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Ibn al-Haytham's Contributions to Optics, Art, and Visual Literacy

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Introduction

In his book, *Secret Knowledge: rediscovering the lost techniques of the old Masters* (2001, 2006), the artist David Hockney reported visual discoveries within some of the best-known European paintings that affect long-held understandings of the development of western art over the course of the past 600 years. Subsequently, a collaboration combining the visual skills of one of the world's greatest artists (Childers, 1996; Langmuir & Lynton, 2000) with the analytical skills of an optical physicist (Charles M. Falco), resulted in Hockney and Falco developing the foundations of a new methodology for extracting information from complex, optics-based images (Hockney & Falco, 2000, 2004, 2005a, 2005b, 2005c). As will be discussed in this paper, this methodology also contributes to our burgeoning understanding of visual literacy.

Visual literacy is not limited to the narrative and symbolic qualities of pictures and images (Duncum, 2001; Hockney, 1998), but it is also rooted in the scientific and cultural study of optics and the visual system (Edgerton & Steinberg, 1987; Greenstein, 1997; Grootenboer, 2007). As we will discuss, the genesis of this concept can be traced to the work of the 11th century Arab polymath, Ibn al-Haytham (Latinized Alhazen or Alhacen), whose scientific exploration of vision significantly impacted the study and practice of visual art, as well as our cognitive capacity to interpret it.

Historic Theories of Vision

During the first two centuries of the Islamic Golden Age (8th-13th centuries), translation of ancient writings on the science of optics offered contemporary intellectuals with various philosophical theories of vision. Euclid, Ptolemy, Galen

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and Aristotle, whose Greek texts were translated into Arabic during this period, provided disparate views on the way the organ of the eye reacts with light to aid in vision. Greek theories were largely appropriated by Islamic scholars until the first quarter of the 11th century, when a new method of inquiry was introduced by Ibn al-Haytham. With the 'scientific method' he introduced to the world, al-Haytham used experimental evidence to develop a remarkably accurate theory of vision. His design and interpretation of elegant experiments became the root source for Western understandings of optics up to the 17th century (Lindberg, 1967).

Born in Basra in 965, Ibn al-Haytham primarily worked in Cairo's al-Azhar Mosque – an epicenter for academic inquiry – where he wrote prolifically on subjects as diverse as poetry and politics. He is primarily known however, for his writings on geometrical optics, astronomy, and mathematics. His landmark seven-volume treatise on the human visual system, *Kitāb al-Manāzir* [Book of Optics], published sometime between 1028 [418 A.H.] and 1038 [429 A.H.], was incorporated throughout the core of post-medieval Western culture. This seminal work initiated an unbroken chain of continuous development of the modern understanding of both optics (i.e. science), as well as understandings related to two dimensional pictorial representations of three dimensional space (i.e. art).

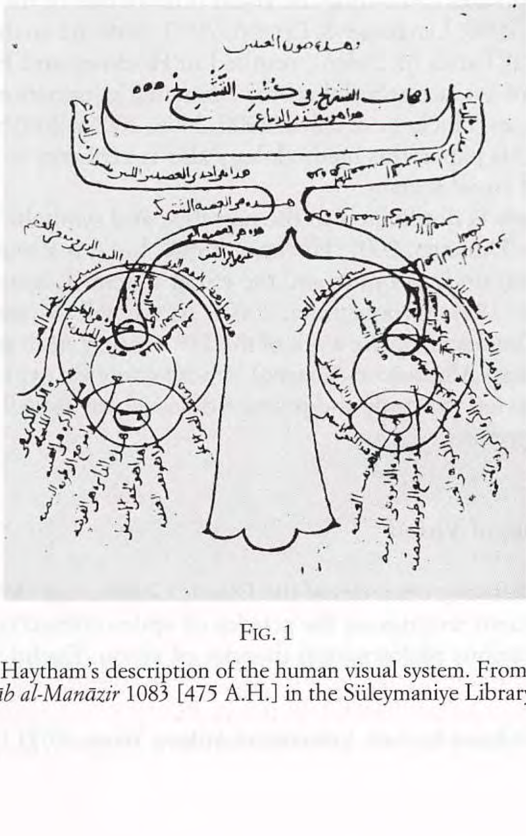

FIG. 1

Ibn al-Haytham's description of the human visual system. From a copy of his *Kitāb al-Manāzir* 1083 [475 A.H.] in the Süleymaniye Library, Istanbul.

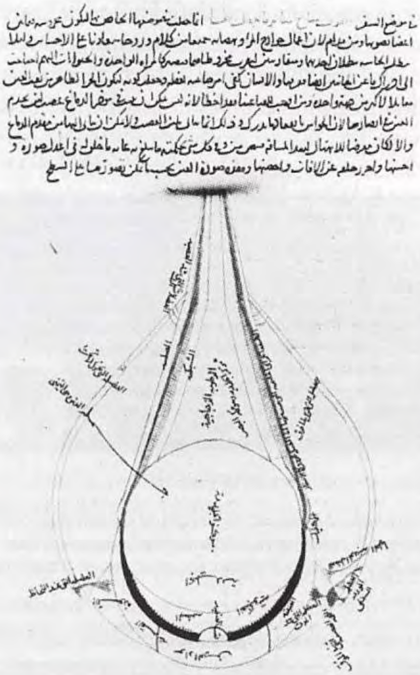

FIG. 2
The anatomy of the eye according to Ibn al-Haytham, from *Kitab al-Manzir*, Museum Victoria.

Prior to the work of Ibn al-Haytham, theories of vision could be broadly classified into one of three categories: extramission, intromission, or a combination of the two. Extramission theories require that some sort of illuminating particles be emitted by the eye. Euclid and Ptolemy are well-known scholars associated with this category (Linberg, 1981). Although there are obvious flaws with extramission theories, they do get the geometry right, with a one-to-one correspondence between points on the object and points on the eye. Intromission theories, with Aristotle as a prominent proponent, postulated that objects continuously sloughed off microscopically thin replicas of themselves that then travelled to the eye of the observer. Intromission theories avoid some obvious problems of extramission theories, such as near and far objects simultaneously being visible the moment the eye is opened. A third alternative, supported by Plato and Galen (and Aristotle, to a lesser degree), combines the two theories, proposing that light emitted by the eye engages in some way with the intervening air and aforementioned replicas, or species (Lindberg, 1967, 1981).

Like others before him, Ibn al-Haytham also recognized that there were problems with all existing theories of vision, but he was uniquely successful in finding a solution that had eluded the best minds of antiquity. He proposed a type of intromission theory of vision, and validated his conclusions by empirical understanding deduced from scientific experimentation. This methodology expanded his understanding beyond the theoretical, which resulted in the incorporation of psychology to explain vision, in combination with the behavior of light and the physiology of the eye.

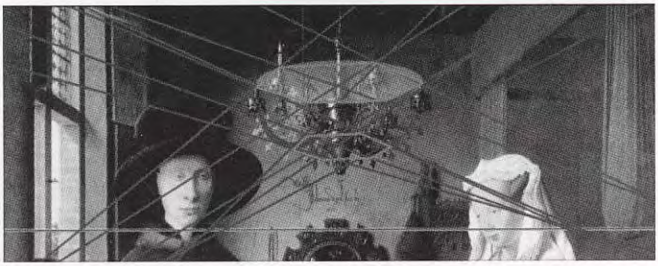

FIG. 3

Jan van Eyck, *The Arnolfini Marriage*, 1434 (detail showing approximately 25% of the 81.8×59.7 cm painting). By tracing the rays of perspective on two dimensional images, specific information can be elicited about the manner in which images are produced.

Ibn al-Haytham also linked sight and vision with the properties of light throughout his studies. His experiments subsequently verified scientific principles commonly associated with what is known today as optical 'ray tracing'. These experiments included using flat and curved mirrors to control and manipulate light, but primarily involved observing the effect of light pouring through apertures of various sizes into darkened spaces (i.e. camera obscura) (Smith, 2001a, 2001b). Perhaps most importantly, they provided him a theoretical basis for the existence of rays; a theoretical construct that he used as a means for describing and interpreting the visual system. These rays are subsequently represented by geometrical lines associated on a point-by-point basis with an object in space.

Al-Haytham did get one important aspect of vision wrong: the fact that an image projected by a lens is upside down and flipped right-to-left apparently was more than he could accept in a theory of vision, even though it is contained within his optical formalism. Leonardo da Vinci also failed to accept this when he approached the problem much later (Kemp, 1977). Ultimately, it would take another five hundred years before Kepler would follow Ibn al-Haytham's formalism to its inevitable and logical conclusion in developing the theory of the retinal image.

Smith (2005) points out that such contrasting theories of vision in the preceding centuries before Kepler had profound epistemological implications on medieval culture. The Platonist perspectivists supporting extromission, for example, suggest that the eye has powers which extend outward as a means for engaging reality which, in a general sense, can be understood as a "visual finger reaching out to palpate things" (Smith, 2005, p. 223). Intromission theories however, are uniquely Aristotlian. They ascribe to the idea that, "Knowledge is inductive...

Sensation and its representations are therefore not to be deprecated as the bearers of falsehood (Platonism) but rather to be prized as the bearers of truth" (Smith, 2001, p. cx).

Perhaps predictably, as cultural understandings of vision and cognition expanded to include these disparate theories, so too did evolving cultural considerations for concepts seemingly unrelated to the science of optics, the impact of which was not relegated to the science community alone but spread out to include the humanities at large.

3. Interdisciplinary dissemination and appropriation of *Kitāb al-Manāzir*

There is little debate that Ibn al-Haytham's seminal work, *Kitāb al-Manāzir*, translated into Latin as *De Aspectibus* in the early to mid-13th century, is largely responsible for the widespread appropriation of its contents by Western European intellectuals (Lindberg, 1967). Smith recognizes that variations exist among the Latin version as compared with the Arabic original, not simply in its organizational structure but in the interpretation of specific terms (2001). From the beginning, however, knowledge of the core principles and experiments detailed throughout the manuscript by its original author were not limited to Western readers alone, or to scientific audiences specifically.

De Aspectibus is first referenced in Bartolomeo Anglicus' *De proprietatibus rerum*, [On the Property of Things] c1220-1230 (Smith, 2001), a monumental and early encyclopedia covering a wide variety of subjects. The text refers to the study of optics and Ibn al-Haytham specifically several times. It was required reading at the University of Paris in 1296, available in the university library of the Sorbonne by 1306, and used widely as reference material at Oxford, Cambridge, Canterbury and Merton College by the mid-fourteenth century (Holbrook, 1998).

Specific proposals contained within *De Aspectibus* however, are most significantly referred to in the well known optics manuscripts, *Perspectiva* by Roger Bacon (c1268), *Perspectiva* by Erazmus Witelo (c1278), and *Perspectiva communis* by John Pecham (c1280) (Lindberg, 1967). Although today we think of these scholars as optical scientists, they approached their work as theologians which, in turn, influenced their interpretation of medieval optical theories. Bacon, for example, was a Franciscan friar, who transmitted his scientific manuscripts to the Papal court in secrecy (Smith, 2005). Pecham and Witelo were priests as well, who relied on Ibn al-Haytham in constructing their own evolving optical theories, but who also took liberties with their interpretations and infused them with spiritual undertones. The work of these scholars, collectively and respectively, had enormous influence on the progression of optical understandings throughout the centuries that immediately followed.

The nature of light, vision and cognition are so directly linked with ontological aspects of the human experience that they also appeal to considerations beyond the scientific. As the encyclopedic and monastic traditions of scholarship propelled intellectual curiosity, and as images increasingly became the popular visual culture of the day, it should not be surprising that the science of optics entered other areas. It is remarkable, though, just how widely it permeated Western European consciousness and the broader culture.

FIG. 4
Woodcut cover image of a 16th century translation of *Perspectiva Communis*, by John Pecham. Edited by Luca Gaurico, c1510.

Popular literary examples published during this period illustrate just how widespread the interest and understanding of optics had become. Ibn al-Haytham, for example, is referred to several times in the epic poem *Roman de la Rose* [Romance of the Rose] by Guillaume de Lorris and Jean de Meun, one of the most widely read works in the French language for 300 years after its publication in c1275 (Ilardi, 2007). In the text the authors describe the properties of mirrors, with the text exhibiting a surprisingly non-trivial understanding of optics. One short passage from these four pages makes its debt to Ibn al-Haytham (Alhacen; Alhazen) quite clear:

> There [in Alhacen's Observations] he will be able to discover the causes and the strengths of the mirrors that have such marvelous powers that all things that are very small – then letters, very narrow writing, and tiny grains of sand – are seen as so great and large and are put so close to the observers – for everyone can distinguish among them – that one can read them and count them from so far off that anyone who seen the phenomenon and wanted to tell about it could be believed by a man who had not seen it or did not know its causes. This would not be a case of belief, since he would have the knowledge of the phenomenon (Ilardi, 2007, p. 44).

A century later Geoffrey Chaucer refers to Ibn al-Haytham in *Canterbury Tales*, written over the period 1387–1400, and the first major piece of literature in the vernacular English language. Chaucer, too, was influenced by his understanding of the content of Ibn al-Haytham's works on vision and optics, as is clear from the following passage:

> They spoke of Alhazen and Vitello and Aristotle, who wrote of curious mirrors and of perspective glasses, as they know who have heard their books.
>
> (NeCastro, 2007, p. 3)

As medieval optical theories increasingly informed scientific inquiry and, furthermore, epistemological frameworks of society and culture, interest in the visual system – particularly how it might be applied to artificial representations of space and spatial perception (i.e. painting and drawing) – were considered for use in the visual arts. Interestingly, although Ibn al-Haytham's developments were disseminated through the works of Bacon, Pecham and Witelo, what transpired was not so much a period of scientific discovery in optics, but rather a prolific period of advancement of *visual literacy*, with the science of optics providing the *syntax* upon which new spatial understandings were constructed. As Greenstein (1997, p. 682) states:

> Because vision is a cognitive process involving inner sense and intellect, optics links sight with semantics, semiotics, and theories of the soul. It makes use of such fundamental Aristotelian concepts as form, substance, accident, quality, individual, universal, species, and whatness.

Art and optics

What influence perspectivist theories of vision had on the visual arts leading up to and throughout the Renaissance, however, has yet to reach a consensus among scholars. Writing on the influence of optical scientists on visual artists Klein (1961, p. 212) states, "We may observe the widespread conviction that there was a close connection between their disciplines, really an identity". He further states, "If one can believe Rafaello Maffei, the ancient science of Alhazen and Vitellio now included artistic applications and was almost identified with the fine arts" (Klein, 1961, p. 212). Kemp (2005) remains cautious of considerations that superimpose perspectivist theories of vision directly upon the development of linear perspective or visual transitions in the visual arts. A more favorable and synergistic point of view, however, can be found the introduction of Smith's (2001) English translation of *De Aspectibus*, where he states:

> The representation of visual space in Renaissance art was the expression of a world-view implicit in the Perspectivist analysis of sight, a world view based upon the 'geometrization' of visual space. If, however, Alhacen and his Perspectivist followers taught Renaissance artists to 'see' the world in such spatial terms, those artists in turn taught early modern thinkers to see the world in those same terms and thus to conceive of it as a Euclidean continuum.

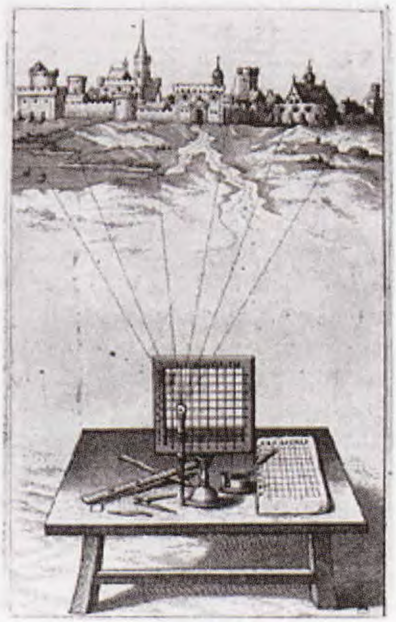

FIG. 5
Illustration of Alberti's picture plane, interrupting the visual rays of the perspectivist pyramid.

Written evidence of this 'Euclidean continuum' is interpretable in the writings of such well known Renaissance masters as Alberti, Ghiberti and da Vinci, and equally important visual evidence is evident in the actual images created throughout the period. Alberti's most notable work, *On Painting*, c1435, for example, employs a model for vision taken directly from Ibn al-Haytham. Greenstein (1997, p. 682) validates a parallelism between Ibn al-Haytham and Alberti's respective models of vision by stating, "Alberti's viewer first sees under aspects [*aspecimus*]; then recognizes by intuition [*intuentes...dignoscimus*]; and finally discerns with greater discrimination [*aspicientes distinctius...discernimus*]". These stages of visual succession imply that Alberti understood spatial perception as a layered and complex cognitive process; one that must account for the perceptual tendencies the viewer applies as a means for interpreting any given scene. There is support for the idea as well that the 'Euclidean continuum' informed Alberti's understanding of the visual pyramid (Lindberg, 1981).

Kemp (1990, p. 345) however, is conservative in his estimate of the influence optics had on transitions in visual art practice evident in painting stating, "Medieval optical science created far more problems than it solved for Renaissance artists". For example, that Alberti is explicit about having composed *On Painting* for artists and demonstrates indifference to debates about which direction visual rays might reach the eye of the viewer, i.e. intromission vs. extromission, is interpreted by Kemp (1997) as a break in Alberti with scientific tradition. Kemp's conclusions, however, do not wholly consider the practical implications which occur when the visual system is oriented and applied to visual art practice, and pre-date the discoveries of the Hockney-Falco thesis by a decade.

Alberti was aware of the debate born out of the perspectivist optical tradition about visual rays; aware enough to put forth that such considerations are 'useless' for artistic purposes (Kemp, 1997). Subsequently, Alberti focuses his attention instead on concepts relative to spatial disposition and composition, and how these two principles are translated and reoriented as objects on a two dimensional picture plane. In short, Alberti was the first to interrupt (in writing) the visual pyramid by placing the canvas perpendicular to the visual rays, specifically at the vertex of the pyramid. Whether Brunelleschi's panel experiments at the Piazza del Duomo or the Piazza della Signoria, in Florence, were actually the first experimental illustration of this effect, will not be discussed here. However, the latter certainly informed the former (Arnheim, 1978; Kemp 1990). The necessary level of understanding for providing audiences with instruction of these advanced visual considerations subsequently required a new form of erudition and language, namely perspective.

Lorenzo Ghiberti's efforts to make a contribution to the discussion appear a decade or so after *On Painting* was first published and immediately translated into Italian. Ghiberti attempted a theoretical understanding of the arts, relying heavily on the optical theories of Pecham, Witelo and others, which in turn relied on Ibn al-Haytham. Ghiberti certainly had access to a 14th century Italian translation of Ibn al-Haytham, given that entire portions of it are incorporated in Book 3 of his *Commentari* (Fragenberg, 1986; Greenstein, 1997, etc.). The book was incomplete at the time of Ghiberti's death but is described by Lindberg (1981, p. 152) as:

> The most transparent case of the influence of medieval visual theory on a quattrocentro artist... he [Ghiberti] presents a complete survey of the mathematical tradition in optics consisting mainly of excerpts and paraphrases drawn from the perspectivists.

Subsequently, by the time da Vinci would consider the works of these same optical scientists, he too would be forced to reconcile for himself the relationship between vision, perception, and pictorial representation.

Kemp's (1977, p. 147) research on da Vinci makes it clear that the artist established an "Increasingly sharp separation between perspective as the science of vision and perspective as a geometrical means for constructing a rational picture space", which da Vinci refers to respectively as 'perspective made by nature' and 'perspective made by art'; or *'prospettiva naturale'* and *'prospettiva accidentale'*. It is also clear that Alberti and Ghiberti's shortcomings in affirming or denying the function of the visual pyramid are too laconic in the mind of da Vinci, who subsequently embarks on an intense period of experimentation, applying a methodology and conducting experiments remarkably similar to those of Ibn al-Haytham (Smith, 2001).

Given the progression of events outlined throughout the preceding sections it seems unusual that an artist like Alberti was so familiar with the perspectivist tradition, and yet so little is known about how he arrived at the principles of linear perspective. Nevertheless, a clear language of visual literacy has been established, beginning most significantly with the work of Ibn al-Haytham and culminating with Alberti's visual pyramid for artistic production during the Renaissance.

5. Conclusion

Consideration of the lineage of medieval optical theories leading up to and throughout the Renaissance is necessary for understanding the methodology Hockney and Falco developed, centuries later, for analyzing well known European paintings, as well as the larger impact of the perspectivist tradition as it relates to realist image production. This methodology is one based on a framework of visual understanding, i.e. visual literacy; one that dates back to the perspectivist tradition and explicitly recognizes the optical principles evident within artificial and natural representations of space.

Smith eloquently and accurately illustrates the complex relationship that exists between visual literacy and reading by interpreting Ibn al-Haytham:

> In likening spatial perception to reading, Alhacen underscores that the ease with which we read 'space', like the ease with which we read words, masks the arduousness of acquiring that reading-skill in the first place. Reading space, in short, is far more intellectual than it is tactile (Smith, 2005, p. 2005).

That the mind of a painter is as intrinsically involved in the creative process, as is his hand in creating paintings, makes original works of art highly complex subjects to analyze. Hockney and Falco however, demonstrated that optical evidence exists within the visual compositions of certain paintings. This evidence is therefore subject to visual (qualitative) as well as optical (quantitative) interpretation.

Such 'optical evidence' might consist of visual elements observed within a painting that do not reflect the perspectivist world-view of the age in which the image was created. Unlike an image projected onto film or canvas, for example, the human eye constantly adjusts its aim and focus as the mind constructs the scene it is viewing. As a consequence, humans do not simultaneously see part of a scene in focus and part of it out of focus. Although modern humans have observed the effect of scenes depicted out of focus countless times in the form of photographs, in movies, and on television, it is not an effect that is part of natural human vision. Hence, a simple example of the indirect use of optics is if an artist has painted a distant portion of a scene as if it were out of focus, replicating the depth-of-field of an image projected by a lens. This is precisely the effect Hockney and Falco identified from their observations of Lorenzo Lotto's *Portrait of a Married Couple*, c1524-5 (Hockney & Falco, 2005).

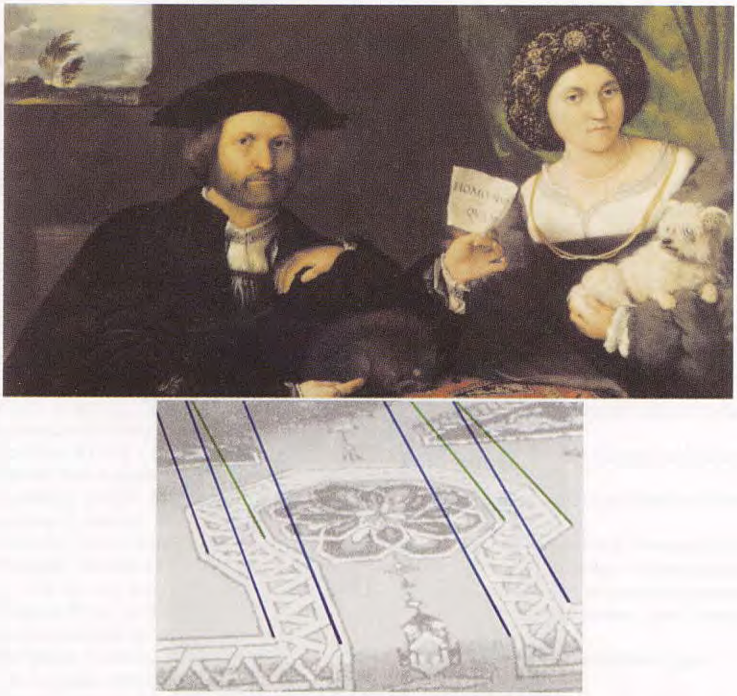

FIG. 6

Husband and Wife, Lorenzo Lotto, c.1523-4. 96cm x 116cm. Hockney and Falco observe that the octagonal pattern in the center of the tablecloth appears to go out of focus - one piece of the optical evidence that Lotto used optics when composing this portion of the painting.

While optically assisted techniques for artistic production are known to have become common by the 19th century, including tracing projected images (Paschall, 2001), earlier use of optics has been difficult to identify and analyze hindered, we believe, by the lack of sufficiently close interaction between art historians with artists and scientists. Sullivan's (2004; 2005; 2006) research of art practice as a verifiable form of research affirms this belief, and suggests that Hockney and Falco's approach for observation and deduction, essentially born out of their practice of art and optics respectively, might account for why their theories were rejected, at least initially, by some art historians (2005).

Additionally, lack of detailed understanding of optics and the history of optics continues to affect interpretation of historic realist images. For example, despite documentary evidence showing that concave lenses and mirrors of high enough quality were available in the first quarter of the 15th century (Ilardi, 2007), such evidence has done little to achieve wide acceptance by historians that a concave mirror can, in fact, project useful images for artists (Campbell, Syson, Falomir, & Fletcher, 2008).

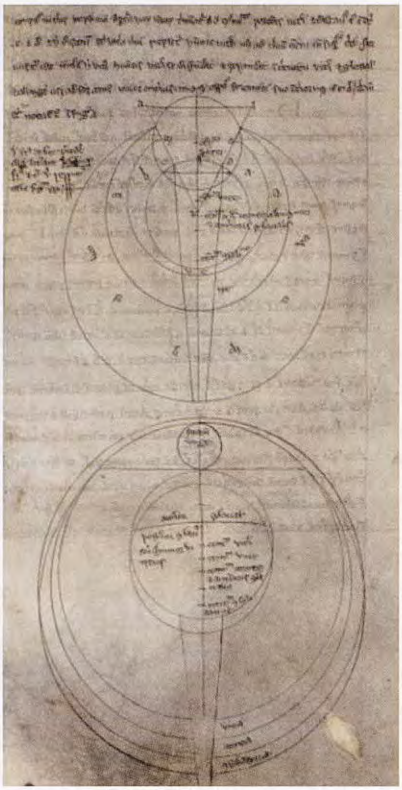

FIG. 7

Roger Bacon's diagrams relating to the scientific study of optics, from *Perspectiva*, British Library, ms. Royal 7 F. VIII, f. 54v.

Despite these challenges, recent study of Hockney and Falco's collaborative process highlights the specific manner in which their respective practice of art and optics enabled them to identify optical evidence within a number of Renaissance paintings, and ultimately demonstrate that artists as early as Jan van Eyck (c1425) used optical projections as aids for producing portions of their paintings (Allen, 2007). Hockney and Falco's methodology of visually interpreting optics-based images stipulates that visually evident compositional details qualify certain paintings as 'photorepresentations' composed both by the hand and mind of the artists, but resulting from optical geometry as well.

Hockney and Falco's methodology and findings have implications for the histories of science and art, as well as science and art education. This unique approach for analyzing works of art is within the long, interdisciplinary, progression towards a new visual language; one historically informed by the science of medieval optics, but put into action by visual artists during the Renaissance.

Acknowledgements

We gratefully acknowledge David Hockney for his invaluable insights on painting through his investigation of over 1000 years of European art. These insights provided the foundation for ongoing work subsequently being pursued with David Graves, resulting in locating documents related to the early use of optics by artists, the origin of which we have traced to the writings of Ibn al-Haytham.

REFERENCES

ALLEN AIMEE L. (2007). *Imaging spaceland: The Hockney - Falco thesis: An arts-based case study of interdisciplinary inquiry,* (University of Michigan, ProQuest).

ARNHEIM RUDOLF (1978). Brunelleschi's peepshow, *Zeitschrift fur Kunstgeschichte*, 41 (1), 57-60 (Deutscher Kunstverlag GmbH Munchen Berlin).

CAMPBELL SYSON, FALOMIR & FLETCHER (2008). *Renaissance faces: Van Eyck to Titian*, exhibition catalog. London: National Gallery of Art.

CHILDERS IAN (1996), *The Oxford dictionary of art and artists,* Oxford University Press.

HOCKNEY DAVID (1937-). "British painter, draughtsman, printmaker, photographer, and designer... by far the best-known and most critically acclaimed British artist of his generation".

DUNCUM PAUL (2001, Winter). *Visual culture: Developments, definitions, and directions for art education*, Studies in Art Education, 42 (2), 101-112.

EDGERTON SAMUEL JR. (1987). *"How shall this be?" Reflections on Filippo Lippi's "Annunciation" in London*, Artibus et Historiae, 8 (16), 45-53.

FALCO CHARLES M. (2005). A. Amira, A. Bouridane, and F. Kurugollu (Ed.), *Analysis of qualitative images*, Proceedings of the Irish Machine Vision and Image Processing Conference (Queen's University Belfast).

FRAGENBERG THOMAS (1986). *The Image and the moving eye: Jean Pelerin (Viator) to Guidobaldo de Monte*, Journal of the Warburg and Courtauld Institutes, 49, 150-171.

GREENSTEIN JACK M., (1997, December). *On Alberti's "sign": Vision and composition in quattrocento painting*, The Art Bulletin, 79 (4), 669-698. Quote found on p. 682.

GROOTENBOER HANNEKE (2007, June). Reading the Annunciation: the Navel of Painting, *Art History*, **20** (30), 349-363.

HOCKNEY DAVID (1998, Autumn). *Is TV dead?: Television as we know it may be dying, but painting certainly isn't*, American Art, 12 (3), 2-4.

HOCKNEY DAVID (2001, 2006). *Secret knowledge: Rediscovering the lost techniques of the old masters*. Thames and Hudson (2001), Penguin Group (2006).

HOCKNEY DAVID, FALCO CHARLES M. (2000). *Optical Insights into Renaissance Art*, Optics & Photonics News, 11, 52.

HOCKNEY DAVID, FALCO CHARLES M. (2004). Proceedings of the Symposium on 'Effective Presentation and Interpretation in Museums': *The Art of the science of Renaissance painting.* National Gallery of Ireland.

HOCKNEY DAVID, FALCO CHARLES M. (2005). Proceedings of Photonics Asia: *Optical instruments and imaging: the use of optics by 15th century master painters.* SPIE, 5638, p. 1.

HOCKNEY DAVID, FALCO CHARLES M. (2005). Proceeding of IS&T-SPIE Electronic Imaging: Quantitative analysis of qualitative images, *SPIE, 5666*, p. 326.

HOLBROOK SUE ELLEN (1998). *A medieval scientific encyclopedia "Renewed by good printing": Wynkyn de Word's English "De Proprietatibus Rerum"*, Early Science and Medicine, 3 (2), 119-156 (BRILL).

ILARDI VINCENT (2007). *Renaissance Vision from Spectacles to Telescopes.* American Philosophical Society. Quote taken from a translation by Charles Dahlberg (Princeton, 1971) of *Roman de la Rose.*

KEMP MARTIN (1977). *Leonardo and the Visual Pyramid*, Journal of the Warburg and Courtauld Institute, 40, 128-149. The Warburg Institute. Regarding da Vinci's separation of the terms "perspective made by nature" verses "perspective made by art," Kemp illustrates that da Vinci considered greatly the differences between the two as they related to optics and art (p. 147 [70]).

KEMP MARTIN (1991). *The Science of Art: Optical Themes in Western Art from Brunelleschi to Seurat.* Yale University Press.

KLEIN ROBERT (1961, September). *Pomponius Gauricus on perspective*, The Art Bulletin, 43 (3), 211-230. College Art Association.

LANGMUIR ERIKA, LYNTON NORBERT (Eds.). (2000). *The Yale Dictionary of Art and Artists.* Yale University Press.

"...His drawings and etchings are among the deftest of this century; posterity may well acclaim him the greatest of modern portraitartists".

LINDBERG DAVID C. (1967, Autumn). *Alhazen's theory of vision and its reception in the West*, Isis, 58 (3), 321-341.

LINDBERG DAVID C. (1971, January). *Lines of influence in the thirteenth- century optics: Bacon, Witelo, and Pecham*, Speculum, 46 (1), 66-83.

LINDBERG DAVID C. (1981). *Theories of Vision from Al-Kindi to Keppler.* University of Chicago Press. Regarding the quote by Alberti on the 'useless' aspects of the debate over ray theory for the purposes of painting, see page 237.

NECASTRO GERARD (Trans. and Eds.). (2007). *The Squire's Tale.* Online resource: http://www.umm.maine.edu/faculty/necastro/chaucer.

PASCHALL W. DOUGLASS, et al. (2001). *Thomas Eakins*, exhibition catalogue. Philadelphia: Philadelphia Museum of Art.

SMITH MARK A. (2001). *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*: Volume One, Transactions of the American Philosophical Society, New Series, 91 (4). American Philosophical Society.

SMITH MARK A. (2001). *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*: Volume Two, Transactions of the American Philosophical Society, New Series, (91)5, 339-819. American Philosophical Society.

SMITH MARK A. (2005). *The Alhacian Account of Spatial Perception and its Empistemological Implications*, Arab Sciences and Philosophy, 15, 219-240. Cambridge University Press.

STEINBERG LEO (1987), *"How shall this be?" Reflections on Filippo Lippi's "Annunciation" in London, part* I, Artibus et Historiae, 8 (16), 25-44.

SULLIVAN GRAEME (2004). *Studio art as research practice.* In E. Eisner & M. Day (Eds.), Handbook of research and policy in art education (pp. 795-814). Mahwah, NJ: Lawrence Erlbaum.

SULLIVAN GRAEME (2005). *Art research as practice: Inquiry in the visual arts.* Thousand Oaks, California: Sage Publications.

SULLIVAN GRAEME (2006), *Research acts in art practice.* Studies in Art Education, 48 (1), 19-35.