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Albrecht Nagel on vision with two eyes

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Abstract

Nagel's book on vision with two eyes was published in 1861, during a period in which German visual scientists were struggling to rescue the doctrine of identical retinal points from the evidence of stereoscopic depth. The long observational history of binocular vision has been dominated by the appearance of a single world with two eyes and its breakdown when the eyes are distorted abnormally. Early in the nineteenth century the flat horopter of Aguilonius (proposed two centuries earlier) assumed curvature in the form of the Vieth-Müller circle which was linked to identical retinal points: there were only two possible states of binocular perception – singleness with images on the Vieth-Müller circle and doubleness otherwise. This elegant edifice was undermined when Wheatstone demonstrated singleness and depth from images with slight retinal disparities. Nagel responded by providing observations on combining simple line stimuli in the two eyes. In the last part of chapter 3 of his book, Nagel describes experiments with lines varying in orientation or curvature with respect to the two eyes; it is in this section that Nagel draws attention to cyclofusion and the involvement of the extraocular muscles in it. Ocular torsion was an issue of considerable contention in nineteenth century visual science. The possibility of torsion in opposite directions seemed fanciful and yet this is what Nagel proposed in order to maintain cyclofusion for lines inclined in opposite directions relative to the horizontal. Similar rotations about the vertical resulted in a depth effect with no cyclovergence. The involvement of cyclovergence remained hotly debated until photographic recording of eye movements verified it.

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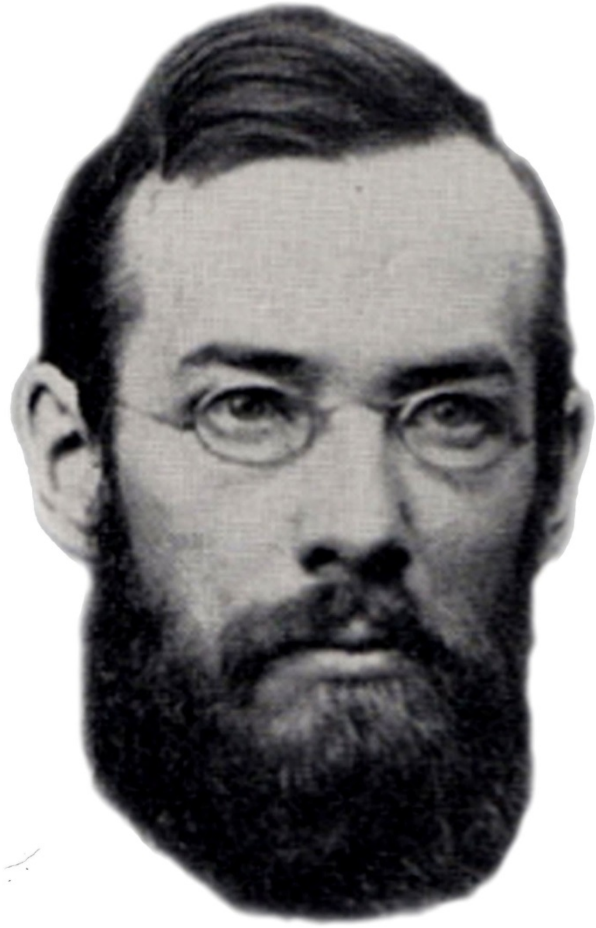
Albrecht Nagel on vision with two eyes

Albrecht Nagel (1833-1895) published his book on *Das Sehen mit zwei Augen*[1] (Vision with two eyes) in 1861 (Figure 1). Three articles in the current volume of *Strabismus* present translations by H. J. Simonsz into English from Nagel's examination of stereoscopic vision. Nagel's book is dedicated to Helmholtz and von Gräfe under whom he had worked before taking up his position at Bonn; he was called to Tübingen in 1864 and remained there for the rest of his life. Part 1[2] of the translation (pp. 2-4 and 19-24 from Nagel's book) provides the Introduction and a section of Chapter 3 (on stereoscopic phenomena) concerned with binocular combinations of two rods. Part 2[3] (pp. 24-38) addresses the question of fusion with disparate images like dots or lines. Part 3[4] (pp. 38-51) presents experiments with lines varying in orientation or curvature with respect to the two eyes. It is in this section that Nagel draws attention to cyclofusion and the involvement of the extraocular muscles in it. In general, Nagel's book reflects the struggles within German visual science to rescue the doctrine of identical retinal points from the evidence of stereoscopic depth perception.



DAS

SEHEN MIT ZWEI AUGEN

UND

DIE LEHRE

VON DEN

IDENTISCHEN NETZHAUTSTELLEN

VON

Dr. ALBRECHT NAGEL,
Privatdocenten der Universität in Bonn.

Mit 4 lithographirten Tafeln und 37 in den Text gedruckten Holzschnitten.

LEIPZIG UND HEIDELBERG.
C. F. WINTER'SCHE VERLAGSHANDLUNG.
1861.

Figure 1. Detail of a portrait of Albrecht Nagel and the title page of his book on vision with two eyes.

The long observational history of binocular vision has been dominated by the appearance of a single world with two eyes and its breakdown when the eyes are distorted abnormally, as in strabismus or with external movement of one eye alone. From the beginning of the seventeenth century, with a growing understanding of the anatomy and dioptrics of eyes, stimulation of the retina could be linked to singleness of vision. At the beginning of the nineteenth century the flat horopter of Aguilonius[5] assumed curvature. First Bell[6] then Prevost[7] proposed that corresponding points fall on a circle passing through the point of bifixation and the centers of the eyes. That is, the horopter is a circle rather than a plane. This was formalized by Vieth[8] and later by

Müller[9], and it has become known as the Vieth-Müller circle. Müller[10] augmented his geometrical description of the circle of single vision by linking it with identical retinal points: "Whenever an object lies out of the 'horopter', its image falls on non-identical points of the retinæ, and it is seen double"[11(p.1201)]. In this way, there were only two possible states of binocular perception – singleness when objects fell on the circumference of the Vieth-Müller circle and doubleness otherwise, and singleness was served by a fixed organic relation between nerve fibers. It is this elegant edifice that Wheatstone[12] undermined with his demonstration of singleness and depth from images with slight retinal disparities: he remarked that "objects whose pictures do not fall on corresponding points of the two retinæ may still appear single"[12(p.384)]. Thus, in the year that saw publication of Wheatstone's article on stereoscopic depth perception we find a statement by Müller denying its possibility. Wheatstone was well aware of the originality of both his observations and his interpretation of them, hence the meticulousness of his experiments in their support. Not only did he argue that singleness and depth could be observed with stimulation of non-identical retinal points but also that the stimulation of identical points could result in double vision. Moreover, the stereoscope, perhaps more than any other instrument, ushered in the era of experimentation for spatial vision. It fulfilled the scientific desire to examine binocular vision by observation and experiment. As Towne[13] put it: "The introduction of the stereoscope inaugurated a new epoch in the physiology of vision, opened a wide field for further inquiry, and suggested additional methods of investigation, while the theory of binocular vision has been greatly modified by results which have been obtained through the medium of the instrument"[13(p.70)].

The impact of Wheatstone's experiments was felt acutely by sensory physiologists in Germany. It was fully appreciated by Nagel who commented that

Wheatstone had shaken the dogma of identical points for the first time and that hardly any physiologists agreed with him; Nagel was not among them. As he noted in Part 1, Volkmann voiced his views that stereoscopic vision threatened the received wisdom and Panum[14] stated similar sentiments. Panum sought to salvage the dogma with his concept of fusional areas so that single vision was expanded to a region around the geometrically constrained circumference of the Vieth-Müller circle. Nagel tried to finesse the problem by proposing separate circles for each eye (see Figs. 7 and 8 in Plates I and II which are reproduced in Parts 1 and 2). Despite praising the stereoscope for facilitating experiments on binocular vision, it was not enlisted for the observations Nagel made with simple line stimuli – he adopted a free-fusion method: "The stereoscope itself is the most insignificant in the experiments that belong here". Much of the material in Part 1 is concerned with describing and justifying free-fusion using the example of viewing two coloured, vertical rods each in the parallel visual axes of the eyes. The interpretation of the ensuing perception is psychological rather than physiological. Using this procedure, Part 2 is concerned with combining pairs of dots or lines with different separations in each eye. The observations with dots are essentially like those made by Wheatstone[12]. Many more manipulations are made with paired vertical or near vertical lines in each eye. The separations and orientations of one or both members of a pair varied and the pairings are illustrated. Somewhat frustratingly, Nagel refers to them in the text but he does not specify the figure numbers to which the observations apply. The final image presented in Part 2 is of a single vertical line in one eye and an inclined one in the other – rather like the first pair of stereoscopic figures in Wheatstone[12] in which the half images were both inclined to the vertical. Wheatstone's stimuli were surrounded by circles to facilitate binocular alignment whereas such assistance was not employed in Nagel's figures. It is Nagel's difficulty with defining the apparent location in space of the single line combination that leads to Part 3. Combinations of inclined lines, curves and crosses are described as well as rivalling vertical and horizontal lines like those examined by Panum[14]. The most novel combination was that involving lines inclined to the horizontal – fusion of the lines was not accompanied by depth but by strong feelings of muscular activity. Nagel argued that the fusion is attained by rotations of the eyes in opposite directions – cyclovergence.

Ocular torsion was an issue of considerable contention in nineteenth century visual science. Speculations that the oblique muscles could rotate the eyes around the z-axis were frequently stated. For example, Bell[15] wrote: “By dissection and experiment it can be proved, that the oblique muscles are antagonists to each other, and that they roll the eye in opposite directions, the superior oblique directing the pupil downwards and outwards, and the inferior oblique directing it upwards and inwards”[15(p.174)]. However, evidence supporting it in humans was hard to find and when it was presented it was usually contended[16]. The possibility of torsion in opposite directions seemed fanciful and yet this is what Nagel proposed in order to maintain cyclofusion for lines inclined in opposite directions relative to the horizontal. Similar rotations about the vertical resulted in a depth effect with no cyclovergence. As Nagel noted, achieving cyclofusion with single lines required a lot of practice and patience. He returned to the issue later[17-19] and showed that the cyclofusion could be produced more readily with arrays of lines. It was largely as a consequence of this demonstration that Hering[20,21] became convinced that cyclovergence occurred. The involvement of cyclovergence remained hotly debated until photographic recording of eye movements verified it and Crone and Everhard-Halm[22] recommended that large stimuli should be used in order to measure it. Readers can observe this for themselves with Figure 2; cyclofusion can be experienced using a simple stereoscopic display with the aid of red/cyan glasses or they can experience it with free-fusion in the manner of Nagel’s observations. The arrays of lines inclined relative to horizontal in the monocular views will appear horizontal with two eyes.

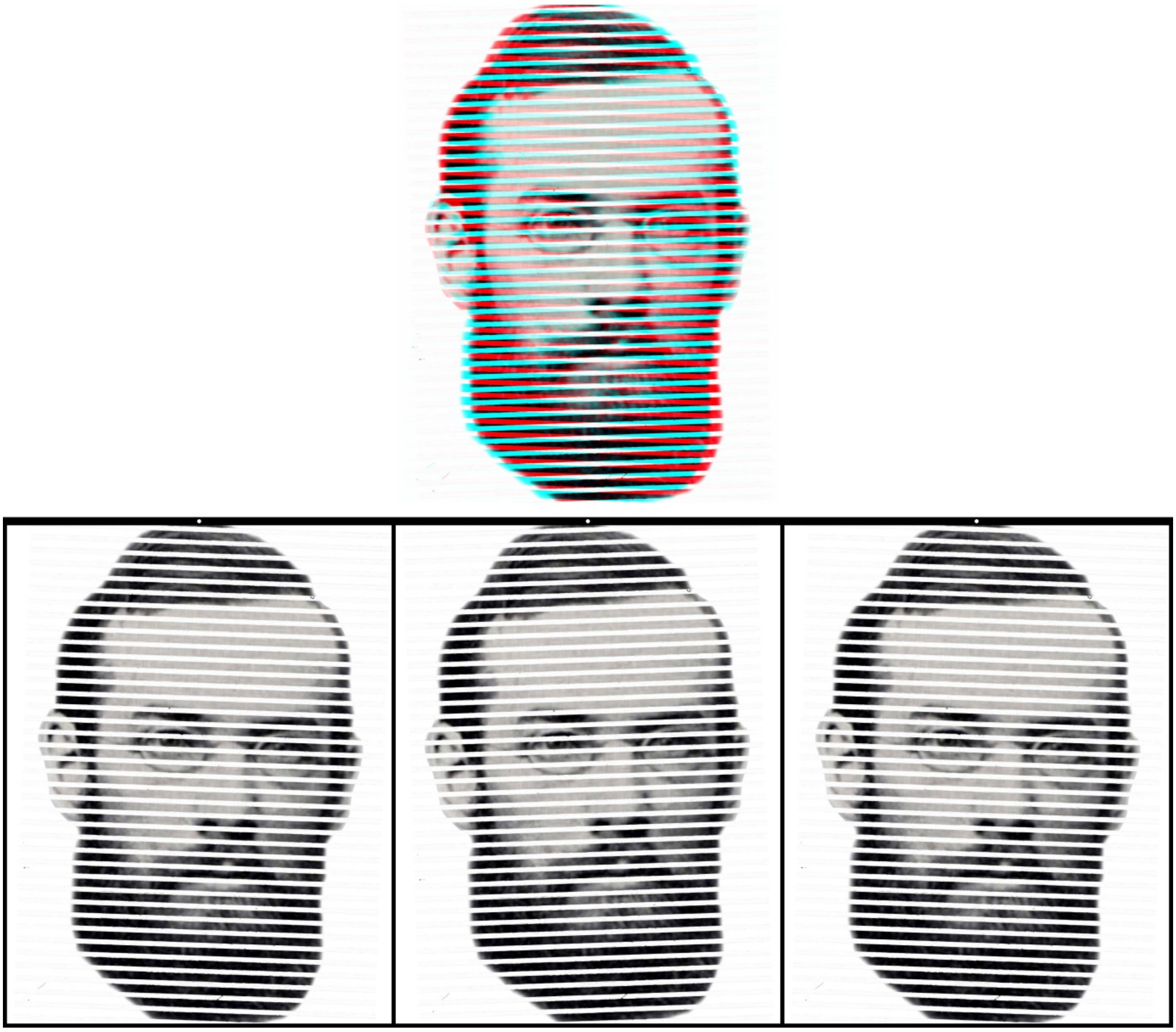


Figure 2. *Nagel’s cyclofusion* by Nicholas Wade. Upper, an anaglyph of Nagel which can be viewed with red/cyan glasses with the combination red/left eye and cyan/right eye. The two portraits and the embedded lines are inclined at 2º clockwise and counterclockwise of horizontal. Lower, the two components are presented in Universal View with the left eye, right eye, and left eye stimuli; the left pair is for uncrossed and the right pair for crossed cyclofusion. Nagel would have viewed the equivalent of the left pair.

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