
Alhacen's Theory of Visual Perception: A Critical Edition, with English Translation and Commentary, of the First Three Books of Alhacen's De Aspectibus, the Medieval Latin Version of Ibn al-Haytham's Kitāb al-Manāẓir by A. Mark Smith

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Before launching into a review of this fine edition, a brief discussion of the name 'Alhacen' is in order. Most scholars are used to seeing the Latin form of the name of the Arab scientist, Abū ʿAlī al-Ḥaṣan ibn al-Ḥaṣan ibn al-Haytham, or Ibn al-Haytham, as 'Alhazen'. But, as Professor Smith argues, Alhacen is an attested form in the Latin, and is closer to al-Ḥaṣan, one of his names (as long as the 'c' is given a 'soft' 's' sound). In fact, according to Smith, the form 'Alhazen' does not appear later, and seems to originate with Risner [1572] in his edition of the *Optica*. Though as an Arabist I would prefer to refer to Alhacen as Ibn al-Haytham, for the sake of consistency and in harmony with Smith's edition, I shall refer to him as Alhacen throughout.

Professor Smith has been active in the field of the history of optics since at least the 1980s. He has published several excellent articles and editions and is certainly well-qualified to produce the present edition. The *De aspectibus* is a large work: the present edition is the first of four planned installments.

Smith's edition contributes to our understanding of the development of optics, a discipline of immense importance in the history of science. The authoritative edition of the Arabic text of the *Kitāb al-Manāẓir* [Sabra 1983] as well as a translation therefrom has long been available [Sabra 1989]. Yet, for detailed study of how this important text impacted Western Latin scientists, the present Latin

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edition is indispensable. Few scholars, even historians of science perhaps, realize the important role that the science of optics has played in the development of the modern scientific way of thinking. As has been cogently argued in several books and articles [see Edgerton 1975, Damisch 1987, Kemp 1990] the science of optics led *via* a correct understanding of the observer's role in vision as well as *via* the creation of linear perspective to a new way of seeing the world, an objective way of distancing oneself from the object of investigation. The development of the capacity to represent things realistically in space contributed to the capacity to visualize and objectify physical objects, which in turn led to the capacity to think in a scientifically objective manner.

Furthermore, the work of Alhacen (*ca* 965–1039) forms a nexus between the science of the ancient Greeks and the Latin scientists of the late Middle Ages. Alhacen's scientific contribution gives the lie to the (not yet extinct) view that Arabic scientists merely preserved the Greek 'legacy', adding nothing original. Here is a clear example of how a scientist from the Arabic-speaking world did more than merely serve as an intermediary between the Greeks and the West in the period before the scientific revolution. We can observe vividly how Alhacen has critiqued the optical theory of each of his Greek predecessors, refuted the dominant ancient view, and created a whole new theory on the basis of retainable elements from the old, a theory that was to survive, in its essentials, until the work of Johannes Kepler.

In this review, I shall discuss Alhacen's treatise and place it within the history of the scientific tradition. I shall draw upon material from Professor Smith's edition, as well as other primary and secondary sources. For the general historical account of optics, I rely on the unsurpassed work of David Lindberg [1976].

In antiquity, visual theory assumed two fundamental and mutually exclusive forms: (1) intromissionism, in which rays (or corpuscles) from the object were thought to enter the eye and produce a sensible impression; and (2) extramissionism, according to which view percipient rays are emitted from the eye to touch the object and carry the perception back to the eye. Several of the greatest ancient thinkers, as well as thinkers in Islam prior to Alhacen, had produced treatises arguing for one position or the other. The issue

was not decided until Alhacen; and then, in the *De aspectibus*, it was resolved irrevocably in favor of intromissionism. Alhacen had much to say in critique of the theories of his Greek predecessors. I shall present a brief historical survey here.

The Greek Atomists were the first to require direct contact between the eye and the object of vision. Accordingly, they suggested that objects radiate corporeal images of themselves that stream through space to enter the eye of the observer. This theoretical perspective received its most mature expression in Lucretius [cf. *De rer. nat.* 4.54-61]. There are many problems with this view that did not pass unnoticed. The most egregious of these is how objects larger than the eye, such as a mountain, can enter the much smaller eye. Alhacen produced several strong arguments against the corporeality of the visual rays.

Plato was the first to mention visual rays emanating from the eyes, a kind of fiery ray that combines with light and rays from the object to produce vision. But his 'theory' must be reconstructed from scattered references throughout the dialogues [cf. *Tim.* 45b-d, *Resp.* 507d-508c]. Although the extramissionist view may seem absurd to us, it actually was a reasonable attempt to account for such things as the apparent glow from the eyes of certain nocturnal creatures in the dark, and the fact that the eyes are the 'agents' of vision, as well as the apparent emotive (or magical) power of certain glances. Alhacen's thorough refutation of extramissionism, as explained below, must rank among his greatest achievements.

In his *De anima* and *De sensu*, Aristotle provided the first complete theory of vision. In establishing this theory he rejects all earlier views, especially the absurdities of an extramitted visual ray: after all, how could such a ray extend all the way to the distant stars to render them visible? Instead, he focused on the visual medium which must be activated by light for vision to be possible. Furthermore, color transforms the medium. The watery substance of the eye then assumes the qualities of the object that are transmitted instantaneously through the transparent medium. But, as Alhacen points out, Aristotle's view does not permit the eye to distinguish directions, since the whole medium is affected by every quality.

The Stoics introduced the idea of a vision-producing pneuma or airy substance which passes between the eyes and the brain and

transforms the medium between observer and object to make the medium itself percipient. Galen adapted these ideas and cloaked them in physiology and anatomy, especially the idea that the transparent medium becomes an extension of the observer's visual apparatus. Two of the most important optical ideas of Galen's passed to his successors were that the optic nerves convey the pneuma, and that the crystalline lens is the main organ of vision [cf. Galen, *De plac. Hipp.* 7.5–7: see de Lacy 1978–1984].

The first comprehensive mathematical treatment of vision was produced by Euclid, who structured his *Optica* [Heiberg 1895] around postulates and theorems, like his better-known *Elements*. Euclid's treatment, unlike that of Aristotle and Galen, is completely lacking in physical, physiological, or psychological aspects of vision, since his chief concern was with perspective, or the way an object appears in relation to an observer. Furthermore, Euclid presented this mathematical theory in terms of the extramitted visual ray.

The primary source of Alhacen's optical knowledge, however, was the second century Alexandrian scientist, Ptolemy [see Smith 1990]. Ptolemy's *Optica* [Lejeune 1956] was the culmination of classical optics, since he was able to rectify problems in the Euclidean account and to integrate the mathematical approach with psychology and physiology [see Smith 1998a]. Ptolemy also provided the classical formulation of the 'visual cone', a bundle of visual rays centered in the eye. Professor Smith has published detailed studies of Ptolemy's optical theory, experience that undoubtedly was of great assistance in preparing the edition of the *De aspectibus* [Smith 1996, 1999].

In the Islamic world, several thinkers appropriated and amplified the Greek optical tradition. Al-Kindī (d. ca 866) was a staunch defender of extramissionism, and his greatest achievement in this field was to produce a version of Euclidean optics that was freed from its inconsistencies, much as al-Kindī contributed two ideas that would be pivotal to Alhacen's approach: (1) 'punctiform analysis' (Lindberg's term), or the idea that there is a point-to-point correspondence between each point on the object and each point on the cornea; and (2) the idea that the central ray of the visual cone is the most powerful in conveying perception. In fact, Alhacen employed the technique of punctiform analysis to refute al-Kindī's extramissionism.

Several other Islamic thinkers contributed to the reception of Greek optical ideas and advanced the understanding of the relation between the physical and the physiological aspects of vision. These included: Ḥunayn ibn Iṣḥāq (d. 877), Avicenna (980–1037), and Averroes (1127–1198), although it is unclear how, if at all, they influenced one another. Ḥunayn took a Galenic perspective and formulated the anatomical understanding of the eye that was to persist for centuries. Avicenna and Averroes both defended the Aristotelian position, and Averroes managed to synthesize Aristotle's views with major elements of other existing theories. Yet, the grand synthesis was to be the work of Alhacen.

Alhacen's intellectual range, as evidenced in the list of his treatises and in the details of his extant works, is truly astounding. Yet, his greatest and most influential achievement was to integrate the anatomical, physiological, physical, and mathematical aspects of vision, in order to produce a kind of intromissionism that survived until Kepler. Earlier forms of intromissionism were inadequate, as he argued in detail, employing several ingenious experiments in thought as well as in fact. Several of Alhacen's optical treatises survive, of which the *Kitāb al-Manāẓir* (*De aspectibus*) is the most important [see, e.g., Sabra 2003]. The *Kitāb al-Manāẓir* (*Book of Optics* or *Treatise on Optics*) was completed between 1028–1038, and in less than a century and a half had appeared in Latin translation as *De aspectibus*, attributed to Alhacen.

Alhacen begins his analysis of vision by noting that bright lights and colors cause the eye pain. So, clearly the eye is receiving something from outside itself and emitting nothing. Extramissionism, as he argues in detail, has superfluous elements. If only the rays returning to the eye are needed; then, since the supposed emitted rays explain nothing, they can be discarded. This is a vivid example of an economy of explanation, often viewed as an application of 'Ockham's Razor'.

Ultimately, Alhacen supposes that each point of the object radiates in all directions and that some of these rays strike the cornea. To avoid the confused impression that would result from all these rays striking the eye at once, he supposes that only rays that strike the cornea at right angles are strong enough to make an impression. The rest are refracted away and weakened. The rays that pass through

the cornea are transmitted to the lens, which further transmits them as a bundle to the optic nerve. There are, however, problems with this view that were not resolved until Kepler derived his theory of the retinal image, the idea that every point of the object was mapped in a one-to-one way onto a reverse image of itself on the retina, which was the true image-sensitive part of the eye [see Lindberg 1986, Smith 1998b].

Alhacen's theory had tremendous influence on western optical theorists such as Roger Bacon, Witelo, John Pecham (among many others), and ultimately Johannes Kepler (1571–1630), who published what is an essentially modern understanding of the eye in his *Ad Vitellionem paralipomena* of 1604 [Donahue 2000]. Conducting simple experiments and calculations, Kepler discovered that the eye's 'crystalline humor' was only a biconvex lens that refracts light, and not the percipient organ as his predecessors had thought. This lens works in conjunction with the cornea to focus incoming light rays on the retina, producing an upside-down image. Kepler was able to demonstrate the causes of myopia, or near-sightedness, and why spectacles could correct the condition.

Smith's edition is in two volumes, the first containing the Latin text of the *De aspectibus* as well as a very helpful historical and textual introduction, and the second containing the English translation. There are other scholarly aids, such as the Latin-English index, and the English-Latin glossary. Each section of the translation has detailed notes explaining passages. I have only one minor criticism. In my opinion as a publisher of the series, The Graeco-Arabic Sciences and Philosophy (Brigham Young University Press, 1999–), I find that a bilingual, facing page edition, though slightly more difficult to produce, is ultimately more satisfactory than dividing a text between two volumes, one for each language. But overall, the present edition has much to recommend it. Numerous helpful diagrams are interspersed within the text. Professor Smith has explained in detail his editorial procedures: that, taken together with his carefully constructed textual apparatus, ensures that we are in a position to understand the character of the edited text. This edition of the *De aspectibus* will likely serve generations of scholars and students seriously interested in understanding the history of optics, perspective, and visual theory.

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