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Understandings of Colors: Varieties of Theories in the Color Worlds of the Early Seventeenth Century

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Abstract

In the early seventeenth century, there existed a myriad of theories to account for color phenomena. The status, goal, and content of such accounts differed as well as the range of phenomena they explained. Starting with the journal of Isaac Beeckman (1588–1637), this essay inquires into the features and functions of conceptual reflections upon color experiences. Beeckman played a crucial role in the intellectual development of René Descartes (1596–1650), while at the same time their ideas differed crucially. Early corpuscular conceptions of colors cannot be reduced to the mechanistic variety of Descartes. Moreover, the optical rather than corpuscular features of Descartes's understanding of colors were essential. A stratification of conceptualizations is proposed that is grounded in various problem contexts rather than philosophical doctrines, thus opening a way to interpret the philosophical parts of color worlds in a more diverse way.

Keywords

Isaac Beeckman (1588–1637) – René Descartes (1596–1650) – historiography of optics – colors – light – optics – corpuscular conceptions – understandings of color

Introduction

> A glass, ground convex on both sides. Today I saw the windowpanes in it; just like in a mirror but double, one small and one large. The large

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> semblance had the color of the windowpanes; the small one was greenish, like the said glass. This is an indication that the large semblance appeared from the surface of the glass, but the small one from the surface of the other side. Thus, that the rays of the windowpanes have entered the glass and rebound against the other side. And the semblance was thus greenish because the rays first entered the green glass and then came out again. For all things seem greenish that one sees straight through it.[1]

Thus wrote Isaac Beeckman (1588–1637) in his diary in April 1628. The note illustrates his perceptive eye and inquisitive mind. Beeckman was headmaster of the Latin School in Dordrecht, a prominent town in the Dutch province of Holland. He kept his diary, *Loci Communi*, from his twenties until his death, recording observations, ideas and readings on natural phenomena and experiences. The diary is a unique document for its time and a treasure trove of early seventeenth-century natural inquiry. The entries range from everyday topics, casual observations on all kinds of phenomena and ideas to more or less systematic accounts of natural philosophy. Like a Leonardo, Beeckman never elaborated and organized his ideas and conclusions and never published them. His notes are preserved in the manuscript that was discovered in the early twentieth century.[2]

The entry quoted above is characteristic of the way Beeckman made everyday observations and reflected upon them. Particular themes return in his reflections, including colors in various manifestations. The observation of reflections in a lens was part of a note in which Beeckman considered ways to determine the curvature of a lens in relation to another lens, in order to give lens grinders instructions for the lenses he needed. Lenses and telescopes became a main interest during his later years. In 1628 he did not make his own lenses, but had already been studying their properties and configurations in

1 "Een glas, dat op beyde syden bol geslepen is, daerin sach ick vandaghe de veynsterglasen gelyck in een spieghel, doch dobbel, eens cleyn ende eens groot.Het groot schynsel was vant coleur daer de vensterglasen van waren; het cleyne was groenachtich, gelyck het voors. bol glas was. Dit was een teecken, dat het groot schynsel scheen van het oppervlack des glas, maer het cleyn van de superficie van dander syde, also dat de stralen van de veynsterglasen in het glas gegaen syn ende tegen dander syde afgesteut. Ende het schynsel was daerom groenachtich, omdat de stralen in het groen glas eerst ginghen ende dan weer uytquamen, want alle dynghen schynen wel groenachtich, die mer maer rechs deur en siet." Isaac Beeckman, *Journal tenu par Isaac Beeckman de 1604 à 1634*, ed. C. de Waard, 4 vols. (The Hague, 1939–53), 3: 45–6.

2 The journal was discovered in 1905 by Cornelis de Waard (1879–1963), who subsequently edited and published it between 1939 and 1953. See Beeckman, *Journal.*

detail. When he turned to lens grinding himself in the 1630s, the discussion of dioptrics began to dominate his diary.[3] While considering the properties of lenses Beeckman also noticed chromatic effects, as the quote above illustrates. With characteristic acuity he described the differences of the reflections on both faces of a respective lens, and immediately began to consider the reasons for the differences in color.

Beeckman's notes contain a fairly coherent and highly original philosophy of nature.[4] More significantly, he is considered to have been the first mechanical philosopher in Europe. Although his notes remained private, his ideas had significant influence, in particular through his acquaintance with Descartes.[5] Nevertheless, despite this connection, there are notable differences between their ideas. The differences regarding light and colors are significant because they indicate a differentiation in early modern conceptualizations of these themes that has not been recognized in the historiography of early modern optics. I will argue that, rather than being characteristic for a corpuscular conception of colors, Descartes' mechanistic philosophy is singular because of the idiosyncratic combination of mathematical and corpuscular conceptions. By differentiating the elements of Descartes' conception the rather monolithic distinction between old and new philosophies of nature can be overcome. A variety of corpuscular and heterologous conceptions is revealed, that also helps to differentiate the interpretation of color practices.

This essay ties in with the increased historiographical interest in the material, artifactual and aesthetical aspects of light and color shown since the 1980s. These cultural studies of light and color have drawn attention to the diversity of conceptions of light and color as well as to the heterogeneity of ways of knowing beyond the strictures of physical explanation.[6] The traditional histo-

3 Fokko Jan Dijksterhuis, "Labour on Lenses. Isaac Beeckman's Notes on Lens Making," in *The Origins of the Telescope*, ed. Albert van Helden, Sven Dupré, Rob van Gent and Huib Zuidervaart (Amsterdam, 2010), 257–70.

4 Klaas van Berkel, *Isaac Beeckman on Matter and Motion: Mechanical Philosophy in the Making* (Baltimore, 2013). This is a translation and part revision of Klaas van Berkel, *Isaac Beeckman (1588–1637) en de mechanisering van het wereldbeeld* (Amsterdam, 1983).

5 John Schuster, *Descartes-Agonistes. Physico-mathematics, Method & Corpuscular-Mechanism 1618–33* (Dordrecht, 2013). See also John Schuster, "Descartes and the Scientific Revolution 1618–1634: an Interpretation" (PhD diss., Princeton, 1977). The main conclusion about Beeckman's significance is shared by Stephen Gaukroger, *Descartes: an Intellectual Biography* (Oxford, 1995).

6 Svetlana Alpers, *The Art of Describing. Dutch Art in the Seventeenth Century* (Chicago, 1983); John Gage, *Colour and Culture, Practice and Meaning from Antiquity to Abstraction* (London, 1993); Sven Dupré, *Galileo, the Telescope and the Science of Optics in the Sixteenth Century.*

ry of optics focused on the development of theories explaining the physical nature and properties of light and colors.[7] This topic tends to be marginal in recent studies of light and color, which is unfortunate. Theorizing was significant for early modern practitioners and the systematizing, publishing and disputing of philosophers constituted a genuine knowledge practice in its own right. Natural philosophy had a clear disciplinary identity, but displayed a range of opinions regarding the ontology and causality in nature. This essay draws attention to this diversity that is often overlooked in the rather dichotomous views of the early modern transformation of conceptions of light and color. In addition it queries how this diversity may relate to the diverse color practices discussed in recent historiography (including this volume). How do the alternative understandings of light and colors present in the diverse practices translate back to the business of theorizing in the early modern 'science' of optics; how can such ways of knowing be understood as 'theories of light and colors'?

Light and Matter in Beeckman's Colors

Light and colors enter Beeckman's diary in various ways. He recorded everyday observations and reflected on what he found, made notes from his readings

A Case Study of Instrumental Practice in Art and Science (PhD diss., Ghent, 2002); Wolfgang Lefèvre, ed., *Inside the Camera Obscura – Optics and Art under the Spell of the Projected Image* (Berlin, 2007); Carolin Bohlmann, Thomas Fink and Philipp Weiss, eds., *Lichtgefüge des 17. Jahrhunderts. Rembrandt und Vermeer – Spinoza und Leibniz* (Munich, 2008); Eileen Reeves, *Galileo's Glassworks: The Telescope and the Mirror* (Cambridge, 2008); Isabelle Pantin, "Simulachrum, species, forma, imago. What Was Transported by Light into the Camera Obscura? Divergent Conceptions of Realism Revealed by Lexical Ambiguities at the Beginning of the Seventeenth Century," *Early Science and Medicine*, 13 (2008), 245–69; Karin Leonhard, *Bildfelder: Stilleben und Naturstücke des 17. Jahrhunderts* (Berlin, 2013); Arianna Borelli, "Thinking with Optical Objects: Glass Spheres, Lenses and Refraction in Giovan Battista Della Porta's Optical Writings," *Journal of Early Modern Studies*, 3 (2014), 39–61.

7 A.I. Sabra, *Theories of Light from Descartes to Newton* (London, 1967); David C. Lindberg, *Theories of Vision from Al-Kindi to Kepler* (Chicago, 1976); For Isaac Newton, see Alan E. Shapiro, ed., *The Optical Papers of Isaac Newton, Vol. 1. The Optical Lectures, 1670–1672* (Cambridge, 1984); John A. Schuster, "Descartes *opticien*. The Construction of the Law of Refraction and the Manufacture of Its Physical Rationales, 1618–1629," in *Descartes' Natural Philosophy*, eds. Stephen Gaukroger, John Schuster and John Sutton (London, 2000), 258–312; Paolo Mancosu, "Acoustics and Optics," in *The Cambridge History of Science. Early Modern Science*. Vol. 3, eds. Katherine Park and Lorraine Daston (Cambridge, 2003), 596–631. A. Mark Smith, *From Sight to Light*: *The Passage from Ancient to Modern Optics* (Chicago, 2014).

and commented on them. In his ongoing efforts to acquire understanding from his experiences, he juxtaposed diverse readings, observations, and so on. Colors for him were primarily a clue to the nature and properties of materials. Besides customary designations of herbs for example, Beeckman employed colors to describe chemical processes. “Brewers say that by boiling long, beer becomes stiff and rigid,” he noted in 1618.[8] He explained that the fire, and the sooty earth it produces, mixes in with the water and grain; it adheres to the beery substance, resulting in a reddish and stony consistency. In the same vein he discussed the forging of iron, as well as other metallurgical processes.[9] Beeckman seems to have entertained alchemical notions of fire being introduced into materials in reactions, transformations that are generally indicated by a reddish appearance. He linked this with his corpuscular ideas, suggesting that fire enters the pores of materials (the pores of metals being so small that they only absorb pure fire without the sooty particles).[10]

Perceptual aspects of light and colors interested Beeckman greatly. On several occasions he discussed how one perceives a complete circle when looking at a point that moves along a circular line: “because the impression or stirring of each point one sees, stimulates the *tunica arachnoides* in such a way that it is felt a long time, this feeling being seeing.”[11] Where exactly this lagging effect takes places is not entirely clear; Beeckman endorsed Kepler’s theory of the retinal image, and the term *tunica arachnoides* sometimes referred to the retina, but he was not explicit here. He used the word *trochus* (hoop) for the effect of the lagging, referring to the perceptual circles produced by moving lights. Apparently he considered the stimulated retina to take some time to re-adapt. Beeckman often made observations while attending divine service:

> When you are sitting straight across and far away from the windows in church you cannot distinctly see the traverse irons to which the glasses are fastened; when you cover the upper part of the windows with the brim of your hat, you will see the irons that appear next to the rim.[12]

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8 “De brouwers seggen, dat het bier doort lange sien tay ende stram wort. […] Ratio est quia ignis se miscet aquae cui grana injiciuntur, ita ut substantia ipsa ignis cerevisiae adhaerescat et inhaerescat, non aliter quàm ignis se miscet terrae fuligine, unde rubedo et consistentia lapidea.” Beeckman, *Journal*, 1: 187.

9 Ibid., 1: 129, 287; 2: 238.

10 Ibid., 1: 287; 3: 18.

11 “[…] omdat de impressie of prickelinghe van elck punt, dat men siet, de tunica aragnoides so prickelt, dat sy dat een tyt lanck gevoelt welck gevoelen is sien.” Ibid., 3: 54.

12 “Als men recht over ende verre van de glasen in de kercke sidt, also dat men de dweersche ysers, daer de glasen aen vast gemaeckt syn, niet bescheelick sien en kan, ist dat men dan

The reason for this, he continued, is that the light that is blocked by the hat would otherwise stir the parts of the arachnoid too much for the brain to distinguish the details of the irons. In the same way he explained why details are seen more clearly when light falls obliquely on surfaces and objects, "because [light] that comes from straight ahead, produces a reflection in the eye from surrounding things; so that the eye filled with light cannot grasp the other things that one principally wants to see."[13] This was also easily tested by looking around carefully when in a church building, Beeckman added. He was particularly interested in such effects of lagging and blinding in visual perception, which indicated that light did not act instantaneously but takes time to have an effect.[14] He thus understood the temporality of light propagation in perceptual terms. In a comment on Bacon he explicated that after-images were perceptual effects, and not caused "because the rays with which one sees keep hanging in the air, as he says […]."[15]

Rainbows and other chromatic phenomena in the air are mentioned briefly, but not given particular attention.[16] In 1626 Beeckman reported that a member of an Arctic expedition claimed that he had observed how rainbows sprang from the land and seas.[17] His amused reply explained that the true cause is in "the nature of concave mirrors, in which the view or appearance stand between

met de voye of randt van de hoet also se opt hooft staedt, het opperste deel van de glasen bedeckt, so sal men de ysers, die aldernaest aen de voorschreven randt van de hoet schynen te staen, heel bescheelick sien, sodat men het onderscheyt merckelick siet datter is tusschen het bescheelick sien van de voorss. naeste ysers ende die leegher staen." Beeckman, *Journal*, 3: 146–7. In my translation, I simplified this rather complicated sentence.

13 "Als men wat subtylick sien wilt, so moet men dat sien door het licht, dat van tersyden kompt, want dat recht van vooren kompt, maeckt van de omstaende saken een reflexie in ons ooghen, dewelcke vervult synde met dat licht, en konnen het ander, dat sy principaelick sien willen, niet vatten." Ibid., 3: 45.

14 "Hinc concludamus, si placet, lucem venire ut perit, atque utrumque fieri non momento, sed in tempore." Ibid., 1: 100.

15 "[…] niet omdat de stralen daerdoor men siet, in de locht blyven hanghen, gelyck hy seght." Ibid., 3: 54. Beeckman refers to paragraph 274 (p. 71) in Bacon, *Sylva Sylvarum*, according to the editor of the Journal, Cornelis de Waard: *Sylva Sylvarum or a Natural History* (London, 1627).

16 Beeckman, *Journal*, 1: 98–9; 2: 76, 85, 361; 3: 237, 317.

17 It is not clear whether this was one of the Barentsz expeditions. The famous observation made on the last expedition during the hibernation on Novaya Zemlya, which Kepler, amongst others, discussed, is also mentioned in the diary: Beeckman, *Journal*, 1: 98–9. Siebren van der Werf et al., "Gerrit De Veer's True and Perfect Description of the Novaya Zemlya Effect, 24–27 January 1597," *Applied Optics*, 42 (2003), 379–89.

the mirror and the eye, as shown in a clean spoon."[18] In order to enlighten his interlocutor that the rainbow was not an actual object but an illusion, Beeckman in typical fashion referred to everyday experiences, comparing it with virtual images in concave mirrors.

Beeckman was a man of quite wide reading, which he further expanded in 1627 when he gained access to the library of the Dordrecht minister Colvius.[19] His reading ranged from classics and their commentators, through Santorio and Zabarella, to Libavius, Gilbert, Bacon and Kepler. In 1623 he read Bacon's *Novum Organum* in detail. He was intrigued by Bacon's aphorism 23 in which he related the regularity of the texture of a body to its color, ranging from orderly (white) over the spectrum of colors to confused (black). The order of texture related to musical proportions, a point on which Beeckman reflected several times, following Bacon's claim that colors are related to harmonic ratios.[20] In discussing the implications of the harmony of colors, Beeckman typically referred to his own singing practice in church. Instead of considering the classical issue of the division of the octave, he said that if there is a relationship between tones and colors, the latter should mix in a similar way to the former. "Thus to find a color that responds to the minor third, it is necessary that from this mixture blue does emerge with the green, in particular in liquid colors, […]."[21] He noted certain consequences of considering color mixing in terms of ratios, but never went much further into the issue of the appreciation of color mixes – which we know is notoriously difficult and fundamentally different from the matter of combining sounds.

The main point of reference in Beeckman's natural philosophical considerations were the works of Johannes Kepler. Here he encountered ingenious and challenging ideas about the nature of things and the order of the cosmos. His ideas on light and colors were also informed by Kepler for whom 'the optical part of astronomy' had been a principal interest. Beeckman began working through *Ad Vitellionem Paralipomena* as early as 1616, taking notes on the issue of the validity of the concept of species. He recorded statements from various authors, while endorsing Kepler's views.[22] Beeckman did not adopt Kepler's

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18 "[…] want, seyde ick, het gaet na de nature van de holle spiegels, in dewelcke de schouwen of schynsels tusschen den spieghel ende d'ooghe staen, als blyckt in eenen schoonen lepel." Beeckman, *Journal*, 2: 361.

19 Berkel, *Beeckman*, 53–5.

20 Beeckman, *Journal*, 2: 251; 317; 329. According to the editor, Cornelis de Waard, the reference is to page 224 in original edition of Francis Bacon's *Instauratio Magna* (London, 1620). Beeckman also refers to Ficino later on.

21 Beeckman, *Journal*, II, 330. "Invento igitur colore qui respondet tertiae minori, necessariò ex ejus mixtione cum viridi emergit coeruleum, praesertim in coloribus liquidis, …"

22 Ibid., I, 99.

ontological reading of the mathematics of light propagation underlying visual species. Whereas Kepler conceived of light as *being* the two-dimenional surface extending radially around a light source, Beeckman interpreted it as some kind of corporeal entity. Kepler only sporadically discussed color but Beeckman considered his ideas to be confirmed by Kepler's writings. "The matter of color is light," Beeckman held from early on, and he regarded this as a break with tradition.[23] He regarded colors to be produced in the interaction between light and materials, rather than mere reflection. "Kepler writes […] that light is not colored by repercussion; by which my opinion of colors is greatly confirmed."[24]

In the late 1620s Beeckman began working with lenses and telescopes. Naturally, he used the lenses he had to hand to inquire into effects of light and colors, such as the greened rays from the introductory quote above. At the same time he followed the ideas on light and colors that he had developed earlier to understand the effects (and defects) of lenses.[25] In a series of notes in early 1632 he contemplated the improvement of telescopes, attending also to color defects.[26] He writes: "And the evil colors, being called irises, arise from the large refraction […]."[27] Accordingly, he proposed the use of large objective lenses – as well as correctors to decrease the obliquity of rays – as the long curvature would minimize refraction. We should bear in mind that until the 1670s, the distinction between chromatic and spherical aberration was not absolute; color defects were generally expected to be corrected by the right shape of lenses.[28] Apparently, Beeckman never tested this idea with the method he had developed earlier: stopping the center of a lens to see how much the focus of the outer parts deviated from the principal focus.

Beeckman never systematically elaborated an account of colors, but through two decades of diary writing contours of a conception of light and colors appear. In an early note on the perception of objects (why we cannot see in the dark), he wrote that light reflects in the pores of materials, thus creating different colors in the form of species we see in various ways.[29] This developed into a general notion that colors are produced by the interaction between light and

23 "[…] colorum materia est lux," Ibid., 1: 327.

24 "Notat Keplerus ad finem ejusdem libri pag. 436 ad prop. 24 lucem non colorari in repercussu, unde magis confirmatur opinio mea de colore." Ibid., 3: 105.

25 An earlier note already pointed out the relationship between colored fringes in a telescopic image and the distance of an object. Ibid., 2: 210.

26 Ibid., 228, 232, 234, 317.

27 "Ende de quade coleuren, irides genoempt synde, die kommen door de groote refractie." Ibid., 3: 232.

28 See also Dijksterhuis, "Labour on Lenses", 261–3.

29 Beeckman, *Journal*, 1: 28.

the material of objects.[30] In this way light, or rays, become colored: color is broken light. Beeckman spoke of refraction, but in a general sense of affection and bending. Beeckman considered black and white to be colors rather than the presence or absence of light. In a late note he measures out the colors between black and white – not as mixtures but as individual entities. The appearance depended on the structure of a material: roughness produces white, smoothness black.

It is interesting that Beeckman thinks of color in terms of the texture of bodies. He had after all noted with interest Bacon's aphorism on colors, although he did not adopt the idea of relating color to regularity. Beeckman explained that the globules of an uneven surface drive apart the rays. The color of light depends upon the amount of dispersion: "When a ray is incident on a rough point it is dissolved in many particulars [...]."[31] This is not necessarily a prismatic conception of colored light, for the account does not explicate whether rays are colored by modification, selection or otherwise. Furthermore, Beeckman combined this optical account of colors being the result of broken light with a perceptual notion in which the cognitive properties of the eye further define the effects of colors. In this respect, he may have been inspired by Johannes Magirus, whose 1608 *Physiologia peripatetica* Beeckman had read. He gave a cognitive interpretation of the classical notion that visual spirits are dispersed by white bodies and converged by black ones.[32] Giving a reason for the paradoxical fact that a bit of blackening enhances the whiteness of whitening, he said that a few black rays intensify the perceptual effect of the white rays by creating contrasting impressions on the retina.[33] The combination of various textures of bodies and the sensitivity of the parts of the eye becomes what we call colors.[34]

New Philosophy

The main thread in Beeckman's philosophical pursuits consisted of the effort to corpuscularize Kepler's novel theories.[35] This meant that his ideas about light and colors were guided by two conflicting points of departure: Kepler's

30 Ibid., 1: 100; 2: 299, 317.

31 "Nam radius in asperum punctum incidens in multas particulas dissolvitur; [...]." Ibid., 3: 329; 358–9.

32 Ibid., 2: 343. I thank Tawrin Baker for this elucidation.

33 Ibid., 2: 158.

34 Ibid., 3: 105–6.

35 Berkel, *Beeckman*, 76–92; Schuster, *Descartes-Agonistes*, 390–4; 471–5.

mathematical understanding of natural phenomena on the one hand, and a radically corpuscular understanding of nature on the other. Kepler in his project to transform mathematics into physics had effectively introduced a mathematical ontology in which the quantitative aspects of nature were the essence.[36] Such a Neoplatonically inspired conception rendered plausible the idea that a two-dimensional surface can be a physical object and that one-dimensional rays can have physical properties and effects. Such immaterial essences were, however, completely at odds with Beeckman's corpuscular understanding of things. He consistently looked for corpuscular accounts of properties and effects, such as the 'refraction' of light at the surface of objects.

Beeckman's project of understanding natural phenomena in corpuscular terms reflects a general trend in early seventeenth-century natural philosophy towards a mechanical understanding of natural phenomena.[37] His notes illustrate some major traits of this development. It was closely linked to artisanal approaches to the world, characterized by material and tangible understandings of phenomena. It was deeply informed by various varieties of alchemical ideas and practices. It constituted a conscious break with the Aristotelian conceptions of scholasticism, replacing qualities and forms by matter and motion, and a revival of classical atomism. Beeckman was a master craftsman, particularly in hydraulics, who developed literary skills and became a school master. In his philosophical pursuits he elaborated a corpuscular understanding of nature. He read philosophical works of classical as well as new authors. He combined this corpuscular thinking with a profound interest in the new mathematical sciences of Kepler, Stevin and others. This combination was quite original; John Schuster considers Beeckman the principal precursor in mechanistic philosophy. Beeckman did not publish his ideas, but he exerted decisive influence through his exchanges with Descartes, Gassendi and Mersenne. The significance of Beeckman for the development of a mechanistic philosophy is undoubted. Still some qualification is needed, for there are crucial differences between his and Descartes' ideas, in particular regarding light and optics. These differences are important, because they undercut the mono-

36 David Lindberg, "Kepler and the Incorporeality of Light," in *Physics, Cosmology and Astronomy, 1300–1700*, ed. S. Unguru (Dordrecht, 1991), 229–50; David Lindberg, "The Genesis of Kepler's Theory of Light: Light Metaphysics from Plotinus to Kepler" *Osiris*, 2 (1986), 5–42.

37 For a recent overview see Daniel Garber, "Physics and Foundations," and Ann Blair, "Natural Philosophy" in *The Cambridge History of Science. Early Modern Science.* Vol. 3, eds. Katherine Park and Lorraine Daston (Cambridge, 2006), 21–86 and 365–306.

lithic interpretation that is usually given to the transition from the old to the new philosophies of nature in the seventeenth century.

In Aristotle light and color are conceptually and ontologically different. Color is the visible quality of bodies, light makes it possible for these qualities to reach the eye.[38] Light actualizes the transparency of the medium so that the colors of bodies can be perceived, and vision can occur. Light is *not* the agent of colors. How colors – the visible qualities – actually travel to the eye is basically irrelevant for the cognitive issues that are central to Aristotelian philosophy. We need to bear in mind, though, that Aristotle's ideas of light and colors are not unambiguous and are scattered across different texts on different topics.[39] The Aristotelian doctrines the moderns criticized were shaped by the commentators of the Middle Ages and the Renaissance. As regards optics, the Jesuit textbooks were instrumental in explicating philosophical notions concerning the nature and properties of light and colors. For example, the strict distinction between real and apparent colors – the permanent colors of bodies and the evanescent colors of the rainbow – only became a prominent topic in early modern textbooks.[40]

In medieval *perspectiva* Alhacen grounded the mathematics of ray-tracing in Aristotelian philosophy, but this changed little in the business of optics. *Perspectiva* discussed the behavior of rays and essentially concerned light or non-light; light or dark, white or black. In other words, regarding the perception of objects, *perspectiva* only considered the direction and contours, not the visual qualities, i.e., the colors of bodies. In *perspectiva* colors were a relatively marginal topic and their physical understanding mainly Aristotelian, although some notion of rays carrying colors did appear in accounts of the rainbow.[41]

Kepler's principal innovation was his new conception of image formation. He did not say very much about color, but what he said is interesting. The

38 Richard Sorabji, "Aristotle on Colour, Light and Imperceptibles," *Bulletin of the Institute of Classical Studies* 47 (1) (2004), 129–40; Rein Ferwerda, *'Aristoteles' over Kleuren* (Budel, 2001), 27–8.

39 Ferwerda, *Kleuren*, collects quotations from various places in Aristotle's corpus, along with the pseudo-Aristotle's 'On Color'.

40 Tawrin Baker, *Color, Cosmos, Oculus: Vision, Color, and the Eye in Jacopo Zabarella and Hieronymus Fabricius ab Aquapendente* (PhD diss., University of Indiana, Bloomington, 2014), 325–40.

41 A.I. Sabra, "The Physical and the Mathematical in Ibn al-Haytham's Theory of Light and Vision," in *Optics, Astronomy and Logic. Studies in Arabic Science and Philosophy*, ed. A.I. Sabra (Aldershot, 1976), 1–20; David Lindberg, "Continuity and Discontinuity in the History of Optics: Kepler and the Medieval Tradition," *History of Technology*, 4 (1987), 431–48; A. Mark Smith, "Getting the Big Picture in Perspectivist Optics," *Isis*, 72 (1981), 568–89.

Paralipomena of 1604 treats of the optical part of astronomy. The new theory of image formation in the eye and in instruments is intended to understand the way optical effects of the atmosphere affect astronomical observations. In addition to the main issue of accounting for atmospheric refraction, Kepler mentioned a couple of atmospheric phenomena that involve coloration.[42] In his discussion of the rainbow he explained how refraction weakens light to specific degrees of chromaticity. He used this to account for other atmospheric phenomena as well as the colors of bodies. In an early manuscript he had compared for example the redness of Mars to the light reflected in a black steel mirror.[43] Kepler did not elaborate on his understanding of colors of bodies systematically, but his remarks are suggestive. To paraphrase Goethe, the less Kepler grasped a subject cognitively, the richer his linguistic rendering.[44] The actual explanation is rather casual, but the significance of Kepler's ideas can be seen in the way he interpreted color in terms of the power of a ray of light, the intensity of light.

Conceiving of color as a property of light, as Kepler did, was a break with Aristotelian tradition and a line of thought in which Descartes continued. Descartes had the same starting point in optics as Beeckman: the works of Kepler. This is not surprising, for Beeckman was instrumental in the early development of Descartes' natural philosophy. Their acquaintance around 1618–19 laid the basis of his program of physico-mathematics in which natural phenomena were explained by the actions of imperceptible particles. Descartes turned Beeckman's corpuscular interpretation of natural phenomena into a systematic natural philosophy.[45] His understanding of refraction, and his eventual discovery of the law of refraction, heavily depended upon Kepler's unsuccessful attempts to find the measure of refraction.[46] Descartes realized this breakthrough in optics during his years in Paris, halfway through the 1620s. In 1629, after he had returned to the Dutch Republic and had renewed his acquain-

42 Johannes Kepler, *Optics: Paralipomena to Witelo and the Optical Part of Astronomy*, trans. William H. Donahue (Santa Fe, 2000). See propositions 12–17 and the appendix to chapter 1, which is a commentary on Aristotle. See also chapter 4, paragraph 9; notes to chapter 6; chapter 7, paragraph 3.

43 Johannes Kepler, *Gesammelte Werke* (Munich, 1938), 4:17–8.

44 "Da er die Sprache völlig in seiner Gewalt hat, so wagt er gelegentlich kühne seltsame Ausdrücke, aber nur dann, wenn der Gegenstand ihm unerreichbar scheint." Johann Wolfgang Goethe, *Zur Farbenlehre. Zweyter Band. Materialen zur Geschichte der Farbenlehre* (Tübingen, 1810), 249.

45 Schuster, *Descartes-Agonistes*; Gaukroger, *Descartes*.

46 Schuster, "Descartes *opticien*."

tance with Beeckman, his work on optics was reinvigorated and he turned his mind to colors.

Cutting and Slicing with Descartes

In July 1629 Pierre Gassendi travelled through the Dutch Republic visiting old and new acquaintances.[47] Among other things, he brought with him an account of parhelia observed by Christopher Scheiner in Rome that spring.[48] He had received the account from Peiresc, and was to distribute it during his journey. That same year, Henricus Reneri (1593–1639) published an account based on his conversations with Gassendi.[49] On 17 July Gassendi called on Beeckman in Dordrecht, who made a careful copy of the figure and the text in his journal.[50] In October Descartes wrote Mersenne that 'a friend' had shown him the account two months earlier.[51] He had ceased all his activities and had set out on an explanation of all sublunary phenomena – "meteors," as they were called. A month later he wrote to Mersenne that he was elaborating a complete physics, an explanation of all natural phenomena, which he called *Le Monde*.[52] The friend Descartes mentioned could have been Beeckman – with whom he had reacquainted in October 1628 – or Reneri, whom he had met through Beeckman that winter. The same letter to Mersenne in October marked the end of his relationship with Beeckman: according to Descartes, the latter had undeservedly claimed credit for certain ideas of his. This personal discord aside, that summer was crucial for Descartes' intellectual development, during which

47 Ferdinand Sassen, "De reis van Pierre Gassendi in de Nederlanden (1628–1629)," *Mededelingen der Koninklijke Nederlandse Akademie van Wetenschappen, Afd. Letterkunde. Nieuwe Reeks* (Amsterdam, 1960), 263–306.

48 Walter Tape, Eva Seidenfaden, and Gunther P. Können, "The Legendary Rome Halo Displays," *Applied Optics*, 47 (**2008**), H72–H84. Eva Seidenfaden, "Found: A Diagram of the 1630 Rome Halo Display," *Applied Optics*, 50 (2011), F60–F63.

49 Henricus Reneri, *Phaenomenon rarum et illustre, Romae observatum, 20 martij anno 1629* (Amsterdam, 1629). Gassendi's own publication appeared in Paris the year after: Pierre Gassendi, *Parhelia, sive soles quatuor qui circa verum apparuerunt Romae die XX mensis martis, anno 1629, et de eisdem Petri Gassendi ad Henricum Renerium epistola* (Paris, 1630).

50 Beeckman, *Journal*, 3: 123–214; 4: 149–51: "Parhelia sive soles iv apparentes circa solem verum, Romae observati Anno 1629 die 20 Martij ab horâ astronomicâ pomeridianâ 2a ad 3am, seu Italicâ 20a ad 21am et paulò plus." For the exact date, see Sassen, *Reis*, 39.

51 Charles Adam and Paul Tannery (eds.), *Oeuvres de Descartes*, 11 vols. (Paris, 1897–1909), 1: 23. Hereafter this text will be referred to as *AT*.

52 Ibid., 1: 70.

he resurrected his philosophical project and laid the basis of his natural philosophy.[53] The project of writing a natural philosophy was eventually abandoned, but the mechanistic account of light and colors was published in 1637 in one the essays joined to his *Discours de la méthode*.

After his initial announcement that he was going to explain meteors and colors, Descartes discussed atmospheric colors in detail with Mersenne over the winter of 1629–1630. In December he wrote about the colors in coronas around a candle flame, in particular the order and separation of the various colors. Mersenne had suggested a comparison between parhelia and such coronas, but Descartes responded that the order of the colors did not match.[54] In his letter to Mersenne of 25 February 1630, he wrote that he could use the motions of tennis balls to account for such colors.[55] Thus Descartes' corpuscular conception of light was introduced to his optics in the form of the famous analogy between light and tennis balls.[56] The full account is found in the essays. In *La Dioptrique*, Descartes compared the properties of light rays to projectile motion to explain reflection and refraction. Light rays are made to deviate from their rectilinear path in the same way the movement of a ball or a stone thrown in the air is altered by objects it encounters on its trajectory. Light rays rebound from hard surfaces and alter direction when passing through the surface of water. In addition to changes in direction, particles can acquire a rotational motion when they interact with surfaces. Such a spin is comparable to the techniques that *joueurs de paume* use: "As those who play tennis experience when their ball encounters uneven ground or when they hit it while slanting their racquet, what they call, I understand, cutting or curling."[57] Spin produced color: the ratio between translational and rotational motion effected the perception of different colors of light: if the rotation is smaller the effect is blue, if larger red and if both are equal the eye perceives white light. Colors were the

53 Schuster, *Descartes-Agonistes*, 390–4.

54 AT 1: 98–106. He tentatively accounted for this by explaining that these coronas appear through a dispersion in the eye. See also *Les Météores*: AT 6, 351–354.

55 Ibid., 1: 117.

56 Gaukroger, *Descartes*, 217–22; Claus Zittel, *Les Météores/Die Meteore* (Frankfurt, 2006), 13–8.

57 "Ce que ceux qui jouent a la paume esprouvent assés, lors que leur bale rencontre de faux quareaux, ou bien qu'ils la touchent en biaisant de leur raquette, ce qu'ils nomment, ce me semble, coupper ou friser." René Descartes, *Discours de la méthode pour bien conduire sa raison, et chercher la vérité dans les sciences. Plus La Dioptrique. Les Meteores. et La Geometrie. Qui sont des essais de cete Methode* (Leiden, 1637). References are to the original edition. The *Discours* is numbered separately; in the essays the page numbering starts again, but is continuous through all three essays. Descartes, *Dioptrique*, 10.

subject of *Les Météores* and spin was not further discussed in *La Dioptrique*.[58] In the eighth discourse of *Les Météores* Descartes solved the age-old riddle of the rainbow.[59] He determined the size and position of the first and second rainbow, thereby arriving at the first exact description of the phenomenon. The secret of the rainbow consisted of the colors seen at specific angles when sunlight is reflected in a drop of water. A single refraction already produced prismatic colors: upon refraction the particles acquire various degrees of spin. In *Les Météores*, he left the distinction between motion and tendency implicit and he did not discuss the motions of ethereal particles in detail.

The tennis ball analogy itself however is not of prime relevance here. It is notoriously problematic, with all kinds of inconsistencies and troublesome implications.[60] Moreover, it is not very central to Descartes' argument; neither in refraction nor in the rainbow is the tennis ball analogy employed as an analytical tool. Rather, as Claus Zittel has argued, Descartes used these and other analogies to render his analyses of phenomena convincing and comprehensible.[61] He did not need to elaborate in detail how interaction with surfaces produces rotations or how the eye distinguishes this variation; what counted was that he showed that colors could be understood as mechanistic effects.

The real significance of Descartes' color theory is the way in which he redefined colors. He based his general understanding of colors on his explanation of the rainbow, turning prismatic colors into the definition of color.[62] Just as light is modified by refraction in a raindrop, it is modified by interaction with objects and materials. Conceiving of prismatic colors as the essence of colors means that color is turned into a property of light. Light in the optical sense, that is: understanding color in terms of the perspectival properties of light – the mathematics of rays, directions, and contours. In *Le Monde* and *Principia Philosophiae*, Descartes drew the philosophical conclusion: all colors are apparent and the real colors of scholastic philosophy are meaningless. This was a groundbreaking conclusion, because colors were no longer qualities that disclose the nature of objects; a color is a mere appearance. Boyle understood this

58 Ibid., 1–12.

59 Ibid., 250–75.

60 Fokko Jan Dijksterhuis, "Jeu de Paume & Jeux de la Raison in Seventeenth-Century Optics," *Nuncius*, 28 (2013), 115–41.

61 Claus Zittel, *Theatrum Philosophicum: Descartes und die Rolle ästhetischer Formen in der Wissenschaft* (Berlin, 2009), 208–28.

62 For earlier expressions of this idea, see John Gage, *Color and Meaning: Art, Science, and Symbolism* (Berkeley, 1999), ch 8.

lesson very well and made it central to his doctrines on light and color.[63] In all this we should bear in mind that there was quite some rhetoric involved in the presentations of Descartes, Boyle and others emphasizing the break of the new philosophies with Peripatetic ideas.[64] Descartes' understanding of scholastic philosophy was largely based on the neo-scholastic textbooks he had studied, and tended to represent in a selective and sometimes biased way.[65]

Rays and Bodies of Color

The key to Descartes' optics is not so much the corpuscularization of colors but their opticalization. This opticalization of color was a continuation of the work of Kepler, in which the perspectival properties of light propagation became the basis of the understanding of light. Descartes solved the age-old puzzle of the rainbow but created a new problem. Aristotle's understanding of colors was based on the properties of natural colors and faced serious difficulties in accounting for the accidental qualities of prismatic colors. Descartes turned the problem upside down: prismatic colors were the essence of color but made it difficult to account for material colors. This created a tremendous puzzle for seventeenth-century natural philosophy. This debate does contain a paradox however: by reducing color to rays, you basically reduce it to light and dark. Newton was to solve this puzzle in an ingenious way. First he identified color with the index of refraction of a ray in his doctrine of the heterogeneity of white light. Then he linked prismatic colors to the colors of bodies through the interference of rays in the inner structure of materials.[66] Although it is a truly magnificent solution, it only made the paradoxes of prismatic and material colors more evident: the spectrum that defines the order of prismatic colors is wholly at odds with the artistic understanding of primaries and their mixing. This was a puzzle that would haunt Enlightenment inquirers of colors up to Goethe, but need not occupy us here.[67]

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63 See for example Shapiro in his introduction to Isaac Newton, *The Optical Papers of Isaac Newton*, ed., Alan E. Shapiro (Cambridge, 1984).

64 Anthony Grafton, *Defenders of the Text: The Traditions of Scholarship in an Age of Science, 1450–1800* (Cambridge, 1991), 1–5. Historians of science often reproduce this rhetoric.

65 I thank Tawrin Baker for pointing this out clearly. Further investigation of this idea was outside of the scope of this essay. See also Baker, *Color*, 325–48.

66 Alan E. Shapiro, *Passions, and Paroxysms: Physics, Method, and Chemistry and Newton's Theories of Colored Bodies and Fits of Easy Reflection* (Cambridge, 1993).

67 Neil Ribe and Friedrich Steinle, "Exploratory Experimentation: Goethe, Land, and Color

Descartes' corpuscular idiom probably contributed significantly to the success of getting across the radical idea that all colors are apparent. At the same time it also concealed the idea's essence: the identification of color with light rays. Descartes' philosophy offered one specific way of understanding light and colors in a corpuscular manner, being integrated with the mathematics of geometrical optics. This combination of corpuscular thinking and (mixed) mathematics is quite typical of Descartes' natural philosophy in general. Equally typical are the idiosyncratic answers he developed for the conceptual puzzles this created, such as the conception of light as a pressure in the ether behaving like moving particles. The various ingredients of Descartes' philosophical stew should be carefully dissected. In optics this means that opticalization and corpuscularization are not one and a kind: the identification of light and color does not presuppose a corpuscular conception of light; nor the other way around.

Beeckman is the ideal example to show that a corpuscular conception of light and color need not imply an optical conception. He conceived of colors as 'refracted' light but he did not reduce them to prismatic colors or affects of rays. The interaction between light – possibly some kind of light particles – and substances altered the properties of light and produced colors. This was not necessarily a matter of rays and their properties; it was light in a general luminous sense. His understanding combined optical aspects with material and perceptual aspects. Beeckman thus operated at the intersection of an optical account of color and a corpuscular approach in a more general sense than Descartes' predominantly optical approach.

The parallels between Descartes and Beeckman further clarify the differences. For both thinkers, Kepler had been the starting point. Descartes' road to tackling refraction was paved by a physical reading of the mathematical analysis of *Paralipomena*.[68] When Descartes met Beeckman again in 1628, he found him systematically working through the work of Kepler, rewriting the immaterial actions in corpuscular terms.[69] They may both have discussed the parhelia of Rome, but it was exactly at this point that they parted ways. Beeckman carefully noted the report from Gassendi, but gave most of his attention to atmospheric colors in general. For Descartes it initiated his analysis of colors and a crucial new phase in the development of his natural philosophy. In Descartes' physical reading of Kepler, the optical understanding of light in terms of the

Theory," *Physics Today*, 55 (7) (2002), 43–9; Sarah Lowengard, *The Creation of Color in Eighteenth-Century Europe* (New York, 2006).

68 Schuster, "Descartes and the Scientific Revolution."

69 Schuster, *Descartes-Agonistes*, 471–5.

properties of rays was dominant. In comparison, Beeckman emphasized the corpuscular interpretation of the effects and perception of light phenomena.

Philosophies and Color Worlds

Early modern corpuscular thinking is often equated with Descartes' mechanistic conception of light and colors. However, this tends to obscure its essentially optical character, namely, that he understands light in (mathematical) terms of rays. Beeckman is but one example to show how Descartes' ideas of combining optical and corpuscular conceptions resonated with others. There were many corpuscular conceptions of light and colors where the optical aspect is entirely absent. These, however, tend to be overlooked in historiography. Broadening our view beyond the historical canon we encounter a great diversity of corpuscular accounts of colors in which the optical approach of Kepler or Descartes is even less prominent, or entirely absent.

A brief assessment reveals a variety of opinions, enriching our view of corpuscular conceptions of colors. William Gilbert linked colors to the elements and discussed the change of color from green to yellow to red when lead is heated.[70] In a similar way, Fortunio Liceti explained how the constitution of materials affects color, and how such color can be altered when they are processed. This phenomenon, seen for example with the tempering of steel, is also referred to by Boyle, as Tawrin Baker explains in his contribution to this volume. In his account of the Bologna stone, *Litheosphorus* of 1640, Liceti described the constitution of variants that emit different colors, in relation to pure gypsum.[71] In his *Ars Magna* (1646), Athanasius Kircher elaborated further on the luminescent properties of the Bologna stone. Pointing out the phenomenon of after-images, he argued that the eye acted in a similar way by absorbing and subsequently emitting light. He performed experiments with mixing various salts and observing the colors of the vapors, arguing that the variety of fluorescent colors showed that the colors are inherent to the salts.[72] The colors produced in fireworks, and the manipulations of substances to create them,

70 William Gilbert, *De magnete, magneticisque corporibus, et de magnete physiologia nova* (London, 1600). See book 2, chapter 3 and 31; book 4, chapter 12 and 13.

71 Fortunio Liceti, *Litheosphorus, sive De lapide Bononiensi lucem in se conceptam ab ambiente claro mox in tenebris mire conservante* (Udine, 1640), 94, 113–4. See also Fortunio Liceti, *De luminis natura et efficientia libri III* (Udine, 1640), 146–9.

72 Athanasius Kircher, *Ars magna lucis et umbrae in decem libros digesta* (Rome, 1646), 35–7; 66–70; 126–7.

likewise created a whole body of experiences with a diverse group of practitioners, as Simon Werrett explains elsewhere in this volume. For the question whether the colors are a property of the substance evaporated by ignition or a result of the reaction produced by ignition, the optical properties of color are largely irrelevant. These men were busy finding out what substances made what colors and how the coloration could be enhanced.

An interesting figure in this context is Johannes Marcus Marci a Kronland. He started from Kepler's optics and the idea that color arises from the force of light, but proceeded in an entirely different direction to that taken by Beeckman and Descartes. Color is a property of light, but on the basis of a very specific understanding of light. In his *Thaumantias* of 1648 he explained that colors are inherent to the sun's light and can be distilled by interactions with materials – including being refracted in a glass prism.[73] Given that light can carry colors and has reactive properties, he concludes that light has a sulphuric nature. The specific colors are identified in the subsequent chromatic stages of metallic reactions. Marci thus also considered light to be a material carrier of properties such as color, but in a chemical rather than a mechanical sense.[74] Marci combined an optical approach to colors with a chemical one.

With Marci our picture of early seventeenth-century color conceptions is further fragmented, or enriched, if one prefers. There were many ways of conceiving of color in material terms. The variety, and even disparity, of these instances makes clear that the notion of a rise of corpuscular thinking in optics does not really help to interpret developments in theories and conceptions of colors in the early seventeenth century. There are no homogeneous doctrines and no clean breaks between schools of thought. Various traditions and developments existed alongside each other and continued to exist. The 'alchemical' approach ran straight into eighteenth–century experimental philosophy; 'perspectivist' conceptions continued from Snellius well into Enlightenment aesthetics, and so on.[75] The picture that arises is a diverse collection with all the conjunctions and disjunctions of a Venn diagram. Descartes and Beeckman combined optical and corpuscular conceptions each in their own way; so did

73 Johannes Marcus Marci, *Thaumantias Liber de arcu coelesti deque colorum apparentium natura, ortu et causis* (Prague, 1648), 83–4; 98–106; 115–21.

74 Margaret Garber, "Chymical Wonders of Light: J. Marcus Marci's Seventeenth-century Bohemian Optics," *Early Science and Medicine*, 10 (2005), 478–509.

75 Fokko Jan Dijksterhuis, ""Will the Eye Be the Sole Judge?" 'Science' and 'Art' in the Optical Inquiries of Lambert ten Kate and Hendrik van Limborch around 1710," *Netherlands Yearbook for History of Art*, 61 (2011), 308–31.

Marci and Boyle, but in completely opposite ways. In the exclusively optical domain we encounter Kepler, while men like Gilbert, Liceti and Kircher are found on the other side in the corpuscular domain. The issue of corpuscularity was very subtle in scholastic philosophy, as the systematic discussion of Zabarella's influence makes clear. Although the substantiality of light, and of color, was rejected, it could be assigned some kind of materiality, a materiality of the medium, for example.[76] The rhetoric following Descartes notwithstanding, positions on either side were not monolithic, and dichotomies between ancients and moderns are not clear-cut. In all this the crucial difference between optical and corpuscular conceptions of colors, which Descartes himself more or less obscured, should be clear and taken into historiographical account.

Conclusion

This exploration shows that the diversity of conceptualizations of light and color in the early seventeenth century was at least as great as the variety of color practices. This is no coincidence, and it is of import to remember the structural relationship at play as well. Conceptualizations are reflections upon experiences, observations, manipulations – of this, Beeckman provides a perfect and hands-on example. Philosophies, theories, and explanations articulate and systematize phenomenological and practical knowledge; the textual practices of philosophers accompany material practices. Natural philosophy had distinct disciplinary features as a way of knowing, but it was far from homogeneous in its content. I would suggest that different conceptions of light and colors point to different color worlds. They systematize and generalize knowledge of rainbows, metals, plants, gems, paints and so on: epistemic objects around which color worlds form and that bring together various ways of knowing, from the operative and descriptive to the philosophical practices of writing, disputing and publishing. The books of Aldrovandi and Hilliard discussed by Pugliano and Leonhard in this volume are examples of the vertical exchange of knowledge. These manual-like books can be considered an intermediate level between the tacit notions of artisans and the systems of natural philosophers. In Beeckman these levels are combined, his reflections on light and colors grounded in his own chemical, perceptual, dioptrical observations, to the point of an effort to conceive of them in the corpuscular and mechanical terms of these direct, tangible experiences.

76 Baker, *Color*, 113–40.

Descartes' color theory is based on his understanding of the rainbow and in this regard reflects the disciplinary predilections of mathematical science for atmospheric phenomena. The distinction of real and apparent colors – and Descartes' privileging of the latter – was also typical of this domain. It appears that it was next to irrelevant for most writers on alchemical, artistic or natural historical matters. Newton solved a puzzle that was specific for this physico-mathematical understanding of light and colors. Through the prominence of *Opticks* in the experimental philosophy of the eighteenth-century non-mathematicians, including artists and connoisseurs who put their pens to paper, had to take the prismatic conception of light and colors into account as well. On the level of philosophies, horizontal exchange between color worlds occurred in reading and commenting on books; exchanges that included misunderstandings when the phenomena underlying a conception of color is not taken into account.

The success of Descartes' account of colors is unmistakable. It did not only dominate the historical narrative but was highly influential in the seventeenth century, in particular in terms of corpuscular elucidation. It remains to be seen to what extent someone like Boyle was aware of the essentially optical aspects of Descartes' examinations. He adopted the corpuscularization of light and colors but did not engage with aspects of ray tracing and image formation. A main reason for Descartes' success was that he offered a coherent, comprehensive and, above all, comprehensible philosophy. He managed to achieve this perhaps because he focused on the prismatic aspect of color. Beeckman never arrived at an encompassing account – not even in his notes. Perhaps this is because he got somehow lost in the wealth of aspects and phenomena he described: materials, reactions, parhelia, after-images, and so on. Maybe that is why he never went beyond a general notion of 'refracted light'. And the same may go for Boyle's reluctance to explicate a doctrine of color, although he systematized his history in a way Beeckman never did.