Perception and optics in the 16th century: some features of Della Porta's theory of vision•

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Abstract

This article discusses introductorily some features related to the visual experience according to how the organ of sight was conceived of in the 16th century. For this purpose it presents the criticism raised by Giovambattista della Porta (1535-1615) against contemporary theories of vision as described in his treatise on optics entitled *De refractione optices partem libri novem* published in 1593. Analysis of Della Porta's optics shows that such debate included the mathematical, physical, anatomical and physiological aspects of vision, defining thus a framework very much different from the one of modern optics.

Keywords

History of science; Optics; Theory of vision; 16th century; Della Porta

Percepção e óptica no século XVI: alguns aspectos da teoria de visão de Della Porta

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Resumo

Este artigo busca apresentar, à guisa de introdução, alguns aspectos ligados à experiência visual concernentes ao funcionamento do órgão visual no século XVI. Para tanto, apresentamos as críticas arroladas pelo estudioso napolitano Giovambattista della Porta (1535-1615) às teorias de visão em seu tratado de óptica, intitulado *De refractione optices partem libri novem*, publicado em 1593. O estudo de óptica de Della Porta mostra-nos que as principais linhas de debates da teoria visual foram definidas considerando-se aspectos matemáticos, físicos, anatômicos e fisiológicos da visão, colocando, dessa maneira, questões muito diferentes comparadas à óptica moderna

Palavras-chave:

História da ciência; Óptica; Teoria da visão; Século XVI; Della Porta

Debates on the boundaries of knowledge and the validity of sensorial or perceptive experience were crucial for the development of natural philosophy in the 16th century. It may be said that the methodological issues then debated led to a shift in the appraisal of the cognitive value of sense-perception.[2] However, there seems to be another side to this shift when it is approached from the perspective of the theoretical framework for the visual experience in the 1500s and 1600s.

• [1] This article derives from a presentation at the V Forum of debates: Interdiciplinary Perspectives on the Arts and the Humanities, São Paulo (Brazil), UNESP/Universidade São Marcos, November 27-29, 2007.

[2] F. Bacon, *Novum organum*, Ed. R. M. Hutchins (Chicago: Encyclopaedia Britannica, 1952), Vol. 30, 105-95; R. Descartes, *Discurso do Método*, in *Obra Escolhida*, 3rd ed. (Rio de Janeiro: Bertrand Brasil, 1994), 39-103; see also the commentaries in this regard by A.G. Debus, *El Hombre y la Naturaleza en el Renacimiento* (México: Fondo de Cultura Económica, 1996), 181-208 and P. Rossi, *Os Filósofos e as Máquinas 1400-1700* (São Paulo: Companhia das Letras, 1989).

Indeed, one of the main goals was to explain how the organ of sight could acquire knowledge about the properties of bodies. In order to achieve it, the natural philosophers of that time took into account not only the anatomical and physiological aspects of the eye but also its mechanism of working.[3] To approach this subject I have focused on the criticism raised by Giovambattista della Porta (1535-1615)[4] against contemporary theories of vision in his optics treatise entitled *De refractione optices partem libri novem* published in 1593.[5]

Regarding the mechanism of working of the eye, several possibilities had been discussed since antiquity, which were taken up once again by Della Porta in the first proposition of the fourth book of *De refractione*[6]. Here he recalls the two traditional views on this matter, namely whether vision is due to the emission of beams from the eyes or to the reception of species of the thing seen, to then adduce arguments pro and con each one of them.

It must be reminded that 16th century optics (also known as perspective)[7] had very peculiar features. At that time, it was not just a mathematical part of physics, as it would become in the 17th century. It was not restricted to the study of physical stimuli and the geometrization of the visual beams, but it was also concerned with the effects to such stimuli in the organ of sight and the consequent perception apprehended by the soul.[8] The goal of optics was to understand vision, perception (within the relationship between vision and what is visible) and eventually cognition, so that it is not rare no find in the corresponding literature sections devoted to the anatomy and physiology of the eye side by side with geometrical and psychological explanations.[9] Moreover, 16th century optics sought to explain "how vision works" in order to elucidate "how things are seen". Therefore, in order to comprehend the mechanism of vision, Della Porta approached not only the study of the anatomy but also the function of each part of the eye.[10] In this way, after pondering on the many aspects linked to the phenomenon of seeing Della Porta tried to point out the causes of vision, for which he took into account the theory of refraction.

The first theory reviewed by Della Porta is the one known as "intromission theory" attributed to the ancient Greek atomists, particularly Democritus. According to this theory, the visible bodies continually emit simulacra that peel off as if "skins" and move towards the eyes. According to Della Porta, this theory as expounded by the ancient was flawed in three regards. First, it made difficult to explain the images reflected in mirrors, particularly one's own image, since it would appear inverted to one's eyes. Then, because without an observer the simulacra perpetually emanating would reach no one, making legitimate to ask, "on whose command the simulacra are

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[3] On vision as the main sense and its connection with knowledge, see G. Spinosa, "Visione Sensibile e Intellettuale: Convergenze Gnoseologiche e Lingustiche nella Semantica della Visione Medievale", *Micrologus: Natura, Scienze e Società* 5 (1997): 119-34; see also the article by Marco Beretta where he states that the anatomy and physiology of the eye were important in order to warrant the truthfulness of the seen things, "From the Eye to the Eye-Glass: A Pre-History of Spectacles", in *When Glass Matters: Studies in the History of Science and Art from Graeco-Roman Antiquity to Early Modern Era*, ed. M. Beretta (Firenze:, Leo S. Olschki, 2004), 249-82.

[4] On Della Porta, see F. Saito, "Instrumentos de Magia e de Ciência: A Observação Mediada em *De telescopio* segundo a *Perspectiva* de Giambattista della Porta" (PhD dissertation, PUC-SP, 2008), 15-7.

[5] G. della Porta, *De refractione optices parte libri novem* (Naples: Io. Iacobum Carlinum & Antonio Pacem, 1593).

[6] Della Porta, IV: 88-92 (Prop. 1). It must be reminded that the discussion on the functioning of vision was indeed very old and that the main theories were considered from multiple perspectives from antiquity to the 16th century, see D. C. Lindberg, *Theories of Vision from Al-Kindi to Kepler*: Chicago: The Chicago University Press, 1976).

[7] Or *perspectiva*, as it was more commonly known at that time. According to Hamou, the term *perspectiva* is the Latin translation of the Greek *optiké*, meaning direct or distinct vision, which to the Greeks was the one that revealed things. For this reason, the Latin versions of Euclid's *Optics* and the medieval treatises on vision were called *perspectiva*. Until the 17th century that meaning coexisted with the one that designated pictorial technique; in order to distinguish between them, "common" or "natural" perspective was opposed to the *perspectiva artificalis* of painters, an expression that must be translated as "artificial vision"; see Ph. Hamou, "Introduction", in *La Vision Perspective (1453-1740): L'Art et laSscience du Regard, de la Renaissance à l'Age Classique* (Paris: Payot & Rivages, 1995), 7-54, on 7.

[8] On this, see V. Ronchi, *Optics: The Science of Vision* (New York: Dover, 1991), 11-20.

[9] See G. Simon, *Archéologie de la Vision: l'Optique, le Corps, la Peinture* (Paris: Seuil, 2003); "La Notion de Rayon Visuel et ses Consequences sur l'Optique Géometrique Grècque", *Physis* 31 (1994): 77-112.

[10] See, Della Porta, III e IV.

present to whom that observes?"[11]. Moreover, Della Porta adduces that this theory could not adequately explain how vision keeps the colors of bodies, since color can only be in the body. Finally, he considers unsound to suggest that vision occurs through the apprehension of "something" emitted from bodies, since in that case an eye would not stand to see many images at one time.[12]

The next theory Della Porta discusses is the one known as "extramission theory"[13], which postulated that vision happens through the emission of beams by the eyes of the observer, which are sent to bodies able to "feel them". However, also this theory was problematic: first, if the beams are corporeal, when one looks, e.g., at constellations all the amount of "light" existing in the eyes would be exhausted or alternatively the beams would never be able to reach them. Then, the beams would have to travel through the air, which was impossible without them having to penetrate some bodies, an idea that Della Porta rated absurd. On the other hand, if the beams are incorporeal, nothing at all could be seen, since "the senses are only in the body"[14].

It must be noticed that both theories assumed that vision requires physical contact with the visible thing. According to the intromission theory, vision was a receptacle for simulacra. Just as touch and taste feel things through direct contact, and olfaction and audition indirectly through the emanations and effluvia released by bodies, also the observer's eye "felt" the visible objects through the simulacra that entered the eyes. On the other hand, the extramission theory postulated the existence of a homolog to light that came out from the eyes and "touched" the visible things giving thus rise to the visual sensation.[15]

Besides these two polar views, Della Porta also recalls several attempts of reconciliation. For instance, Plato (c.427-347 BCE) had formulated a "co-radiation" (*corradiantia*) theory according to which vision happens thanks to the encounter of two beams, one emitted by the eyes and the other sent by bodies when illuminated by a source of light.[16] By the same token, Galen (c. 129-199 CE), inspired in Plato, explained that vision was due to the union of the beams emitted by the eyes and the surrounding air. Galen as well as the Stoics believed that "a subtle matter" emerged from the eyes and mixed with the air and made it tense. Then, in the presence of a source of light, "effluvia" emanated from the visible thing and changed that peculiar air. In this way, vision happened through the qualitative alteration of a *medium* prepared to perceive the visible thing with which it entered in contact.[17]

According to Della Porta, Galen had rejected both the theories of emission and reception because none was able to explain two features from a natural standpoint. First, the intromission theory did not explain how the "spectrum" of a mountain or any other thing larger than the eye could pass through the small orifice of the pupils. On the other hand, the theory of emission failed to explain how the "spirit of sight" (*spiritus intuitivus*)[18], i.e. the visual beam, could extend so far and diffuse so broadly as to encompass all things available to vision.[19]

Galen's theory, as a fact, was an alternative to Aristotle's (c.384-83BCE), who had held that the eye received no visible thing whatsoever, as in the atomistic theory, but "became" the thing

[11] Ibid., IV: 88 (Prop. 1).
[12] Ibid., IV: 88 (Prop. 1).
[13]Its origin is associated to Euclid; see Lindberg, *Theories of Vision,* 12-6.
[14] Della Porta, IV: 8 (Prop. 1); also Ptolomeus accepted the idea of emission of visual beams. However, whereas according to Euclid the visual beam was a mere mathematical abstraction, Ptolomeus conceived of the visual flux as a physical and material reality; on this see, Simon, "Notion de Rayon Visuel".
[15] Visual beam and luminous beam were two different notions; see Ibid.
[16] Della Porta, IV: 89 (Prop. 1); on the emanation of visual effluvium see Plato, *Timaeus*, 45b-d; *Theaetetus*, 156d-e; here I used the 3rd ed. Portuguese translation by C. A. Nunes (Belém [PA]: EDUFPA, 2001).
[17] Although very similar since it also assumed the emission of visual effluvia towards the environment, Galen's visual theory did not seek to reconcile the extramission and intromission theories; the significance he gave to the environment in the visual process follows the Stoics; see Lindberg, *Theories of Vision,* 10-1.
[18] This is, the emanation of visual effluvia, fire or optic *pneuma* (according to the Stoics) in the widest sense.
[19] Della Porta, IV: 89 (Prop. 1).

itself.[20] However, Aristotle seems to have rejected the emission and mixing of beams.[21] In his view, bodies send their visible qualities (viz. color and consequently, shape) to the eye of the observer through the air or transparent medium. In the presence of light the latter is actualized and affected by the colors of bodies that provoke a qualitative change in it that, thus, is communicated to the eye of the observer.[22]

However, it seems that Della Porta did not understand Aristotle's theory in this way, since he only pointed to the features that characterized it as an intromission theory. In this way, he depicted Aristotle and the Peripathetics as opposing the older, mainly Platonic, extramission theory.[23] As a fact, Della Porta seemed more favorable to the intromission theory and he sought for arguments against the theories of emission to begin with Euclid's theory of visual beams.

According to Della Porta, Euclid (fl. 300BCE) would have showed that vision is due to the emission of beams from the eye to the visible thing, mainly due to the shape of the eye itself. Olfaction, audition and taste were receptacles because their corresponding organs are concave, whereas the eyes are convex. In this way, due to the nature of things, the convex shape of the eyes is not fit to receive species, but very much the opposite, it is fit to irradiate visual beams. On the other hand, Euclid would have noticed that vision could not occur through simulacra travelling from bodies to the eyes because if it were so, when one opens a book, e.g., all the letters on a page would go spontaneously to the eyes.[24] Della Porta comments that other scholars, such as Heliodorus Larisseus, had asserted that the extramission theory could be verified in nocturnal animals, as owls and cats, whose eyes shine in the darkness. By the same token, other "Platonic" authors seemed to admit the existence of a force emanated by the eyes in such a way that corrupt beams could corrupt things and the soul of people. This was how sorcerers made trees dry and cursed people just by looking at them; to look at a wolf for just one second made one lose his voice; the basilisk killed a man in one blink; menstruated women corrupted and blurred a mirror by simply staring fixedly at it.[25]

Against Euclid, Della Porta observes that the convex shape of the eye makes it fitter to receive beams than to emit them. The study of anatomy, furthermore, showed that the convexity of the eye was not only the fittest for its function, but also to explain many accidents.[26] Regarding the second argument, Della Porta tried to show that vision happens in time. Thus, when one opens a book its letters do not jump instantaneously to the eyes, but are led to them in a minimal fraction of time[27]. Finally, Della Porta comments:

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[20] D. C. Lindberg, "The Science of Optics", in *Science in the Middle Ages,* ed. D. C. Lindberg (Chicago: The University of Chicago Press, 1978), 338-68, on 340.

[21] There is some disagreement on this regarding: according to some scholars, the visual beams also appeared in Aristotle's theory, see e.g. A. Jones, "Peripatetic and Euclidean Theories of the Visual Ray", *Physis* 31 (1994): 47-76; others stress the ambiguities found in Aristotle's vision theory that persisted in later optical theories, see e.g. Th. Frangenberg, "Egnatio Danti's Optics: Cinquecento Aristotelism and the Medieval Tradition", *Nuncius* 3, no. 1 (1998): 3-38; "Perspective Aristotelianism: Three Case-studies of Cinquecento Visual Theory", *Journal of the Warburg and Courtauld Institutes*, 54 (1991): 150-8.

[22] The difference seems to be the role of the observer: in Aristotle's theory, he was passive, whereas Galen held the environment as a tool and stressed the active role of the observer; see Lindberg, "Science of Optics", 341; *Theories of Vision*, 6-11.

[23] It seems that Aristotle neither accepted the receptionist theory as formulated by the atomists; one reason was that he refused to admit the emanation of material effluvia. When he formulated a more precise definition of transparency, light and color he seemed to have placed the focus on the medium between the visible thing and the observer, stressing its significance for visual perception, which nonetheless occurred passively; see Lindberg, *Theories of Vision*, 6-9.

[24] Della Porta, IV: 89-90 (Prop. 1).

[25] Ibid., IV: 90 (Prop. 1).

[26] Ibid., III: 70 (Prop. 2); convexity derives from the rounded shape of the eye. According to Della Porta, such shape was the fittest because it endowed the eye more mobility and the ability to perceive things around it. Moreover, it was necessarily rounded due to geometrical, and consequently anatomical reasons; see Ibid., III: 68-71 (prop. 2); the accidents of vision are dealt with in Book V.

[27] See Prop. 4; Ibid. IV: 95-7.

> "[...] If animals see at night this is because of the excellence of vision; because [they] are vigorous in sight so that they see in the darkness with a peculiar shine because of the nature endowed [to them] by the creator; but in us it happens otherwise, because we forsake this good quality of sight. And the animals that charm or annihilate with the sight, this does not happen through the emission (*extramissio*) of beams, but by impregnating the air contiguous to them and gradually passing to its neighbor until reaching the man […]"[28].

In this way, according to Della Porta, vision can happen only via the reception of simulacra (*imagines*):

> "The form of the visible thing has the material nature in the thing itself, but taken up by light it separates suddenly from matter and comes out due to some immaterial reason and the more it, arising from the thing, comes close to the eye, the more, from the widest base, it adjusts to one's pupil and eye, as [it happens] with liquid bodies that also penetrate places by themselves. Whence, from the pyramidal lines of the beams, reveals the shape from it to the eye and reaches the lens with the cone […]" [29]

It must be noticed that the simulacra, which were separated from their bodies by light, did not have a material nature. Different from the older notion of *idola*, the *simulachra* were not conceived by Della Porta as corpuscles or pieces of the visible things projected into the air. This is to say, the terms *simulachrum* and *idola* (a variant from the Greek term *eidolon*) were often considered exchangeable by ancients and medievals.[30] Its first and oldest meaning was "corporeal images" arising from visible things that entered the eyes of the observer to cause the visual sensation. The *idola* carried with them the "images" of the size and shape of the visible thing and flowed continually from it to the eye.[31] This meaning, however, changed in the 16th century, when the Latin term *species* began to be used more frequently and that, different from the *simulachra,* was not necessarily material. Moreover, species travelled along the beams of the visual pyramid being progressively reduced, so that they could penetrate the pupil. In this flux from the visible thing towards the eye of the observer, the *species* led inside the eyes the elements able to define the shape, color and position of bodies. Moreover, in a second sense, these terms (*species, simulachra, idola* and *imago*) also designated the image of the visible things, whence the confusion.[32]

According to Della Porta, the simulacra were led to the eyes from pyramidal lines, so that they revealed to the eye the physical and geometrical dimensions of the visible bodies.[33] However, Della Porta warned that the formation of a cone would be more fitting than a pyramid since in this way the beams could concentrate in its vertex. Moreover, the pupil was round so that the boundaries of all vision had to be circular. As a fact, this was shown by linear perspective. By referring to Albrecht's Dürer (1471-1528) portico, Della Porta observes that although when Euclid

[28] Ibid., IV: 93 (Prop. 1).
[29] Ibid., IV: 91 (Prop. 1).
[30] As a whole, there was no rules for them, and in many occasions were further replaced by *spectrum* and *imagos*; see V. Ronchi, *Galileo e il Cannocchial* (Udine: Idea, 1942): 13-26; *The Nature of Light*, 59-60; on the discussion about the materiality of beams or species, see P. Potestà, "Il *De luce et visibili paradoxon* di Bartolomeo Benvoglienti Senese: Una Soluzione Quattrocentesca ad Antiche Questioni di Ottica", *Physis* 29 (1992): 35-69.
[31] See, e.g., Democritus, in *Os Filósofos Pré-socráticos*, ed. G. S. Kirk, J. E. Raven & M. Schofield (Lisboa: Fundação Calouste Gulbenkian, 1994), 452-4.
[32] Ronchi, *Galileo e il Cannocchiale*, 13-26; *The Nature of Light*, 59-60.
[33] Both arguments are developed by Della Porta in Propositions II and VI, respectively.

had postulated the existence of a visual pyramid, he named it cone, he had never actually alluded to a cone but to a multi-sided pyramid.[34]

In this regard, it must be kept in mind that Euclid's theory was not merely an extramission theory, but it was a mathematical theory of vision. As a fact, most of the 58 theorems of his *Optics* seem to deal only with problems of perspective, this is, with issues related to the appearance of an object as a function of its spatial relation to the observer.[35] Thus, the problem of the nature of the visual beams and their encounter with the visible things had been virtually omitted.

In Della Porta's view, Euclid's visual beams were mere geometrical constructions, useful to demonstrate the properties of vision. However, they were not fitting to explain in a physiological manner the visual process inasmuch they did not explain how the visual qualities, such as the colors of bodies, were communicated to the organ of sight. Furthermore, as it was mentioned above, Della Porta favored the intromission theory of vision.

To prove that vision was due to the penetration of simulacra into the eyes, Della Porta adduces three arguments. The first concerns a phenomenon now known as "retinal persistence of image"[36]. This is, upon looking straight to light or its reflection on a smooth surface the impression is kept in the retina, so that one continues to "feel it" after closing the eyes. In this regard, it must be noticed that the image was not generated in the retina.[37] Although Della Porta conceived of the eye as a miniature *camera obscura*, he did not use this analogy as starting point for a novel understanding of the visual process. The reason was that if the simulacra were to pass through the lens and go beyond it, the image would be inverted. In this way, rather than conceiving of the lens humor as a lens inserted in the opening of a *camera*, Della Porta maintained that it was a screen on which images were projected. Moreover, he asserted that evidence for the simulacra as penetrating the pupil could be also found in medical records, since some diseases of the eyes, as e.g. cataracts could be healed by removing the coagulated humor and restore, thus, vision.[38]

Lastly, Della Porta also sought to give geometrical demonstration of the fact that when one observes something obliquely, it is seen in a refracted manner, so that it appears in some other place. According to him this could only be possible if vision happened through the reception of simulacra.[39]

With this argument grounded on the theory of refraction, Della Porta was asserting that vision could happen in a perfect or imperfect manner inasmuch the visual process happens partly directly and partly indirectly (viz. refracted).[40] In this way, the cone made between the eye and the visible thing consisted of different kinds of beams and, according to Della Porta, vision was more imperfect the more the beam diverged from the straight axis of the pyramid (Figure 1)[41]:

> "Be EF the pupil of the eye, K the center of the eye, EFIO the eye, MGHN the lens. Be from center K drawn the pyramidal lines to the opposed plane CD, therefore, everything contained in pyramid CD is perfectly seen, from all, axis PK [is seen] the most perfectly as possible. Be also the part CAB of the plane, and come B to point O, [it] will be refracted towards H, will go to Y; the side of

[34] Della Porta, IV: 97-8 (Prop. 6); Della Porta describes the portico developed by Dürer which had been described in the fourth book of his treatise of geometry, *Instituciones de Geometría* (México: Universidad Nacional Autónoma de México, 1987), 246-8; on the impact of Dürer's invention for the history of perspective see J. J. Gómez Molina, ed., *Máquinas y Herramientas de Dibujo* (Madrid: Cátedra, 2002), 178-206.
[35] Euclid, *Ottica*; see also Lindberg, *Theories of Vision,* 11-4; Jones, 48-56, notes that Euclid did not make clear whether the beams were physically real; according to him there are two different versions of *Optics*.
[36] Della Porta, IV: 91 (Prop. 1).
[37] It was Kepler who, later on, established the generation of the image in the retina, see J. Kepler, *Les Fondements de l'Optique Moderne: Paralipomènes a Vitellion (1604)* (Paris: J. Vrin, 1980), 303-400.
[38] Della Porta, III: 73-4 (Prop. 5).
[39] Ibid., IV: 91 (Prop. 1).
[40] Ibid., IV: 98-9 (Prop. 7).
[41] Ibid., IV: 100 (Prop. 7).

K and B will meet HY in Y and the point of thing B will be seen in Y. Similarly, the point A of the plane will come to I, it will be refracted towards G, will go to L and will meet the extended side of KA in L, and point A will be seen in L, not in its place where it is, nor with the same colorful color, but as we have said, it will cover the clarity and the indistinct volume of things and the farther it goes back from L, more imperfectly it will be seen; but vision [is] less blurry in L than in Y and less in D than in L […]"[42]

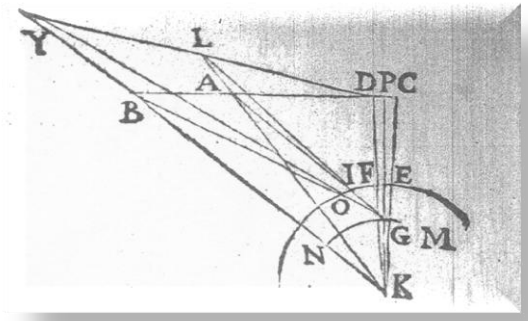

Figure 1

In this way, the central beam (this is, the axis of radiant pyramid PK) that hit perpendicularly the lens was the strongest and most vivid among all beams, so that the more the simulacra come close to the eye, the more they accommodate, i.e., reduce their size in order to penetrate the pupil. Such simulacra were thus "images" that represented the totality of the visible things. In this way, by establishing an analogy between the visual cone and the hopper of a mill, Della Porta implied that the simulacra penetrated the eye in the same manner as water glides through a funnel (Figure 2)[43]:

"Be ABCD the visible thing, FG the pupil of the eye, HI the lens; pyramid BCLM runs in a straight line that if would fall as far as to K it would be a perfect pyramid, but since it meets the lens it is broken by the surface HI of the latter. Be also a refracted pyramid AE, and come E to the eye G, it is refracted towards M, thus, A towards L; it will run to meet the lens HI, it will be cut and ABFGLM will be like a hopper".[44]

[42] Ibid.
[43] Ibid., IV: 103 (Prop. 9).
[44] Ibid.

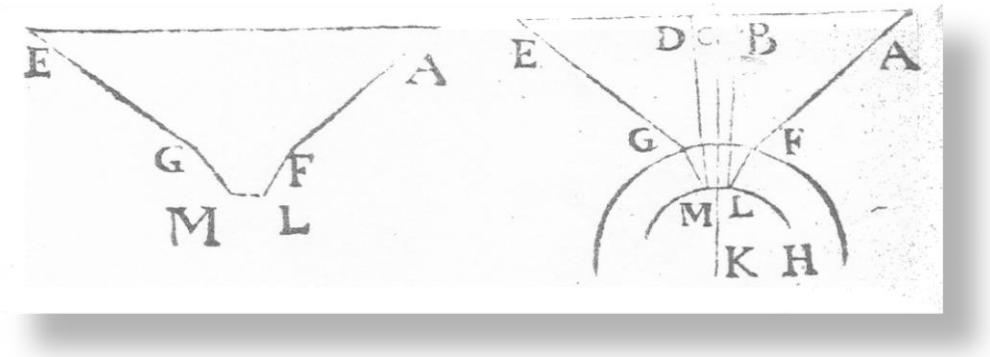

Figura 2[45]

Conclusion

It may be said that 16th century optics asked very different questions than modern optics. The reason, as mentioned above, was the purpose optics had until that time, namely to explain "how things are seen". In this way, as it was briefly discussed here, analysis of Della Porta's optics shows that, at that time, the main lines of debate on visual theory were drawn by taking into account mathematical, physical, anatomical and physiological aspects of vision. This indicates that the theoretical framework for the visual experience in the 1500s cannot be understood without taking into account the interaction among such aspects that in turn composed a wide range of possible interfaces between these fields of knowledge.

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[45] Ibid., IV: 103 (Prop. 7).