The Sensory Core and the Medieval Foundations of Early Modern Perceptual Theory

By Gary C. Hatfield and William Epstein***

IN THE EIGHTEENTH and nineteenth centuries the majority of theories of visual perception were built upon the view that during the process of vision there occur two conscious states with quite different phenomenal properties. The first state is a mental representation of the two-dimensional retinal image. The second is our experience of the "visual world" of objects distributed in depth. According to the then commonly accepted theory, the mental correlate of the retinal image is the truly immediate component of perception, and it provides the raw material from which the mind generates the three-dimensional visual world. Yet this retinal correlate—the "sensory core"[1] of the perceptual process—typically goes unnoticed, and the percipient takes his experience of the three-dimensional visual world to be direct and unmediated.[2] Although it may seem odd that an unnoticed state of consciousness should be viewed as the psychologically fundamental component of the visual process, that which we have labelled the "sensory core" has played a central role in visual theory since Berkeley drew his celebrated distinction between the immediate

*Department of the History of Science, University of Wisconsin, Madison, Wisconsin, 53706.
**Department of Psychology, University of Wisconsin, Madison, Wisconsin, 53706.

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[1]We have chosen to use the term "sensory core" to refer to a conscious state with the phenomenal properties of the retinal image, without arousing unwanted connotations about its psychological status (as, say, a form of experience produced by a special attitude) and without implying anything further about its epistemological status (as, say, an incorrigible "given"). Our "sensory core" shares the phenomenal properties of James Gibson's "visual field" (*The Perception of the Visual World,* Boston: Houghton Mifflin, 1950, Ch. 3). Our usage of the term "sensory core" is parallel to E. G. Boring's "core" of perception ("The Perception of Objects," in Herschel W. Leibowitz, *Visual Perception,* New York: Macmillan, 1965, pp. 67–85, on pp. 69–70), a term which he derived from E. B. Titchener. Our usage does not correspond to Roderick Firth's (pp. 216–219 of "Sense-data and the Percept Theory," in R. Swartz, ed., *Perceiving, Sensing and Knowing,* Garden City: Doubleday, 1965, pp. 204–270), but our "sensory core" shares the phenomenal properties of the "sense-data" he attributes to Locke and Berkeley (pp. 215–216).

[2]The 18th-century philosopher Thomas Reid summed up this position well in his discussion of "visible appearances" (his name for the sensory core). After remarking that these appearances "are never made the object of reflection, though almost every moment presented to the mind," he explained that "the mind has acquired a confirmed and inveterate habit of inattention to them; for they no sooner appear, than quick as lightning the thing signified [a solid object] succeeds, and engrosses all our regard. They have no name in language; and, although we are conscious of them when they pass through the mind, yet their passage is so quick and so familiar, that it is absolutely unheeded; nor do they leave any footsteps of themselves, either in the memory or imagination"; Thomas Reid, *An Inquiry into the Human Mind* (4th ed.; Edinburgh, 1785), Ch. 6, Sec. 3, in his *Works,* 2 vols., ed. William Hamilton (Edinburgh, 1863), Vol. I, p. 135. Reid's views were not anomalous; Nicholas Pastore, *Selective History of Theories of Visual Perception* (New York/London: Oxford University Press, 1971), esp. Chs. 1–10, has shown that the concept of a mental representation of the retinal image was a central theme in 18th- and 19th-century perceptual theory.

and mediate objects of vision. This paper will explore the theoretical context within which the notion of a sensory core developed.

Historically, the motivation for assigning the sensory core a content distinct from the visual world has come from geometrical optics. Unless it were believed that the spatial properties of objects as represented in the sense organ (say, by the retinal image) are different from the spatial properties of objects themselves, there would be no reason to question that perception of the visual world is simply a matter of directly apprehending the optical stimulation available at the retina. Consider the perception of a circle oblique to the line of sight. The circle projects an ellipse on the retina, yet a slanted circle is manifest in the visual world; the sensory core, in representing the retinal projection, thereby differs from the phenomenally direct apprehension of the circle. The postulation, on optical grounds, of a difference between the spatial attributes of objects themselves and the representation of those attributes in the stimulus pattern is logically anterior to the concept of sensory core, for without the supposition of such a difference, mere reception of the stimulus (which would now be assumed to share the spatial attributes of the seen object) could be viewed as adequate for perception of the spatially elaborated visual world. However, adherence to this optical distinction (between an object and its retinal projection) is not *sufficient* motivation for the postulation of two phenomenally distinct conscious states (the sensory core and the visual world). For one thing, it might be maintained that the phenomenal character of everyday experience in fact corresponds to the spatial features of the retinal projection; this would amount to denial, on phenomenological grounds, that there is a visual world distinct from the sensory core. Or some other kind of two-stage theory might be maintained, for instance, that the stimulus representation (the retinal projection) never enters consciousness, but, say, is processed into the visual world through physiological mechanisms.[3] Indeed, a survey of the history of the psychology of vision would reveal that theories of vision in which a sensory core is postulated are but one species of two-stage theories of vision, and that an initial stage in which spatial properties of objects are represented as they are projected upon the retina may be postulated without it being supposed that this initial stage is consciously accessible. In any event, it can be seen that a second precondition of the distinction between the sensory core and visual world is the conjunction of the following two beliefs: (1) that a projective representation enters consciousness, and (2) that nevertheless we typically do apprehend (in a phenomenally direct manner) the objective spatial properties of objects.[4]

Our paper will focus upon medieval and seventeenth-century theories of vision, culminating in the work of Berkeley. Thus, even though the concept of sensory core derives its historical significance from its widespread employment during the eighteenth and nineteenth centuries, the historical situation has dictated that we focus upon an earlier period, since the concept whose development we wish to understand has its foundations in an optical tradition stretching back to Greek antiquity and including both Arabic and medieval Latin components. Our investigations have led us to believe that the development of this concept resulted from alteration within,

[3]These "physiological mechanisms" are to be understood as noncognitive; another possibility, one that we shall invoke below, is that the projective pattern is represented and processed cognitively, but that these cognitive operations are not even in principle available to consciousness.

[4]The importance of these two notions in 18th- and 19th-century visual theory is evident from Pastore, *Selective History,* pp. 11–13 and 178–181.

rather than the radical overthrow of, the psychology of vision as it had come to be conceived in this optical tradition. If our interpretation is correct, it was not a change in the theory of the psychology of vision that engendered the idea of a sensory core, but rather the introduction of the theory into a new metaphysical context.

ANCIENT AND MEDIEVAL OPTICS AND THEORY OF SPATIAL VISION

The discovery that the three-dimensional attributes of objects are not represented in the sense organ in a direct or simple manner was not trivial. In several types of ancient visual theory, no difference was postulated between the spatial properties of objects and those of the optical stimulus, because it was believed that the stimulus to vision shares the attributes of the seen object. According to the extramissionist position, vision proceeds from the eye to the object, and the properties of the object are known by direct contact. Galen and some of the Stoics shared the view that something is extramitted from the eye into the air, transforming the air into an instrument of sensation (standing in relation to the eye as a nerve to the brain) and thereby allowing for direct apprehension of the object's spatial properties. For intromissionist theories, something proceeds from object to eye and represents the object to the sensitive soul. The *eidolon* of the ancient atomists, a film of atoms emitted from the surface of the object, was conceived to convey a three-dimensional representation of that surface directly to the sense organ and through the optic nerve to the soul.[5] According to the theories considered so far, whether the eye reaches out to the object itself, or something comes to the eye and stands for the object, the spatial attributes of the thing that is sensed are identical to those of the object.[6]

The ancient writers just considered were concerned either with explaining the physical process of perception (perhaps in the service of epistemology) or with providing a description of the optical process for medical purposes. There was a third tradition in antiquity, in which geometry was employed in the analysis of vision.[7] This tradition, whose most prominent members were Euclid and Ptolemy, provided a geometrical analysis of the field of vision in terms of a visual pyramid formed by rays extramitted from the eye to points on seen objects. According to this analysis, information about the viewer-relative situation of objects with respect to the horizontal and vertical dimensions is provided by the ordering of the rays within the visual pyramid to the right or left of one another and above or below one another. Information about distance is provided by the length of each ray from the eye to the object. In other words, to each of the three dimensions of Euclidean space there

[5] For a summary of the theories mentioned in this paragraph, as well as other ancient theories, see David C. Lindberg, *Theories of Vision from al-Kindi to Kepler* (Chicago: University of Chicago Press, 1977), pp. 2–11, and the bibliographical references mentioned there.

[6] The idea that the eye receives three-dimensional copies of objects has its attractions, and as late as 1823 C. J. Lehot, in his *Nouvelle théorie de la vision* (Paris, 1823), put forth the theory that "the points of the luminous cones which penetrate the eye form, in the vitreous humor, at a certain distance from the retina, images in three-dimensions, and vision is effected by the perception of these images," the vitreous humor being the sensitive portion of the eye (Pt. I, pp. 42–43). Conversely, the idea that a mere image might be sufficient for the apprehension of the three-dimensional world has obvious difficulties, and in antiquity the equivocality of images for size and distance was used as an argument against the view that the proper object of vision is an image: Theophrastus, *On the Senses,* trans. George M. Stratton, in *Theophrastus and the Greek Physiological Psychology before Aristotle* (New York: Macmillan; London: Allen & Unwin, 1917), pp. 97–99 (the image in question was the pupillary image).

[7] On the division of ancient optical thought into these three traditions, see Lindberg, *Al-Kindi to Kepler,* p. 1.

corresponds a dimension of the visual pyramid.[8] It follows that if a percipient is to receive determinate information concerning the spatial features of a seen object, all three of the dimensions of the visual pyramid must be apprehended. Thus the objective size of an object is inadequately represented by visual angle; distance, the third dimension in the visual pyramid, must also be taken into account.[9] A similar point may be made about shape. The relative order within the visual pyramid of those rays that meet the edges of the object does not bear determinate information about the object's shape; information about the lengths of these rays is also required.[10] Here then is the sort of optical distinction between elements in the optical pattern (visual angle, projective shape) and properties of objects themselves (size, shape) that is logically prerequisite to the idea of the sensory core.

The observation that information about the lengths of the rays is required for the discrimination of size and shape is not present in Euclid's *Optics*. It is, however, present in Ptolemy, who went beyond the geometry of the relationship between eye and object to concern himself with the actual processes—physical, physiological, and psychological—that occur during vision.[11] Following Aristotle and others, Ptolemy held that light and color are the proper objects of vision and that the mediate objects of vision—size, shape, location, motion, and rest—are discriminated through the differentiation of light and color.[12] Yet as we have seen, mere differentiation within the ordering of the rays forming the visual pyramid would not be sufficient for the apprehension of size and shape (and the same holds for location and motion). Ptolemy was not only aware of this geometrical fact, but he also realized that despite the inadequacy of, say, visual angle for size, observers typically do apprehend objective size.[13] Hence he recognized not only an *optical* distinction between objective size and visual angle, but also a *psychological* distinction between the discrimination of visual angle and the visual apprehension of size. Moreover, he gave a psychological explanation (albeit a very sketchy one) of the process by which distance and visual angle are conjoined in size perception. Lejeune has characterized Ptolemy's view as follows: "The information furnished by visual angle is not accepted in its 'raw' form. Long practice has accustomed us to make an appropriate estimate of the effects of the distance and obliquity of an object upon its apparent size, and we manage to restore the true size of the object."[14]

One might wonder what led Ptolemy to characterize the psychological processes involved here as an estimation (*existimare*), and whether the observer is conscious, or at least potentially conscious, of the elements (distance and visual angle) upon which

[8] Ptolemy, *Optica* II 26, ed. A. Lejeune, *L'optique de Claude Ptolémée dans la version latine d'après l'arabe de l'émir Eugène de Sicile* (Louvain: Bibliothèque de l'Université, 1956), p. 25. Euclid, *L'optique et la catoptrique,* trans. P. Ver Eecke (Paris: Albert Blanchard, 1959), pp. 1–2. Euclid does not consider the lengths of the visual rays, but only their ordering within the visual pyramid. Cf. A. Lejeune, *Euclide et Ptolémée, deux stades de l'optique géométrique grecque* (Louvain: Bibliothèque de l'Université, 1948), pp. 89–95.

[9] Ptolemy, *Optica* II 63, ed. Lejeune, pp. 45–46; cf. Lejeune, *Euclide et Ptolémée,* pp. 95–101.

[10] *Ibid.,* 64–73, ed. Lejeune, pp. 46–50; cf. Lejeune, *Euclide et Ptolémée,* pp. 103–107.

[11] As far as can be determined, Euclid intended his work to present geometrical optics in a way that would be of use to scenographers. Lejeune says that the *Optics* of Euclid is "no more than a treatise on perspective. It systematically ignores every physical or psychological aspect of the problem of vision" (*Euclide et Ptolémée,* p. 172, cf. pp. 93–95). E.g., as far as vision was concerned, Euclid identified size with visual angle (*L'optique,* trans. Ver Eecke, Props. 2–8, pp. 2–7). Lejeune stresses Ptolemy's concern for the physiological and the psychological as a way in which optics had progressed since Euclid (*Euclide et Ptolémée,* pp. 172–177).

[12] Aristotle, *De anima* 418a 9–30. Ptolemy, *Optica* II 6–11, ed. Lejeune, pp. 13–16.

[13] Ptolemy, *Optica* II 52–63, ed. Lejeune, pp. 38–46.

[14] Lejeune, *Euclide et Ptolémée,* pp. 96–97.

the corrective estimations operate. Lejeune has concluded that Ptolemy "did not consider this operation as a judgment fully conscious and distinct from sensation itself,"[15] a turn of phrase that brings to mind the unnoticed judgmental processes described by latter-day theorists. It would, however, be hasty to identify Ptolemy's theory with more recent theory in all its essentials.

Between the time of Ptolemy and the seventeenth century, the most significant contribution to visual theory was that of the Islamic natural philosopher Alhazen (c. 965–1039). He made the intromissionist theory viable by applying ray geometry to the problem of how the eye receives a spatially coherent impression despite the fact that each part of the eye is bombarded by entities transmitted from every part of the visual field. In addition, Alhazen integrated his theory of geometrical and physiological optics into a detailed account of the physiology and psychology of vision, including a thorough treatment of spatial vision.[16] Each of these achievements is germane to our inquiry.

Alhazen's establishment of a geometrical basis for the intromission theory depended upon his argument that the arrangement of points in the field of vision is reproduced in the physiological process generated at the crystalline humor (which he, in the tradition of Galen and Ptolemy, considered to be the seat of vision) by incoming radiation. Essentially he adapted the visual pyramid of Euclid and Ptolemy to the intromissionist position. For Alhazen, the pyramid consists of those rays that fall at right angles to the surface of the crystalline humor.[17] As in the theory of Euclid and Ptolemy, the pyramid has its base on the objects in the field of view and its vertex in the eye; unlike the previous theory, the direction of the rays is from object to eye. A cross-section of the pyramid is physiologically received by the crystalline humor through an act characterized as a "sensing." Of the luminous rays received at the surface of the crystalline, only the luminosity and color of each ray—and not the arrangement of the rays or the spatial information conveyed by that arrangement—is sensed by the eye itself.[18] This act of sensing occurs through an alteration produced by each luminous ray in the "visual spirit" present in the crystalline humor, whereby the visual spirit takes on the *form* of light and color.[19] The alteration suffered by each punctiform area is transmitted, by a "quasi-optical" process involving refraction and

[15] *Ibid.,* p. 99.

[16] For an evaluation of Alhazen's role in the development of optical theory, see Lindberg, *Al-Kindi to Kepler,* Ch. 4. On the physiological and psychological aspects of Alhazen's theory, see A. I. Sabra, "Sensation and Inference in Alhazen's Theory of Visual Perception," in *Studies in Perception,* Peter Machamer and Robert Turnbull, eds. (Columbus: Ohio State University Press, 1978), pp. 160–185. In constructing our summary of Alhazen's views we have used these authors as a guide to Alhazen's *De aspectibus* (esp. Bk. I, Secs. 16–19 and Bk. II, Secs. 1–41, ed. Friedrich Risner, *Opticae thesaurus Alhazeni Arabis libri septem,* Basel, 1572, pp. 8–12, 24–57; all subsequent references are to this edition, which has been reprinted, New York: Johnson Reprint, 1972).

[17] The perpendicular is selected from the sheath of rays converging on a single point of the crystalline by a *weakening* of all but the unrefracted (perpendicular) rays, or by a *special receptivity* of the crystalline to perpendicular rays (Lindberg, *Al-Kindi to Kepler,* pp. 75–78; Sabra, "Sensation and Inference in Alhazen," pp. 165–166).

[18] Alhazen, *De aspectibus,* Bk. II, Sec. 6, pp. 26–27. Cf. H. Bauer, "Die Psychologie Alhazens," *Beiträge zur Geschichte der Philosophie des Mittelalters,* 1911, *10* (5): 29–32, and Sabra, "Sensation and Inference in Alhazen," pp. 173–174. Alhazen thus adopted the traditional view that light and color are the proper objects of vision (Bk. II, Secs. 17–18, p. 35).

[19] Alhazen adopts an Aristotelian view of the reception process; Aristotle had maintained that the sense organ accepts the *form* (in this case color) of the sensible thing without the matter, thereby taking on the properties of the sensible thing (cf. Lindberg, *Al-Kindi to Kepler,* pp. 8–9 and 78–79). Incidentally, the term "visual spirit" refers to a substance that serves as the soul's agent in the eye; it is not a "spiritual" (ghostlike) substance (Alhazen attributes density to it), but neither is it the inert matter of Descartes' "animal spirits," since it is endowed with sentience.

rectilinear transmission, from the crystalline humor through the vitreous humor and down the optical medium residing in each of the optic nerves (which were believed to be hollow and filled with visual spirit).[20] This process is described as the transmission of a coherent "form"—bearing point-for-point correspondence to the objects in the field of vision—from the surface of the crystalline through the eye and optic nerve. In the optic chiasma the separate transmissions from each eye join to form a single impression, and this unified punctiform representation of the field of vision is received by the *ultimum sentiens,* the faculty of sense that completes the act of vision.[21]

The *ultimum sentiens* avails itself of the spatial information present in the cross-section of the visual pyramid in order to apprehend the objects of vision other than light and color (Alhazen listed twenty such objects in all, including spatial properties such as size, shape, solidity, and motion).[22] However, as the geometry dictates, the arrangement of points within the cross-section provides direct information about only two dimensions: the third dimension, depth or distance, is lacking.[23] In fact, Alhazen embraced the intromissionist counterpart of Ptolemy's geometrical observation that elements of the visual pyramid such as projective shape are indeterminate for objective properties such as shape. He was aware that a circle oblique to the line of sight would produce an elliptical pattern at the surface of the crystalline, and that visual angle does not specify the objective size of an object (distance, too, must be taken into account). Furthermore, and of greater interest for our story, Alhazen saw that an account was needed of the phenomenological fact that we typically apprehend circles as circles, even though they are oblique to the line of sight, and that we typically are able to discriminate the sizes of objects, even though this discrimination requires taking distance into account.[24] His viewpoint thus included the two notions which historically have been associated with the concept of sensory core, that spatial properties as received at the eye (e.g., an ellipse) differ from objective properties (e.g., a rotated circle), and that we nonetheless apprehend the latter. In essence, we may say that Alhazen realized that a mere understanding of the geometry of visual stimulation is not sufficient to explain the perceptual achievements of the human percipient:

[20] The transmission within each eye proceeds rectilinearly, with one refraction at the posterior edge of the crystalline; this refraction, which is toward the normal (and hence away from the optic axis), serves both to keep the rays from crossing (which would produce an inverted ordering) and to direct the rays toward the opening of the optic nerve (which was thought to be centered at the rear of the eye, along the axis of vision). Because of the special efficacy of the visual spirit, within the optic nerve the transmitted entity follows the path of the nerve without its ordering being affected. Lindberg, *Al-Kindi to Kepler,* pp. 69–85, provides a thorough treatment of the physiology of this process; cf. Sabra, "Sensation and Inference in Alhazen," pp. 166–168. Figure 1 (below) illustrates the path of transmission according to a follower of Alhazen.

[21] Alhazen, *De aspectibus,* Bk. II, Secs. 1–6, pp. 24–27. The reception of the forms of light and color by the opaque body of the *ultimum sentiens* in the optic chiasma occurs by an "illumination" and "coloring" of this body (Sec. 6, p. 27).

[22] *Ibid.,* Sec. 15, p. 34. Additional objects of vision, or "intentiones visibiles," include number, similarity, and beauty.

[23] *Ibid.,* Sec. 24, p. 39: "Remotio rei visae non comprehenditur per se." Especially telling is Alhazen's treatment of the perception of solidity (or corporeity), in which he says that vision immediately apprehends the longitude and latitude of bodies opposite the eye, but not the third dimension: "visus . . . comprehendet statim extensionem illius corporis secundum longitudem & latitudem, & non remanet nisi dimensio tertia" (Sec. 31, p. 47). Cf. Bauer, *Die Psychologie Alhazens,* pp. 55–56.

[24] Alhazen clearly states that any pair of diameters on a circle are seen as equal even when the circle is oblique to the line of sight (*De aspectibus,* Bk. II, Sec. 36, p. 51). With respect to size, he says "virtus distinctiva distinguet quantitatem rei visae, non considerabit angulum tantum, sed considerabit angulum & remotionem simul" (Sec. 38, p. 51; on the *virtus distinctiva,* see below).

psychological processes must also be invoked. While this realization was also implicit in Ptolemy, Alhazen went further in developing an account of these psychological processes.

Since, on Alhazen's account, only a two-dimensional arrangement of luminous points is represented in the cross-section of the pyramid transmitted to the *ultimum sentiens,* the apprehension of objects in three dimensions must involve more than the mere passive reception of the stimulation carried by the optic nerves. The activity by which the *ultimum sentiens* goes beyond the stimulation it receives consists of "reasoning" and "distinguishing" (*rationem* and *distinctionem*); these judgmental activities are performed by the *virtus distinctiva.*[25] Alhazen offered an extended treatment of the psychology of visual judgments, but it will suffice here to observe that in cases where the judgments are performed over and over again, the faculty of judgment need not go through the entire process of judging (by "iteration of arguments") each time it is confronted with a particular set of sensory data; rather it comes to perform these judgments through recognition (*cognitionem*) of significant features, or signs (*signa*), that lead it to assign a particular set of properties to the objects seen. Judgment by recognition takes place so quickly that we do not perceive that we judge.[26] It is in this way that distance, size, and shape are perceived. Distance is apprehended through a judgment of the number of regular-sized intervals composing the continuous ground space between the observer and the distal object, or, since the process occurs frequently, through a judgment by recognition.[27] From the distance to an object together with visual angle, the size of the object can be apprehended, again through judgment by recognition.[28] Similarly, apprehension of the distance to various points in the field of vision can be used to apprehend the solidity and shape of seen objects.[29] Thus, in general, according to Alhazen the visual apprehension of the spatial properties of the visual world is made possible by an unnoticed process of judgment.

The essentials of Alhazen's theory of vision are, in fundamental ways, parallel to those of the standard theory of the eighteenth and nineteenth centuries. First, pertaining to the effective stimulus for vision: while the two-dimensional array of light and color transmitted to the *ultimum sentiens* is not an optical image (such as the real image formed by a lens or the virtual image of mirror vision), the geometrical qualities it shares with the retinal image are striking (e.g., point-for-point correspondence with luminous points in the field of vision and ambivalence with respect to actual size). One might choose to characterize the physiology of vision according to Alhazen as the transmission of an "image" or "picture" of the objects in the field of vision through the optic nerve to the brain. Such a characterization would serve to emphasize that the immediate object of vision according to Alhazen shares the essential properties of what was taken to be the immediate object of vision by Kepler:

[25] *Ibid.,* Sec. 10, pp. 30–31.

[26] Sabra, "Sensation and Inference in Alhazen," pp. 171–179, gives a thorough account of Alhazen's statements on perceptual judgment in general (*De aspectibus,* Bk. II, Secs. 10–12, pp. 30–32), but does not deal with particular cases such as distance, size, or shape. Our discussion of these cases is of course not exhaustive, and a thorough treatment of Alhazen's psychology of vision is much needed.

[27] Alhazen's discussion of the apprehension of distance is long and complex (involving a distinction between the apprehension of mere outness as opposed to location, Bk. II, Secs. 23–24, pp. 38–39); we have focused upon the apprehension of the amount of distance for moderate distances, in which case distance is apprehended "per cognitionem" (Sec. 25, pp. 39–42; Secs. 39–40, pp. 53–56).

[28] *Ibid.,* Sec. 38, pp. 51–53.

[29] *Ibid.,* Secs. 31, 36, pp. 47–48, 50–51.

an arrangement of points of light and color reproducing the two-dimensional arrangement of points in the field of vision.[30]

But it is with respect to his thoughts about the psychological processes that occur during spatial vision that Alhazen's theory exhibits the most striking resemblance to later theory: distance is not immediately perceived (i.e., is not perceived by sense alone) but is apprehended by means of a judgmental act; size is apprehended by means of a judgment that takes distance into account; a circle oblique to the line of sight is perceived to be a circle through a judgment concerning the distance to various parts of the circle. And so it is not surprising that Bauer, in his 1911 study of Alhazen's psychology, remarked that in the field of spatial perception Alhazen "touched upon a series of the most important psychological problems, and his explanations anticipate in a surprising manner thoughts that were again taken up only in the most recent development of psychology."[31] Bauer drew particular attention to what he characterized as Alhazen's theory of "unconscious inference,"[32] a term that immediately calls to mind Helmholtz's nineteenth-century version of the psychology of unnoticed judgments. Is it true then that all of the central elements of later psychology of vision were present in Alhazen (or perhaps even Ptolemy)?

The one element not clearly present is the sensory core, where the referent of this term is taken to be a consciously accessible representation of the field of vision in two dimensions. The difficulty in deciding whether Alhazen (or Ptolemy)[33] employed the concept of sensory core lies deeper than a simple failure of these authors to state clearly an opinion on the matter. To ask whether sensory stimulation is, at a particular point in the process of vision that begins with the reception of light at the eye and ends with an experience of the visual world, experienceable or not, is to ask a question that makes sense only within certain intellectual frameworks. Among many authors in the seventeenth and eighteenth centuries, to ask this question would have been to ask whether something was an *idea,* since ideas were the only legitimate objects of awareness. It is not clear what the medieval equivalent to this question would have been. This lack of clarity probably results from the fact that in the psychology of the Middle Ages (at least as manifested in the optical tradition) there was no clear distinction between the physiological and the mental. As Bauer has remarked, for Alhazen and other Arabic as well as Latin authors (who were following Aristotle in this regard), the mental was not limited to the conscious.[34] Thus if we ask whether the "sensing" of light and color by the eye and the "judging" of the pattern of stimulation by the *virtus distinctiva* are physiological or mental events (where these terms are restricted to something close to their modern significations), the answer comes out as a confused "both," or perhaps "neither." They are like mental events insofar as they are described in the mentalistic language of sensing and judging.[35] Yet

[30] Lindberg has especially emphasized the degree to which Kepler's optical work remained within an intellectual framework provided by Alhazen (*Al-Kindi to Kepler,* p. 86). Incidentally, a second feature of standard post-Keplerian theory is found in Alhazen: the independent transmission of points of stimulation from the receptive surface of the eye into the brain, which is a key feature of the so-called "constancy hypothesis" (on the importance of this hypothesis in the history of perceptual theory, see Pastore, *Selective History,* pp. 11–12 and *passim*).

[31] Bauer, *Die Psychologie Alhazens,* p. 54.

[32] *Ibid.,* pp. 56–57.

[33] See Lejeune, *Euclide et Ptolémée,* p. 99, for the ambiguities in Ptolemy on this point.

[34] Bauer, *Die Psychologie Alhazens,* p. 11.

[35] Alhazen remarks that the rational processes by which the act of vision is completed are of the same type as other rational processes, but that we are able to ascertain this only through a second reasoning process, which is a reasoning about the reasoning that occurs during vision (*De aspectibus,* Bk. II, Sec. 13, pp. 32–33). But Alhazen's view that the rational processes in vision are properly cognitive processes is, of

they are like physiological events in that they take place at early or middle stages in the chain of physio-psychological processes that proceed from the eye toward the central cavities of the brain. Our intuition that events characterized as mental (described in mentalistic language) should be accessible to consciousness is not fulfilled. One is led to believe that the attempt to apply the modern categories "physiological" and "mental" to medieval visual theory is misguided.

In sum, the explanation of spatial vision provided by Alhazen (and, to a lesser extent, Ptolemy) contained the central features of the standard eighteenth- and nineteenth-century explanation. Included in Alhazen's theory was an optical distinction between objective spatial properties and spatial properties as received at the sense organ, as well as a physio-psychological distinction between spatial properties as represented in the sensory processes transmitted from the eye to the brain and spatial properties as apprehended in experience. If, despite the parallels between his explanation of vision and that of later thinkers, Alhazen did not employ the concept of sensory core, the reason is to be found in his conception of mind, rather than in factors internal to his theory of vision.

VISUAL THEORY AFTER ALHAZEN

Alhazen's major work on vision was available in translation to the Latin West by the early thirteenth century; his theory and its derivatives dominated optical science until the time of Kepler. A rapid survey of the relevant texts has suggested that with respect to the psychology of vision, Alhazen's chief followers in the West—Bacon, Pecham, and Witelo—were in fundamental agreement with the master: "no visible intention except light and color is perceived by sense alone";[36] distance from the observer to the visual object "is not perceived by sight, but is determined by reasoning";[37] indeed, all of the objects of vision except light and color "are apprehended not by sense alone but by the cooperation of argumentation and the discriminative faculty, intermingled almost imperceptibly."[38] As is illustrated by Figure 1, taken from Witelo but representative of Pecham and Bacon (and Alhazen as well), there was similar agreement on matters of ray geometry and the physiological process of transmission: vision takes place by a pyramid of rays reaching the eye (those rays received perpendicularly at the surface of the crystalline, which are represented in the diagram by the lines proceeding from *gbc,* the visual object, to each eye); a cross-section of this pyramid, the points of which stand in a one-to-one correspondence to points in the field of vision, is directed into the optic nerve by refraction of the rays travelling through the eye; and the impressions received by the two eyes are reduced to unity by being brought together in the nervous system (at *kad*).[39]

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course, not evidence that he believed the premises of those operations (the transmitted "form") were ever phenomenally accessible.

[36] John Pecham, *John Pecham and the Science of Optics: Perspectiva communis,* ed. and trans. David C. Lindberg (Madison: University of Wisconsin Press, 1970), Bk. I, Sec. 61, p. 139.

[37] *Ibid.,* Bk. I, Sec. 63, p. 141; cf. Roger Bacon, *Opus majus,* Bk. V, Pt. 2, Dist. 3, Ch. 3, trans. Robert Burke (N.Y.: Russell and Russell, 1962), p. 523, and Witelo, *Perspectiva,* Bk. IV, Sec. 9 (ed. Risner, *Opticae thesaurus*), p. 121.

[38] Pecham, *Perspectiva communis,* Bk. I, Sec. 56, p. 137; cf. Bacon, *Opus majus,* Bk. V, Sec. I, Dist. 10, Ch. 3, and Witelo, *Perspectiva,* Bk. III, Secs. 60 and 63, pp. 111–113.

[39] Bacon, *Opus majus,* Bk. V, Pt. 1, Dists. 5 and 6, Ch. 2, pp. 449–453, 456–458; Pecham, *Perspectiva communis,* Bk. I, Secs. 32–38, pp. 117–123; Witelo, *Perspectiva,* Bk. III, Secs. 17–20, 37, pp. 92–94, 102–103. The diagram is from Witelo, *ibid.,* p. 103, where it is introduced in a discussion of binocular single vision. It is clear from the text on p. 102 that lines *gu* and *cx* should be directed toward the center of

Remarkable as it may seem, there was nearly complete agreement on the principles underlying Alhazen's theory of vision among post-Keplerian visual theorists, including Kepler himself. Of special interest to us is the continuation of Alhazen's treatment of the psychology of vision, which we will examine presently. But the principles of Alhazen's optical analysis were also continued. This is not to say that Kepler and his followers believed the crystalline humor to be the seat of vision—all of the writers we will discuss accepted Kepler's view that vision takes place by means of the retinal image. It is rather that in terms of the analysis of the effective stimulus for vision, it makes little difference if the seat of one-to-one correspondence is moved from the crystalline humor to the retina. Assuredly, the retinal image is inverted and is a true optical image, but these facts do not change the principle of one-to-one correspondence. Viewed in terms of the overall process of vision, the Keplerian lens system simply functions to establish a one-to-one correspondence in a fashion different from Alhazen's selective reception of rays perpendicular to the crystalline.[40] Moreover, the essential features of Euclid's and Ptolemy's geometrical analysis of the field of vision were applicable in post-Keplerian dioptrics. Particularly, the relationship between objective size and shape and optically received size and shape remained the same: the static retinal projection is indeterminate for the objective properties.

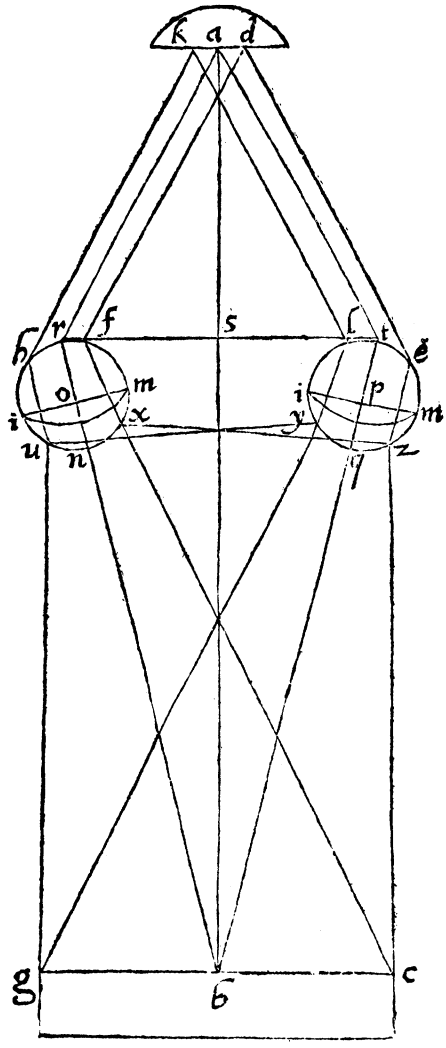

***Figure 1. The visual system according to Witelo. The visual object is represented by* gbc; *the optic nerves are represented schematically by* hrf-kad *and* lse-kad, *and* kad *is the* ultimum sentiens.**

The discovery of the retinal image did necessitate a change in the conception of the physiological transmission of stimulation from the eye to the brain. The notion that the stimulus to vision is an image formed across the posterior hemisphere of the eyeball is incompatible with the "quasi-optical" transmission of a cross-section of the visual pyramid directly into and through the optic nerve. Yet, as we shall see, the

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the eye *o*, and *gy* and *cz* should be directed toward the center of the eye *p*, in which case the lines would be received perpendicular to the surfaces *unx* and *yqz*. This inaccuracy also occurs in a 14th-century manuscript version of the drawing, reproduced in A. C. Crombie, "The Mechanistic Hypothesis and the Scientific Study of Vision: Some Optical Ideas as a Background to the Invention of the Microscope," in *Historical Aspects of Microscopy,* S. Bradbury and G. L'E. Turner, eds. (Cambridge: Royal Microscopical Society, 1967), pp. 3–112, Fig. 10.

[40] Kepler and later writers explicitly treated the lens system as a means of establishing a one-to-one

arrangements proposed by Kepler and his successors to effect his transmission did not deviate from the spirit of Alhazen's theory. Despite major alterations in the conception of the transmission process itself, the same characterization of post-ocular transmission as we have applied to Alhazen—the transmission of a "picture" or "image" through the optic nerve—remained applicable for at least two centuries after Kepler.[41]

Two views of post-retinal transmission are discernible in the seventeenth century. The first stems from Kepler himself. What Kepler did was to provide an interpretation of the transmission process that was consistent with his new understanding of the eye's structure and function but that remained within the ontological framework of the traditional physiology of nervous transmission. In both Kepler's account and the accounts of Alhazen and others, the key role in the reception of light and color and the transmission of the received impressions to the seat of visual judgment is played by "visual spirit."[42] Whereas for Alhazen the transmission could be seen as a direct extension of the received rays of light into and through the optic nerve, to Kepler it was clear that anything resembling an optical transmission had to end at the opaque surface of the retina. Kepler denied that visual spirit was an "optical body," but retained the view that the image or picture received at the eye is transmitted by means of the visual spirit to the seat of visual judgment, or, as he termed it (in Aristotelian fashion), the "common sense."[43] He described the transmitted entity as an "immaterial image" (*spiciem immateriatam*).[44] Both the affection (*passio*) of the visual spirit by light and color and the transmission of the immaterial image were considered by Kepler to be "occult" or "obscure" processes, belonging to "the realm of the wonderful."[45] The image itself was thought to be produced by and to correspond to the retinal image, and so to bear a point-for-point correspondence with the objects before the eye. Vision was pretty much equated with the immaterial image. Insofar as this was the case, there was no room in Kepler's views for the concept of a sensory core distinct from the visual world, since there was no basis for the distinction itself. The

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correspondence between points in the field of vision and points on the surface of the retina: Kepler, *Ad vitellionem paralipomena* (1604), in his *Gesammelte Werke* (Munich: Beck, 1939), Vol. II, pp. 153–156, trans. A. C. Crombie, in *Melanges Alexandre Koyré* (Paris: Hermann, 1964), Vol. I, pp. 150–157; Descartes, *Dioptrique,* in Charles Adam and Paul Tannery, eds., *Oeuvres de Descartes* (Paris: Vrin, 1969–1975) (this edition of Descartes' works will be referred to as AT), Vol. VI, p. 109, trans. P. Olscamp, in *Discourse on Method, Optics, Geometry, and Meteorology* (New York: Bobbs-Merrill, 1965), pp. 91–95.

[41] Robert Smith's *A Compleat System of Opticks* (London, 1738) provides a brief but representative statement of the 18th-century view of post-retinal physiology: speaking of the "pictures" painted upon the retina, Smith says "these pictures propagated by motion along the fibres of the optick nerves into the brain are the cause of vision" (p. 27).

[42] Kepler, *Ad vitellionem, Werke,* Vol. II, p. 152, trans. Crombie, pp. 148–150; *Dioptrice* (1611, reprint, Cambridge: Heffner, 1962), Prop. 61, pp. 23–25, trans. F. Plehn, *Dioptrik,* Ostwald's Klassiker der exakten Wissenschaften, No. 144 (Leipzig, 1904), pp. 28–30. Kepler shared the earlier view (n. 19 above) that visual spirit is the agent of the soul.

[43] Kepler's denial that visual spirit is an optical body came in *Ad vitellionem, Werke,* Vol. II, p. 152, trans. Crombie, pp. 148–149, a work in which he did not take a firm stand on post-retinal transmission (cf. Lindberg, *Al-Kindi to Kepler,* pp. 203–204); in the later *Dioptrice* he clearly stated that an image is transmitted to the common sense, but he equivocated on the role of the optic nerve in this transmission, Prop. 61, pp. 23–24, trans. Plehn, pp. 29–30.

[44] *Dioptrice,* p. 24, trans. Plehn, p. 29.

[45] *Ibid.,* and *Ad vitellionem, Werke,* Vol. II, pp. 152–153, trans. Crombie, pp. 148, 150. While Kepler maintained that the process of transmission is beyond the scope of the *laws* of optics, he countered that since "optics" derives its name from "vision," it is "wrong to exclude it [the transmission process] from the science of Optics simply because, in the present limited state of our science, it cannot be accommodated in Optics" (*Werke,* Vol. II, p. 152, Crombie, p. 148).

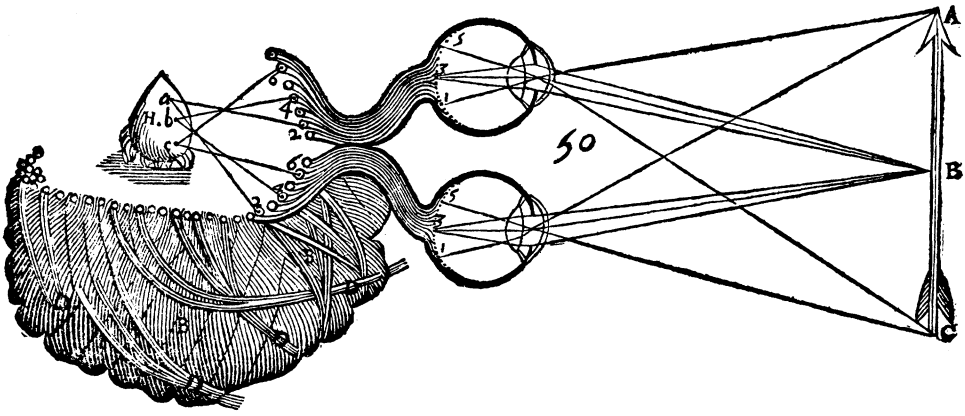

Figure 2. The visual system according to Descartes.

visual world was equated with a mental correlate of the retinal image.[46]

The second view of post-retinal physiology discernible in the seventeenth century stems from Descartes. It differs from the first view and from the position of Alhazen and his Latin followers, not in its conception of the psychologically effective features of the transmitted stimulus, but in the ontology of the physiological process. Descartes' physiological ideas often involve "adaptive modifications" of earlier ideas, and his views on the physiology of vision are no exception.[47] Indeed, his treatment of post-retinal physiology is essentially a recasting of the view shared by Alhazen and others into his new ontology, with its strict division between mechanistically conceived physiological processes in the nervous system and sensations in the soul. For the quasi-optical transmission of the forms of light and color through the efficacy of the visual spirit, or the transmission of an immaterial image through the special power of a mysterious spiritual agent, Descartes substituted the mechanical transmission of a "material image" to the seat of visual judgment. As illustrated in Figure 2, the transmission from the two eyes results in the formation, on the surface of the pineal gland (*H*), of a single "image" or "picture" composed of a pattern of motions (*abc*) that bear a one-to-one correspondence to the motions comprising the retinal image (1-3-5), and hence to points on the visible object (*ABC*).[48] Comparison of Figure 2 with Figure 1 reveals that although there are differences—primarily with respect to the anatomical destination of the transmitted entity (in the pineal gland as opposed to the optic chiasma) and the operations of the eye upon incoming rays of

[46] *Ad vitellionem, Werke,* Vol. II, p. 153, trans. Crombie, p. 150. Cf. E. G. Boring, *Sensation and Perception in the History of Experimental Psychology* (New York: Appleton-Century-Crofts, 1942), p. 223.

[47] On Descartes' "adaptive modifications" see Thomas S. Hall's commentary to his translation of Descartes' *Treatise of Man* (Cambridge, Mass.: Harvard University Press, 1972), nn. 85 and 40, and pp. xxxi–xxxiii.

[48] Descartes describes the transmission process in the *Treatise of Man,* trans. Hall, pp. 83–86; cf. *Dioptrique,* AT, Vol. VI, p. 137, trans. Olscamp, p. 100. The drawing is from the posthumous French edition of Descartes' *L'homme* (Paris, 1664, reprint in Hall), p. 71; it was not done under the supervision of Descartes but was produced by La Forge at the time of the posthumous edition, under contract from the editor, Clerselier (Hall, p. xxxv). There is no mention in the text of the "reinversion" of the pineal image as suggested by the drawing; cf. N. Pastore and H. Klibbe, "The Orientation of the Cerebral Image in Descartes' Theory of Visual Perception," *Journal of the History of the Behavioral Sciences,* 1969, *5*:385–389.

light (formation of a retinal image through the refractive power of the lens, versus the singling out of perpendicular rays)—the principle underlying the two views of post-ocular transmission is the same: the nervous system transmits the ordered array of stimulation received at the two eyes to the brain and combines the two transmitted impressions into one. Yet for Descartes the transmitted entity, just as the light proceeding from objects to the eye, is in the material realm; it has nothing of the character of sensation. The mind senses, rather than the eye.[49] At the pineal gland body and mind are "united," so that motions in the material nervous system produce sensations in the mind.

These sensations serve for the apprehension of the qualities known by vision. In his *Dioptrique* (1637) Descartes listed six principal qualities: light and color, which alone are proper to vision, and four spatial qualities, location, distance, size, and shape.[50] Descartes made clear that these qualities are not apprehended by direct inspection of the pineal image, as if we had other eyes in our brain with which to gaze at this physiological "picture." The pineal image causes sensations only insofar as it acts upon the mind; the movements that constitute this picture, "acting immediately on our mind inasmuch as it is united to our body, are so established by Nature to make it have certain sensations."[51] He explained the sensing of light and color according to the principle of psychophysical correspondence: the nature of our mind is such that the "force" and "character" of the movements that affect the soul in the brain cause us to have sensations of light and color.[52] Similarly, through an "institution of Nature," sensations of location and distance are produced directly in the soul by the arrangement and character of motions in the brain.[53]

In the case of the perception of size and shape, Descartes did not rely entirely upon the principle of psychophysical correspondence, but rather invoked psychological processes of the sort described by Alhazen and his followers. He was aware that size and shape are not directly determined by visual angle and retinally projected shape. Rather, we must estimate or judge them: the size of objects "is estimated according to the knowledge, or the opinion, that we have of their distance, compared with the size

[49] Descartes, *Dioptrique,* AT, Vol. VI, pp. 117–121, Olscamp, p. 87.

[50] *Ibid.,* p. 138, Olscamp, p. 101.

[51] *Ibid.* In applying the term "causes" to the relationship between the pineal image and the mind we do not mean to preclude the possibility of an occasionalistic interpretation of this relationship; indeed, there is strong evidence that Descartes was implicitly committed to an occasionalist metaphysics for both mind-body and exclusively material interations, on which see Gary C. Hatfield, "Force (God) in Descartes' Physics," forthcoming in *Studies in History and Philosophy of Science,* esp. n. 87, and the literature mentioned there.

[52] *Ibid.* Descartes points out that in order for us to have sensations, there need be no resemblance between the physiological event (motions in the brain) and the mental event (the sensation of light and color). He thus rejected the traditional physiology, derived from Aristotle, in which the form of the light and color is received by the visual spirit through a process which is an illumination and a coloring (see n. 21 above). In place of this view in which the sensitive soul takes on (comes to "resemble") the properties of the object, Descartes substituted his "no resemblance" theory of sensory physiology and psychophysical correspondence, on which see Willem van Hoorn, *As Images Unwind: Ancient and Modern Theories of Visual Perception* (Amsterdam: University Press, 1972), pp. 164–167, and Pastore, *Selective History,* p. 21.

[53] Descartes, *Dioptrique,* AT, Vol. VI, pp. 134–137, Olscamp, pp. 104–105; *Treatise of Man,* trans. Hall, pp. 94–100. Position is apprehended because the motions in the brain are uniquely determined with respect to both the position of the eyes within the head and the position of a luminous point upon the retina (by means of the latter we know that the object is situated at some point along the line of sight drawn from that retinal location). Furthermore, distance can be known through the effect upon the mind of brain states that mediate the accommodation and convergence of the eyes (in the case of accommodation, Descartes built upon the one important difference between pre- and post-Keplerian dioptrics, the necessity to provide an accommodative mechanism for changing the focal length of the eye; the potential use of convergence as a gauge of distance could, in principle, have been a part of pre-Keplerian psychology of vision).

of the image they imprint in the fund of the eye," and "shape is judged by the knowledge, or opinion, that we have of the position of various parts of the objects, and not by the resemblance of the pictures in the eye; for these pictures usually contain only ovals and diamond shapes, yet they cause us to see circles and squares."[54] In the *Dioptrique* Descartes did not provide a thorough analysis of these estimations and judgments. In particular, he did not reveal how the mind is able to base its judgments of the size of objects upon "the size of the image they imprint in the fund of the eye," even though the mind has no direct access to the retinal image. An answer that suggests itself on principle is that when Descartes spoke of the mind's judgments being based upon retinally projected size, he meant retinally projected size as it is represented in a mental correlate of the pineal image, since events at the eye affect the mind only by virtue of the intervening nervous transmission to the pineal gland, and then only insofar as the pineal events themselves cause the mind to have sensations.

Descartes' view that only a mental correlate of the pineal image is truly sensed found clear expression in a passage from the *Objections and Replies* (1641). In this passage Descartes distinguished among three grades of sense activity: (1) "the immediate affection of the bodily organ by external objects," which in the case of vision includes retinal stimulation and transmission to the surface of the pineal; (2) "the immediate mental result, due to the mind's union with the corporeal organ affected" (i.e., the pineal); and (3) "all those judgments which, on the occasion of motions occurring in the corporeal organ, we have from our earliest years been accustomed to pass about things external to us."[55] Using the example of the perception of a staff, he clarified the relationship among the three grades:

> But from this [the first grade of sensation] the second grade of sensation results; and that merely extends to the perception of the colour or light reflected from the stick, and is due to the fact that the mind is so intimately conjoined with the brain as to be affected by the motions arising in it. Nothing more than this should be assigned to sense, if we wish to distinguish it accurately from the intellect. For though my judgment that there is a staff situated without me, which judgment results from the sensation of colour by which I am affected, and likewise my reasoning from the extension of that colour, its boundaries, and its position relatively to the parts of my brain, to the size, the shape, and the distance of the said staff, are vulgarly assigned to sense, and are consequently here referred to the third grade of sensation, they clearly depend upon the understanding alone.[56]

The first grade of "sensation" comprises only the motions in the nervous system and so is not a true mental sensing. The second grade—the immediate mental result of nervous motion—is what properly belongs to sense. The mind cannot base its judgment of size directly upon the relative size of the retinal image (since this image is part of the first grade of sense), but rather judges from the extension and boundaries of the color patch present in sensation.

The distinction between the first and second grades of sense spans the boundary between body and mind. The distinction between the second and third grades is, interestingly, a distinction between types of mental events that occur during vision. The first term of the distinction—the second grade—is, however, unfamiliar to the ordinary observer, who takes the judgments of the third grade to be primary. Even

[54] Descartes, *Dioptrique,* AT, Vol. VI, pp. 140–141, Olscamp, p. 107.
[55] Descartes, *Objections and Replies,* AT, Vol. VII, pp. 436–437, trans. E. Haldane and G. Ross, *Philosophical Works of Descartes* (N.Y.: Dover, 1955) (referred to hereafter as HR), Vol. II, p. 251.
[56] AT, Vol. VII, pp. 437–438, HR, Vol. II, p. 252.

though these judgments "depend upon the understanding alone" and therefore fall outside the category of sense, they are "vulgarly" considered to be sensations. This confusion results from the fact that phenomenally speaking we experience objects as being of a particular size and at a certain distance and are not aware that our ostensibly direct apprehension of objective size and distance is actually mediated by the second grade of sense and the judgments performed upon it. Descartes says that the reason we confusedly assign these judgments to sense "is just that in these matters custom makes us judge so quickly, or rather we recall the judgments previously made about similar things; and thus we fail to distinguish the difference between these operations and a simple sense perception."[57] Our experience of objects in space is determined by the outcome of judgmental processes. In spite of, or because of, our experiencing the outcome, we fail to notice the judgmental process itself, presumably including that upon which the judgment is based (spatial properties as represented in the second grade of sense). Thus, in the tradition of Alhazen and his followers, Descartes held that the judgments (or recollections of previous judgments) underlying spatial vision occur so quickly that we fail to notice that we in fact do judge.

There is a crucial difference between Descartes' treatment of these unnoticed perceptual judgments and that of previous writers. We have seen that for Alhazen it was difficult to decide—and most likely not appropriate to ask—whether the sensory impressions upon which judgments are made are in principle available to consciousness. With Descartes there is no doubt. The second grade of sensation is an event in the soul, an idea, and by virtue of this fact alone must be available to consciousness. Descartes identified the mental with the conscious; he contended that we can have no ideas of which we are not aware.[58] If percipients typically are not aware of the second grade of sensation, this fact is to be explained away by recourse to the habitual and rapid nature of the judgments. But the second grade remains in principle experienceable.

It should now be apparent that Descartes' distinction between the second and third grades of sense corresponds to the distinction between the sensory core and the visual world. The second grade of sensation is a mental representation of the retinal image; the third grade is the ostensibly direct experience of solid objects at a distance, which actually results from unnoticed judgmental processes performed upon the unnoticed sensory core.

One might wonder what prompted Descartes to assert the existence of a mental representation of the retinal image and thereby to commit himself to a species of visual ideas that are distinct from ordinary visual experience and yet unfamiliar to the typical observer. Descartes' inclusion of the second grade of sensation in his analysis of vision does not seem to have resulted from an experiment in phenomenology. Nowhere does he claim to have experienced the second grade of sensation; we have seen that he was forced to explain why we typically do not experience it. Thus it seems unlikely that Descartes' postulation of a sensory core was the product of new introspective techniques;[59] more likely, it was a hypothetical construction based upon

[57] *Ibid.* The statement that we "recall the judgments previously made about similar things" is reminiscent of Alhazen's process of judgment through recognition.

[58] *Replies,* HR, Vol. II, p. 115: "there can exist in us no thought of which, at the very moment that it is present in us, we are not conscious." Cf. *Meditations,* HR, Vol. I, p. 169. Descartes used the word "thought" to signify "everything that exists in us in such a way that we are immediately conscious of it. Thus all the operations of will, intellect, imagination, and of the senses are thoughts" (*Ibid.,* Vol. II, p. 52).

[59] We are not implying that phenomenological considerations never entered Descartes' thought on perception; indeed, his observation that objects appear of constant size at different distances (see above) is

Descartes' knowledge of the properties of the retinal image and his belief that the topological properties of that image are retained while being transmitted physiologically to the pineal gland where they become represented in sensation.

The belief that a mental correlate of the retinal image is available to consciousness was never central to Descartes' treatment of vision, and its introduction may be seen as a byproduct of his separation of the physiological from the mental. This separation restricted the domain of the mental to events occurring in a substance that is divorced from processes in the eye or neural pathways (except at the pineal); together with the view that every state of this mental substance is a conscious state, it led to the implication that every truly sensory state is conscious. So the second grade of sensation, as a true sensory state, must be available to consciousness. However, the postulation of a sensory core distinct from the visual world was in no way a *necessary* byproduct of these factors. In principle, Descartes could have extended the principle of psychophysical correspondence to include all of our spatial ideas; that is, he could have imagined a mechanism by which the brain states bearing information about, say, distance and visual angle, interact with one another and with the mind to produce a sensation directly representing objective size. One could proffer a number of speculations about why Descartes did not do so, though it is enough here to remark that the distinction between the second and third grades of sensation was not merely, or perhaps even primarily, intended to capture a purely psychological distinction between two stages in the process of spatial vision; it also served epistemology in that it distinguished between passively produced sensations which are not susceptible to error and actively produced judgments, which are. Thus the distinction allowed Descartes to assign the error in spatial illusions to the fallibility of the judging intellect, a move that would have been more difficult on a purely psychophysical account of spatial vision.[60]

In any event, although the distinction between the second and third grades of sensation was not necessitated by Descartes' new ontology, the properties of the second grade of sensation may nonetheless be understood in terms of Descartes' assimilation of the traditional account of spatial vision to that new ontology.[61] The traditional view (of Alhazen and others) had it that during vision, unnoticed judgments are performed upon a sensory impression that represents the spatial properties of objects according to the projective geometry of optical stimulation. Descartes accepted both the traditional view of the geometry of the visual stimulus and the view

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explicitly phenomenological. However, it is an observation regarding the *third* grade of sensation. We have found no instances of his speaking of direct phenomenal access to the *second* grade; when he wished to illustrate its properties, he used perspective drawings as an example (*Treatise of Man,* Hall, p. 68; *Dioptrique,* AT, Vol. VI, pp. 113, 147), an example which clearly depends upon the geometrical relationship (as specified by theory) between the retinal image and a perspective projection, rather than upon phenomenal considerations.

[60] The passages quoted above regarding the three grades of sensation arose in the context of considering the question of perceptual error, which Descartes assigned to the implicit judgments of the third grade of sensation (HR, Vol. II, pp. 252–253). On a purely psychophysical account, spatial perception would result from the lawful interaction of matter with matter and of matter with mind (the first and second grades of sensation, in which no falsity can reside, p. 252).

[61] It is not known whether Descartes was directly familiar with Alhazen's optical work. He was, however, familiar with Witelo (and hence with Witelo's version of Alhazen's theory), whom he mentioned several times (under the name "Vitellion": AT, Vol. I, p. 239; Vol. II, p. 142; Vol. III, p. 483), and from whom he apparently copied a table of refractions (Vol. X, p. 8). It is likely that he was familiar with one of the Nuremberg editions of Witelo, and not Risner (Vol. I, p. 241). Descartes also knew of Roger Bacon's optical work (Vol. II, p. 447).

that judgments serve to combine elements (such as visual angle and distance) that are represented separately in the optical array. His new ontology demanded that once the point-for-point transmission of the visual stimulus has its effect upon the mind (as it must if it is to serve as a basis for judgment), the resulting state is undeniably mental and therefore necessarily available to consciousness. And this state must in principle be available to consciousness even if Descartes did not draw attention to this fact. Such are the unexpected consequences that occur when explanatory schema cross the boundary from one ontology to another.

BERKELEY'S NEW THEORY

While there were adherents of the concept of sensory core[62] between the time of Descartes and the publication of Berkeley's *Essay Toward a New Theory of Vision* (1709), Berkeley's work provided the first significant elaboration of the psychology of vision after Descartes' *Dioptrique* and was the primary vehicle by means of which the sensory core became a standard feature of visual theory for the next two centuries. Unlike the theories of the previous writers with whom we have been concerned, Berkeley's treatment of vision, where it was not epistemological or metaphysical, was psychological: it was primarily concerned with the associative connections among the *ideas* that comprise the immediate and mediate objects of vision.[63] The keystone of Berkeley's analysis of the psychological or ideational processes of vision was his theory of visual language, according to which the ideas of vision bear the same sort of relationship to the ideas of other senses, such as touch, as words bear to their referents.[64] Just as through a process of association words come to suggest their referents, the ideas proper to vision come to suggest ideas of the tactual properties, such as the idea of distance. These tactual ideas constitute our experience of a three-dimensional world and are commonly mistaken for ideas proper to the sense of vision. Berkeley termed them the secondary objects of vision, thereby distinguishing them from properly visual ideas while recognizing that phenomenally these tactual ideas seem to belong to vision.[65] And so according to Berkeley, our everyday experience of the visual world results from associative connections formed between properly visual ideas and tactual ideas, these tactual ideas being responsible for our perception of depth or distance.[66]

[62] Jacques Rohault, in his *System of Natural Philosophy* (1671), trans. Samuel Clarke (London, 1723), espoused the Cartesian point-for-point transmission of the retinal image into the brain, where there arises "an *immaterial* Image, or that Sensation in which Sight properly consists" (Pt. I, Ch. 32, Secs. 1 and 2, p. 248); he contrasted this sensation with the judgments that lead us to think we directly apprehend objects at a distance (*ibid.*, Sec. 11, pp. 250–251) and with the judgments involving situation and distance, by which "we easily conceive what the *Bigness* of the Object is at a given distance" (Sec. 23, p. 254). Malebranche also accepted the sensory core–visual world dichotomy (Pastore, *Selective History,* pp. 46–49), as did Locke, *Essay Concerning the Human Understanding* (London, 1690), Bk. II, Ch. 9, Secs. 8–10.

[63] Berkeley, *The Theory of Vision, or Visual Language Vindicated and Explained* (1733), in *Works on Vision,* ed. Colin M. Turbayne (New York: Bobbs-Merrill, 1963), Secs. 37, 43. Berkeley contended that the psychological side of visual theory had been neglected by previous writers in favor of physical considerations (ocular anatomy, the nature of light) and the study of vision in connection with lenses and mirrors.

[64] Berkeley introduced his linguistic theory of vision as the conclusion of the *New Theory* (Secs. 147, 148), whereas he begins with it in the later *Theory of Vision Vindicated* (Secs. 38–40). For a thorough discussion of Berkeley's linguistic theory of vision, see Turbayne, *Works on Vision,* editor's commentary, pp. vii–xlv.

[65] Berkeley, *New Theory,* Sec. 50.

[66] According to Berkeley the link between the proper and secondary (tactual) objects of vision is not mediated through active judgments of the intellect (as Alhazen and Descartes believed), but through a passive, associational process. Berkeley clearly distinguishes the associational process of *suggestion* from the judgmental process of inference in the *Theory of Vision Vindicated,* Secs. 42 and 16. He does speak of

The proper or immediate objects of vision constitute the sensory core in Berkeley's theory and are therefore of primary interest in the present context. In the *Theory of Vision, or Visual Language, Vindicated and Explained* (1733), Berkeley explained that the proper objects of vision are pictures.[67] He did not mean that the mind directly contemplates the retinal image, for he denied that the images on the retina "are, or can be, the proper objects of sight"; these images are in the tangible realm, being "tangible figures projected by tangible rays on a tangible retina."[68] While the images on the retina are sometimes referred to as pictures, Berkeley preferred to emphasize the distinction between the visual and the tactual by reserving that term for the visual ideas immediately present to the mind:

> Pictures, therefore, may be understood in a twofold sense, or as two kinds quite dissimilar and heterogeneous, the one consisting of [ideas of] light, shade, and colors; the other not properly pictures, but images projected on the retina. Accordingly, for distinction, I shall call those "pictures" and these "images." The former are visible and the peculiar objects of sight.[69]

But, as Berkeley tells us, while we do not perceive our retinal images, they nonetheless bear some correspondence to the pictures that constitute the proper objects of sight:

> It is to be noted of those inverted images on the retina that, although they are in kind altogether different from the proper object of sight or pictures, they may nevertheless be proportional to them; as indeed the most different and heterogeneous things in nature may, for all that, have analogy, and be proportional each to other.[70]

Berkeley explained the nature of this proportionality by the extended use of an example involving a "diaphanous plane" divided into equal squares, similar to the painter's device. He compared the "image" that may be constructed upon this plane to the retinal image and explained that the visual "picture" itself (the proper object of vision) answers to the image on the diaphanous plane, in such a way that "what has been said of the images must in strictness be understood of the corresponding pictures."[71] Thus, according to Berkeley, the proper objects of vision are visual ideas of light and color, phenomenally present as a picture; this picture is correlated with

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"sudden judgments" in the *New Theory* (Sec. 20), but when he comes to explain the connection between the immediate and mediate objects of vision, he speaks of one idea "suggesting" another and not of inferences from one idea to another (Secs. 45, 47, 50, 51, etc.).

[67] Some passages in the earlier *New Theory* may suggest that Berkeley did not include form (retinally projected shape) among the proper objects of vision, from which it would follow that the immediate object of sight could not be a picturelike correlate of the retinal projection (e.g., Sec. 29; cf. Pastore, *Selective History,* pp. 72–73). Berkeley did deny that sight and touch perceive a common set of shaped and extended objects (*New Theory,* Secs. 127–143). Instead, he maintained that the *visual* shape and magnitude are ideas different in kind from *tactual* shape and magnitude, and thus that visual space (as represented in the immediate object of vision) and tactual space constitute separate, independent realms (Secs. 136–143). Thus even though he denied that vision immediately apprehends the spatial world of touch, he did include peculiarly visual spatial ideas within the proper objects of vision.

[68] *Theory of Vision Vindicated,* Sec. 142.

[69] *Ibid.,* Sec. 51. Berkeley's statement that the proper object of vision is a picture should not be taken in a boringly literal sense to imply that the proper object of vision is planar and hence localized in three-dimensional space. It was perhaps to avoid the long arguments surrounding the problem of geometry (*New Theory,* Secs. 149–158)—arguments easily misread as a denial that form is proper to vision—that Berkeley chose simply to characterize the proper objects as "pictures" in the more popular *Theory of Vision Vindicated.*

[70] *Theory of Vision Vindicated,* Sec. 53.

[71] *Ibid.,* Sec. 57.

the retinal image, but it is not our retinal images that we see.[72]

The fact that the ideas proper to vision are correlates of the retinal image while our everyday visual experience is of the visual world was not something that Berkeley could pass over without comment. As Berkeley admitted, "we cannot, without great pains, cleverly separate and disentangle in our thoughts the proper objects of sight from those of touch which are connected with them."[73] The result is that we do not experience the sensory core in its primitive form, but only its elaboration into the visual world. Yet a key premise in Berkeley's own polemic against the "received view" (that vision results from judgments of lines and angles) was that "no idea which is not itself perceived can be the means of perceiving any other idea."[74] An obvious tension arises. Berkeley surmounted this apparent embarrassment by drawing attention to a similar occurrence in the perception of speech: even though we must hear the words of the speaker in order to understand the thought that they convey, we hardly notice the words themselves, but pay attention to the meaning, and "even act in all respects as if we heard the very thoughts themselves."[75] The difficulty that we experience in separating the proper objects of vision from the ideas of touch

> . . . will not seem strange to us, if we consider how hard it is for anyone to hear the words of his native language pronounced in his ears without understanding them. Though he endeavors to disunite the meaning from the sound, it will nevertheless intrude into his thoughts, and he shall find it extremely difficult, if not impossible, to put himself exactly in the posture of a foreigner that never learned the language, so as to be affected barely with the sounds themselves and not perceive the signification annexed to them.[76]

While Berkeley is essentially repeating the argument from habit found in Descartes and Alhazen, the metaphor of speech perception provides concreteness to the claim that we perceive the proper objects of vision and yet are not aware of them as such. We give primary attention to the ideas of touch because, just as with the meanings of words, they are found to be functionally significant. It is the tactual world of mediate vision with which our tactual body must interact and from which it can receive injury.[77]

The reasons that could be put forth for Berkeley's allegiance to the distinction between ideas of vision and touch, and thus to a typically unnoticed form of visual experience distinct from the visual world, would take us far into his immaterialism.[78]

[72] Thus while we agree with Gary Thrane's assertion, in his "Berkeley's 'Proper Object of Vision,'" *Journal of the History of Ideas,* 1977, *38*:243–260, that Berkeley's proper object of vision is a "free-floating" bidimensional array, we cannot agree that Berkeley took the proper object of vision to be the retinal image itself (pp. 243, 255). On Berkeley's immaterialistic account, the flow of causality is not from the "photosensitive surface" of the retina to the mind, but from God to the mind; the surface of the retina is in the "tangible realm" and can be known only through tactual ideas.

[73] *New Theory,* Sec. 159.

[74] *Ibid.,* Sec. 10.

[75] *Ibid.,* Sec. 51.

[76] *Ibid.,* Sec. 73.

[77] *Ibid.,* Secs. 59, 147.

[78] As an immaterialist, Berkeley could not allow that sight and touch perceive the same objects; he must show that the visual world that we seem to directly apprehend, and which agrees with our tactual ideas, is really mediately perceived by means of those same tactual ideas (or, rather, by means of associative connections established with previous tactual ideas), from which our properly visual ideas are really quite distinct. On his immaterialist account, each of the senses constitutes a separate realm, so that any regular connection between the ideas of separate sensory modalities is owing not to the fact that a single object is being sensed but to the benevolence of God in providing us with a coherent set of sensory ideas that exhibit cross-modal regularities (*New Theory,* Sec. 147; *Theory of Vision Vindicated,* Secs. 38–40, 29). For a recent study of Berkeley's immaterialism and theory of vision, see George Pitcher, *Berkeley* (London: Routledge & Kegan Paul, 1977).

The particular form that Berkeley attributed the proper objects of vision may, however, be understood in terms of the received tenets of visual theory. Berkeley found it to be "agreed by all that distance of itself and immediately, cannot be seen,"[79] and thus he could use tradition to support his view that the proper object of vision contains no direct representation of the third dimension and is a correlate of the retinal projection. In essence, he simply accepted from the optical tradition the theoretical postulation of a mental correlate to the retinal image. When he described the properties of the proper objects of vision in his *New Theory,* he described them in a manner that would be consistent with a mental correlate of the retinal image, but provided no argument for doing so.[80] He apparently assumed the point would be obvious enough, as it would have been to anyone familiar with previous visual theory. He certainly did not provide an argument based upon an empirical confrontation with the pure proper objects of vision themselves, and in fact spent more effort than had Descartes in explaining away the lack of such confrontation. And when in *Visual Language* he sought to provide a detailed explication of the proper objects of vision, he turned to the painter's device for constructing a projective drawing, not to any special phenomenological considerations.

In sum, even though Berkeley disputed many features of the received theory of vision, he did not dispute the view that our immediate visual experience is a picture-like correlate of the retinal image. In this sense Berkeley's proper object of vision may be identified with Descartes' second grade of sensation. There is, however, a shift in emphasis. With Berkeley the fact that the proper object of vision is potentially experienceable no longer remains in the background. This shift of emphasis was in part brought about simply by the fact that Berkeley devoted more effort than had Descartes to developing his psychology of vision, in which the key distinction was that between the immediate and mediate objects of vision (sensory core and visual world). But underlying Berkeley's special concern to treat vision solely in terms of ideational processes was his immateralist metaphysics, in which *to be* is to be perceived is to be an idea in the mind of a perceiver.[81] Insofar as Berkeley's metaphysics served to emphasize the distinction between the immediate and mediate objects of vision as two ideational states, it left its mark on subsequent visual theory. For after Berkeley the distinction between the sensory core and visual world became a widely accepted feature of visual theory, and remained so throughout the nineteenth century. While the view that the sensory core is fundamental in the process of vision has been strongly challenged, it retains adherents even today.[82]

CONCLUSION

When the concept of sensory core emerged in the seventeenth century, it was a product of theory rather than of new phenomenological techniques. The crucial development was the inclusion in Descartes' visual theory of a distinction between

[79] *New Theory,* Sec. 2.

[80] Berkeley introduces the distinction between the immediate and mediate objects of vision in Sec. 50 of the *New Theory* and proceeds to describe their respective properties without further ado.

[81] Berkeley, *A Treatise Concerning the Principles of Human Knowledge* (Dublin, 1710), Pt. I, Sec. 3.

[82] The challenges to the concept of sensory core provide gauges of its prior acceptance: see William James, *Principles of Psychology* (New York/London, 1890), Vol. II, pp. 203–282, and Wolfgang Kohler, *Gestalt Psychology* (New York: Liveright, 1947), Ch. 3. In the early development of the concept of "sense data" among philosophers, the sense data were attributed the phenomenal properties of the sensory core, and this seems to have been a borrowing from the psychologists (Bertrand Russell, *Our Knowledge of the External World,* 1914, reissued, London: Allen & Unwin, 1922, pp. 75–76). A recent adherent to a notion

two mental states, one corresponding to the retinal image, the other to experience of the visual world. Descartes' theory, however, was not uniquely responsible for the character of the sensory core—its two-dimensional, imagelike form—but only for the fact that it was conceived as available to consciousness (and hence conceived as the mental state we have named "sensory core"). Since the time of Alhazen (or, if we make allowances for differences owing to extramissionism, since Ptolemy), the effective stimulus for vision had been conceived as an entity that provided information about only two dimensions of the field of vision and which therefore required further enrichment by means of psychological operations in order to be elaborated into a world in depth. Descartes accepted this view of visual stimulation and the operations applied to it, and translated the view into his mechanistic physiology and particular form of mind-body dualism. A product of the translation was that the initial sensing of the two-dimensional stimulus pattern came to be viewed as a mental event in the Cartesian sense, and therefore as an event available to consciousness. Berkeley, who shared Descartes' equation of the mental with the conscious, incorporated the accepted view of visual stimulation into an associative learning theory of spatial perception. His immaterialism led him to have a particularly heightened awareness of the distinction between the sensory core and visual world. Though later thinkers tended not to accept Berkeley's metaphysical views, his theory of vision had a lasting impact.

According to our analysis, Descartes' introduction of the concept of sensory core into the psychology of vision resulted in part from factors "external" to his visual theory. The argument is neither that Descartes' particular view of the mind and body *demanded* the concept of sensory core—we mentioned above that conceivably he could have developed a physiological mechanism sufficient for the generation of the visual world—nor that the concept is inconceivable on any other view of mind and body. Rather we are arguing that in fact it was the Cartesian view of mind as applied to the traditional conception of the visual stimulus and the psychological process of spatial vision that resulted in the introduction of the concept of sensory core. While the current state of the historiography of medieval and Renaissance psychology does not allow us to delve further into the matter, it appears that the significant difference between Descartes' view of mind and that of his medieval predecessors was Descartes' unification of the mind into a single, rational, conscious entity. Medieval writers, including those in the optical tradition, generally followed Aristotle in dividing the mind into parts, such as sensitive and rational, and also divided it into several faculties or "internal senses."[83] Within this context it was appropriate to refer to events all along the chain of processes leading from the eye to the seat of visual judgment in mentalistic language, without conceiving of them all as belonging to consciousness. Descartes rejected the Aristotelian division of the soul. His unified conception of consciousness, which was dominant (though not unchallenged) well into the nineteenth century, provided a framework for continued adherence to the concept of sensory core.

The reader may wonder why we have, in the course of this paper, focused our

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that is reminiscent of the sensory core is Irvin Rock, *An Introduction to Perception* (New York/London: Macmillan, 1975), p. 562: "It is plausible to suppose that the first step in a very rapid process is a perception correlated with features of the proximal stimulus."

[83] Bacon, *Opus majus,* Bk. V, Sec. 1, Dist. 10, Ch. 3, p. 500, and Bk. V, Sec. 2, Dist. 3, Ch. 8, p. 543. On the partitioning of the mind into various internal senses, see Nicholas Steneck, "Albert the Great on the Classification and Localization of the Internal Senses," *Isis,* 1974, *65*:193–211.

attention so steadfastly on the emergence of the concept of sensory core, and whether we have not produced a distorted picture by examining a question that does not obviously present itself upon an examination of either Alhazen's or Descartes' optical writings. We sympathize. One could write a history that emphasized the continuity and shared features of the psychology of vision from Alhazen to Descartes. Such a history would be a study of the development of one of the major viewpoints in the history of perceptual psychology: the view that the stimulus to vision is inherently impoverished with respect to the spatial properties of objects, so that the inadequate information contained in received stimulation must be enriched by judgmental or associative processes, or, to put it differently, so that the mind must construct the visual world by applying past experience to the inherently ambiguous sensory core. Our paper constitutes a portion of that history. If we have chosen to emphasize the concept of sensory core, it is because the notion that the psychologically fundamental component of the visual process is a conscious state representing the retinal projection played such a dominant role in eighteenth- and nineteenth-century visual theory. Indeed, it was just that aspect of the sensory core which distinguishes it from Alhazen's transmitted "form"—its status as a conscious event—that became the target of criticism during the late nineteenth and early twentieth centuries.