

# IBN AL-HAYTHAM ON EYE AND BRAIN, VISION AND PERCEPTION

Charles G. Gross

U.S.A.

*Ibn Al-Haytham was the major figure in the study of optics and vision in the middle ages and his influence was pervasive for over 500 years. His original theory of vision is briefly outlined. Less wellknown are his insights into visual physiology and visual perception, some of which are described.*

Ibn al-Haytham was the major figure in the science of optics and the study of vision between Classical civilization and the Renaissance. He was born in Basra in 965 and died in Cairo in 1040 and was later known in Europe as Alhazen<sup>1</sup>. His work represents the first major advance in optics after Euclid and Ptolemy of Alexandria and in visual physiology after Galen. We must wait until Kepler and Newton in the 17th and 18th Centuries for further fundamental understanding of the nature of light and until at least Helmholtz in the 19th Century for further advances in understanding visual perception. For further progress on many of the perceptual and psychological questions considered by Ibn al-Haytham, we still have to wait. Like Leonardo, Ibn al-Haytham was a polymath, contributing to astronomy, mathematics, philosophy as well as a variety of other subjects. Unlike Leonardo, who had little or no impact on successive generations of scientists, Ibn al-Haytham's influence was pervasive and usually recognized well into the 19th and 18th Centuries. As a practising neurophysiologist and neuropsychologist of vision, I will concentrate on summarizing some of Ibn al-Haytham's major contributions to the physiology and psychology of vision. Before doing so, however, let me briefly describe the principal approaches to light and vision of the ancient world that provided the background for Ibn al-Haytham's work.

Euclid and Ptolemy held an extromission view of vision: vision was due to a stream of rays issuing from the eye and somehow apprehending objects.

Galen had provided a very detailed description of the eye and the optic pathways that was hardly surpassed before Vesalius<sup>2</sup>. Particularly crucial for Ibn al-Haytham's theory of vision, as we shall see, was Galen's view that the crystalline humor (our lens) was the sensitive or photoreceptive portion of the eye. Galen, however, had little interest in optics and accepted an intromission view.

In his great work *Kitab al Manazir* or Optics, Ibn al-Haytham carefully examined the extromission theories of his predecessors and systematically demolished each of them.

Against the extromission theory he writes, "The act of vision is not accomplished by means of rays

emitted from the visual organ"... , rather, "vision is accomplished by rays coming from external objects and entering the visual organ"<sup>3</sup> . Essentially Ibn Al-Haytham took a new view of light, combined it with Ptolemaic optics, Galenic anatomy and the results of his own extensive experiments and produced a plausible intromission view that lasted until Kepler.

As he put it, "from each point of every coloured body, illuminated by any light, issue light and colour along straight lines that can be drawn from that point"<sup>4</sup> . Following Galen, Ibn al-Haytham believed that the crystalline humor was the sensitive surface whose receipt of light was the first step of the visual processes<sup>5</sup> . But, if from every point of every object, light travelled to the crystalline humor, then those light rays would intermix and total confusion would result <sup>6</sup> . How could a point-to-point correspondence between the visual field and the crystalline humor, essential to Ibn al-Haytham's theory of vision, be maintained? Ibn al-Haytham postulated that only light rays orthogonal to the surface of the crystalline humor passed through it. The others were refracted and refracted rays were weaker and not perceived<sup>7</sup> . Thus, a topographically ordered point-to-point representation of the visual world entered the crystalline humor.

Ibn al-Haytham had used a camera obscura in his extensive optical experiments<sup>8</sup> and compared it to the eye<sup>9</sup> . (He seems to have been the first to do either). Thus, he realized that if the light rays orthogonal to the curved surface of the crystalline lens continued, they would project an inverted image on the back of the eye.

Since the notion of an inverted image was unacceptable, he postulated precisely the appropriate refraction at the interface between the crystalline humor and the vitreous humor so that the rays leaving the latter would be parallel. Thus, they would provide a right-side-up topographic representation of the visual world to the back of the eye (retina) which he viewed as an extension of the optic nerves <sup>10</sup> . Even after Kepler finally elucidated the formation of the retinal image, the problem of how an inverted image could yield vertical perception perplexed him and was not satisfactorily handled until Molyneux and Berkeley at the beginning of the 18th Century<sup>11</sup> .

Beyond the receipt of light by a sensitive surface (the crystalline humor for him), Ibn al-Haytham realized that strictly optical considerations were no longer required. He did stress, and correctly so, that the point-to-point representation had to be maintained and conveyed to the ultimum sensus in the anterior part of the brain<sup>12</sup> .

The importance of Ibn al-Haytham's idea of a point-to-point projection of the visual world into the brain cannot be over-emphasized. Indeed, it forms one of the bases of modern visual physiology<sup>13</sup> .

Although the importance of Ibn al-Haytham's theory of vision and its pervasive influence for over half a millenium have been well recognized, there has been relatively little close examination of his original views on psychological processes in perception and their influence. Let me indicate some of his ideas in this area that deserve much more study and attention than they have yet received.

He was the first to recognize the crucial importance of eye movements for perception. It is only in recent years that it has been recognized that there is indeed no perception without eye movements and that eye movements are crucial to building up our consciousness of the visual world<sup>14</sup> .

Ibn al-Haytham realized that the reception of light by the eye is only the very first step in perception. Beyond this passive process, active processes such as attention, comparison and memory are required before conscious visual experience occurs <sup>15</sup>.

Particularly startling is his realization that a series of logical inferences must occur before sensation can be transformed by the brain into perception. He stressed that the speed of perception demands that these inferences themselves be imperceptible; that is, unconscious to the observer.

This is a clear adumbration of Helmholtz's theory of unconscious inference that played so major a role in the 19th Century and continues to pervade the modern study of vision <sup>16</sup>. It would be valuable to explore to what extent Helmholtz was aware of Ibn al-Haytham's ideas on the role of unconscious inference in perception. Helmholtz does cite Alhazen in other contexts, such as when reviewing previous explanations of the moon illusion <sup>17</sup>. Furthermore, Ibn al-Haytham's use of the time required for a perception has, in the last decade, become one of the principal methods for analyzing the "unconscious inferences" that underlie perception <sup>18</sup>.

Among Ibn al-Haytham's other perceptual insights was his understanding of the crucial role of visual contrast. For example, he realized the color of an object depends on the color of the surroundings <sup>19</sup> and that the brightness contrast provided an explanation of the invisibility of stars in the day time <sup>20</sup>.

My main conclusion is that this remarkable man deserves much further study. Although Ibn al-Haytham's unique synthesis of physics, mathematics and physiology into a new theory of vision and its historical importance have been recognized, his insights into the psychology of perception and their influence remains an important and potentially fertile field of research.

## REFERENCES

1. For biographical information see A. I Sabra in "Dictionary of Scientific Biography," ed. C.C. Gillispie (New York, 1972), vol. 6, P.189.
2. POLYAK, S.I. (The Retina checago 1941) and the vertebrate visual system (Chicago 1957).
3. ALHAZEN, "Opticae Thesaurus", ed. S. Risner (Basel, 1672), bk. 1, chap. 5, secs 14 & 23. Trans. in Polyak, op. cit (1957) P.17.
4. ALHAZEN, op.cit., bk. 1, chap. 5, sec. 19. Trans, Lindbeg, op. cit., P.73
5. Ibid., bk. 1, Chap. 4, secs. 16 and 23. Trans. in Polyak, op. cit (1941), P. 122 and translations from the Arabic Ms. Fatih 3212, by A.I. Sabra in "Studies in Perception: Interrelations in the History of Philosophy and Science," ed. P.K. Machamer and R.G. Turnbull (Columbus, 1978), P.167
6. ALHAZEN, op.cit., bk. 1, chap. 5, sec. 14. Trans. Lindberg, op.cit., P.73
7. Ibid., sec. 18 Trans. Londberg, op.cit., P.74
8. RUSSEL, po.cit., S.B. Omar, "Ibn al-Haytham's Optics: a study of the origins of experimental science" (Minneapolis, 1977) ch.2
9. ALHAZEN, op.cit., bk. 1, chap. 5, sec. 29, Trans. in Polyak, op.cit P.133
10. ALHAZEN, op.cit., bk.2, chap. 1, secs. 2 - 6. Cited in Lindberge, op.cit., P.81
11. BORING op.cit., P.222
12. ALHAZEN, op.cit., bk. 1., chap. 6, sec. 27. Trans. from Ms. Fatih 3212 by op.cit., P. 168
13. C.G. GROSS, C.J. BRUCE, R. DESIMONE, J. FLEMING and R. GATASS IN "Multiple cortical somatic sensory-motor, visual and auditory areas and their connectivities", ed. C.N. Woolsey (New York, 1980).
14. E.G.: A.L. YARBUS, "Eye movements and Vision", Trans. from Russian by B. Haigh (New York, 1967).

15. SABRA, op.cit., P.169; S.B. Omar, "Ibn al-Haytham's optics: a study of the origins of experimental science". (Minneapolis, 1977) chap. 2
16. H.V. HELMHOLTZ, "Handbook der physiologischen optik", (Hamburg, 1909 - 11); E.G. Boring, "A History of experimental psychology", 2nd ed. (New York, 1950), P.308; Brett, op.cit., P.255.
17. HELMHOLTZ, op.cit., English trans. (1925) vol. III, P.360
18. E.G. see M. POSNER & R.F. Mitchell, Psych. Rev., 74, 342 (1967)
19. ALHAZEN, op.cit, bk.1, chap. 3, cited in Ronchi, op.cit. 48; Boring, op.cit, P.165
20. Ibid., chap. 1, sec. 2. Cited in Ronchi, op.cit. P.47.