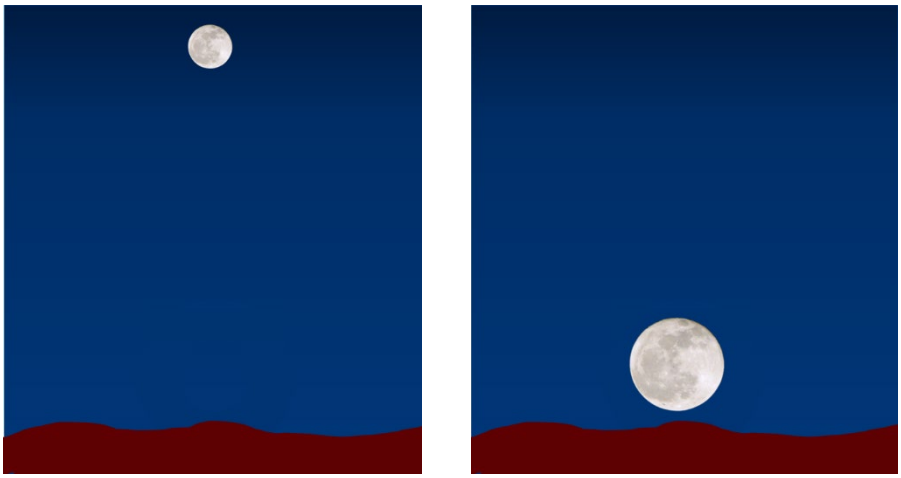
Summary of *Ibn al-Haytham's Analysis Of the Moon Illusion*, a Bisan Lecture by A. Mark Smith

Mark Smith, professor emeritus of history at the University of Missouri, delivered the first Bisan Lecture of 2023 as a Zoom webinar on January 11. His subject was how the Arab scholar Ibn al-Haytham, writing a millennium ago in Cairo, sought to explain the Moon Illusion—a striking phenomenon that (almost) all of us have experienced, and that has been the subject of science writing from antiquity to today. When the moon is viewed on the horizon at moonrise or moonset (image at the right below), it appears much larger to most people than when it's higher in the sky (image on the left). This despite the fact that its true visual size—the angle it spans at our eyeballs—is almost exactly the same in the two cases. (By the way, the moon looks bigger on the horizon in the images below because it was drawn bigger—not because of the Moon Illusion. Whether or not the illusion can be captured in undoctored photos was an issue in the Q & A after the talk.)



The Moon Illusion is discussed at the very end of Ibn al-Haytham's monumentally influential treatise on vision, the *Book of Optics*. Mark explained that the surviving Arabic manuscripts are few and fragmented, while the Latin translation, *On Appearances*, remained a key scientific source up to the seventeenth century, and survives in numerous high-quality manuscripts. Mark has spent the better part of his career creating a critical edition of the Latin book, including an English translation and extensive explanatory commentary.

Mark used the Moon Illusion as a way to make Ibn al-Haytham's contribution to science accessible to a non-technical audience. The key source for the *Book of Optics* was Ptolemy's *Optics*, written in the second century CE. But Ibn al-Haytham had to adapt Ptolemy's analysis to his own fundamentally different idea of how vision works.

Ptolemy thought that we see things because our eyes emit rays of "luminous flux" out into the world. When one of these rays hits a tiny spot on an object, a return ray is reflected back to our eye along the same path, carrying information about that tiny spot of object: its color, its consistency, and—critically for Mark's story—how far the luminous flux ray had to travel to encounter that spot. The object is thus represented in the eye as a two-dimensional array of pixels

(as we'd call them now), each containing information about color and distance from a returning ray. It's the distance information that, according to Ptolemy, accounts for our perception of depth in the world we see.

Ibn al-Haytham thought that we see objects because of light rays that emanate from tiny spots on the objects themselves, not from rays of luminous flux that emanate from our eyes. Each tiny spot on an object emits light rays in all directions, but the only ray that counts is the one that ends at the center of the eye. These incoming rays have the same geometry as Ptolemy's returning rays; as for Ptolemy, an object is thus represented in our eye by a two-dimensional array of tiny pixels, each with information about a tiny spot of object. Crucially missing in that pixel, however, is any information about the distance of the object. An entirely different account of depth perception was required.

For Ibn al-Haytham, the array of tiny pixels that arrives in our eye at any moment in time is not intrinsically organized into a scene containing recognizable objects with defined positions relative to us and one another. Such organization is imposed on the array in our brains to create the visual world as we perceive it. Our brains progressively impose this organization as we experience the world as very young children. Thus, for example, we learn to perceive a familiar object such as a human that spans a shorter vertical space in the array as being farther away, not smaller, than a similar object spanning a longer vertical space. By an early age, this orderly imposition is so instantaneous and automatic that it seems intrinsic to the world, and is impossible (or very hard) to override by subsequent worldly experience.

Mark likened the two-dimensional array as it arrives in the eye to the famous pixelated painting by the French artist George Seurat pictured below. Seurat created the painting by delivering tiny drops of colored paint to a flat piece of canvas with the tip of his paintbrush. Yet we, as adults at least, can't help perceiving the painting as an idyllic Parisian scene with attractive people spread out along a riverbank that recedes far into the distance.

In some circumstances, Ibn al-Haytham argued, our brains impose a false organization on the incoming array of pixels, leading to misperceptions such as the Moon Illusion. In particular, to a child the earth seems flat with a flat sky above. As the moon overhead apparently moves along this flat sky farther and farther away toward the horizon, the size of its image on the incoming array of pixels should get smaller and smaller, just as the pixelated representations of distant people in Seurat's painting get smaller and smaller the farther away they stand on the river bank. But in actual fact, unbeknownst to the organization quick-set in our brains in early childhood, the moon remains at the same distance from us as it descends toward moonset, so it's perceived to be getting bigger and bigger. It's as if Seurat had included a figure far away on the riverbank taking up as much vertical space on the canvas as a person in the foreground; the faraway person would seem to be a giant, not an ordinary human being.

Ibn al-Haytham's analysis of perception seems remarkably plausible and modern—much more so than Ptolemy's "luminous flux" for instance. But Mark reminds us how innovative his adaptation of Ptolemy's ideas was at the time. His writing seems modern because of the enormous influence his work had on the historical development of modern optics.

As Mark thanked the audience for their "kind attention," he projected a picture of an auditorium full of snoozing attendees. In fact, judging by the lively activity on the Chat and the audience questions that were posed to Mark after his presentation, his virtual audience was full of engaged attendees. Unsurprisingly, most of the questions and comments concerned the Moon Illusion, not the technical details of Ibn al-Haytham's optics. Whether the illusion can be captured photographically, or can only be experienced out in the real world, has already been mentioned. Are overeducated observers with deep knowledge of astronomy fully susceptible to the illusion? Do people who can only see out of one eye still experience the illusion?

It makes you think.