Ieliodorus and 4th century ꞌisual science

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Summary

In the belief that the leaders among the ancients were probably about as intellectually competent as those of today, I am not willing to draw any firm conclusions that suggest that they were naive. On the contrary, I am inclined to suspect that they were influenced by they contemporary indoctrinations just as we are today.

One of these was the concept of natural law, which Heliodorus cited in several instances to justify some of the 14 points. Another was the overriding influence of geometric science in the justification of a concept. This is especially illustrated in the geometric properties of the cone of vision. Geometric science was so firmly entrenched at that time as to have screened out any direct observation of, for example, the erroneously derived visual field as being only 45° in any direction instead of well over 90°.

Direct observation, experimentation , and measurement appear to have been considered only with great caution, to be accepted only upon the word of esteemed authority, popular familiarity, or after derivation by logic or geometry. Even today we do not view this to be without considerable merit as we challenge anecdotal science reports and compute the validity and reliability coefficients of laboratory data and other statistics. Facts are few; illusions are rampant.

Personally, having done this exercise, I no longer challenge the historians' interpretation of ancient visual science documents that the eye emits some sensory rays to see with. Nor, as an optometrist, will I question the intellectual competence of a nonscientist patient who fails to appreciate the astronomer's light year, or who doubts that the world is round, especially if his or her name happens to be Plato, Euclid, or Heliodorus

Introduction

For those of us who have had at least an elementary course in physic the concept that light travels from visible objects to the eye, rather than reverse, is so commonplace that we have difficulty even imagining otherwise. But most people of this world have not had an elementary course in physics, and they have never perceived light in apparent motion, for our senses can tell us only that light is instantaneous wherever it is or goes. It requires no humanly measurable amount of time to get there. In terms of traveling or transportation, light and vision are one and the same phenomenon.

When I started teaching optometry over 50 years ago I became aware of the allegation that Euclid (ca. 280 B.C.), often referred to as the Father of Optics, theorized that visual rays proceed from the eye to the object. Science historians routinely credit others among the most sophisticated ancients with having the same concept. My very limited knowledge of any of the ancient languages did not allow me to contest this allegation, but my strong indoctrination in modern optics supprted my disbelief that Euclid et al really meant what the classic translators have been interpreting them to mean. It long remained my suspicion that what the translators have been interpreting as eye-to-object visual "rays" perhaps should have been interpreted simply as visual "paths" or "pathways" without implying any directional eye-to-object attribute.

Recently I received a photocopy of rare document on optics published in both Greek an Latin in 1610. The Greek had been copied directly for scribal copy of a manuscript of Heliodorus of Larissa identified with the fourth century A. D., or a bit earlier. Because it appeared never to have been traslated into English I enlisted the help of Byron Stayskal, a Classic scholar at Indiana University who had had extensive language training in Greek, Latin, and German. Together we published our translation in *Optometry and Vision Science* (Vol. 69, No. 1, January 1992, pp. 76-79).

In terms of my suspicion it was fortunate that Mr. Stayskal had no formal background in optics and visual science so that he was not as biased as I by modern vocabulary and concepts of light propagation, optics, and visual science. This meant many hours of conference and debate between us to interpret the true meanings of Greek terms and expressions in the original text that pertain to refraction, focus, visual acuity, etc. for which there were no direct synonyms in Greek. We also gained some insight by comparisons with the Latin and a more recently available German translation.

Theory and comment

The Heliodorus thesis summarizes the knowledge of visual of science in 14 brief statements of principles as seemed to prevail among the most sophisticated thinkers throughout several centuries before and after the original period of writing and scribal multicopying. I should like to restate these in my own very free interpretation rather in the meticulous phraseology of our published translation as shown here serially on slides. Then I propose to comment freely on the explanatory notes given by Heliodorus in support of these principles.

1. Vision is accomplished by projection from our eyes.

This underlying theme is supported by the argument that the eye is spherical but not hollow like other organs of perception. We shall see that additional supportive arguments are expressed further on.

2. The projection is light.

This is supported by reference to occasionally observed flashes from one's eyes and by the assertion that some people, such as Roman emperor Tiberius, can see at night. Reference is also made to the eyes of nocturnal animals which are often seen to shine like fire at night. It is suggested that the ocular projection, or vision, is directly comparable to the light from the sun, differing only in their origins.

3. The ocular light, called vision, projects in straight lines, and these lines together form a right-angled cone with its apex at or within the eye.

It is argued that because vision is instantaneous it is most logical that its rays be straight lines, as in the "shortest distance between two points" definition of a straight line.

It is also argued that the circular cross-section of the cone subtends the maximum visual field area most efficiently, a feature that is advantageous to living creatures and compatible with nature in providing the maximum instantaneous view in a single glance.

4. The projected light has the shape of a cone, not a cylinder.

The argued logic here is that if it had a cylindrical form its diameter at all distances would only be equal to that of the pupil and would therefore limit visibility to small objects.

5. The visual cone is right-angled.

The author argues that nature does not favor the indefinite and confusing shapes and boundaries of the visual field that would prevail with an obtuse or acute angle cone. His apparent logic may be attributable to the geometric concept that a right angle is unique whereas other angles are infinite in size and number. He further asserts that the definity of a right-angled cone is appropriate to the nature of rational creatures. He believes this to be supported by the observation that only a quarter part of the spherical sky is seen at a single fixation. By the same geometric analysis only a quarter of the horizon may be seen at once. By further geometric analysis he points out that upon standing at the periphery instead of the center of a large circle half of the total circle would be visible in one glance.

The author reminds the reader that when one says that a quarter of the sky is seen in its entirety at a single glance he my seem to be contradicting Euclid, who, in this *Elements* declares that "nothing is seen in its entirety in one glance". Then by way of explanation he makes a distinction between seeing an object as a whole and an object in detail, i. e., between the visual field and the visual acuity. In the later case we my find it necessary to make more than a single fixation to see small details which fall between rays emitted from the eyes.

6. The intensity of light, or density of visual rays, is not uniform across the cone.

Here, again, a geometric explanation is given that the rays of the luminous cone emerging through the pupil must spread out or diverge from each other so as to occupy the total space throughout the length and diameter of the cone.

7. Anything that is visible subtends a right or acute angle at the vertex of the visual cone, but never an obtuse angle.

Once more the science of geometry is employed to defend the concept. An object whose extremities touch both ends of a diameter at the base of the visual cone will subtend a right angle at the vertex. An object whose extremities touch the periphery of the base at any other pair of points, or are of lesser length, will subtend only an acute angle.

8. Anything subtending a larger angle appears to be larger.

This is attributable to the inference that the larger object is contacted by more visual light, that it interceps more visual rays.

9. Our best acuity is near the axis of the cone of vision.

By way of supporting evidence it is pointed out that to see sharply we must turn our gaze so as to place the axis of the visual cone directly on the object to be examined. In a rare use of experimental evidence the example is given of searching for a needle which we may not find until we view it with the axis of the cone or with rays near the axis.

10. It is natural that sight should operate most effectively in the straight ahead position.

It is pointed out that we instinctively direct the axis of the visual cone forward, that we may even employ a mirror to make posteriorly or laterally located objects seem in front of us.

11. The apex of the optical cone is located somewhat posterior to the plane of the pupil. The circumferential edge of the pupil circunscribes one quarter of an imaginary sphere, thereby defining the cone.

It is interesting that with his pervasive dependence on geometry the author did not eleborate on this point, if only to show that the apex of the visual cone is automatically one pupillary radius behind the plane of the pupil.

12. Whatever is seen either directly ahead or by reflection or refraction of our vision.

As before, the emphasis is on the role of the emitted ocular rays by descriptions of their reflection at the mirror-like surface of still water when we view reflected objects located outside and above the water, and their refraction when we view objects that swim or lie beneath the surface. Refraction is clearly identified with transparency.

13. Vision and the sun are similar.

This point is discussed at considerable length. While the similarities are in terms of reflection, refraction, pathways, instantaneousness, linearity, color rendition, color filtering, and transparencies, there is not suggestion that the sun's rays and the visual rays are to be considered one and the same entity. Even Plato is quoted as saying that of the organs concerned with perception, vision was most like the sun. Both are light, but of two kinds.

14. The angle of reflection equals the angle of incidence.

This is explained geometrically as a law of nature en terms of the shortest reflected pathway between the point of origin and the point of termination when the reflection occurs at a flat surface. Refraction is also discussed a bit ambiguously except to indicate that its angular behavior is the same for sunlight as for visual light.