NAZARİYAT

Optical Problems and Light Terminology in The Writings of ʿAlī Qūshjī (D. 879/1474)

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Abstract: This study seeks to provide a historical perspective on optical problems by analyzing issues related to optics addressed by ʿAlī Qūshjī in his works *Sharḥ al-Tajrīd* and *Taʿlīqāt ʿalā Mabāḥith al-Aghāliṭ al-Ḥissiya min Sharḥ al-Mawāqif* and examining his use of different optical terms such as "*aḍ-ḍaw'* (الضوء)", "*an-nūr* (النور)", and "*ash-shuʿāʿ* (الشعاع)". In his work *Sharḥ al-Tajrīd*, ʿAlī Qūshjī offers a detailed exploration of the faculty of sight, drawing insights from mathematicians and natural philosophers on the nature of visual perception. He examines the formation of images in mirrors, delves into the concept of *ḍaw'* (light), and discusses its significance in visual and color perception, as well as the limitations of conceiving *ḍaw'* as an object. He concludes by addressing the challenges associated with seeing in the dark. In his treatise *Taʿlīqāt ʿalā Mabāḥith ʿal-Agalit al-Ḥissiya min Sharḥ al-Mawāqif*, ʿAlī Qūshjī further investigates topics such as the relative motion of an observer on a ship, methods for determining the size of objects reflected in mirrors using similar triangles, and the occurrence of different colors. Throughout his writings, he intricately weaves optical problems with broader issues in natural philosophy, discussing theories of motion and the physiology of the eye while bolstering his arguments with geometric representations. Additionally, he utilizes various terms for light when addressing light phenomena in both his *Sharḥ al-Tajrīd* and *Taʿlīqāt*.

Keywords: ʿAlī Qūshjī, history of Islamic optics, history of Ottoman optics, optics, *Sharḥ al-Tajrīd, Taʿlīqāt ʿalā Mabāḥith ʿal-Agalit al-Ḥissiya min Sharḥ al-Mawāqif.*

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DOI dx.doi.org/10.12658/Nazariyat.10.2.M0238en
https://orcid.org/0000-0003-3851-0682
Received: 1 February 2024 Accepted: 26 September 2024

Atıf© Aydın, Sena. "Optical Problems and Light Terminology in The Writings of ʿAlī Qūshjī", *Nazariyat* 10/2 (October 2024): 165-205.

هُوَ الَّذِي جَعَلَ الشَّمْسَ ضِيَاءً وَالْقَمَرَ نُوراً وَقَدَّرَهُ مَنَازِلَ لِتَعْلَمُوا عَدَدَ السِّنِينَ وَالْحِسَابَ ۚ مَا خَلَقَ اللَّهُ ذَٰلِكَ إِلَّا بِالْحَقِّ ۚ يُفَصِّلُ الْآيَاتِ لِقَوْمٍ يَعْلَمُونَ

"He who made the sun a shining radiance and the moon a light, determining phases for it so that you might know the number of years and how to calculate time. God did not create all these without a true purpose; He explains His signs to those who understand."[1]

Interpreting the optical knowledge of a scholar like ʿAlī Qūshjī (d. 879/1474) in the Ottoman classical period (1300-1600) through the lens of his works, *Sharḥ al-Tajrīd* and *Taʿlīqāt ʿalā Mabāḥith al-Aghāliṭ al-Ḥissiya min Sharḥ al-Mawāqif,* poses several challenges. A primary challenge lies in the limited emphasis on the science of optics during this era. There is a lack of comprehensive documentation concerning optical works produced in this period and an absence of clear records of the scholars who contributed to this field. Understanding how Qūshjī uses varied terms for light, such as "*ad-ḍaw'* (الضوء)", "*an-nūr* (النور)", and *ash-shuʿāʿ* (الشعاع), adds complexity. Therefore, this research is limited to a doctoral-level review of the optical debates in ʿAlī Qūshjī's works *Sharḥ al-Tajrīd* and *Taʿlīqāt ʿalā Mabāḥith al-Aghāliṭ al-Ḥissiya min Sharḥ al-Mawāqif*.

ʿAlī Qūshjī was part of the mathematical and astronomical community in Samarkand. This community's scientific practices were shaped by the traditions of perspectival realism that began developing with the philosopher al-Ghazālī (d. 505/1111) and continued through al-Tūsī (d. 672/1274) and his followers. The influence of these practices can be observed in the individuals of Samarkand and in the works that were taught and compiled in that environment.[2]

1 *The Qur'an* (*Oxford World's Classics*), trans. M. A. S. Abdel Haleem (Oxford: Oxford University Press, 2005), Jonah 10/5, 128.

2 The concept of perspectival realism highlights the significance of depicting truth from various viewpoints rather than adhering to a single, dogmatic perspective. This notion posits that each approach can capture a distinct aspect of truth and has significantly influenced the development of cultural centers such as Merv, Meragha, Tabriz, Bursa, and Samarkand. For a deeper exploration of this topic, refer to İhsan Fazlıoğlu's work, "Between Reality and Mentality: Fifteenth Century Mathematics and Natural Philosophy Reconsidered." *Nazariyat: Journal for the History of Islamic Philosophy and Science* 1/1 (October 2014): 1-33.

ʿAlī Qūshjī acquired his foundational knowledge in mathematics and astronomy from prominent scholars such as Ulugh Beg (d. 853/1449), Qāḍizāda al-Rūmī (d. after 844/1440), and Ghiyāth al-Dīn Jamshīd al-Kāshī (d. 832/1429) in Samarkand. Later, at the persistent invitation of Sultan Mehmet II (d. 886/1481), Qūshjī traveled to Istanbul with his entourage, bringing his works and ideas along. He joined the scholarly circle of Sultan Mehmet II, where he contributed significantly to the academic community. Through ʿAlī Qūshjī, the mathematical and astronomical knowledge from Samarkand was transferred to the Semâniyye and Hagia Sophia madrasas, leading to a reformation of their curricula.[3]

ʿAlī Qūshjī authored *Sharḥ al-Tajrīd*, in which he explored various optical problems during his discreet visit to Kirman. He traveled quietly, concerned that Ulugh Beg and Qāḍizāda might disapprove of his journey. While in Kirman, he had the opportunity to study Naṣīr al-Dīn al-Ṭūsī's *Tajrīd al-Kalām* and its commentary, as well as several other texts. Later, he presented his own commentary on al-Ṭūsī's work to Abū Saʿīd Gūrkānī (d. 873/1469).[4] Another text in which he discussed optical problems is *'Ta'līkāt alā Mabāḥis 'al-Agalit 'al-Hissiyah min Sharh al-Mawāqif*.[5]

Our study focuses on the polymath ʿAlī Qūshjī and his more than 60 attributed works.[6] These include critiques of Peripatetic and Ashʿarī theological views, interactions with Illuminationist ideas, and arguments for removing Peripatetic metaphysics and physics from astronomy.[7]

We are particularly interested in the optical problems that captured ʿAlī Qūshjī's attention and how he addressed them. Furthermore, we aim to understand how the optical content in his works, *Sharḥ al-Tajrīd* and *Taʿlīqāt ʿalā Mabāḥith al-Aghāliṭ al-Ḥissiya min Sharḥ al-Mawāqif,* reflects the intellectual traditions of various schools

3 İhsan Fazlıoğlu, "Ali Qūshjī", *Yaşamları ve Yapıtlarıyla Osmanlılar Ansiklopedisi*, v. I, İstanbul 1999, 216-219.

4 Cengiz Aydın, "Ali Qūshjī", *TDV Islâm Ansiklopedisi*, 2: 408-10. Istanbul: TDV Publications, 1989.

5 For this text discovered by Tofigh Heidarzadeh, see Tofigh Heidarzadeh, *Ali Kuşçu'nun astronomi eserleri*, Thesis (MA), Istanbul University Institute of Social Sciences, Department of History of Science, Istanbul 1997.

6 Müjgan Cunbur, Ali Kuşçu Bibliyografyası: Ölümünün 500. Yıldönümü Dolayısıyla (Ankara, Başbakanlık Basımevi, 1974), 40-41 as cited in Hasan Umut, *Theoretical Astronomy in the Early Modern Ottoman Empire: ʿAlī al-Qūshjī's Al-Risāla al-Fatḥiyya,* 14.

7 Fazlıoğlu, "Between Reality and Mentality", 1-33; F. Jamil Ragep, "Freeing Astronomy from Philosoɵ phy: An Aspect of Islamic Influence on Science", *Osiris*, 2001, vol. 16, 49-64+66-71.

of thought regarding the natural sciences during the classical period of the Ottoman Empire (1300-1600). We will explore the extent to which ʿAlī Qūshjī's treatment of optical issues aligns with the *manāẓir* tradition based on the optics of Ibn al-Haytham (d. c. 430/1040) and Kamāl al-Dīn al-Fārisī (d. 718/1319). This inquiry aims to understand how ʿAlī Qūshjī's work interacts with this scientific tradition. Additionally, we seek to know how ʿAlī Qūshjī engages with the natural philosophical (*mashshāʾī*) line rooted in Ibn Sīnā's (d. 428/1037) natural philosophy, particularly in terms of understanding vision, light, and the mechanics of optical phenomena. We will also inquire whether ʿAlī Qūshjī incorporates aspects of Suhrawardī's (d. 587/1191) Illuminationist (*Ishrāqī*) philosophy into his optical discussions.

Finally, we will examine how ʿAlī Qūshjī reconciles these diverse intellectual currents with theological lines, particularly those related to the concept of the Indivisible Part (*al-juzʾ lā yatajazzâ*). In summary, this study aims to unravel how ʿAlī Qūshjī's works on optics fit within or critique four intellectual traditions: the *manāẓir* tradition of Ibn al-Haytham and al-Fārisī, the natural philosophy of Ibn Sīnā, Suhrawardī's Illuminationism, and theological concepts such as the Indivisible Part. By doing so, we hope to gain a clearer understanding of how ʿAlī Qūshjī approached optical problems and situated himself within the broader intellectual landscape of his time.

In his work *Sharḥ al-Tajrīd,* ʿAlī Qūshjī discusses various topics, including the faculty of vision, the perspectives of mathematicians and natural philosophers on visual perception, and the proofs they present. He explores the formation of images in mirrors, perceiving two visions of one object, and the precedence of light (*ḍawʾ*) and color in visual perception. He also addresses the explanation of white and black colors, the dependence of color perception on *light*, the nature of *light* not being an object, primary and secondary lights, and issues such as vision in the dark. In his treatise *Taʿlīqāt ʿalā Mabāḥith al-Aghāliṭ al-Ḥissiya min Sharḥ al-Mawāqif*, he further discusses topics like vision in the dark, the relative motion of an observer on a ship, the determination of the size of an object seen in a mirror using the geometry of similar triangles, and the occurrence of different colors.

When discussing optics, ʿAlī Qūshjī uses specific terms such as *ad-ḍawʾ* (الضوء), *an-nūr* (النور), and *ash-shuʿāʿ* (الشعاع). These terms have deep roots in the philosophical and scientific tradition of Islamic thought, tracing back to the works of Ibn Sīnā and earlier scholars. Each term carries distinct meanings in the discourse on light and optics. *Ad-ḍawʾ* (الضوء) is often used to refer to physical, visible light that emanates from a source like the sun or a lamp. It is connected to the tangible aspects of

light as interacting with physical objects, producing visibility and clarity in the world. *An-nūr* (النور) carries a more abstract and often metaphysical meaning. It is typically associated with illumination and divine light in philosophical and theological contexts. It can also refer to spiritual enlightenment or inner illumination in Islamic mysticism. *Ash-shuʿāʿ* (الشعاع), meaning 'ray' or 'beam,' is more technical and is used to describe the emission of light in straight lines, such as rays of light that travel from a source and can be perceived by the eye. ʿAlī Qūshjī's use of these terms reflects a nuanced understanding of the different dimensions of light. His choice of terminology in different contexts highlights the complexity of optical knowledge. By using terms like *ad-ḍawʾ, an-nūr,* and *ash-shuʿāʿ,* Qūshjī demonstrates a sophisticated, inherited terminology related to light that emerged from earlier thinkers such as Ibn Sīnā, Ibn al-Haytham, et al.[8] This terminology addresses not only the physical properties of light but also its metaphysical and epistemological implications.

Ibn Sīnā's *Kitāb al-Shifāʾ off*ers a thorough exploration of the complex relationship between light and color. In the first chapter, which focuses on light, transparency, and color, he introduces the concepts of *ḍawʾ, nūr,* and *shuʿāʿ* as fundamental elements of vision. According to Ibn Sīnā, these concepts establish a crucial link between perception and the perceived. He emphasizes the importance of understanding the subtle differences in meanings within a technical context despite their similarities in foundational aspects. Consequently, he elaborates on the definitions and implications of *ḍawʾ, nūr,* and *shuʿāʿ*.[9] The term *ḍawʾ*, often used in discussions about light, is defined by Ibn Sīnā as a characteristic that the eye perceives in primary light sources such as the sun and fire. This perception occurs independently of any associated colors, including white, black, or red.[10] The second term for light, *nūr*, refers

8 For example, Elaheh Kheirandish's study of the concept of *iʿtibār* in early Islamic optics based on the book of optics by Aḥmad ibn ʿĪsā, a pre-Ibn al-Haytham scholar, has shown us that the concepts of *shuʿāʿ* and *nūr* can be used together in the text. In the text, the term *shuʿāʿ* is used to mean ray of light and *nūr* to mean luminosity. Elaheh Kheirandish, "Footprints of "Experiment" in Early Arabic Optics", *Early Science and Medicine*, vol. 14, No. 1/3, 79-104. See 90-91.

9 Ibn Sīnā, *Kitāb al-Shifāʾ*, *al-Ṭabīʿiyyāt*: *al-Nafs*, ed. Georges C. Anawati - Saīd Zāyid (Cairo 1975), 79. For the Turkish translation of the work, see Ibn Sīnā, *Kitab al-Shifāʾ: al-Nafs*, prepared by Mehmet Zahit Tiryaki. Ankara: TUBA Turkish Academy of Sciences, 2021. 182-206.

10 If a mass of light, characterized as *ḍawʾ,* is positioned between the eye and the air, it can become visible without requiring a physical body. In this context, *ḍawʾ* is defined as the quality of illuminating bodies, while color is seen as the quality of illuminated bodies. Furthermore, *ḍawʾ is* described as the reason for the emergence and transmission of color, as well as the perfection of transparent objects in terms of their clarity. For detailed information, see Ibn Sīnā, *al-Ṭabīʿiyyāt: al-Nafs,* 80-86.

to the type of light reflected from objects, revealing their colors such as black, white, and green.[11] The third term for light, *shuʿāʿ, is* used when light is present on an object. When it is refracted (انكسر), it is seen as color.[12]

Ibn Sīnā utilizes a range of terms for light[13], indicating its nature as an accident. In contrast, Ibn al-Haytham emphasizes the sources from which light originates and distinguishes between primary and secondary light. The meanings associated with these terms by Ibn Sīnā can be traced through the language employed by ʿAlī Qūshjī when he examines various optical phenomena[14]. Additionally, the optical inquiries of Fakhr al-Dīn al-Rāzī (d. 606/1210) reflect a synthesis of insights from both Ibn Sīnā and Ibn al-Haytham[15], particularly in theoretical discussions concerning the rela-

11 According to Ibn Sīnā, *nūr* can be understood as a fluctuation on surfaces or as an essence that flows over them. When *nūr* interacts with a mass, it produces colors such as white, black, and green. *In essence, nūr* is the manifestation of color. For detailed information, see Ibn Sīnā, *al-Ṭabīʿiyyāt: al-Nafs,* 80-86.

12 According to Ibn Sīnā, *shuʿāʿ* that produces color is not a body. It has a natural movement in various directions. Ibn Sīnā argues that when *shuʿāʿ* descends to the earth or enters an environment, the figurative discourse here is different from the thing itself; instead, *shuʿāʿ* is the result of an impulse. A less commonly used term is *barīq*, which refers to the light in an object illuminated by the light of another object, such as a mirror's surface. For detailed information, see Ibn Sīnā, *al-Ṭabīʿiyyāt: al-Nafs,* 80-86.

13 David C. Lindberg, *Theories of Vision From Al-Kindi to Kepler* (Chicago: The University of Chicago Press, 1976). 58-87.

14 Sena Aydın, *Searching for the truth of light: Problems of rainbow, halo and color in the ottomans (1300-1600)*, (İstanbul: İstanbul Medeniyet University, Institute of Graduate Studies, Department of Philosophy, PhD Thesis), 2022.

15 In his article, A. I. Sabra argues that some Arabic-language scholars, biographers, and scribes who lived between the mid-first and late thirteenth centuries were familiar with Ibn al-Haytham's *Kitāb al-Manāẓir* and were even aware of some of its features, e.g., Fakhr al-Dīn al-Rāzī (d. 606/1209) referred to Ibn al-Haytham's book in his *al-Tafsīr al-kabīr* and in his Persian *Jāmiʿ al-ʿulūm*, he listed the names of the visible features/qualities in the second volume of Ibn al-Haytham's work. However, according to Sabra, for more than two hundred years no one provided any substantive information about the book's main theses and arguments, as it was down by Kamāl al-Dīn al-Fārisī in his *Tanqīḥ al-Manāẓir*. All assumptions about the content of Ibn al-Haytham's *Kitāb al-Manāẓir* circulated in Arabic in the Middle East from the late thirteenth century until Mustafa Nazif's publications in the twentieth century, Sabra states that it is derived directly or indirectly from Kamāl al-Dīn al-Fārisī's *Tanqīḥ al-Manāẓir* and perhaps to a small extent from Fārisī's own summary of *Tanqīḥ* in *Kitāb al-Baṣāʾir fī ʿilmi al-manāẓir*. The research we aim to carry out to respond to this claim is undoubtedly on the use of the arguments and proofs of Ibn al-Haytham's *Kitāb al-Manāẓir* in the works of Fakhr al-Dīn al-Rāzī, a fundamental reference source in the Ottoman scholarly mentality, and the circulation of this knowledge among Ottoman scholars through al-Rāzī. See A. I. Sabra, "The 'Commentary' That Saved the Text: The Hazardous Journey of Ibn al-Haytham's Arabic 'Optics'", *Early Science and Medicine* 12/2 (April 2007), 117-133.

tionship between light and color, as well as the different types of light. These topics deserve further scholarly investigation. This study examines the specific optical problems addressed by ʿAlī Qūshjī, drawing primarily on the works of Ibn Sīnā, Ibn al-Haytham, and Fakhr al-Dīn al-Rāzī. It also explores the fundamental principles concerning light propagation underpinning his narrative.

1. The Faculty of Vision

The work *is* systematically organized into six chapters (*maqṣad*), subdivided into sections. The second section, dedicated to substances and accidents, addresses fundamental substances, physical bodies, the intellect, the soul, and various accidents. It additionally examines the five senses and their respective categories. In his analysis of visual perception within the context of the five senses, ʿAlī Qūshjī incorporates optical information. He initiates the discussion on optics in his *Sharḥ al-Tajrīd by* exploring the physiological structure of visual perception in a section titled "The Faculty of Vision." He characterizes this faculty as a force that converges at the junction where two hollow nerves, originating from the anterior cavity of the brain, merge near two nipple-like appendages. The nerve from the right side extends to the right pupil, while the nerve from the left side extends to the left pupil. The convergence point of these nerves is identified as the site where the faculty of vision manifests and where light (*nūr*) is gathered. ʿAlī Qūshjī emphasizes that these two nerves possess a hollow structure to accommodate a component of the soul responsible for sight, distinguishing them from other, more overt senses. The process of visual perception is contingent upon the acknowledgment of light (*ḍaw'*) and color. Through *ḍaw'* and color, the observer perceives attributes such as shape, quantity, and movement associated with the object being viewed. In response to the argument regarding the need for an intermediary in the observer's perception, ʿAlī Qūshjī asserts that the object perceived directly is *ḍaw'* itself. Color, akin to other visible attributes, becomes discernible through *ḍaw'*. The phrase "perceived in person" does not imply that visibility relies on an initial attachment to the object; rather, it indicates that visibility occurs without the requirement of a mediator. The observer first perceives primary *ḍaw'* before subsequently perceiving the secondary object that may be incidentally associated. Throughout this discourse, ʿAlī Qūshjī distinguishes between primary and secondary accidents, as well as between essential and accidental motion. The perception of light is classified as primary, whereas the perception of the image related to that light is characterized as secondary. It is crucial to note that the perception of

light does not depend on observing another object; however, the perception of color is contingent upon the surrounding light's presence.

ʿAlī Qūshjī articulates two distinct perspectives on the perception of light (*ḍaw'*) and color. The first perspective positions light as the primary element of perception, while the second focuses on color. It is posited that the perception of color inherently depends on the presence of light. When an object's color is recognized, accompanying attributes such as its image, shape, size, movement, and beauty are also discerned. Therefore, the color of the object is considered primary, and the object itself is viewed as secondary following the perception of light. This indicates that our understanding of the world through our visual faculties evolves alongside our experience of light and color. ʿAlī Qūshjī notes that within the Ash'arite philosophical tradition, the concept of "*Ru'yat Allāh*" (the vision of God) suggests that the pupil of the eye remains unaffected during the act of vision.[16] ʿAlī Qūshjī posits that the concept of "*Ru'yat Allāh*" is contingent upon specific conditions. He notes that philosophers have articulated these conditions, which the Mutazilites subsequently adopted.

ʿAlī Qūshjī outlines ten general conditions necessary for visual perception: i) The visible object must be positioned in front of the observer or, in certain circumstances, equivalent to being in front, as exemplified by observing accidents. For instance, when one sees their reflection in a mirror, the object should be aligned with the observer's line of sight. ii) The object's distance from the observer should be within a reasonable range. According to ʿAlī Qūshjī, this condition is contingent upon factors such as the observer's visual acuity, the size of the object, its distance, as well as the brightness or dullness of its color. iii) The object must not be excessively close, as visual perception may diminish significantly when the object is brought too near to the observer. iv) The object of perception should not be tiny. ʿAlī Qūshjī states that this condition similarly depends on the observer's eyesight and the proximity of the object. v) There must be no obstruction between the observer and the visible object. A "veil" is defined as a dense material that obstructs the passage of *shuʿāʿ*. ʿAlī Qūshjī argues against the notion that such a veil could possess brightness or color, as illustrated by colored glass, which does not entirely obscure objects behind it. In contrast, the earth, devoid of brightness and color, still impedes the view of what lies beyond. Therefore, according to ʿAlī Qūshjī, it is erroneous to ascribe properties of brightness and color to the veil. vi) The visible object must be illuminated by prima-

16 ʿAlā' al-Dīn ʿAlī b. Muḥammad al-Qūshjī, *Sharḥ al-Tajrīd al-ʿaqā'id: al-mashhūr bi al-Sharḥ al-jadīd*, vol. 2 (Qom: Rā'id, 1398), 2nd ed., 246-247.

ry or secondary light sources. vii) The visible object must have adequate density to obstruct light penetration. ʿAlī Qūshjī disputes the idea that this requirement implies that thin objects, such as water and glass, are invisible, as empirical evidence suggests otherwise. Certain transparent substances, including the heavens, the sphere of aether, and pure air, permit the passage of light and, consequently, are not perceived. ʿAlī Qūshjī identifies gradients of density and opacity in materials, noting that while water and glass are deemed opaque, they do not conceal objects positioned behind them, rendering them visible due to their density.[17]

According to ʿAlī Qūshjī, when an object possesses density, its attributes—including *ḍaw'*, color, shape, quantity, smell, and taste—should be discernible, as the object's density influences both smell and taste. For visibility, an object must have *ḍaw'* and sufficient density to reflect that light effectively. Furthermore, ʿAlī Qūshjī identifies three additional conditions beyond the seven previously enumerated: viii) the integrity of sensory perception, ix) the intent behind the perception, and x) the presence of transparency between the observer and the object in question. Notably, the final condition emphasizes eliminating barriers between the observer and the observed.[18]

When addressing the physiological structure of visual perception, it is crucial to recognize the role of *ḍaw'* as fundamental to our experience of perception, particularly regarding the influence of light on color. ʿAlī Qūshjī will subsequently examine this topic in greater detail, treating it as a discrete area of inquiry. As *ḍaw'* traverses objects, such as curtains, it is transformed into rays (*shuʿāʿ*). Upon reaching the nerves that connect to the brain, which facilitate visual perception, it is called illumination (*nūr*). Within the ten conditions of visual perception, Ibn al-Haytham notably distinguishes between primary and secondary light sources, especially in the sixth condition, which explores how visible these differing sources illuminate objects.[19]

The concept of *ḍaw'* is consistently referenced throughout the text. It serves as a foundational understanding of light that exists independently of interaction with any object, unlike the terms *nūr* and *shuʿāʿ*. Following a detailed examination of the physiological structure and the ten conditions essential for visual perception, ʿAlī Qūshjī proceeds to explore the various conflicting theories regarding the nature of visual perception.

17 *Sharḥ al-Tajrīd,* 248-249.

18 *Sharḥ al-Tajrīd,* 248-249.

19 A. I. Sabra, *The Optics of Ibn al-Haytham, Books I-III, on Direct Vision*, (London, The Warburg Institute, 1989), 22.

2. Notable Perspectives of Mathematicians and Natural Philosophers on Visual Perception

ʿAlī Qūshjī provides an insightful examination of three notable perspectives among philosophers regarding the phenomenon of visual perception. Mathematicians primarily support the theory of *shuʿāʿ*. This theory posits that vision is initiated when a ray, or *shuʿāʿ,* emanates from the eye in the form of a cone, with its vertex at the center of the eye and its base on the visible surface. Within this framework, mathematicians are divided into two distinct groups. One group asserts that the cone is solid, while the other argues that it consists of straight lines of *shuʿāʿ* that encircle the eye. These lines converge at the center of the eye and extend outward discretely toward the observed object. Consequently, the eye's ability to perceive adjusts in accordance with these lines, which leads to the conclusion that anything located between them may remain unseen, potentially obscuring thin features of the visible object. A third theory among mathematicians proposes that a single ray of *shuʿāʿ* extends from the eye. Upon reaching a visible object, this ray rapidly traverses the surface in length and width, forming a cone of perception.[20]

Following the discussion of mathematicians, ʿAlī Qūshjī provides a comprehensive overview of the significant perspectives of natural philosophers concerning visual perception. He acknowledges that Aristotle and his followers, including Ibn Sīnā, embraced the theory of *inṭibāʿ*. This theory suggests that the spatial relationship between the eyes and visible objects establishes a condition that allows the form of a visible object to be transmitted to the eyes. However, vision cannot occur solely through the imprint (*inṭibāʿ*) of the form onto the eyes; otherwise, a single visible object might be perceived as two, since its form would be projected onto both eyes. Rather, the form of the visible object must pass through the two internal nerves and subsequently be conveyed to common sense. Additionally, ʿAlī Qūshjī highlights a third perspective espoused by a group of philosophers regarding visual perception. According to this view, the transparency between a visible object and the eye is defined by the quality of the light (*shuʿāʿ*) within the eye. This characteristic enables the transparent medium to serve effectively as a tool for vision.[21]

The three perspectives on visual perception articulated by ʿAlī Qūshjī—*intromission, extramission,* and *intermediary* theories—trace their origins back to Ancient

20 *Sharḥ al-Tajrīd,* 249.

21 *Sharḥ al-Tajrīd,* 250.

Greece. Early philosophers introduced the *intromission* theory, which asserts that vision depends on the perception of a thin layer of atoms that separates from the surface of visible objects. In contrast, proponents of *extramission* posited that vision is produced by rays emanating from the eye. A notable contribution came from Aristotle (d. 322 BC), who was the first to explore the nature of light and color, positing that visual perception is contingent upon the medium's qualities. Euclid (d. 275 BC) also significantly advanced the field by establishing geometric optics and providing a mathematical framework for understanding visual perception. This expansion of discourse ultimately influenced the Islamic world, where these theories evolved into the concepts of *shuʿāʿ* (*extramission*) and *inṭibāʿ* (*intromission*).[22]

The mathematical theories of visual perception articulated by Euclid and Ptolemy, which are grounded in the notion of visual rays forming a cone of vision, were further developed and defended by al-Kindī (d. 873 CE). His contemporary, Ḥunain ibn Isḥāq (also d. 873 CE), adopted the Galenic theory of vision, distinguishing it from other ancient perspectives by integrating anatomical and physiological details regarding visual perception. One of the early critiques of the extramission theory emerged from al-Rāzī (d. 923/924 CE), who authored several important works on optics. Additionally, another notable challenge to the Euclidean and Galenic theories was presented by al-Rāzī's contemporary, al-Fārābī (d. 950 CE). Avicenna, recognized for his robust arguments against the extramission theory, categorized the Euclidean theory of vision into four segments to systematically refute each aspect.[23]

In this text, it is crucial to understand that ʿAlī Qūshjī regards Aristotle, who supported the intermediary theory, as a theorist of *inṭibāʿ,* alongside Ibn Sīnā, who dedicated considerable effort to refuting alternative theories of vision apart from Aristotle's. Despite his familiarity with Ibn al-Haytham's optics, which provided an accurate scientific explanation of direct vision, ʿAlī Qūshjī chose to engage with the arguments presented by mathematicians and natural philosophers. He meticulously analyzed the theories of *shuʿāʿ* and *inṭibāʿ* rather than referencing Ibn al-Haytham's theory of the new object. This decision reflects the writing style typical of commentary texts from the Ottoman classical period, which demanded rigorous scrutiny of evidence and arguments when addressing any scholarly issue.

22 Sena Pekkendir, *The Entrance of modern optics to Ottoman science* (Boğaziçi University, Master's thesis, 2015), 4-33.

23 Lindberg 43-47, Pekkendir 16-17.

3. Evidence offered by Mathematicians in Explanation of Visual Perception

ʿAlī Qūshjī presents a concise introduction to the theories of *shuʿāʿ* (*extramission*) and *inṭibāʿ* (*intromission*) before engaging with these concepts in greater detail. He articulates that the medium separating the eye from an object does not impede the penetration of *shuʿāʿ,* thereby facilitating visual perception. Conversely, if the medium is sufficiently dense to obstruct *shuʿāʿ*, the eye will be unable to perceive the object. This phenomenon occurs because the *shuʿāʿ* must navigate through the intervening space to reach the visible object. For those seeking further insights, ʿAlī Qūshjī recommends existing scholarly works on mirrors and optics. Additionally, he addresses several objections raised against the mathematicians' theories. A significant objection posits that if *shuʿāʿ* is classified as an accident, it cannot be transferred or moved. On the other hand, if it is regarded as a physical entity, it would be incapable of exiting the eye. He questions the mechanics by which *shuʿāʿ can* penetrate celestial spheres and disperse across half the world instantaneously. Furthermore, he notes that when the eyelids are closed, shuʿāʿ vanishes, only to reemerge the instant the eyes are opened. ʿAlī Qūshjī also raises a vital objection about the nature of the movement of *shuʿāʿ*, which he argues is neither voluntary nor natural. The absence of volition is evident; were *shuʿāʿ* to exhibit natural motion, it would travel in a single direction. Moreover, he challenges the assertion that the movement of *shuʿāʿ* is compulsory, noting that compulsory movement cannot occur in the absence of natural movement. In cases where the source of movement is unknown, natural motion would be directional, thus rendering any deviation from this trajectory contradictory.[24]

The third objection to extramission theory suggests that if visual perception were contingent upon light *shuʿāʿ* emanating from the eye, this light would dissipate in the presence of wind and could shift away from the observer's line of sight. As a result, individuals might perceive an object that is not directly in front of them rather than the intended object they are focused on. Additionally, ʿAlī Qūshjī raises a pertinent concern regarding the notion that vision occurs when *shuʿāʿ* exits the eye. This would imply that the experience of sight depends on the duration for visual rays to reach the objects being viewed. For example, there would be an observable time lag between perceiving the moon and the fixed stars, as the latter are significantly more distant. Nonetheless, we can see the fixed stars almost immediately upon opening our eyes.[25]

24 *Sharḥ al-Tajrīd,* 250-251.

25 *Sharḥ al-Tajrīd,* 251.

ʿAlī Qūshjī claims that these objections can be refuted by re-interpreting the extramission theory. He says that according to the extramission theory, visual rays neither leave the eye and are dispersed by the wind and reach a different direction from their intended destination, nor do they need a time constant to reach each object they aim at. The extension of the *shuʿāʿ* in the form of a cone, with the surface of the object as the base and the observer's eye as the vertex, as advocated by the *shuʿāʿ* theorists, is a purely metaphorical discourse.[26] The extramission or *shuʿāʿ* theory, first articulated in Ancient Greece by Euclid, the pioneer of geometric optics, has garnered the attention of mathematicians for centuries. This theory provides a geometric framework for elucidating optical phenomena, including visual perception. Proponents of the *shuʿāʿ* theory recognized that an actual cone of visual rays does not emanate from the eye. Nonetheless, they identified significant advantages in employing this mathematical model, which allowed them to strengthen their arguments in academic discourse and respond effectively to various objections. Furthermore, it is important to examine how proponents of the *shuʿāʿ* theory approached the concept of light's motion. Notably, ʿAlī Qūshjī regarded the motion of light as casuistic, emphasizing that the identity of the mover remains undetermined and that the motion is not necessarily unidirectional.

4. Evidence offered by Natural Philosophers for Explaining Visual Perception

ʿAlī Qūshjī reviews the arguments presented by natural philosophers in support of the theory of *inṭibāʿ*, which pertains to the concept of imprint. One compelling argument asserts that when an individual gazes at the sun's disk for an extended period and subsequently closes their eyes, they will continue to experience the sensation of seeing the sun. Similarly, when one observes a vibrant green surface and then shuts one's eyes, the image of that greenery remains vivid in one's mind. Furthermore, if the observer redirects their attention to a different color, they will perceive this new color not in its pure state, but rather as intermixed with the lingering impression of green, and this image will persist for a certain duration. In response to an objection that the image exists solely in the imagination rather than in the eye itself, ʿAlī Qūshjī clarifies that imagination and observation are distinct cognitive states. Representing

26 *Sharḥ al-Tajrīd,* 251.

a visible form in the imagination, particularly when the eyes are closed, aligns with the theory of *inṭibāʿ* and signifies an imaginative process separate from direct observation. According to ʿAlī Qūshjī, the act of visualizing a form with closed eyes is grounded in a shared understanding of perception.[27]

ʿAlī Qūshjī asserts that it is unnecessary to claim that the physical body of an object is entirely mental when examining the imprint of a visible object's form on the eye. He argues that when the impression of a perceived form is realized within the sensory faculty, it requires corresponding acknowledgment in the mind. Furthermore, he indicates that "imprint of the visible form" warrants a more precise definition. In the context of the theory of *inṭibāʿ*, registering objects in the eye also applies to other sensory modalities. For instance, the forms we hear are registered in the faculty of hearing, those we taste are recorded in the sense of taste, and the objects we smell are noted in the sense of smell.[28]

The second evidence natural philosophers offer in support of the theory of *inṭibāʿ* is that a visible object can be perceived at its actual size when positioned moderately close to the observer. As the object moves further away, it appears smaller, and at increasingly great distances, it may seem like just a dot. According to these philosophers, this variation in the perception of size due to distance is possible only when the visible form is conceptualized as being influenced by a lens. This imagined lens encompasses the angle of a cone, which does not physically exist. The apex of this cone is at the center of the lens, while its base extends to the surface of the visible object. As the distance from the object increases, the angle of this cone becomes narrower, resulting in a smaller image captured through a narrower fragment projected onto the lens compared to that of a larger object seen up close. The differences in size that observers perceive primarily arise from the distance at which they view the objects. The observer's viewpoint determines this cone angle. Considering the base of the cone, objects should be perceived consistently at all distances, as posited by the theory of *shuʿāʿ,* regardless of whether the angle is weak or strong. Consequently, when advocates of the *shuʿāʿ* theory assert that *shuʿāʿ* emanates from the eye, they associate the perceived sizes of objects with the dimensions of the *shuʿāʿ* cone.[29]

27 *Sharḥ al-Tajrīd,* 252.
28 *Sharḥ al-Tajrīd,* 252.
29 *Sharḥ al-Tajrīd,* 252.

The third argument presented by natural philosophers in support of the theory of impression highlights the distinct nature of visual perception compared to other senses. Specifically, the eye's ability to perceive is contingent upon light reaching it from the object being observed; there is no need for any sensory output from the eye itself. Rather, the perceived form is transmitted to the eye. ʿAlī Qūshjī notes that earlier scholars believed that if the form observed during visual perception were captured in a lens, the observer would only perceive an image as large as the focal point. This assertion rests on the notion that a size exceeding what is present in the observer's eye cannot be accurately recorded. Additionally, when viewing a pictorial representation, the actual distance of the object remains elusive to the eye. In addressing these claims, ʿAlī Qūshjī asserts that when the visible form is imprinted in the eye, the external image is perceived accurately in terms of size, direction, proximity, and distance. He emphasizes that the image seen is not the object itself but rather an instrument facilitating perception. Furthermore, he points out that the light entering a sparrow's eye cannot possibly encompass vast distances, as it is fundamentally limited and can only capture an extent of approximately ten leagues from any observer, whether avian or human.[30]

On the other hand, ʿAlī Qūshjī presents a counterargument to the notion that when an observer examines a visible object, the intermediary transparent medium becomes negligible and influences the visual perception of subsequent observers within that same medium. If the *shuʿāʿ* entering an observer's eye could alter the mediating transparent medium, it would suggest that visual perception could be shared between individuals, potentially allowing a blind person to gain sight. Empirical evidence illustrates that when light interacts with reflective surfaces, such as mirrors, an observer can see their face due to the reflection of light. In this instance, the angle of reflection from the shiny mirror is equal to the angle of the incoming *shuʿāʿ*. ʿAlī Qūshjī explicitly cites Ibn al-Haytham's *Kitāb al-Manāẓir* (Book of Optics) to support his argument. When an observer stands before a shiny mirror, they can perceive their face reflected therein, as light enters their eye and is reflected from the opposing surface. This reflection occurs without conscious perception; it merely represents the image of the face being mirrored. Furthermore, if the face is positioned close to the mirror, the reflected lines will be shorter; conversely, if it is farther away, the reflected lines will be longer. Therefore, the appearance of the observer seems to change with the depth of the mirror.[31]

30 *Sharḥ al-Tajrīd,* 253-254.

31 *Sharḥ al-Tajrīd,* 254

Ibn al-Haytham serves as an essential reference for the arguments utilized by ʿAlī Qūshjī in support of his theory of *inṭibāʿ*. He posits that when an individual gazes at the disk of the Sun for an extended period and subsequently closes their eyes, they continue to perceive a semblance of the Sun. Furthermore, after observing vibrant greenery and then closing one's eyes, one can still visualize the greenery. Ibn al-Haytham demonstrated that light does not originate from the observer's eye; he conducted experiments illustrating that light emanates from the observed object. In the first book and the fourth chapter of his work, *Kitāb al-Manāẓir,* he explains the new-intromission theory of light in detail. Additionally, he identified that the discomfort and glare resulting from prolonged observation of an object support the notion of an external influence on visual perception.[32] Therefore, light must come from an object and enter the observer's eye. ʿAlī Qūshjī effectively adopted Ibn al-Haytham's explanations of visual perception and supported the theory of *inṭibāʿ* using his evidence and arguments.

5. The Problem of Representing Images in a Mirror

ʿAlī Qūshjī presents three thoughtful arguments challenging the followers of the *inṭibāʿ* theory, which asserts that the observer's face is imprinted in a bright mirror and that this image is subsequently transferred to the eye: i) If the image of the face were to be painted in a bright mirror, it would necessarily occupy a fixed position. The disappearance of an object should not affect its reflected position. For instance, when a wall changes color under reflected light, that color remains in a specific location and does not shift with the object's movement. This is akin to observing the reflection of a tree in water; when the water is displaced, the reflected image moves correspondingly. ii) When an image is reflected in a mirror, it may appear on the visible surface or within a perceived depth. The apparent image should be visible on the surface; however, reflections can vary in size depending on the distance between the mirror and the object. ʿAlī Qūshjī argues that the notion of depth in a mirror is misguided; such depth does not exist, and one cannot perceive the density of an image located within the thickness of the mirror. iii) If the image seen in the mirror were genuinely imprinted on its surface, it should be possible to represent a large mountain within the mirror. Nevertheless, this is not feasible, as the concept of largeness cannot be accurately depicted on a smaller scale. These arguments contribute to a deeper under-

32 David C. Lindberg, *Theories of Vision From Al-Kindi to Kepler*, The University of Chicago Press, Chicago 1976, 60.

standing of the nature of reflection and optical phenomena, highlighting significant considerations in the discourse on visual perception.[33]

ʿAlī Qūshjī expands upon the first argument by noting that the image of a face is reflected at a specific location on a shiny surface. This location aligns with the conceptualization of a cone originating from the center of the lens. At this point of reflection, the angle of light incident upon the surface equals the angle of reflection. The base of the cone is positioned on the face's surface, indicating that the observer's position relative to the face influences the observed angle. In addressing the second argument, he asserts that a visible object would be a face as represented on a shiny surface. Conversely, if the visible object were a painted image, it would not appear larger than the dimensions of the shiny surface itself. He recognizes the painted image as a significant tool of vision. In response to the third argument, ʿAlī Qūshjī contends that it is indeed possible to perceive a large image on a smaller surface. What cannot occur is the application of a large form to a smaller one. During the phenomenon of reflection (*inṭibāʿ*), the form of an object does not need to correspond in size.[34]

Quṭb al-Dīn Muḥammad ibn Muḥammad, the grandson of Qūshjī, provides a thoughtful response to ʿAlī Qūshjī's assertion in his work, *Risāla fi'l-hāla wa qawsi quzaḥ*. Qūshjī posits that the image in a mirror is inherently different from the object itself, observing that the image appears to approach objects that are close to the mirror while receding from those that are more distant. He further claims that no corresponding depth in the mirror exists that relates to the object's depth. In response, Quṭb al-Dīn articulates that the face occupies a distinct spatial relationship with the mirror, from which a conceptual cone emerges, centered on the eye. The light reaching this specific point from the mirror will reflect, with the angle of reflection aligning with the angle at which light from the base of the cone interacts with the surface. Moreover, this spatial relationship is subject to change as the observer's position shifts.[35] The challenge of accurately depicting an image in a mirror, as explored through the grandfather-grandson narrative, presents a significant issue worthy of further examination in the history of optics. As we gather additional data on this topic, a thorough analysis of the geometric and optical considerations that arise from the visual ray cone when representing a three-dimensional human form on a two-dimensional mirror surface—without depth—will become feasible.

33 *Sharḥ al-Tajrīd,* 255.

34 *Sharḥ al-Tajrīd,* 256.

35 Quṭb al-Dīn Muḥammad ibn Muḥammad, *Risāla fi'l-hāla wa qawsi quzaḥ* (Hagia Sophia, 2414), 17b-18a.

6. Seeing a Single Object as Two in Visual Perception

ʿAlī Qūshjī presents a comprehensive examination of the interpretation of multiple arrows within the visual ray cone, which symbolize various visible objects and the phenomenon of perceiving a single object as two distinct entities. Advocates of the shuʿāʿ theory assert that the two arrows emanating from the eyes converge into a single line, thereby facilitating the perception of a singular object. Conversely, when multiple arrows are present, the object may be perceived as more than one. In response to this assertion, ʿAlī Qūshjī contends that the rods of two cones cannot converge. He clarifies that when two arrows from a visible object occupy the same spatial position, the object is perceived as singular. In contrast, if the positions of the arrows diverge, the object is likely to appear more numerous. Concerning the concept of *inṭibāʿ*, it has been suggested that the mere imprinting of the visible image upon the lens is inadequate to facilitate the process of vision, resulting in the perception of an object as if it inherently appears in pairs. However, ʿAlī Qūshjī underscores the necessity for the image to be transmitted from the two lenses to the convergence point of the optic nerves, where the images must be synthesized into a single representation. This synthesis allows the object to be perceived as one. Should the transmission of the two images fail to coincide at this convergence point, the object may be perceived as multiple entities, particularly if one of the nerves is misaligned.

Proponents of the *shuʿāʿ* theory may present objections to this statement based on two key points. First, consider a scenario where two objects are positioned before us: one at a distance of ten arms' length and the other at one arm's length. The closer object does not obstruct our view of the farther one. When we focus our gaze on the nearer object, it appears as if we are not observing the more distant object at all; thus, we perceive the closer object as a single entity. Conversely, when we shift our focus to the more distant object, it presents itself as singular, while the closer object manifests as two distinct entities.[36]

If the perception of a single object as two is attributable to a nerve disorder, it could be argued that one of the objects might be seen as singular while the other is perceived as dual. This would imply that within the structure of two nerves, one nerve must remain functional while the other deteriorates, a concept that ʿAlī Qūshjī finds fundamentally contradictory. Furthermore, ʿAlī Qūshjī contends that if the perception

36 *Sharḥ al-Tajrīd,* 256-257.

of two objects within one is due to the multiplicity of arrows or their positions—as suggested by some—it would be impossible to perceive one object as singular while the other is dual. The configuration of arrows would have to be either singular or simultaneously dual, a scenario that ʿAlī Qūshjī regards as unattainable. In addition, he addresses a second objection from proponents of the *shuʿāʿ* theory, which posits that dimension serves as a body with a latent soul. Those who misinterpret the continuity of dimensions within intersecting nerves may struggle to follow the nerve accurately. According to ʿAlī Qūshjī, if it were valid for dimension to precede or follow the nerve, it would imply that numerous individuals might experience strabismus (misalignment of the eyes) in various contexts. This phenomenon could lead to the perception of a single form crossing a junction point as two distinct forms.[37]

7. Premises in Visual Perception: *Ḍawʾ* and Color

In the second part of his treatise on optics, ʿAlī Qūshjī reexamines critical optical phenomena by investigating the foundational elements of visual perception. He highlights *ḍawʾ* and color as the primary components that are perceived, distinguishing *ḍawʾ* as an essential quality and color as an incidental characteristic. Qūshjī provides an extensive array of examples, which include light, color, sides, volume, distance, position, shape, separation, union, number, movement, rest, softness, hardness, transparency, density, shadow, darkness, beauty, ugliness, similarities, and differences. These concepts are intricately related, and their organization reflects various subdivisions within the topic. For instance, writing and embroidery can be classified under position, while straightness, curvature, concavity, and convexity fall under shape. The concepts of multiplicity and scarcity pertain to numbers, whereas emotional expressions such as laughter and crying are associated with movement and shape. Furthermore, facial expressions, such as a smiling face or a frown, correspond to notions of tranquillity and form.[38]

ʿAlī Qūshjī articulates that the fluid moisture of the eye plays a crucial role in distinguishing between dryness and drought. He posits that our perception encompasses not only the essence of an object but also its visible characteristics. When referring

37 *Sharḥ al-Tajrīd,* 257.

38 *Sharḥ al-Tajrīd,* 299.

to these characteristics, he highlights explicitly *ḍaw'* and color. The ability of an object to present itself alongside its attributes is a defining quality of concrete entities, with light and color being the initial aspects that we observe. He critically examines a prevailing misconception that the essence of an object is the first element perceived, arguing that perception should not be contingent upon other factors. Some propose that the perception of subsequent objects relies on the first object seen. In contrast, ʻAlī Qūshjī asserts that *ḍaw'* is the primary aspect we perceive, as our awareness of color is fundamentally dependent on our recognition of light. He identifies two extremes of color: blackness and whiteness, and two extremes of *ḍaw':* weakness and strength. Furthermore, ʻAlī Qūshjī maintains that color possesses an inherent truth, firmly dismissing assertions that claim colors lack substantive reality.[39]

In his analysis of color, Qūshjī, drawing upon the perspectives of Fakhr al-Dīn al-Rāzī, asserts that the perception of color is inherently linked to the perception of *ḍaw'*. He argues that, in contrast to the positions held by Ibn Sīnā and Ibn al-Haytham, the light should not be regarded as the source of colour's existence; rather, it catalyzes its manifestation.[40] The issues surrounding color are thoroughly examined in his work, *Sharḥ al-Tajrīd,* and his treatise on optics, where he discusses white and black within a comprehensive metaphysical context. However, given that our current study prioritizes a technical analysis of these issues, we will defer the exploration of these metaphysical contexts to future research endeavors.

8. Explanation of the Colors White and Black

ʻAlī Qūshjī elucidated the concept of whiteness as the result of *ḍaw'*-illuminated air interacting with minuscule transparent particles, as observed in phenomena such as water foam and snow. These particles consist of finely divided water, and there is no significant interaction among them to generate color. The incorporation of air into these particles is facilitated by light (*shuʻāʻ*) emitted from celestial bodies. When this *ḍaw'* is reflected off the surfaces of the particles, certain rays converge, producing a visual perception akin to whiteness. For instance, when sunlight illuminates a water basin, its *ḍaw'* reflects off a non-shiny wall, appearing white to the observer. However,

39 *Sharḥ al-Tajrīd,* 300

40 İhsan Fazlıoğlu, "İlm-i Menâzır", TDV Islamic Encyclopedia, https://islamansiklopedisi.org.tr/ilm-i-menazir#2-osmanlilarda (29.01.2024).

suppose the observer perceives this *ḍaw'* as concentrated on the particles. In that case, they may erroneously conclude that it is truly white, as distinguishing between the object and its similar reflections proves challenging. The observed phenomenon is external and does not constitute actual whiteness. According to ʿAlī Qūshjī, whiteness exists not in an objective reality but within the realm of imagination. This notion is further illustrated by the example of shattered glass particles resembling dust. He argued that this example surpasses snow and water foam in demonstrating that whiteness is not genuinely realized in such cases. In the context of snow, the interaction between water and air particles promotes the formation of color through an appropriate mixture. Conversely, in ground glass, the particles remain dry and rigid, resulting in a perceived whiteness without any adhesion. For example, the fracture in a thick piece of glass presents a white appearance as a consequence of light reflection, attributable to the distance and properties of its material. The diminutive size and proximity of the particles do not lend themselves to easy conceptualization in this situation.[41]

According to ʿAlī Qūshjī, blackness is conceptualized as the antithesis of whiteness. He articulates that blackness results from the absence of openings in an object's depth that would permit the entry of air and *ḍaw', and* the perception of various colors arises from the interaction between transparency and differing compositions of air. In addressing the views of certain philosophers who assert that water induces blackness by displacing air from an object, ʿAlī Qūshjī maintains that the transparency of water is fundamentally distinct from that of air. Until *light* penetrates the surface of an object, darkness remains, thereby fostering the perception of blackness. Furthermore, when fabric becomes wet, its color often shifts toward blackness, reinforcing that water contributes to this phenomenon. Some philosophers challenge the concept of whiteness and advocate for the permanence of blackness. They argue that while whiteness can incorporate all colors except black, an entity must lack blackness to accommodate other colors effectively.[42]

ʿAlī Qūshjī presents a compelling critique of the philosophers' stance, arguing that the essence of whiteness can encompass elements that are not white without necessitating their absence. In this context, "acceptance" refers to the convergence of two actions. He cites Ibn Sīnā, reiterating that the combination of air and transpar-

41 *Sharḥ al-Tajrīd,* 300.

42 *Sharḥ al-Tajrīd,* 301.

ency contributes to the manifestation of whiteness. However, he also highlights that whiteness can emerge independently of this scenario, exemplified by a hard-boiled egg. Notably, a hard-boiled egg can exhibit a white appearance even when it is devoid of space and air, as the boiling process removes air and increases the egg's density. Similarly, a herb known as Mother Mary's herb is described as transforming into vinegar when subjected to cooking in zinc until it dissolves.[43]

ʿAlī Qūshjī articulates that the combination of black and white yields gray, akin to the color of dust. He refutes the assertion that one of these colours preserves its original essence while the other transforms. Qūshjī presents several compelling arguments against this perspective. Firstly, if either black or white were to maintain its intrinsic nature, the resulting object would be perceived as wholly black or entirely white. Secondly, if the object's identity remained unaltered, it would exhibit a pure white or deep black hue without blending. Lastly, according to ʿAlī Qūshjī, such a scenario would result in the emergence of a color distinct from both black and white. ʿAlī Qūshjī offers a thoughtful examination of the relationship between black and white, emphasizing how these two colors interact and unite.[44]

In exploring the concept of whiteness, ʿAlī Qūshjī draws upon Ibn Sīnā's framework, which articulates the color white concerning air and light. Furthermore, he thoroughly examines transparency, detailing its division into minuscule particles, which can merge and engage with light on their surfaces.[45] ʿAlī Qūshjī underscores the example of ground glass, highlighting that the experience of whiteness is primarily a product of the imagination. In his analysis of black, he draws upon Ibn Sīnā's narrative, which posits that blackness is perceived without light and transparency. Furthermore, he elucidates the role of water in this phenomenon; when water is applied to objects, it displaces the air surrounding them, preventing light from penetrating their surfaces.[46] That black and white may lose their distinct essences when they are combined appears to have been a significant focus for ʿAlī Qūshjī. Although exploring the nature of black and white is inherently rich in metaphysical implications, this study will refrain from addressing that area. Instead, it will emphasize a technical analysis of the relevant issues at hand.

43 *Sharḥ al-Tajrīd,* 301-302.

44 *Sharḥ al-Tajrīd,* 302.

45 Ibn Sīnā, *al-Ṭabīʿiyyāt*: *al-Nafs*, 95.

46 Ibn Sīnā, *al-Ṭabīʿiyyāt*: *al-Nafs,* 95-96.

9. Dependence of Color Perception on *Ḍaw'*

ʿAlī Qūshjī posits that the existence of color is independent of *ḍaw';* instead, light is essential for the perception of color. While light is not a necessary condition for the existence of color, it plays a crucial role in facilitating our ability to perceive it. Scholars such as Ibn Sīnā and Ibn al-Haytham argue that the manifestation of color in objects is contingent upon the presence of light. Although colour may not be visible in darkness, the potential for the object to reveal its colour remains intact once illuminated. ʿAlī Qūshjī further elaborates that Ibn Sīnā supports this view. He suggests that the lack of color perception in darkness may stem from either its absence in our perception or the presence of obstacles that hinder visibility. However, the latter explanation is invalid, as darkness does not inherently obstruct sight. For example, an individual in a dark cave can still perceive a group of people outside who have ignited a fire.[47]

ʿAlī Qūshjī critically examines the notion of sighting, asserting that it is not an essential condition, as demonstrated by the fire visible within the confines of a dark cave, which is illuminated by *ḍaw'*. He cites the work of Ibn al-Haytham, who articulates that when an object is perceived in a specific color, such as white, and is illuminated by a weak *ḍaw'*, a subtle whiteness is discernible. In contrast, a more intense *ḍaw'* results in a more pronounced whiteness. If an even stronger *ḍaw'* is applied, the whiteness appears even brighter. These varying degrees of whiteness reflect differences in their inherent strength. Each color is associated with a specific degree of *ḍaw'* corresponding to its strength or weakness. Therefore, the existence of any perceived color is contingent upon an appropriate degree of *ḍaw'*; if all degrees of *ḍaw'* were to cease, then all colors would likewise vanish.[48]

ʿAlī Qūshjī challenged the assertion that the elimination of the color perceived as specific to the order of *ḍaw'* is merely an issue related to an unknown factor rather than a true elimination. He also scrutinized the idea that a layer of color could exist independently of the *ḍaw'* and still be observable in darkness. Qūshjī argued that differences in color perception are manifest through the emergence of color, which is influenced by varying levels of *ḍaw',* as demonstrated in his earlier examples. He clarified that the development of color and its subsequent perception depend significantly on the strength of *ḍaw'*; *a* weak dazzle results in a correspondingly subdued

47 *Sharḥ al-Tajrīd,* 303.

48 *Sharḥ al-Tajrīd,* 303-304.

perception of color, while a strong dazzle produces a more pronounced perception. When perceptions of color, exhibiting varying intensities of dazzle—sometimes weak and at other times strong—are processed by perception, the latter tends to emphasize the more intense dazzle due to its more significant impact. As a result, the perception of the stronger color becomes dominant. Given this analysis, Qūshjī proposed that color should be distinctly regarded apart from dazzle.[49]

ʿAlī al-Qūshjī, in his discussion of the thoughts of Fakhr al-Dīn al-Rāzī, argues that the presence of *ḍaw'* is not necessarily a condition for the existence of color. Instead, he asserts that a body's receptivity to *ḍaw'* is dependent on the existence of color. While it may be reasonable to consider color as contingent upon *ḍaw'*, ʿAlī al-Qūshjī also suggests that it is plausible to discuss light existing independently of color, as illustrated by *ḍaw'* interacting with a crystal. Both *ḍaw'* and color can change in perception based on sensory experiences. For example, when sunlight illuminates a white or black object, the perception of these two colors creates distinctly different appearances on the surface. One aspect is directly observable through the senses, while the other is perceived as the cause of the observation. In response to the assertion that color serves not as an additional condition but simply as an expression of itself, ʿAlī al-Qūshjī clarifies that the visible object is represented on the surface solely by its apparent white or black color. Philosophers differentiate between the absolute revelation of *ḍaw'*, the concealment of the absolute represented by darkness, and the intermediate state referred to as shadow. The gradient of shadow varies according to distanceʿAlī al-Qūshjī, in his discussion of the thoughts of Fakhr al-Dīn al-Rāzī, argues that the presence of *ḍaw'* is not necessarily a condition for the existence of color. Instead, he asserts that a body's receptivity to light is dependent on the existence of color. While it may be reasonable to consider color as contingent upon light, ʿAlī al-Qūshjī also suggests that it is plausible to discuss light existing independently of color, as illustrated by light interacting with a crystal. Both light and color can change in perception based on sensory experiences. For example, when sunlight illuminates a white or black object, the perception of these two colors creates distinctly different surface appearances. One aspect is directly observable through the senses, while the other is perceived as the cause of the observation. In response to the assertion that color serves not as an additional condition but simply as an expression of itself, ʿAlī al-Qūshjī clarifies that the visible object is represented on the surface solely

49 *Sharḥ al-Tajrīd,* 303-304.

by its apparent white or black color. Philosophers differentiate between the absolute revelation of *ḍaw'*, the concealment of the absolute represented by darkness, and the intermediate state referred to as shadow. The gradient of shadow varies according to the distance from these extremes. When the eye becomes accustomed to a particular brightness level, it may perceive heightened illumination levels as intensified brightness or gleam (*barīq* and *lamʿa*) from these extremes. When the eye becomes accustomed to a particular brightness level, it may perceive heightened illumination levels as intensified brightness or gleam (*barīq* and *lamʿa*).[50]

On the other hand, ʿAlī Qūshjī posits that there is no additional quality that enhances the appearance of color, a position he substantiates with evidence. For instance, an entity that emits light at night, such as a firefly, displays *ḍaw'* in darkness. Conversely, although a lamp exhibits a strong *ḍaw'*, this radiance becomes less discernible when illuminated by the moon. Similarly, the moon's brightness cannot be perceived in the presence of the sun. ʿAlī Qūshjī challenges the notion that the appearance of *ḍaw'* indicates an excess beyond color, asserting that the manifestation of *ḍaw'* in objects is merely the reflection of colors perceived by the senses. He contends that *ḍaw'* is not an additional quality beyond color and its appearance. Moreover, he disputes Fakhr al-Dīn al-Rāzī's claim that *ḍaw'* represents an extra quality in terms of existence, noting that white and black can blend within *ḍaw'* while maintaining their distinct essences. According to ʿAlī Qūshjī, if crystal or water exists in darkness, any *ḍaw'* that falls upon them does not confer color. Thus, he concludes that *ḍaw'* should not be understood as merely a manifestation of color.[51]

ʿAlī Qūshjī posits that in the examination of *ḍaw'* and color, the more robust color tends to exhibit greater prominence. He exemplifies this by stating that a strong color, such as black, appears more dominant than a weaker color, like white. ʿAlī Qūshjī asserts that there is no contention regarding the truth and causes related to these colors, as nothing external to the color black influence its perception. He challenges the notion that stronger colors are intrinsically opposed to weaker ones, arguing that blackness exists outside their essence. To support this viewpoint, he explores the relationship between the essence of particles and their inherent equality. Additionally, he elucidates why black particles do not incorporate white ones,

50 *Sharḥ al-Tajrīd,* 305.

51 *Sharḥ al-Tajrīd,* 305.

highlighting their distinctions in quiddity, essence, strength, and weakness within a thorough metaphysical framework.[52]

In ʿAlī Qūshjī's exploration of the relationship between *ḍaw'* and color, he offers a nuanced critique of the views held by Ibn Sīnā and Ibn al-Haytham, who assert that colors emerge from light. In contrast, Qūshjī aligns his perspective with that of al-Rāzī, who posits that while *ḍaw'* is instrumental in the manifestation of color, it does not serve as the foundation for its existence. This distinction allows for the assertion that color possesses an independent existence.[53] It is particularly noteworthy that ʿAlī Qūshjī established a connection between the existence of each perceived color and a corresponding level of *ḍaw'*. In modern physics, one can explain color by noting that the various hues in white light are influenced by different degrees of refraction. This relationship can be effectively demonstrated through an experimental setup in which light is directed through a glass prism in a darkened environment. The intricate relationship between light and color was a significant area of inquiry for Ottoman scholars, resulting in a substantial body of literature dedicated to this topic.[54]

10. *Ḍaw'* not being a substance

ʿAlī Qūshjī articulates that some philosophers contend that *ḍaw'* is constituted of minute particles that detach from the illuminating source and subsequently integrate with the illuminated object. This viewpoint arises from the intrinsic mobility of *ḍaw'*, as all entities of essence must possess a physical form. However, ʿAlī Qūshjī respectfully challenges this notion, emphasizing that the qualities of objects—referred to as accidents—vary according to their positions. These philosophers argue that when *ḍaw'* descends from the sun to the Earth, it is influenced by the movement of the light source, enabling it to reflect off various surfaces—similar to the behavior of a lamp when it is repositioned. In contrast, ʿAlī Qūshjī asserts that all occurrences related to *l*ight are reactions to the illuminating source itself. He posits that the presence of a dense object in the path of light facilitates the manifestation of *ḍaw'* within that object, maintaining that any perceived movement is, in fact, an illusion.[55]

52 *Sharḥ al-Tajrīd,* 306-307

53 Hanoğlu, *Fahruddîn er-Râzî'nin 'Kitâbu'l-Mulahhas fi'l-Mantık ve'l-Hikme' Adlı Eserinin Tahkîki ve Değerlendirmesi,* 137-138.

54 Aydin, 205-226.

55 *Sharḥ al-Tajrīd,* 308.

The perception of motion may be regarded as illusory for several reasons. First and foremost, it involves the phenomenon of *ḍaw'* appearing in the lower part of the observer's field, seemingly descending from the upper portion. If *ḍaw'* were descending, it would be observable at the midpoint between the two points. However, according to ʿAlī Qūshjī, this assertion is problematic, as the speed of *ḍaw'* is rapid beyond conventional comprehension. The visibility of light on an object depends on its position and alignment relative to the illumination source. When this alignment shifts, the light once visible on one side diminishes and re-emerges on the opposite side. This phenomenon can create the impression of movement, suggesting that light is transitioning from one object to another. Moreover, when *ḍaw'* occurs in front of an object illuminated by a different source, it typically appears in opposition to that illumination. The visibility of *ḍaw'* concerning the illuminator is essential for its perception. Under these circumstances, it is assumed that movement occurs, facilitating the transfer of *ḍaw'* from the illumination source to its corresponding object.[56]

In contrast to its owner, the shadow exhibits mobility and aligns with their movements. Philosophers generally agree that a shadow is not a physical entity. They argue that a shadow does not possess genuine movement; rather, it appears to vanish from one location and reappear in another due to changes in alignment. In response to this viewpoint, ʿAlī Qūshjī offers two primary arguments: If a shadow were an object, it would not be hidden from our perception. When a shadow envelops an object, greater brightness of *ḍaw'* would enhance its covering effect. However, the observable perception of the object contradicts this assertion. As the brightness of the visible object increases, so does its clarity in the observer's eye. Qūshjī contends that obstruction is fundamentally opposed to enhancement. An obstacle between the observer and the object impairs visibility. This principle does not hold if the obstruction is dense and transparent, as it allows *shuʿāʿ* to pass through. For example, a piece of glass or crystal can significantly improve the clarity of what lies behind it, and it is often utilized by individuals, particularly the elderly, to facilitate reading small text. Moreover, ʿAlī Qūshjī notes that thinner glass can be beneficial for those with diminished eyesight. He emphasizes the magnifying effect of a convex lens, highlighting its capacity to gather light and enhance vision.[57]

56 *Sharḥ al-Tajrīd,* 308.

57 *Sharḥ al-Tajrīd,* 308-309.

Returning to the topic of the movement of *ḍaw'*, ʿAlī Qūshjī presents the argument that if *ḍaw'* were to be considered a moving body, its movement in various directions would only be validated if it were intentional. Conversely, if it were characterized as a natural movement, it would occur exclusively in either an upward or downward direction. When the sun rises above the horizon, the movement of *ḍaw'* from the fourth heaven to the earth linearly extends across the surface. Similarly, if *ḍaw'* were to enter a dark room through a small opening and that opening was subsequently covered, the room would promptly descend into darkness. In this instance, no object exits the dark room, and there exists no alternative pathway for *ḍaw'* to enter except through the covered hole. According to ʿAlī Qūshjī, the disappearance that occurs when the hole is covered pertains to *ḍaw',* which indicates that *ḍaw'* is treated as an accident rather than a substance. He defines an accident as something that maintains permanence in a specific position and is prepared to emerge in a body based on its arrangement.[58]

It is notable that ʿAlī Qūshjī posits that the motion of light is not a natural or voluntary phenomenon but rather an illusion. He discusses the thin lenses utilized by elderly individuals to read small print, emphasizing their effectiveness for those with deteriorating eyesight. Further investigation is warranted as to whether the convex lenses to which he refers were employed as magnifying lenses or if eyeglasses—known to have been in use in the Mamluk regions during the fourteenth century[59]—were available during ʿAlī Qūshjī's time.

11. Primary and Secondary Lights

According to Qūshjī, *ḍaw'* comprises two distinct components. The first component is the original light emanating from a direct source, such as the sun, which is why it is referred to as *ḍaw'*. The second component is derived from an alternative illumination source, such as the moon, representing the concept of *nūr* articulated in the Qur'anic verse. In this context, ʿAlī Qūshjī cites the fifth verse of Surah Yunus.

"هُوَ الَّذِي جَعَلَ الشَّمْسَ ضِيَاءً وَالْقَمَرَ نُوراً"

58 *Sharḥ al-Tajrīd,* 309-310.

59 Amir Mazor, "Spectacles in the Muslim World: New Evidence from the Mid-Fourteenth Century", *Early Science and Medicine,* 18-3 (2013). 291-305.

Translated, "It is He who made the sun a shining radiance (*ḍiyāʾ*) and the moon a light (*nūr*)".

Qūshjī elucidates the concept of accidental lights, categorizing them into two distinct classifications. The first, referred to as primary *ḍawʾ,* denotes light that emanates from an inherent illuminator, such as the light generated by the moon or the Earth when illuminated by the Sun. The second classification, secondary *ḍawʾ,* occurs when light is provided by an external source, exemplified by the Earth's illumination during twilight (*isfar*) following sunset. This secondary light is identified as a shadow when cast against the illuminated atmosphere. We observe that ʿAlī Qūshjī followed Ibn al-Haytham's definition[60] of the light emanating from the illuminator as primary light and the light emanating from the object in which the primary light is reflected as secondary light, and supported his narrative with the Qur'anic verse. In the problem of the types of light in the Ottoman renewal period, we see that Ibn Sīnā's different definitions of light, such as *shuʿāʿ*, *ḍawʾ*, *barīq*, and *nūr*, and Ibn al-Haytham's distinction between primary (self-illuminating) and secondary (illuminating from others) light, were adopted by al-Rāzī. Ottoman scholars added a new dimension to the issue of the types of light by questioning which of the types of light, namely *shuʿāʿ*, *ḍawʾ, berīk*, and *nūr,* were primary and which were secondary; they defined *shuʿāʿ* and *ḍawʾ* as essential and primary lights, and *berīk* and *nūr* as accidental and secondary lights.[61] We observe that ʿAlī Qūshjī followed al-Rāzī, who took Ibn al-Haytham's primary/secondary distinction as a basis and followed Ibn Sīnā's terminology of *shuʿāʿ, ḍawʾ, barīq*, and *nūr.*

12. Seeing in the Dark

The last issue addressed in the section on optics within Qūshjī's *Sharḥ al-Tajrīd* corresponds with the first issue presented in the optical narrative of his treatise *Taʿlīqāt ʿalā Mabāḥith al-Aghāliṭ al-Ḥissiya min Sharḥ al-Mawāqif*[62], namely the problem of

60 Sabra, 22.

61 Aydin, 216.

62 The other edition of the work, entitled *Risāla fī taḥḳīḳ al-abṣār*, was discovered by Tofigh Heiderzadeh in the manuscripts section of the Tehran University Library and was published in 1071 AH. In this study, the copy of *Taʿlīqāt ʿalā Mabāḥith al-Aghāliṭ al-Ḥissiya min Sharḥ al-Mawāqif* was used to analyze the text, *and* the drawings in the *Risāla fī taḥḳīḳ al-abṣār* were utilized. See Tofigh Heiderzadeh, *Ali Kuşçu'nun astronomi eserleri,* (Istanbul: Istanbul University Institute of Social Sciences, Department of History of Science, Master's thesis, 1997), 100.

darkness. To analyze ʿAlī Qūshjī's understanding of darkness, we can consider the associated narratives under a unified theme. Qūshjī defines darkness as the absence of a faculty—the lack of *ḍaw'*—in the presence of illumination. He asserts that darkness is not a physical quality, in contrast to the perspectives of certain philosophers. If this were the case, an individual in a cave could not perceive those outside in the illuminated environment. According to Qūshjī, the surrounding presence of *ḍaw'* is crucial for visibility, and the cave presents an obstruction to this condition. He posits that if evidence can demonstrate the absence of *nūr* in an object, one can conceptualize a scenario specific to the air beyond the darkness. A comparable experience of darkness occurs when one's eyes are closed. Moreover, ʿAlī Qūshjī notes that some scholars have posited that darkness constitutes a physical entity, referencing a segment of the first verse of Sūra al-Anʿām as supporting evidence for this assertion.

"وَجَعَلَ الظُّلُمَاتِ وَالنُّورَ"

That is, "He is the creator of darkness and *nūr*." Qūshjī opposes the philosophers' claim that what is created is only what exists. He argues that the Creator can create a special nothingness, such as blindness, just as he created the existing.[63] Thus, ʿAlī Qūshjī completes his book on optics with his narrative on darkness.

In his treatise *Taʿlīqāt ʿalā Mabāḥith al-Aghāliṭ al-Ḥissiya min Sharḥ al-Mawāqif,* ʿAlī Qūshjī elucidates an optical narrative using the concepts of *ḍaw'*, *nūr, and shuʿāʿ*, while systematically addressing the various optical theories attributed to Ibn Sīnā. The analysis of vision begins with the assertion that undermining the credibility of sensory phenomena ultimately compromises intuitive understanding. It is essential that the senses adequately prepare the soul for the insights that emerge from them, which can vary in intensity. Moreover, ʿAlī Qūshjī argues that conjecture can indeed lead to certainty, contingent upon its frequency of occurrence. He stresses that while sensory perception is a necessary foundation for rational judgment, it does not take precedence over reason. Additionally, he highlights the importance of the will as a critical factor in the pursuit of knowledge, affirming its essential role in this endeavor.[64]

63 *Sharḥ al-Tajrīd,* 311.

64 ʿAlī Qūshjī, *Taʿlīqāt ʿalā Mabāḥith al-Aghāliṭ al-Ḥissiya min Sharḥ al-Mawāqif,* Beyazıt State Library, Veliyyüddin Efendi, 297.4 fol. 183b.

ʿAlī Qūshjī addresses the complexities of visibility in darkness by emphasizing the importance of distance and darkness for observing a distant fire at night. He elucidates that the *ḍaw'* present in the air, illuminated by the fire, does not function in the same manner as moonlight, which diminishes in brightness when sunlight is present; this distinction allows for a clear observation of the fire. In referencing Ibn Sīnā's narrative, ʿAlī Qūshjī notes that the visual glow *shuʿāʿ* surrounding the fire does not fully penetrate the darkness. For an observer, the body of the fire can become indistinguishable from the illuminated air, and the resulting dazzle may merge with the fire's *shuʿāʿ*. Consequently, the observer perceives both elements as unified entities, recognizing their essence as fire. He further explores the implications of illuminated air around the fire without darkness, asserting that the fire would distinctly differentiate itself from the air in well-lit conditions. Therefore, it is possible to distinguish between the fire and the illuminated air in both dark and light settings. In response to Ibn Sīnā's assertion that the visual glow does not entirely penetrate the darkness, ʿAlī Qūshjī points out, "Do we not observe that planets appear more visible on moonless nights than when the moon is present?" He also highlights the necessity for the fire to be positioned within a certain distance, as an increased separation can lead to the perception of the air merging with the fire's *shuʿāʿ*. If the volume of illuminated air is twice that of the fire, the air will merge with the fire by one-third. However, when the fire is situated at a significant distance, it may be perceived as merely one-tenth of its intensity.[65]

Consequently, ʿAlī Qūshjī adheres to Ibn Sīnā's illustration of the "man in the cave," a widely recognized parable that scholars have cited in later centuries to illustrate the concept of visibility in darkness. In this example, when an individual is positioned within a dark cave, and *nūr* shines on an object outside the cave, that object becomes perceptible to the person inside. Notably, the dark air that separates the observer from the object does not hinder the ability to see.[66] ʿAlī Qūshjī contemplated a dark cave and the relationship between the fire outside and the illuminated air surrounding it. He posited that the amount of illuminated air was twice the volume of the fire itself, leading him to conclude that the air contributed a third of the fire's illumination.

65 Qūshjī, *Taʿlīqāt,* 183b.

66 Ibn Sīnā, *al-Ṭabīʿiyyāt*: *al-Nafs,* 81

13. Relative Motion of the Observer

ʿAlī Qūshjī, while referencing Ibn Sīnā, provides an insightful explanation regarding the interaction between the observer and the object through a transparent medium of varying textures. He posits that when the medium possesses consistent thickness and thinness, the viewer perceives the object accurately in size. In contrast, disparities in texture—whether the reflective surface is thin or thick—can lead to altered perceptions. Specifically, a thinner slope in the reflective medium causes the object to appear larger, while a thicker slope results in a smaller appearance. This phenomenon is further illustrated by the experience of viewing objects through clear water, demonstrating that clarity is achievable under favorable conditions. Notably, the medium that separates the observer from the object comprises layers that tend to be thinner in texture than typical water. Ibn Sīnā employs the analogy of a cone to clarify this principle: an observer situated closer to the cone perceives it as larger due to the wider angle encompassed by the pupil. Thus, the perception of an object's size is contingent upon its distance from the observer—objects appear larger when they are closer and smaller when they are farther away. Addressing Ibn Sīnā's assertion that the rays of light originate from a single point of intersection, ʿAlī Qūshjī indicates this perspective neglects that the convergence of two nerves forms the origin of the rays. In optics, he affirms that the point at which the rays emerge is the center of the lens.[67]

ʿAlī Qūshjī cites Ibn Sīnā's explanation regarding the observer's position concerning an object. For instance, a rider on a horse maintains a consistent relative position whether the horse is in motion or at rest. Similarly, an observer aboard a ship recognizes that the distance to the shore changes momentarily as the ship moves closer. Although the observer remains stationary on the ship, the perceived alterations in distance suggest that the shore is the source of movement. As the ship progresses toward the shore, the passenger notes the decreasing distance while observing the moon's movement toward the East. ʿAlī Qūshjī concurs with this perspective but contends that it does not accurately reflect the original text and its explanation. He argues that the assertion that clouds move exclusively East while the moon travels West lacks precision. Utilizing the analogy of the ship's passenger, they perceive the distance separating them when the observer gazes at the moon. Employing the clouds as a reference point may lead the observer to conceive that the moon is

67 Qūshjī, *Taʿlīqāt,* 184a.

traversing that distance simultaneously with its motion. Ibn Sīnā also elucidates that if the clouds possess a thin quality, the moon will likely appear to move rapidly in any direction, irrespective of its relative position to the clouds.[68]

ʿAlī Qūshjī's analysis of the relativistic motion of an observer on a ship invites a critical reevaluation of the historical framework surrounding the problem of relativity[69], particularly the commonly accepted beginnings associated with Galileo. Galileo exemplified the principle of relative motion through a ship moving at a constant speed relative to the shore while purposefully neglecting air resistance. He illustrated this concept by dropping an object from the top of the mast. When the ship is stationary, the object descends vertically. However, in the case of a moving ship, the object still appears to fall directly downward to an observer on the vessel. In contrast, a stationary observer on the shore would perceive the object's trajectory as curved. This curvature arises from the ship's constant horizontal velocity, resulting in two distinct components of motion: a downward acceleration due to gravity and a uniform horizontal motion attributable to the ship's movement. This understanding introduces the concept of frames of reference, allowing for measuring an object's position in three-dimensional space relative to its coordinates within a defined rectangular coordinate system. Therefore, a comprehensive historical reassessment of the problem of relativity is warranted. Valuable insights can be drawn from notable figures such as Ibn Sīnā and ʿAlī Qūshjī, who acknowledged each other's contributions. A thorough investigation into the development of the problem of relativity—specifically concerning how different frames of reference are perceived by observers—before the time of Galileo represents a significant area for further exploration.

14. Determining the Size of an Object Appearing in a Mirror with Similar Triangle Geometry

ʿAlī Qūshjī utilizes a geometric representation to illustrate the dimensions of an object as observed in a mirror. He defines the length of the mirror as line A B and the length of the face as line G D, as shown in Figure 1. The observer is positioned between points G and D. When a line E R is drawn from the observer perpendicular to the mirror's surface, it is assumed that this line extends to point T, from which it is

68 Qūshjī, *Taʿlīqāt,* 184a-184b.

69 Longair, 43-45.

reflected to point D, the endpoint of the face. A perpendicular line D B is also drawn from point D to the mirror's surface. This results in forming two triangles: R E T and T D B. The angles within these triangles are congruent due to the relationship established by line R B, which indicates that the angles of incidence and reflection are equal. ʿAlī Qūshjī concludes that it has been demonstrated that the straight line reflected from radial lines to the length of the face measures half that length.[70]

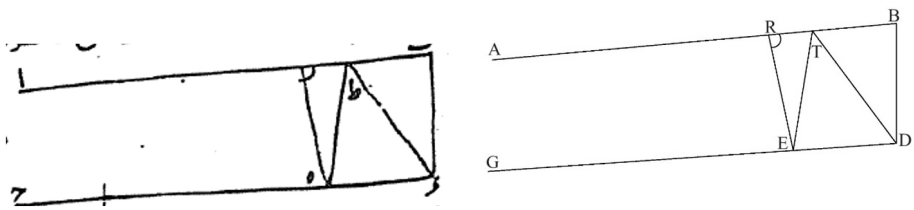

Figure 1: Determining the Size of the Observer Looking into the Mirror

ʿAlī Qūshjī articulates that the angle at the apex of the ray cone allows an object to be perceived as if it were seen in a mirror. This optical effect is achievable exclusively when the amount of light reflected by the rays is half that of the object. The apparent size of the visible object is determined solely by the dimensions and narrowness of the viewing angle. It is important to note that the width of this angle does not influence the quantity of light reflected from the object, nor does it correspond with the length of the object's face. Instead, since the size of the face is understood as an area, the base of the cone of light—after reflection—aligns with this length. Thus, the angle at the cone's apex deviates from a straight path and corresponds to the size of the object's face.[71]

In applying Ibn Sīnā's expression, Qūshjī notes that the *shuʿāʿ* across the width of the face reflects exclusively from a curved line that corresponds to that width. By considering the distance from the eye to the center of a circle as equal to the radius and significantly less than half the width of the face, we can define a semicircle with center E, denoted as A B G D, to illustrate the extent of reflection. The observer, designated as O, is positioned at half the width of the face, referred to as W O R. A line

70 Qūshjī, *Taʿlīqāt,* 185a.

71 Qūshjī, *Taʿlīqāt,* 185a-185b.

extending from the center E to point B functions as the circle's radius. When examining the lines of *shuʿāʿ* that emanate from the eye O G and extend to point G (the center of the mirror), these lines reflect toward the right side of the face, which must be congruent with the width of the face itself. This is substantiated by the principle that the angle of incidence is equal to the angle of reflection, thereby facilitating this mode of reflection. Hence, the curvilinear angle O G D is equivalent to the angle of reflection R G B. Additionally, ʿAlī Qūshjī observes that if we take H to W, we generate a line G E and half an angle O G B. Upon drawing an arc O G with center E, it becomes clear that this arc will be equal to arc G B.[72]

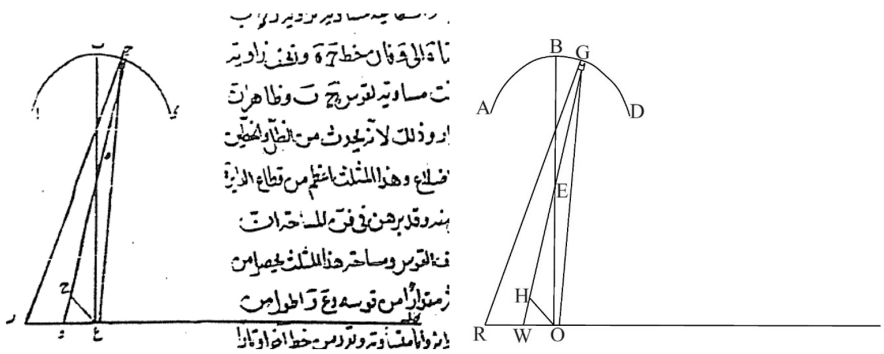

Figure 2: Angles Associated with the Visual Cone in a Mirror

IIn the realm of measurement (masāḥa), it has been established that the area of a sector can be determined by multiplying the radius by half the length of the arc. Additionally, the area of the corresponding triangle is calculated by multiplying the radius by half the width. Furthermore, research has demonstrated that the shadow cast by an object is larger than the arc it produces and extends beyond half of that arc. This observation arises from lines originating from a point, defined by equal angles, return from an alternative point as strings that approach a perpendicular orientation. As a result, the distance from that point to the line is minimized. For illustrative purposes, the distance from point A to line H is depicted in Figure 3.[73]

72 Qūshjī, *Taʿlīqāt,* 185b-186a.

73 Qūshjī, *Taʿlīqāt,* 186a.

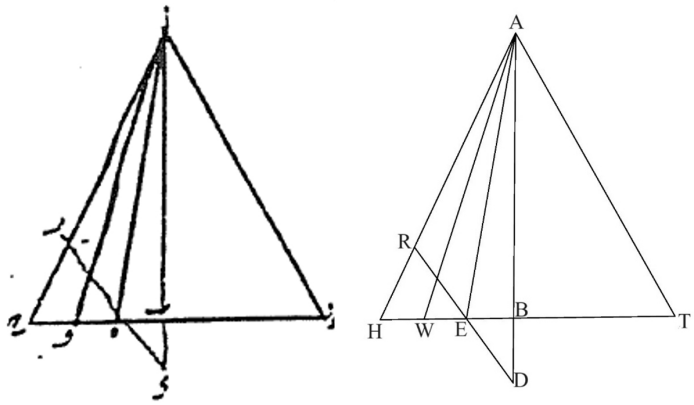

Figure 3: Explaining the Width of the Face in a Mirror with Similar Triangle Geometry

The resulting triangles E R H and E B D are opposite from the vertex E because their two angles, E, are equal. The triangles A R E and A E D also share the common side A E. The side B E is equal to the side E W (Figure 3) and O R is longer than G B (Figure 2) and this is what is demanded in the text. Thus, it is proved that O R is half the width of the face, which is longer than half of G B (Figure 2), in the words of ʿAlī Qūshjī.[74] ʿAlī Qūshjī calculated the width of an observer's face in a mirror by analyzing the position of the vertex of the ray cone within the mirror, treating the observer's face as the base of this visual ray cone. He utilized the principles of similar triangle geometry, subtracting a triangle from the tangents drawn from the circle's center. This mathematical approach was grounded in the foundational work of Ibn Sīnā and was further refined through geometric principles.

15. Occurrence of Different Colors

Certain colors can be harmoniously combined, taking into account factors such as intensity, light, and darkness. For example, the amalgamation of yellow and blue results in green, while green and white can further merge with other hues, such as copper. ʿAlī Qūshjī emphasizes that the potential combinations of colors are indeed infinite. He observes that some colors can originate from minute parts of plants and animals, captivating anyone who witnesses the astounding variety present in such

74 Qūshjī, *Taʿlīqāt*, 186a.

small entities. Building upon these insights, ʿAlī Qūshjī further clarifies Ibn Sīnā's assertions by explaining that heat can darken moist elements through the dissolution of their wet components. This process leads to the detachment and separation of denser parts, a phenomenon observable in materials such as wood, burned beverages, and human skin when subjected to excessive exposure to fire or sunlight.[75]

The concept of color formation, briefly discussed by ʿAlī Qūshjī, was elaborated upon by Ibn Sīnā through an examination of the varying degrees of mixing white and black. Ibn Sīnā contended that when light is combined with blackness, the result is a smoky hue; when black predominates over light, it produces redness, whereas light prevailing over black yields a bright yellow[76]. Furthermore, Ibn Sīnā noted that the combination of yellow and black—lacking bright elements—gives rise to greenness. ʿAlī Qūshjī subsequently built upon Ibn Sīnā's insights by exploring the interactions among green, yellow, and blue. It is reasonable to investigate how the interplay of colors, described in the literature as varying degrees of light and darkness mixing, develops over time. Qūshjī examined the metaphysical contexts of black and white and considered their natural derivation in his treatise.

16. Obtaining White and Black in Nature

Whiteness in dry soil can be produced by reflecting light from one part of an object to another, thus enhancing its surface appearance. Similar to the effects of salts, slurries, and coal in wet materials, a substance can assume an ashen quality when cooling. This process leads to the condensation of its components and the creation of empty spaces between them. In this context, air fills the surfaces of these components, facilitating the reflection of light. This phenomenon parallels the behavior of snow, frost, and disordered materials disturbed and folded by heat. As cold binds these materials together, it generates whiteness. In contrast, blackness may emerge in dry soil through condensation, thereby capturing and extracting contents from a transparent medium—similar to processes occurring in trees and crops. Moreover, extreme cold can be described as "burning" the material, impacting even the organs of animals. This process reflects the transformation of dark humors in animals and the mud beneath clay. These elements typically exhibit a dry nature, and

75 Qūshjī, *Taʿlīqāt,* 186a.

76 Ibn Sīnā, *al-Ṭabīʿiyyāt*: *al-Nafs,* 99.

when exposed to cold, they transition to a darker state, akin to the black stones found in mountainous regions and other landscapes.[77] In his analysis of the emergence of blackness and whiteness in dry soil, Qūshjī establishes a connection between these colors and the influences of temperature and humidity. In his treatise, he enhances this discussion by incorporating optical problems with significant geometric relevance, differentiating it from his previous work.

Evaluation

This study presents a thorough examination of the optical content within ʿAlī Qūshjī's works, specifically *Sharḥ al-Tajrīd* and *Taʿlīqāt ʿalā Mabāḥith al-Aghāliṭ al-Ḥissiya min Sharḥ al-Mawāqif*. The analysis is organized into a systematic listing that allows a focused exploration of the physics problems described in these texts. Each of the sixteen issues identified is carefully analyzed, accompanied by a historical evaluation that enhances our understanding of the context. Additionally, we have approached the terminology associated with light with precision, noting the specific contexts in which terms like *ḍaw'*, *shuʿāʿ*, and *nūr* are utilized. Exploring light terminology within the history of Islamic physics requires comprehensive analysis, drawing upon examples from a range of sources. On the other hand, we can say that in his work and treatise, ʿAlī Qūshjī used ḍaw' as the most basic concept of light and the primary one, while light was called *shuʿāʿ* when it penetrated through objects and *nūr* when it reached the nerves of the brain in the context of the physiology of vision.

ʿAlī Qūshjī's study of optics shows the importance of a complete approach to natural philosophy in Islamic physics. Different theories complement and enhance each other. He examines light's motion. He identifies three types: natural motion (spontaneous), voluntary motion (made by choice), and constrained motion (limited by outside factors). He finds that light's motion is mostly speculative, highlighting the challenges in understanding how light behaves. To understand ʿAlī Qūshjī's ideas about light, one needs to understand specific terms about motion. Vision studies include many specialized terms from eye physiology. How images form in mirrors relies on geometric concepts like the visual ray cone and similar triangles. Therefore, grasping optical principles requires knowledge of geometry and other areas of natural philosophy.

77 Qūshjī, *Ta'līkāt,* 186a.

A crucial part of ʿAlī Qūshjī's work is his choice of primary sources. Our research shows that studying Ibn Sīnā's ideas on optics helps trace the development of this topic during the Ottoman period. Ibn Sīnā sees the understanding of geometric phenomena as a prerequisite for optics as muqaddimas/preliminaries in his different narratives on optics. This makes him a key reference for ʿAlī Qūshjī. Ibn al-Haytham also plays a significant role in ʿAlī Qūshjī's discussion of optics. ʿAlī Qūshjī frequently refers to ideas from Ibn al-Haytham's famous book, *Kitāb al-Manāẓir*. This use of earlier philosophical insights not only strengthens ʿAlī Qūshjī's theories but also shows how optics connects to the broader field of Islamic philosophy and science.[78]

ʿAlī Qūshjī exhibits a deep understanding of the works of Ibn Sīnā, Ibn al-Haytham, and Fakhr al-Dīn al-Rāzī, esteemed figures in the Islamic optical tradition. It is essential to compile a thorough inventory of the optical topics addressed by Ibn al-Haytham and Ibn Sīnā—both of whom are regarded as foundational to the history of Islamic optics—as well as those discussed by Fakhr al-Dīn al-Rāzī, who adeptly integrated their insights across various theoretical dimensions. A critical step in systematizing the study of Islamic physics involves identifying and cataloging the problems articulated in these texts. Establishing the technical framework shaped by distinct physics problems will facilitate the development of a comprehensive narrative of the history of science that incorporates both historical and social contexts. This article aims to investigate the optical issues prioritized by ʿAlī Qūshjī and the terminology he employed. As research continues along the continuum from Ancient Greece to contemporary physics, the historical progression of each issue within the Islamic optical tradition will become increasingly apparent.

78 We know of the existence of *Kitāb al-Manāẓir* in the Topkapi Palace Library thanks to the palace catalogue, which lists nearly 7000 works, prepared in manuscript in 908/1502-3 and published in 909/1503-4 by ʿAṭūfī, who was known as the librarian of Beyazıd II. See Elaheh Kheirandish. "Books on Mathematical and Mixed-Mathematical Sciences: Arithmetic, Geometry, Optics, and Mechanics." *Treasures of Knowledge: An Inventory of the Ottoman Palace Library (1502/3-1503/4)*, ed. Gülru Necipoğlu, Cemal Kafadar, and Cornell H. Fleischer, 857-90. Leiden: Brill, 2019.

References

Primary Sources:

'Alā' al-Dīn 'Alī b. Muḥammad al-Qūshjī, *Sharḥ al-Tajrīd al-'aqā'id: al-mashhūr bi al-Sharḥ al-jadīd*, vol. 2 (Qom: Rā'id, 1398), 2nd ed.

'Alī Qūshjī, *Ta'līqāt 'alā Mabāḥith al-Aghāliṭ al-Ḥissiya min Sharḥ al-Mawāqif,* Beyazıt State Library, Veliyyüddin Efendi, 297.4 fol. 183b-186a.

Ibn Sīnā, *Kitāb al-Shifā', al-Ṭabī'iyyāt: al-Nafs*, ed. Georges C. Anawati - Saīd Zāyid (Cairo 1975).

Ibn Sīnā, *Kitāb al-Shifā': al-Nafs*, prepared by Mehmet Zahit Tiryaki. Ankara: TUBA Turkish Academy of Sciences, 2021.

Quṭb al-Dīn Muḥammad ibn Muḥammad, *Risāla fi'l-hāla wa qaws quzaḥ* (Ayasofya, 2414), 17b-18a.

Shihāb al-Dīn al-Suhrawardī, *Ḥikmat al-ishrāq: Philosophy of Illumination*, trans. Eyüp Bekiryazıcı - Üsmetullah Sami (Istanbul : Presidency of the Manuscript Society of Turkey, 2015).

Taqī al-Dīn al-Rāṣid. *Kitāb nūr ḥadīqat al-abṣār wa nūr ḥaqiqat al-anẓār : On the nature of light and the formation of vision.* Translation. Hüseyin Gazi Topdemir. Ankara : Turkish Academy of Sciences (TÜBA), 2017.

Secondary Sources:

Aydın, Cengiz. "Ali Qūshjī", *TDV İslâm Ansiklopedisi*, 2: 408-10. Istanbul: TDV Publications, 1989.

Aydin, Sena. *Searching for the truth of light: Problems of rainbow, halo and color in the ottomans (1300-1600)*, (İstanbul: İstanbul Medeniyet University, Institute of Graduate Studies, Department of Philosophy, PhD Thesis), 2022.

Cunbur, Müjgan. Ali Kuşçu Bibliyografyası: Ölümünün 500. Yıldönümü Dolayısıyla (Ankara, Başbakanlık Basımevi, 1974).

Fazlıoğlu, İhsan. "Ali Kuşçu". Yaşamları ve Yapıtlarıyla Osmanlılar Ansiklopedisi, 1:216-19. Istanbul: Yapı Kredi Yayınları, 1999.

F. Jamil Ragep, "Freeing Astronomy from Philosophy: An Aspect of Islamic Influence on Science", *Osiris*, 2001, vol. 16, 49-64+66-71.

Fazlıoğlu, İhsan. "Between Reality and Mentality-Fifteenth Century Mathematics and Natural Philosophy Reconsidered" *Nazariyat: Journal for the History of Islamic Philosophy and Science* 1/1 (October 2014): 1-33.

Fazlıoğlu, İhsan. "İlm-i Menâzır", TDV Islamic Encyclopedia, https://islamansiklopedisi.org.tr/ilm-i-menazir#2-osmanlilarda (29.01.2024).

Hanoğlu, İsmail. *Fahruddin er-Razi'nin Kitâbu'l-Mulahhas fi'l-Mantık ve'l-Hikme adlı esrinin tahkiki ve değerlendirmesi*, Ankara: Ankara Üniversitesi Sosyal Bilimler Üniversitesi Felsefe ve Din Bilimleri Anabilim Dalı, Doktora Tezi, 2009.

Heidarzadeh, Tofigh. *Ali Kuşçu'nun astronomi eserleri*, Thesis (Master's degree), Istanbul University Institute of Social Sciences, Department of History of Science, Istanbul 1997.

Kheirandish, Elaheh. "Footprints of "Experiment" in Early Arabic Optics", *Early Science and Medicine*, vol. 14, No. 1/3, 79-104.

Kheirandish, Elaheh. "Books on Mathematical and Mixed-Mathematical Sciences: Arithmetic, Geometry, Optics, and Mechanics." *Treasures of Knowledge: An Inventory of the Ottoman Palace Library (1502/3-1503/4),* ed. Gülru Necipoğlu, Cemal Kafadar, and Cornell H. Fleischer, 857-90. Leiden: Brill, 2019.

Lindberg, David C. *Theories of Vision From Al-Kindi to Kepler*, The University of Chicago Press, Chicago 1976, 60.

Longair, Malcolm. *Theoretical Concepts in Physics, An Alternative View of Theoretical Reasoning in Physics,* (Cambrdige: Cambridge University Press, 2020), 440.

Mazor, Amir. "Spectacles in the Muslim World: New Evidence from the Mid-Fourteenth Century", *Early Science and Medicine,* 18-3 (2013). 291-305.

Pekkendir, Sena. *The Entrance of modern optics to Ottoman science* (Boğaziçi University, Master's thesis, 2015), 4-33.

Ragep, F. Jamil. "Alī Qushjī and Regiomontanus: Eccentric Transformations and Copernican Revolutions," *Journal for the History of Astronomy*, 2005, 36:359-371.

Sabra, A. I. *The Optics of Ibn al-Haytham, Books I-III, on Direct Vision*, (London, The Warburg Institute, 1989), 22.

Sabra, A. I. "The 'Commentary' That Saved the Text: The Hazardous Journey of Ibn al-Haytham's Arabic 'Optics'", *Early Science and Medicine* 12/2 (April 2007), 117-133.

The Qur'an (*Oxford World's Classics*), trans. M. A. S. Abdel Haleem (Oxford: Oxford University Press, 2005), Jonah 10/5, 128.

Umut, Hasan. *Theoretical Astronomy in the Early Modern Ottoman Empire: ʿAlī al-Qūshjī's al-Risāla al-Fatḥiyya,* (Montreal, McGill University, Institute of Islamic Studies, 2019), 548.

Üçer, İbrahim Halil. İslam Düşünce Atlası: Yenilenme Dönem. takdim Tahir Akyürek, tashih Semih Atiş. (Konya : Konya Büyükşehir Belediyesi Kültür Yayınları, 2017), 2. cilt.