The Fire That Comes from the Eye

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One of the earliest ideas about vision is that it depends on light that streams out of the eye and detects surrounding objects. This view was attacked in its own time and finally disproved more than 2000 years later. Yet the idea of a beam leaving the eye persisted in beliefs both about the evil eye and the power of a lover's gaze. It is still widely held among both children and adults. NEUROSCIENTIST 5:58–64, 1999

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Vision: Out of the Eye: Extramission Theories

One of the earliest neuroscientists we know of was the pre-Socratic Alcmaeon of Croton (ca. 450 BCE). He was the first to advocate the brain as the seat of sensation and cognition and the first to dissect parts of the visual system (1). Presumably after observing phosphenes resulting from a blow to the head, he noted "The eye obviously has fire within it, for when one is struck this fire flashes out. Vision is due to the gleaming. . . " (2).

This idea of vision depending on the "fire in the eye" was elaborated by Plato (427–347 BCE) in his cosmological (and rather antiscience) dialogue the *Timaeus*, which was enormously influential in the middle ages and beyond (1). Plato argued that visual fire streams out of the eye and combines with daylight to form a "single homogeneous body" which serves as an instrument for detecting and reporting visual objects:

> Such fire as has the property, not of burning, but of yielding a gentle light, they [the Gods] contrived should become the proper body of each day. For the pure fire within us is akin to this, and they caused it to flow through the eyes.. . . Accordingly, whenever there is daylight round about, the visual current issues forth, like to like, and coalesces with the daylight and is formed into a single homogeneous body in a direct line with the eyes, in whatever quarter the stream issuing from within strikes upon any object it encounters outside. So the whole. . . is similarly affected and passes on the motions of anything it comes in contact with. . . throughout the whole body, to the soul, and thus causes the sensation we call seeing (3).

Theories of vision such as this one, which depend on something streaming out of the eye, are known as extramission theories. Later, the great mathematician Euclid (ca. 300 BCE), in his *Optika*, developed a rigorously and narrowly geometric extramission theory. In this theory,

> Rectilinear rays proceeding from the eye diverge infinitely [and] those things are seen upon which the visual rays fall and those things are not seen upon which the visual rays do not fall. . . (4).

The astronomer and mathematician Ptolemy (127–148) carried Euclid's extramission ideas further and combined them with Galen's (129–199) work on the anatomy of the eye. Whereas Euclid had postulated discrete rays leaving the eye that became separated with increasing distance, Ptolemy argued that the visual rays formed a continuous bundle or cone (5).

Vision: Into the Eye: Intromission Theories

There was an almost equally old but different view of vision among the Greek Natural philosophers, namely that vision involves something entering the eye from the object seen, a class of visual theory known as intromission theory. The first intromission theories were those of the atomists, such as Democritus (ca. 420 BCE) and Epicurus (ca. 341–270 BCE). They believed that isomorphic images (or eidola) streamed off objects and entered the eye, where they were sensed (2, 5). As Epicurus put it,

> For particles are continually streaming off from the surface of bodies though no diminution of the bodies is observed. . . And those given off maintain their position and arrangement. . . it is by the entrance of something coming from external objects that we see shapes and think of them (5).

The later atomist poet Lucretius (ca. 60 BCE) had a similar view. He called the images coming from objects *simulacra*; in his poem "On the Nature of Things," he compared them to the skin cast off by cicadas and snakes and the membrane (caul) covering the head of a new born calf (5).

In Aristotle (384–322 BCE) we find the first detailed discussion of vision. He argued that the atomist view is wrong, because if objects put out copies of themselves, these would be objects themselves; but this is impossible because the copies would overlap on their way to the eye and two objects can not be in the same place at the same time (5). The Alcmaeon-Plato extramission view is also inadequate because:

> In general it is unreasonable to suppose that seeing occurs by something issuing from the eye; that the ray of vision reaches as far as the stars, or it goes to a certain point and there coalesces with the object as some [Plato] think (5).

Instead, Aristotle developed a rather complicated intromission theory. He assumed that a transparent medium, something like the modern ether, is found in air and water and is necessary for vision. Light is the state of this transparent medium. The color of an object (black and white are types of colors) moves the transparent medium and since the medium is continuous between the object and the eye, movement of the medium is

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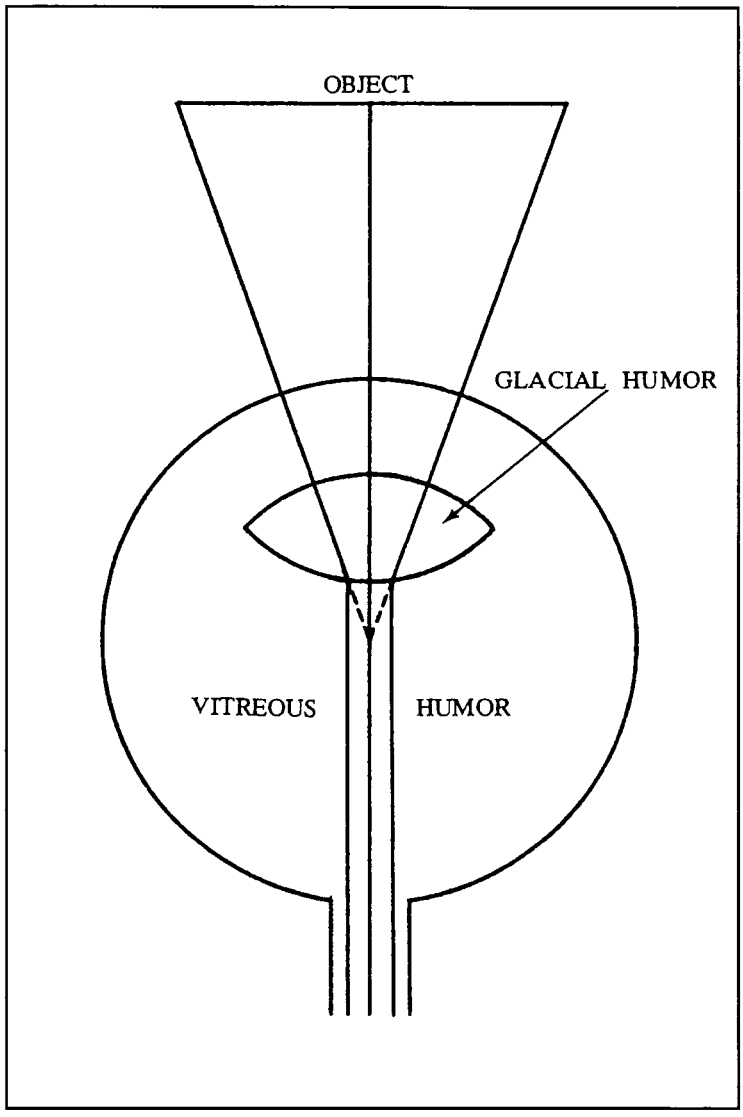

Fig. 1. Alhazen's intromission theory of vision combines elements of earlier intromission and extramission theories. Only the rays from the object that fall perpendicular to the surface of the crystalline humor (our lens) are sensed (reproduced from Lindberg DC, The Beginnings of Western Science, University of Chicago Press, p. 82, copyright 1992, with kind permission from the University of Chicago Press).

sensed by the eye, yielding visual sensation (5).

Alhazen's Synthesis

In Europe, soon after the deaths of Ptolemy and Galen, interest in studying the natural world declined and then virtually disappeared. Scientific inquiry gradually shifted to Islamic centers of learning, first in Baghdad and then in Cairo and Cordoba. Translation of Greek scientific works into Arabic began in the 8th century, and by the end of the 9th century, the achievements of Greek science were being actively discussed and often extended (6).

The nature of vision and light were of great interest to Islamic scientists. Some natural philosophers such as Al-Kindi (d. 866) defended and expanded Euclid's extramission views. Others such as Avicenna (980–1037), probably the most important Arab natural philosopher, mounted an assault on extramission and built on Aristotle's theories of vision (5). The primary achievement of Islamic visual science was to merge the two strains of Greek visual theory and eliminate the inadequacies of each. The architect of this synthesis was Ibn al-Haythem (965–1040), known in the West as Alhazen (7). When translated into Latin in the beginning of the 13th century, Alhazen's *Book of Optics (De Aspectibus)* dominated physiological optics in Europe for 200 years until Kepler.

Alhazen's achievement had two parts. The first was to destroy extramission theory forever (at least among optical scientists) with a series of irrefutable arguments. For example, he pointed out that bright light produces pain in the eye and that when we look at the heavens it would hardly be possible for the eye to put out enough material to fill the space up to the stars. The second and more original contribution was to introduce a fundamentally new type of intromission theory which incorporated Euclid's rays and the visual cone of Ptolemy's extramission theory. Alhazen argued that although every point on a visible object sends light in every direction, only one ray from each point falls on the eye perpendicularly. All the others fall obliquely, are refracted and thereby weakened to virtual ineffectiveness. The sensitive part of the eye (the crystalline humor or lens, following Galen) responds only to the perpendicular rays and these form a cone with the visual field as the base and the center of the eye as the vertex (5, 6; Fig. 1).

Thus, Alhazen not only eliminated extramission theory but built a new intro-

Box 1: Neural Mechanism of Phosphene Formation

If phosphenes are not caused by fire in the eye, what are they caused by? Otto Grusser and his colleagues in Berlin studied the effect of eyeball deformation in the cat on the activity of retinal ganglion cells (9). They found that deformation caused a marked increase in the activity of retinal ganglion on-cells and a marked decrease in the activity of off-cells. Such pattern of activity is certainly consistent with a phosphene-like perceptual effect. Grusser et al. suggested that the deformation caused retinal stretch, which in turn caused an increase in the surface of horizontal cells, which, he suggests, should depolarize them. Horizonal cell depolarization should indeed cause the increase in excitation of the on-ganglion cells and increase in the inhibition of off-ganglion cells, the result they observed.

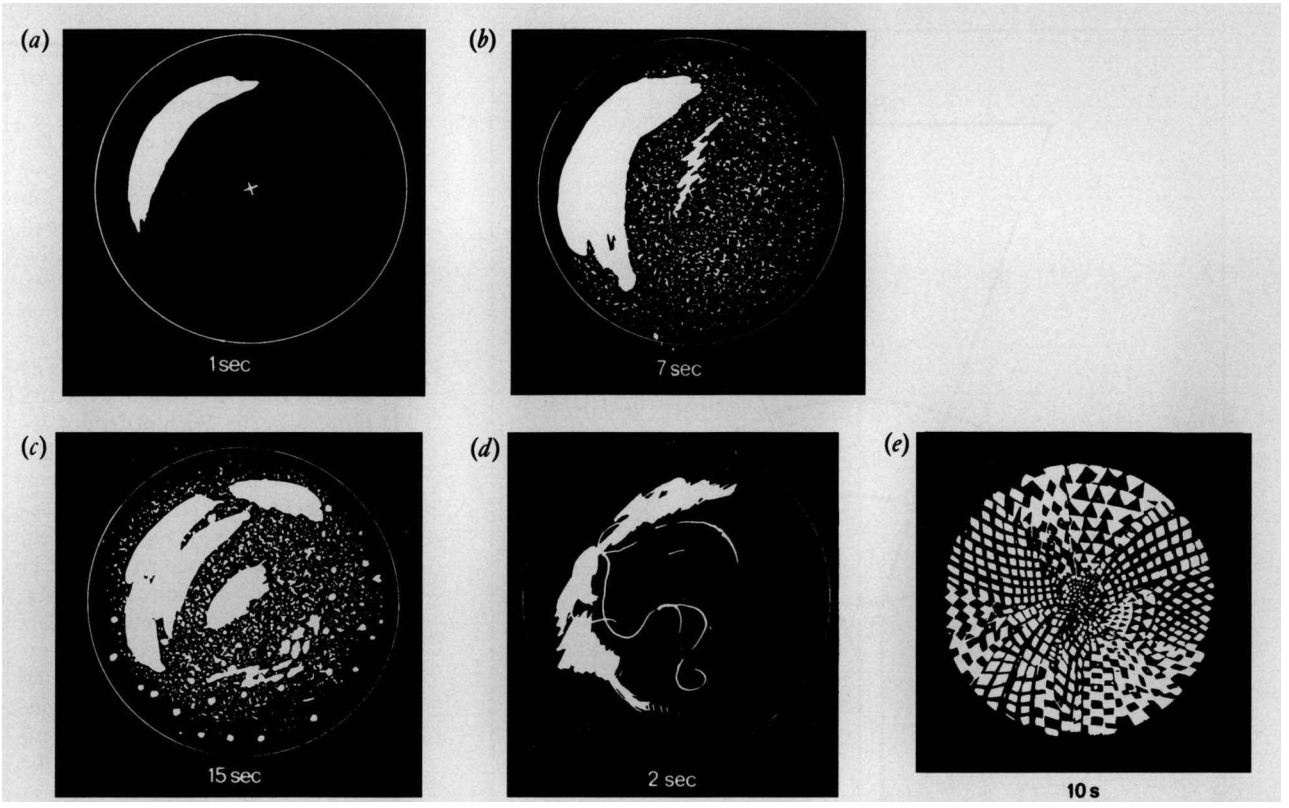

Fig. 2. *a-c,* Development of deformation phosphenes after pressure on the right temporal eyeball at different intervals and after release (*d*). *e*, simultaneous bilateral indentation of both temporal eyeballs produces a patterned and flickering phosphene (reproduced from [8] with kind permission from Kluwer Academic Publishers).

mission theory using the geometric ideas of Euclid and Ptolemy and the anatomico-physiological ideas of Galen. His theory became "enormously influential" and became the basis of most of the subsequent work in optics in Europe between the 13th and 17th centuries (5). Indeed, it led directly to Kepler's (1571–1630) theory of the retinal image (1611) and modern visual science (5).

The Fire in the Eye Is Quenched

Deformation phosphenes, the "fire in the eye" caused by pressure to the eyeball, continued to be observed after Alcmaeon and to demand explanation. Aristotle, having rejected the idea of light emitted from the eye, decided that phosphenes were due to "self-reflection" within the eye (8). Much later, Kepler still believed that pressure on the eye produced light. Since he realized that the retina was the sensitive surface he assumed that deformation of the eyeball produced sparks which stimulated the retina. He decided that the sparks were produced by mechanical irritation of the iris because "light can impossibly have its seat in the lens or vitreous body because then it would disturb the process of vision" (8).

Unlike Kepler, Descartes (1596–1650) rejected the idea of a physical light in the eye. Rather, he suggested that a blow on the eye produced vision in the same way he thought that light did, namely by moving the small fibers of the optic nerve. Newton (1642–1727) also thought that rather than producing light, pressure on the eye mimicked the action of light on the retina (8):

> Do not these colors arise from such motions, excited in the bottom of the eye by the pressure and motion of the finger, as, at other times are excited there by light for causing vision?

These and other speculations were offered for phosphenes other than fire in the eye. However, the first experimental refutation of fire or light in the eye came in 1719 from the Italian anatomist Giovanni Morgagni (1682–1771). His experiment was very simple indeed. Morgagni pushed his eye to produce phosphenes and had his assistant look into his eye (Morgagni's) to see whether any light came out. He found (8):

> Even when [the assistant] observed extremely carefully and very bright light appeared to me [Morgagni] he could never observe any light by himself.

Georg Langguth, professor of anatomy and botany at the University of Wittenberg, extended Morgagni's observations. To find out whether light is generated in the eye, he pushed his eye in the dark and, with a mirror, tried to see if light came out of his eye. Then, he wrote,

> A friend, who became curious about these phenomena... visited me in the dark room. I briefly explained to him what I was doing. The doors were closed and I asked him to observe my eyes very closely. While I was perceiving the small light [the phosphenes], he was not able to observe any small flashes or oscillating light. Thereafter, he performed the same experiment on himself... I could never discover any light leaving his eyes (8).

Thereafter, Morgagni and Langguth's experimental disproof of light in the eye was generally accepted, although their

Fig. 3. Drawings of evil eyes. Illumination accompanying a prayer against the evil eye on an Ethiopic scroll in the collection of Princeton University Library (12).

names gradually dropped out of the textbooks. For a modern view of the neural bases of deformation phosphenes see Box 1. For some drawings of deformation phosphenes, see Figure 2.

Persistence of Extramission Views

Despite the decline of extramission views under the widespread influence of Alhazen's *De Aspectibus* and its disappearance among visual scientists after Kepler's demonstration of the inversion of the retinal image, extramission views remained and still remain widely held. Extramission views may be found in at least four main arenas. The first is the widespread belief in the "evil eye." The second is in a long tradition in love poetry. Third and most surprisingly, strong extramission beliefs have been demonstrated in a high proportion of children and college students in the United States. Finally, most people believe they can feel someone staring at them.

The Evil Eye

> "The evil eye approached and the storm sent no rain. . . . the milk was no longer plentiful . . . the vigor of men was restrained. . . (Sumerian incantation, ca. 4000 BCE)."
>
> "A glance of the Medusa turned men to stone."
>
> "Simon ben Johai and Rabbi Jochanan could with their looks transform people into a heap of stones" (Talmud).
>
> "Almost would the infidels strike thee down with their very looks when they hear the warning of the koran" (Koran).
>
> "Witches may kill by their looks" (G. Mackenzie, *Laws and Customs of Scotland*, 1674).

A survey in 1962 at American University Hospital in Beirut indicated that 81% of 379 Armenian, Maronite Christian, and Sunni Muslim mothers sampled believed that the 'evil eye' affected their infant's health.

The foregoing (10) are all examples of the "evil eye," the belief that there are individuals whose glance can produce harm, disease, or death. Fear of the evil eye may be one of the oldest and most widespread superstitions. Freud called it "the most uncanny and universal." It is ubiquitous among cultures of Semitic and Indo-European origin and those that have come under their influence. The evil eye is usually the envious eye, and thus is often directed against the innocence of babies, the beauty of women, and the wealth of the powerful and is often attributed to the outcast, the ugly, and the other (10).

There are a virtually infinite variety of preventives against the evil eye: spitting, gestures, charms, incantations, and amulets that vary from community to community. Some seem to be very old, such as making the sexual gesture, "fig" or "fico," by putting the thumb between the first and second figure, which is reported to be of Roman origin and still common in older Italian and Jewish communities in New York. Again among older, more traditional people in this country, when a child or valued object is praised, the praise is often coupled with such phrases as "God bless it" among Irish and Italians and "keinahora" (no evil eye) among Jews (10, 11) (see Figs. 3 and 4).

There have been a number of different interpretations of the resiliency and

power of the superstition of the evil eye, ranging from the psychoanalytic to comparison with gaze aversion in primates (10). What is clear is that the evil eye is the most widespread example of belief in something coming out of the eye, a very powerful extramission belief indeed.

Love Beams

> "My lady carries love within her eyes;
> All that she looks on is made pleasanter,"
>
> "Whatever her sweet eyes are turned upon,
> Spirits of love do issue thence in flames"
>
> "In such eyes as hers are
> One surely stands whose glance can murder men"
>
> "For me, out of her eyes comes the sweet light
> That makes me heedless of each other lady;"

These quotations from four poems of Dante Alighieri (13) are in a tradition of love poetry extending from the Classic poets through Arabic poetry to the Renaissance and beyond (14, 15). In this tradition, the eyes of the Lady shoot arrows, darts, or fiery beams to induce love in the beholder, a tradition that has been termed the "the aggressive eye topos" (15). This theme seems to derive from Plato, as in the passage about his extramission theory of vision quoted above from the *Timaeus* and in his discussion of love in his *Phaedrus*.

There often seems to be a close affinity between the evil eye and the love arrows that the eye sends in the poetry of courtly love (14, 16). Indeed the third of the above quotes from Dante may be an example of this. On the other hand, the eye beams in Donne's "The Extasie" seem more innocent and mutual than deadly or envious:

> "Our eye-beams twisted and did thred
> Our eyes, upon one double string" (17).

Other quotes illustrating beams of love issuing from the eye are given in Box 2.

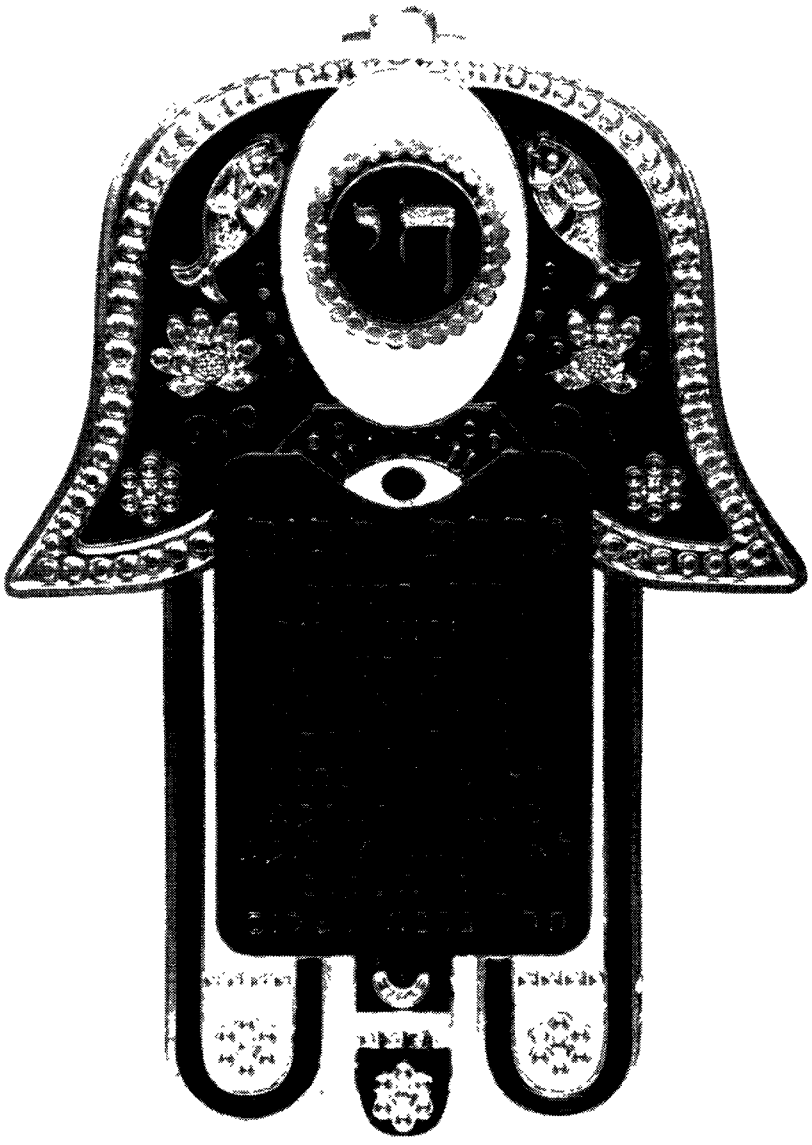

Fig. 4. Amulet against the evil eye (courtesy of E. Issac). The Hebrew inscription exhorts the evil eye to keep away. Sometimes a representation of an eye is found instead of a central text. Among Jews this configuration is known as a hamesh hand or hand of Miriam and among Arabs as a hamsa hand or hand of Fatima. It is found both in this bilaterally symmetric form and in a more realistic one with only one thumb. Similar amulets and wall plaques are readily found in the Middle East and in "New Age" shops around the world.

Extramission among School Children and College Students

Piaget observed that children seem to think that seeing involves something coming out of the eye and even noted the similarity of this view with pre-Socratic extramission theory (19). Inspired by Piaget's observation, Gerald Winer and Jane Contrell carried out an extensive and systematic examination of the views of children and adults about the nature of vision and particularly whether it involves something going out of the eye or something entering the eye (21–24).

When they asked whether something goes out of the eyes in the process of seeing, 57% of elementary school children and 33% of college students said yes. When asked to choose among "in", "out," or "both" as answers, 75–80%

Box 2: Love and Extramission

"The flaming rays of your lightning-like eye,
Instantaneously pierce my heart."
Olivier de Magny (15)

"For your eyes, lady, caught and held me fast."
Francesco Petrarca (13)

"The sparkling Glance that shoots Desire,
Drench'd in these waves, does lose its fire."
Andrew Marvell (17)

"What joyes shall seize thy soul, when she
Bending her blessed eyes on thee
(Those second smiles of Heav'n) shall dart
Her mild rayes through thy melting Heart."
Richard Crashaw (17)

"Love-darting eyes. . . "
John Milton (27)

"Then flash'd the living lightning from her eyes,
And screams of horror rend th' affrighted skies."
Alexander Pope (18)

"If beams from happy human eyes
Have moved me not;"
Robert Lewis Stevenson (18)

"Lesbia hath a beaming eye
But no one knows for whom it beameth."
Thomas Moore (19)

"Lo! as that youth's eyes burned at thine, so went
Thy spell through him, and left his straight neck bent."
Dante Gabriel Rossetti (19)

"A lover's eye will gaze an eagle blind"
William Shakespeare (19)

of the children and 24–33% of the college students gave one of the two extramission answers ("out" or "both"). Furthermore, among those who choose extramission, about 90% of the school children and 77% of the college students thought the eye's output aided vision and 59–63% thought it was necessary (21, 22). Winer and Contrell found essentially the same level of belief of extramission under a great variety of different conditions and ways of asking the question, for example whether the questions or answers were verbal or pictorial, oral or written and whether they were about luminous or nonluminous objects (21–24).

Winer and Cottrell found that from the third to the eighth grades, the belief in extramission tended to decline and the belief in intromission tended to increase, a change that was more pronounced in the college students (21–24). However, the incidence of college students believing in extramission was little changed "as a function of having received lessons, reading, and tests on perception in introductory psychology classes" or "having received readings on visual perception, immediately prior to [the] tests (25, 26)."

There has been considerable research on "naive physics," indicating that children and adults often have erroneous beliefs about such things as trajectories of falling objects (for example, see ref. 27). However, there is little in ordinary experience that would contradict these "naive" or "intuitive" views, nor are the correct views normally taught in elementary school. By contrast, antiextramission experience, such as the discomfort from looking at a bright light, is common, and the elements of vision, such as the inversion of the image on the retina, are repeatedly taught in schools. As Winer et al. put it after more than 20 studies on the subject ". . . the source and apparent strength of extramission beliefs in children and adults is somewhat of a mystery" (23).

The Feeling of Being Stared At

In 1898, the distinguished Professor of Psychology E. B. Titchener wrote in *Science* (28);

> Every year I find a certain proportion of students, in my junior classes, who are firmly persuaded that they can 'feel' that they are being stared at from behind, and that a smaller proportion believe that, they have the power of making a person seated in front of them turn around and look them in the face.

After much discussion of this feeling (after all, he was the great champion of Introspection psychology), he concluded

> . . . I have tested... the 'feeling of being stared at,' at various times, in series of laboratory experiments conducted with persons who declared themselves either peculiarly susceptible to the stare or peculiarly capable of 'making people turn around.' As regards such capacity, the experiments have invariably given a negative result. . .

A later study followed this up and found that 68–86% of the students in a college class claimed to have the feeling of being stared at (29). Because this "feeling of being stared at" implied some sort of belief in something coming out of the eye (that is, an extramission view), Contrell and Winer included questions about staring in some of their studies of extramission described above.

Confirming the earlier studies, they found that 93% of college students said they could "feel the stare of other people" (30). Surprisingly, the proportion giving this answer went down with grade level, so that the percents for the 5th, 3rd, and 1st grades were 80%, 75%, and 68%, respectively. This belief in feeling stares was clearly different from some kind of belief in extrasensory perception, because "thinking about a person was not necessary to having one's gaze felt by another."

The finding that the ontogenetic trend for belief in the ability to feel stares was opposite of that for the belief that there are emissions from the eyes implies that the two extramission beliefs are somewhat different. Apparently, the belief in the efficacy of staring is more developmentally advanced than the belief that vision involves something leaving the eye.

Cognitive Development and the History of Science

There are several cases of striking similarities between the beliefs of children and naive adults and theories held by premodern scientists. One example concerns

motion. Naive or intuitive ideas about the motion of inanimate objects (such as an object dropped by a moving person or the path of an object emerging from a curved tube) very closely resemble the "impetus" theory held by 14th century Aristotelians (27). Another example is the relationship between heat and temperature. Very similar ideas about the identity of heat and temperature are held by naive moderns as were held by a group of 17th century Italian scientists forming the Accademia del Cimento and known as "the Experimenters" (31).

Is the belief in extramission among children and many naive adults another parallel between the ontogenesis of cognition and the history of science? Certainly, there are similarities between Greek extramission theory and naive beliefs about vision. However, the parallels between the stages of ontogenetic development and historical development of visual science may be somewhat less compelling than for motion and heat. Before Alhazen, intromission theories, however incorrect, were held during the same time period as were extramission theories. Furthermore, at least one type of extramission theory, that of belief in the detectability and efficacy of staring, increases rather than decreases with general cognitive development.

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