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Diskussionsbeiträge N.F. 1

Hans Belting

Perspective: Arab Mathematics and Renaissance Western Art

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Mi, 7. November 2007	**Prof. Hans Belting**
18 Uhr	„Blickwechsel zwischen zwei Kulturen: Perspektive als
A 703	arabische Sehtheorie und als westliche Bildtheorie"
Mi, 19. Dezember 2007	**Prof. Andreas Reckwitz**
18 Uhr	„Kreativsubjekt und Moderne. Zu einer Archäologie der
A 703	kulturellen Konstruktion von Kreativität"
Mi, 30. Januar 2008	**Prof. Karl Schlögel**
18 Uhr	„Probleme eines Narrativs der Gleichzeitigkeit in der
A 703	Geschichtsschreibung"

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Perspective:
Arab Mathematics and Renaissance Western Art

Hans Belting

Spain is the right place for recalling a historical encounter of Western with Arab culture. Pictorial perspective was invented in Renaissance Florence, but not only borrowed its name but also the mathematical theory of visual rays from an Arab treatise whose Latin translation seems to have been made in Spain. I am speaking of the "Book of Optics" *(Kitāb al-Manāzir)* of Ibn Al-Haitham, also known as Alhazen, a well known authority of the 11th century. The Latin name of the book, *"Perspectiva"* or *"De Aspectibus"* later was abandoned in the first printed edition of Fredric Risner and replaced by *Optics*, the originally Greek term. Alhazen's treatise had been "famous and came in everybody's hand" in al-Andalus, as we know from 12th century Arab sources. The Latin translation was to have a lasting success first in the scholastic philosophy of perception and cognition where it was commented on and debated by so-called "perspectivists" Vitelo, Roger Bacon and John Peckham, and later in the Renaissance among artists like Filippo Brunelleschi, the builder of the dome cupola in Florence, and humanists like Leon Battista Alberti, the author of the first text on painting that included the theory of art perspective. I have studied Alhazen and Renaissance perspective as an art historian with interests in the visual tradition of cultures and not as a historian of science or a mathematician. My research has been part of a project which deals with the history of looking or the history of the gaze[1]. But, you may ask, how do mathematics enter this project? It is their visibility which concerns us here. In Arab art, this visibility was the role of geometry that became a kind of visual medium of mathematics, whereas in Renaissance art, the equivalent was what was rightly called "Mathematical Perspective" and which materialized in pictures never seen before.

It is in what follows important to distinguish visual theory, a former Arab project, from pictorial theory that became a Western concern. The role of mathematics differed accordingly, as we will see. Among the many Arab mathematicians, Alhazen stands out for two reasons, not only because he revolutionized ancient optic theory, and thus provided a new calculation for the process of viewing, but also because his book on Optics, for reasons entirely historical and circumstantial, became in Latin translation the guide for Western visual theory that was, in turn, the basis of perspective, the most important picture model in Western culture. It was only after five centuries that Kepler who used Risner's edition, and Descartes took the first steps beyond his theory. George Saliba may be right that Arab astronomy even was of value to Copernicus in developing his theory, as he maintains in his recent book "Islamic Science and the Making of the European Renaissance". My approach, though I seem to follow the same path, is different because I speak of a transfer of science to art, meaning the linear perspective of the Renaissance, and also for the fact that the Western appropriation of this Arab mathematical theory allows new insights into the cultural techniques of two worlds. The difference not only is one between science and art, but also one of their cultural significance in the context of their own visuality and aesthetics.

It would be misleading to speak merely of influence in the dual history of perspective, both as science and as art. Renaissance authors more often were inclined to follow Euclid, Ptolemy and Vitruvius than Alhazen, though they read such ancient authorities already with the Arab knowledge in mind. In fact, I am more interested in the transformation of visual theory into pictorial theory, as the latter was a new Western project of no concern at all for Arab scientists. As regards the former, I am inclined to think that it was the *an-iconic* culture in which Alhazen lived, and which applies to Islamic societies at large, that helped him to dismantle the ancient authorities and to break with their dependance on bodies and idols in visual perception. I am here speaking not of the usual story of the transmission of ancient theory via Arab authors and translators but, on the contrary, of a revolution in scientific thought that, in my case, still waits for a cultural explanation. Ancient and Arab theories differ in the same way, as the two visual cultures are marked by a very different relation to images and bodies, and this applies, on the other side, equally to Arab science and its Renaissance followers.

Alhazen's contribution to science, as a mathematician, is certainly well studied by historians of science but he is not a familiar name outside this discipline and never mentioned in studies on perspective. Even historians of science, in my view, have not paid enough attention to a most revealing part of his thinking which for me is of central importance. This is the image question which divides Arab from ancient theory as radically, as it also marks the great divide to Renaissance thinking. Even authorities like Abdelhamid Sabra who published the first critical edition of Alhazen's book in translation from the Arab text in 1989[2], despite his careful study of Alhazen's terminology, so different from the Greek one, does not acknowledge Alhazen's reluctance to deal with anything mimetic and pictorial, while concentrating entirely on geometry and light which in Western thought, however, figure as abstractions. The term *ṣūra* which in Latin was translated as *species*, abandons the image connotations of ancient texts. It was understood to denote the disembodied perceptional "forms" which any object, dot by dot, transmits to the surface of the eye, while *khayal* concerns those properties which change with the changing conditions of perception. Ma'ānī, always used in the plural, mostly refers to the multitude of characteristics of the perceived object, but also to the impressions it leaves in the spectator, thus linking shape and appearance. *Al-nuqus*, finally, signifies the decorative and mostly geometrical "figures" which embellish such an object. All these terms, as is usual in Arab language, are polysemic, but they lack the meaning of the overall "Gestalt" or integral *image*. It was left to Western thinking to postulate that a physical, hand made picture, with all its difference from mental images, can represent a given object with enough precision and likeness. Only then, in pictorial perspective, visuality and cognition or, in the terms of today's neuroscience, external and internal representation seemed to coincide.

Two examples may serve to illustrate Alhazen's singular position in optical theory as well as his indifference to iconic experience. This is first the dark chamber (*al bayt al-muzlim*) which Alhazen invented, before it was invented again in the late Renaissance, and which was reconstructed recently in the Institute for Arab and Islamic Sciences in Frankfurt[3]. Alhazen used his invention preferently to prove that light extends in straight lines from all points on the shining object through the surrounding medium and radiates on all facing objects. However, he does not pay any attention to the images which are carried by the light into the chamber, much as he is disinterested in any mirror images but instead studies reflection and refraction of light in front of the mirror. Secondly, his theory of mental images later served as an inspiration for the Descartian separation of mind and sight. Images of the world or of corporeal objects do not appear in the eye but only are created in the brain, "the first sentient", as he writes in his second book. He thus proceeds in two different steps. First, he discusses the mechanics of the optical process whose laws are those of the light and allow for mathematical calculation. Then, he develops a new psychology of perception that complements the optical process properly being. "The forms of seen objects occur in the soul and take shape in the imagination" (Sabra, 1989, p. 217). "When sight faces an object whose form then occurs in the eye, the sentient will have a general perception of the form as a whole" (p. 211). "In vision by glancing, sight perceives manifest properties alone without thereby ascertaining the form of the seen object. Sight does not perceive what an object really is, by glancing" (p. 223). Thus, there emerges an invisible barrier between the outer senses and mental images, and the latter have no equivalent within the eye nor in front of the eye, in terms of pictures or seen images.

As a result, there can be no physical image or artefact, as it was invented in Western culture, to reproduce perception in perspective. The geometry of rays which carry their single forms, as in a mosaic, from spots on the surfaces of visible objects to spots on the surface of the eye, is one thing and the integral image which emerges in the brain is another. The Renaissance took the opposite road when it introduced pictorial perspective with the idea of constructing pictures which tell me how I see, or, to put it differently, which reproduce my perception mirror-like. The two cultures share the same mathematical theory but differ in its practical application and significance. The Renaissance used geometrical construction of the visual field as a subtext or invisible grid for pictures, the latter being not *geometrical as such* but only *geometrical by their making*. Nevertheless, it meant a revolution when the Western picture, with the method of linear or pictorial perspective, was intended to represent and focus on an individual gaze. It then was understood to be "analogous", as modern terminology has it. This meant analogous not only to the visual world but also to the visual activity of the eye. Perspective painting, as a result, was identified with the very condition of looking. The introduction of the individual gaze, as a mathematical point for measuring the visual field, appropriated a former divine privilege in watching the world as one's own image.

Let me, however, come back to Alhazen, the mathematician, who also figures as eye-witness and theoretician of Arab visuality and mentality[4]. It is no mere coincidence that his major work was written in the same era when two visual creeds of Arab culture were developed in their lasting form. The one is the so-called "proportionate writing", a canonical scripture style that provided the matrix for all further Koran writing. The other is the so-called "Girih Style", a term derived from the Persian word for knot, a completely abstract style of geometrical decoration that was to shape the history of Islamic art for centuries[5]. Both inventions go back to the "Sunni revival" at the Abasid court of Bagdad and both are in a way equivalent, as they interrelate in their geometrical purity and their use of mathematics. It therefore is no mere accident that Alhazen, in his book on Optics, uses both geometrical ornament and scripture as examples when he explains how our perception works and how it uses memory and comparison, before recognizing each individual element in a system. His examples reveal how central it was in Arab aesthetics both to contemplate geometry on walls and vessels and to read as well as to watch geometrical style writing. In fact, both reveal a mathematical order whose rules were to guide the eye und to offer visual education. In buildings of the so-called "brick style", geometry and writing are inseparable on outer walls where they are similarly constructed with the same layered bricks. For the training of scribes, Ibn Mugla, a 10th century authority, used a certain number of moduls such as rhombic dots, and thus standardized all letters in the new scripture style. And the mathematician Abu al-Woja al Buzjani, of the next generation, wrote popular mathematical guide books which artisans were to read in order to handle geometrical construction. Mathematics lived on in geometrical decoration which had become a "Symbolic Form" in Arab culture, a term which Erwin Panofsky had used to introduce Renaissance Mathematical Perspective but which equally lends itself to explain visual programs in other cultures.

Geometry, we may conclude, serves as the equivalent of what pictures are in Western culture. At the same time, however, it functions quite differently from pictures, if we consider that one of its main goals was to protect the eye from all sensuous distraction. Some writers of Alhazen's times compare the ornament with a soap that cleanses clothing from stains. Geometry served as a medium for purifying the world of the senses while at the same time representing the supreme reign of light in the world. The light is not just there to illuminate bodies, as it does in Western art, but has a superior existence. For Alhazen, mathematics in turn had a superior beauty, as it is based on calculation, a beauty not just seen but 'read' in a cognitive act of perception. Alhazen often stated that he wanted to bridge physics and mathematics, the one being material and the other abstract, and we may observe the same tendency in Islamic art where geometry transforms the physical reality of its objects and buildings into the mathematical beauty of tile patterns that, like a skin, obscure or eclipse the corporality of vessels or buildings underneath.

The complex patterns in Islamic ornament recently have found attention among physicists and mathematicians. Peter J. Lu and Paul Steinhardt have studied what they call "Girih-tiles", a "special set of equilateral polygons decorated with lines. These tiles enabled the creation of increasingly complex periodic girih patterns, and by the 15th century, the tesselation approach was combined with self-similar transformations to construct nearly perfect quasi-crystalline Penrose patterns, five centuries before their discovery in the West" [6]. It is here no space for entering this debate, but I would like to add that 15th century mathematical treatises dealt with the construction of so called *Muqarnas*, niche and vault patterns that were a building location where mathematicians could prove their invention and originality[7].

The close relation of art and mathematics in Islamic culture needs no further proof, but we must briefly look at the Western case which invites for what I would like to call a *blickwechsel* or cross cultural view, an argument which I will pursue in greater detail in my forthcoming study. Renaissance mathematical perspective is certainly a subject that has been thoroughly studied, but it appears in a new light when discussed in the usually neglected context of Arab visual theory, represented by Alhazen's book on "Perspectiva". Renaissance thought was focussed so exclusively on the revival of ancient culture that the use of a new, mathematical theory of different origin was obliterated, just as it also was ignored in modern research. Even Erwin Panofsky failed to recognize this important intervention and instead unsuccessfully tried to rediscover an ancient practice of pictorial perspective which, in fact, was more a case of Vitruvian scenography.

But the transformation of a visual theory of ultimately Arab provenance via scholastic reinterpretation into Renaissance pictorial theory is a paradox case which I only can mention and not fully discuss in my paper. The term *species*, serving as a common translation from Arab terms quoted above, already provided an occasion for reappropriating Alhazen's concept with the new and unprecedented meaning of image, picture and idol. Thus, the significance of the Arab theory was subject to a gradual change. The result was a new controversy over the part of sight in cognition and also over the role of images in perception, a controversy which gradually departed from Alhazen's arguments. Medieval philosophers may have been irritated by the unwelcome intervention of what they suspected to be images, in their own discourse of cognition, while late medieval Italian artists like Giotto, even before embarking on linear perspective, began to depict things not *as they were*, but *as they were seen* according to distance and angle of sight, thus experimenting with what they understood as species. The debate whether the painter Giotto prepared linear perspective hundred years before its invention, now finds a possible solution. He rather embarked on representing the visual act, as represented by the concept of *species*, while a mathematical method of constructing space was still lacking.

In order to understand the invention of linear perspective, it is also most important to consider another, equally neglected contribution to the new handling of vision and space. This is a redefinition of Alhazen's visual theory by Biagio Pelacani, a philosopher from Parma (+1416) whom I want to introduce in this context, since he claimed to have invented mathematical space and thereby also having defined the empty space, i.e. space as such. Though he was well studied by philologists like Graziella Federici Vescovini[8] his name is lacking in most of the studies on perspective. Pelacani who had a new understanding of Alhazen's optical theory and criticized the so called "perspectivists" and Alhazen editors for missing the point, wrote a treatise on perspective which is a study of visual theory. In his own theory, the notion of space added a new element to Alhazen's theory which caused a second change of direction, like the one that previously had been taken with the re-iconization of visual theory in scholasticism. A space with an ordered geometry of its own, a unified space of the visual field, was a most radical reorienation of Arab thought, since it was related to an individual look which was of no concern for Alhazen and his followers. Such a newly defined space, a looking space, was meant to control and counterbalance the problem of eye deception that inevitably happens because of the permanent illusions of perception, via mathematical measuring. Thus, this new concept promised to offer a solution for a problem which Alhazen had regarded as unresolvable except with the help of imagination and memory. In fact, Pelacani offered a new confidence in the location of objects and in their interrelation in the visual field, with in other words a guaranteed visual topology independent of light changes and air condition. Hence the new discussion of orthogonals, viewing point, vanishing point and the visual pyramid that became basic concepts for the invention of mathematical perspective.

We may now speak of *representing geometry*, just as speaking, in the Arab context, of *represented geometry*. What is the difference? While geometry in a way represents a certain branch of mathematics, on the Arab side it is represented as a symbolic system of viewing and was a subject of its own. We could say that in representing geometry not just as a tool or method but for its own sake and for its own beauty, Arab artisans represented mathematics which otherwise are un-representable, and looked beyond the discipline of mathematics toward a cosmic principle. The difference of mathematical perspective in the West is obvious. Here, geometry is representing something else which is not geometry. It helps to construct a picture of the world on the basis of visual geometry, a picture of a *world seen* and a visual space, as it opens in front of the eyes and represents an individual look. I am therefore inclined to call Renaissance perspective an attempt to *measure our view*, while Alhazen's visual theory could be described as the project to *measure light* and thus to follow and reconstruct its abstract geometrical traffic in a sublunar world of objects.

We may conclude that linear perspective, as a "symbolic form" in the Cassirer sense and as the most important picture technique ever invented in Western culture, is anything but a rebirth or *re-naissance* of ancient art. Every culture, with its privileges or taboos of seeing, shapes a certain way of thinking, as it is, in turn, shaped by norms or vetos of looking. Also scientific theories, in our case those of Optics, are the expression of local habits and customs. It was a given mentality which helped Arab scientists to overcome Graeco-Roman doctrines of perception , as they knew them from ancient texts. The synthesis of physics and mathematics resulted in dematerializing ancient models of perception. Arab Optics, in turn, in the West offered the basis for calculating the process of perception in mathematical terms. But this transfer of knowledge only could materialize in pictures, after a Western mathematician, Pelacani, had provided a theory of mathematical space as such, beyond being the traffic space of light. Thus, the newness and difference of the pictures of perspective are explained by the fact that they are mathematical constructions whose geometry is that of visual theory. It was the historical encounter with Arab science which helped to create the visual culture of the Renaissance.

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1 Cf. My forthcoming book, in German, on pictorial perspective and Arab geometry, centered on Alhazen, Brunelleschi and Western philosophy and due to appear in spring 2008 (Munich, Beck). The book that is in print allows me to refrain from a full coverage of footnotes and to present this text as a first notice for English readers.

2 A.I. Sabra, ed., The Optics of Ibn Al-Haytham, Books I-III on Direct Vision (Vol. I and II, London, The Warburg Institute 1989)

3 Fuat Sezgin and Eckhard Neugebauer, ed., Wissenschaft und Technik im Islam (Katalog des Instituts der Arabisch-Islamischen Wissenschaften (Frankfurt 2003, Vol. III chapter 6)

4 For his esthetics, cf. José Miguel Puerta Vilchez, Del Pensamiento Estético Arabe. Al-Andalus y la estetica classica (Madrid 1997) and Gülru Necipoglu, The Topkapi Scroll. Geometry and Ornament in Islamic Architecture (Getty Center, Santa Monica 1995)

5 Oleg Grabar, The mediation of ornament (Mellon Lecures, Princeton 1992) and Oleg Grabar, Islamic Art and Beyond (Ashgate Publ. Ltd. 2006)

6 Peter J. Lu and Paul J. Steinhardt, Decagonal and Quasi-Crystalline Tilings in Medieval Islamic Architecture, in: Science Vol. 315, February 2007, p. 1106.

7 Mohammad Al-Asad, A geometrical analysis, in: Necipoglu, 1995, p. 349 and Yvonne Dold-Samplonius, Calculating surface patterns and volumes in Islamic architecture, in: Jan P. Hogendijk - Abdelhamid I. Sabra, ed., The enterprise of science in Islam. New perspectives (MIT Press 2003), p. 235.

8 Graziella Federici Vescovini, Studi sulla propettiva medievale (Turin 1965) and many other of her later writings.

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