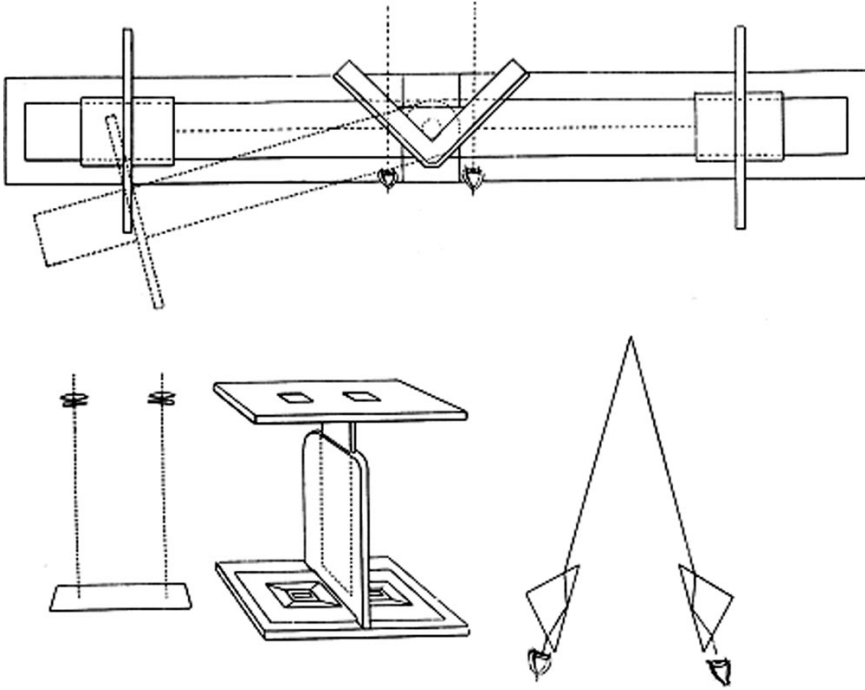
Having established that dissimilar pictures, when viewed in the stereoscope, produce the appearance of depth, Wheatstone conducted a series of systematic manipulations of the figures in order to discover the nature of the relationship. In his first article (Wheatstone 1838) he demonstrated that the sign of disparity (crossed or uncrossed) determined the relative depth seen (nearer or farther), that there was a limit to the disparity yielding singleness of vision, that eye movements were not involved (because depth was seen in disparate afterimages), and that radically different pictures or colours resulted in rivalry. The article was rapidly translated into German, first in summary (Wheatstone 1839), and later in a full translation (Wheatstone 1842); much of the subsequent experimental work on binocular vision was conducted in Germany. William James (1842–1910) shrewdly observed that Wheatstone’s paper “contains the germ of almost all the methods applied since to the study of optical perception. It seems a pity that England, leading off so brilliantly the modern epoch of this study, should so quickly have dropped out of the field. Almost all subsequent progress has been made in Germany, Holland, and, *longo intervallo*, America” (1890, pages 226–227).

Wheatstone’s original drawings for the stereoscope are shown in figure 2. Of the twelve paired drawings, eleven were used to demonstrate that stimulation of the two eyes with slightly different pictures could lead to depth perception. The odd one, which involved presenting a thick vertical line to the right eye and a thick inclined one with a thin vertical to the left (*Fig. 23* in figure 2), was taken to show “that similar pictures falling on corresponding points of the two retinae may appear double and in different places” (page 384). He reported that the thick lines combined to be seen in depth and the thin line remained visible and vertical. That is, the vertical lines, falling on corresponding retinal points, were not combined. This observation created such controversy that Hering (1862) referred to it as the Wheatstone Experiment (see Ono and Wade 1985).

Wheatstone’s second article on binocular vision was published fourteen years later. He described and illustrated an adjustable mirror stereoscope, a prism stereoscope, and a pseudoscope for reversing disparities (see figure 3). The main purpose of these was to extend the range of conditions under which the two eyes could be stimulated:

“Under the ordinary conditions of vision, when an object is placed at a certain distance before the eyes, several concurring circumstances remain constant, and they always vary in the same order when the distance of the object is changed. Thus, as we approach the object, or as it is brought nearer to us, the magnitude of the picture on the retina increases; the inclination of the optic axes, required to cause the picture to fall on corresponding places on the retinae, becomes greater; the divergence of the rays of light proceeding from each point of the object, and which determines the adaptation of the eyes to distinct vision of that point, increases; and the dissimilarity of the two pictures projected on the retinae also becomes greater. It is important to ascertain in what manner our perception of the magnitude and distance of objects depends on these various circumstances, and to inquire which are the most, and which the least influential in the judgements we form. To advance this inquiry beyond the point to which it has hitherto been brought, it is not sufficient to content ourselves with drawing conclusions from

observations on the circumstances under which vision naturally occurs, as preceding writers on this subject mostly have done, but it is necessary to have more extended recourse to the methods so successfully employed in experimental philosophy, and to endeavour, wherever it be possible, not only to analyse the elements of vision, but also to recombine them in unusual manners, so that they may be associated under circumstances that never naturally occur” (Wheatstone 1852, page 2).



**Figure 3.** Above, the mirror stereoscope with adjustable arms, below left and centre, the prism stereoscope, and below right, the pseudoscope for reversing perspective differences (all from Wheatstone 1852).

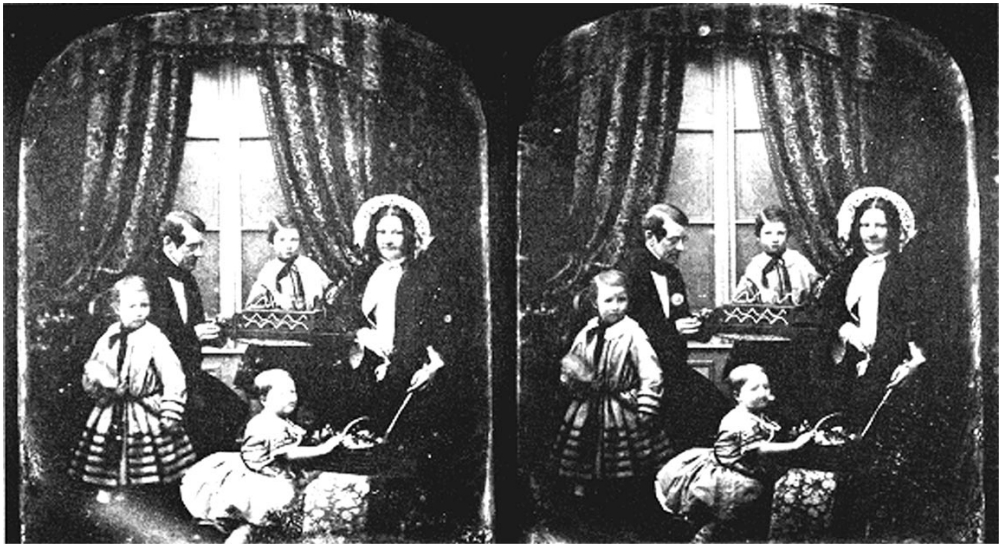
Wheatstone used the stereoscope with adjustable arms to vary the four circumstances mentioned in the quotation (retinal size, convergence, accommodation, and disparity). He found that “The perceived magnitude of an object, therefore, diminishes as the inclination of the axes becomes greater, while the distance remains the same; and it increases, when the inclination of the axes remains the same, while the distance diminishes. When both of these conditions vary inversely, as they do in ordinary vision when the distance of an object changes, the perceived magnitude remains the same” (Wheatstone 1852, page 3). He applied the pseudoscope to reverse the normal relations between monocular and stereoscopic cues to depth: “With the pseudoscope we have a glance, as it were, into another visible world, in which external objects and our internal perceptions have no longer their habitual relation with each other” (Wheatstone 1852, page 12). He remarked on the difficulty of perceiving reversals of relief with the pseudoscope, and the illuminating conditions that are necessary for such reversal.

In 1839, the year after Wheatstone’s first article on the stereoscope appeared, his friend, William Henry Fox Talbot (1800–1877), made public his negative–positive photographic process. In fact the term ‘photographic’ was used first by Wheatstone (Arnold 1977). He immediately grasped the significance of photographing scenes from two positions, so that they would be seen in depth when mounted in the stereoscope. To achieve this end, he enlisted the assistance of Henry Collen (1800–1875) to take stereoscopic photographs of Charles Babbage (1792–1871); a single camera was used to

take photographs from different positions because it was difficult to find two cameras that were optically equivalent. Collen described it thus:

“In 1841, when I was one of the very few who undertook to make use of Mr. Talbot’s process, Mr. Wheatstone not only had the idea of making photographic portraits for the stereoscope, but at his request, and under his direction, in August of that year, I made a pair of stereoscopic portraits of Mr. Babbage, in whose possession they still remain; and if I remember rightly, Mr. Wheatstone has previously obtained some daguerreotype portraits from Mr. Beard for the stereoscope” (Collen 1854, page 200).

The reason for Collen’s letter to the *Journal of the Photographic Society* was that Antoine Claudet (1797–1867) had claimed to make the first photograph for the stereoscope (Claudet 1853). Wheatstone did not express a preference for metal-plated daguerreotypes or paper printed calotypes (or talbotypes as they were also called), and the only stereoscopic photograph of him of which I am aware is a daguerreotype taken by Claudet in the mid 1850s (figure 4). The device that Wheatstone is manipulating in the photograph is a wave machine, demonstrating the propagation of orthogonal waves (see Holland 1999, 2000). A similar model is on display at the Science Museum, London.



**Figure 4.** Stereoscopic daguerreotype of Charles Wheatstone, his wife Emma, and their children Charles Pablo, Arthur William Frederick, and Florence Caroline; the photograph was taken by Antoine Claudet in the 1850s. (Reproduced by the kind permission of the National Portrait Gallery, London.)

Historically, more attention has been vested in the instrument, the stereoscope, than in the observations Wheatstone made with it. This most probably relates to the colourful disputes that have raged regarding the priority of its invention. The source of most of the disputes was David Brewster (1781–1868), although his claims have not been sustained (see Wade 1983). A second factor is that the fusion of the stereoscope with photography provided a popular platform for the instrument, and many versions of it were subsequently patented (Gill 1969). The first, brief report of Wheatstone’s stereoscope appeared in 1833, in a book by a physiologist at King’s College, London (Mayo 1833). The mirror stereoscope was not presented to scientific audiences until the summer of 1838. It was then displayed at the Royal Society of London in June, and presented to the British Association for the Advancement of Science, which was meeting at Newcastle, in August. In each case Wheatstone delivered a paper describing the instrument and experiments he had made with it. The report in the *Athenaeum*

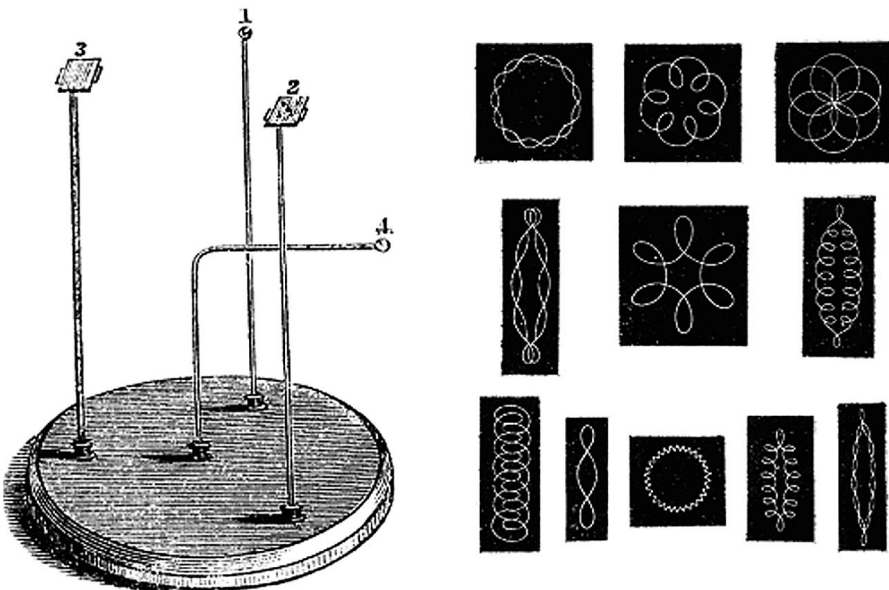
following the Newcastle meeting noted that:

“Sir David Brewster was afraid that the members could scarcely judge, from the very brief and modest account given of this principle, and the instrument devised for illustrating it, by Professor Wheatstone, of its extreme beauty and generality. He considered it as one of the most valuable optical papers which had been presented to the Section. He observed, that when taken in conjunction with the law of visible direction in monocular vision (or vision with one eye), it explains all those phenomena of vision by which philosophers have been so long perplexed” (Anon. 1838, page 650).

This contrasts starkly with the opinions Brewster (1856) stated in his history of the stereoscope, and in his letters to *The Times* in 1856 (see Wade 1983).

Wheatstone did not commence his researches in vision with binocular phenomena. The family business, initially located in Gloucester and later in London, concerned the manufacture of musical instruments. This appealed to Wheatstone’s mechanical ingenuity, and among his inventions was the concertina. Wheatstone was led to the study of vision through the visual expression of acoustic phenomena. Indeed, his first scientific paper was on acoustical figures (Wheatstone 1823), and he later expressed these with a philosophical toy of his invention, which he called the kaleidophone (figure 5). The kaleidophone was an extension of a method described by Thomas Young (1773–1829), in which silvered wire was attached to a piano string so that its vibration could be observed with the aid of a magnifying glass (Young 1800). Wheatstone constructed the kaleidophone to amplify the vibrations so that they could be seen by the naked eye. Silvered glass beads were attached to the ends of rods having different cross-sections and shapes; when the rods were bowed or struck, Chladni figures could be seen in the light paths traced by reflections from the beads.

Wheatstone was well acquainted with other members of the scientific community in London who were active in the 1820s inventing philosophical toys, particularly Peter Mark Roget (1779–1869) and Michael Faraday (1791–1867); these instruments combined scientific study of phenomena with popular amusement. The effects visible with the kaleidophone are based upon visual persistence, and Wheatstone took an active



**Figure 5.** Left, Wheatstone’s kaleidophone, or phonic kaleidoscope, and right, some of the paths traced by reflections of light from the glass bead on rod 1 after it has been struck or bowed at different points (from Wheatstone 1827).

interest in extending the uses to which it could be put. In 1833 he delivered a lecture on Joseph Plateau's (1801–1883) studies of visual persistence, and he employed the effect in his own investigations on the velocity of electricity (Wheatstone 1834).

Wheatstone delivered few lectures. He was appointed Professor of Experimental Philosophy at King's College, London in 1834, and gave eight lectures in his first year, but none thereafter (see Bowers 1975). Most of his papers to the Royal Institution were delivered by Faraday. He was acutely shy, and even refrained from contributing to a small debating society of which he was a member. His personal interactions, by contrast, were said to be charming and lucid. Despite this reluctance to engage in public performance he was frequently enmeshed in personal and legal disputes regarding the priority of his inventions. His interests in electricity resulted in the development of electric clocks, telegraphs, and chronoscopes. With regard to electric clocks and telegraphs he was in dispute with Alexander Bain (1810–1877), who claimed Wheatstone had misappropriated his inventions (see Wade 2001). William Fothergill Cooke (1806–1879), with whom Wheatstone developed the electric telegraph, later severed their relationship acrimoniously (see Bowers 1975). Wheatstone (1845) maintained that his design of the electromagnetic chronoscope had been copied by scientists on the Continent. The dispute with Brewster over the invention of the stereoscope, aired in the correspondence columns of *The Times*, was not of his making, and he demonstrated his skill in literary combat in despatching Brewster's partial view of history.

Wheatstone's biography (Bowers 1975) was written to mark the centenary of his death; a second edition has been published for the bicentenary of his birth (Bowers 2001). Bowers stated that "Only in electrical measurements are Wheatstone's methods still in daily use" (1975, page 217). On the contrary, the stereoscope, and the methods Wheatstone introduced to examine binocular vision, are in constant use in vision laboratories throughout the world. He transformed not only our vision of pictures, but also our understanding of some intricacies of spatial perception. The sympathetic portrait of this shy but influential thinker shown in figure 6 appeared with Wheatstone's obituary notice in *Nature*. To this notice were added the comments of Signor Volpicelli of the Academia dei Lincei: "Our countryman, Leonardo da Vinci, in 1500, or thereabouts, conceived and was the first to affirm, that from a picture it was not possible to obtain the



**Figure 6.** Charles Wheatstone after a frontispiece engraving in *Nature* 1876 13.

effect of relief. But Wheatstone, reflecting profoundly in 1838, on the physiology of vision, invented the catoptric stereoscope, with which he philosophically solved the problem of the optical and virtual production of relief” (1876, page 502).

The bicentenary of Wheatstone’s birth will be celebrated by several disparate groups, like the Institute of Electrical Engineers and the Concertina Society. We should also mark his pioneering research in stereoscopic vision.

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