

Descartes's Epistemic Commitment to Telescopes and Microscopes

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ABSTRACT: In the *Optics*, Descartes claims that telescopes and microscopes lead to morally certain knowledge. It is unclear, however, that Descartes's expressed confidence in these instruments is warranted. In this article, I show how a limited range of telescope and microscope observations could lead to morally certain knowledge for Descartes, and how observations beyond this range admit of enough reasonable doubt to undermine moral certainty. I also explain moral certainty as a form of knowledge in Descartes's scientific practices, his epistemic commitment to optical instruments, and I offer an explanation for why Descartes never used optical instruments in his scientific endeavours.

RÉSUMÉ : Dans la *Dioptrique*, Descartes prétend que les télescopes et les microscopes donnent accès à des connaissances moralement certaines. Cependant, il n'est pas certain que la confiance accordée par Descartes à ces instruments soit justifiée. Dans cet article, je montre comment une gamme limitée d'observations effectuées à l'aide d'instruments d'optique pourraient mener aux connaissances moralement certaines pour Descartes, et comment d'autres observations allant au-delà de cette gamme introduisent suffisamment de doute raisonnable pour saper cette certitude morale. Enfin, j'interprète la certitude morale comme une forme de connaissance dans l'empirisme de Descartes, j'explique son engagement épistémique envers les instruments d'optique, et j'éclaire les raisons pour lesquelles il n'a jamais employé d'instruments d'optique dans ses propres recherches scientifiques.

Keywords: Descartes, telescopes, moral certainty, Cartesian science, Cartesian epistemology, reasonable doubt, probability

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1. Introduction

In the *Optics*, Descartes writes that telescopes and microscopes reveal a “way for us to attain a knowledge of nature much greater and more perfect than [our forebears] possessed.”¹ To claim that these optical instruments help us to attain *knowledge* of nature is significant because Descartes holds knowledge to a high standard. For Descartes, knowledge must be either metaphysically or morally certain.²

Metaphysically certain knowledge is the strongest form of knowledge that “cannot in any way be open to doubt.”³ Examples of metaphysically certain knowledge include Descartes’s belief of his existence, as well as his belief that God exists.⁴ Because all observations using optical instruments are subject to extravagant doubts, such as the doubts raised by the sceptical arguments in the *Meditations*, these observations cannot lead to metaphysically certain knowledge. That being said, Descartes notes:

It would be disingenuous, however, not to point out that some things are considered as morally certain, that is, as having sufficient certainty for application to ordinary life, even though they may be uncertain in relation to the absolute power of God.⁵

Moral certainty is a lesser grade of certainty because it is not immune to extravagant doubts. Morally certain knowledge is a less demanding grade of

¹ *Optics* (AT VI, 81-82; CSM, 152). The full sentence reads “[c]arrying our vision much further than our forebears could normally extend their imagination, these telescopes seem to have opened the way for us to attain a knowledge of nature much greater and more perfect than they possessed.”

² Descartes’s “whole aim was to reach certainty (*Discourse*, AT VI, 29; CSM, 125).” See also Descartes to Regius, 24 May 1640 (AT III, 64-65; CSMK, 147). My discussion does not rely on truth as a criterion of certain knowledge for Descartes because the literature is divided on whether truth plays a role in Cartesian knowledge. Clarke (1982, 132-164) argues that Cartesian certainty, especially in scientific contexts, is not focused on truth. Garber (2001, 111-129) is also sympathetic to Cartesian moral certainty not requiring truth as a criterion. Frankfurt (2008, 138) argues that clear and distinct ideas are merely indubitable and not that they are a true correspondence with reality. Curley (1978, 112-114, 118) and Vinci (1998) focus on the relationship between knowledge and truth for Descartes. Notably, Van de Pitte (1988, 462) writes, “Descartes equates certainty with truth only in the very special case where no doubt could possibly enter in, i.e., the case of perfect certitude.”

³ *Meditations* (AT VII, 38; CSM, 27). See also Morris (2016, 101).

⁴ *Meditations* (AT VII, 38; CSM, 27); *Meditations* (AT VII, 45; CSM, 31).

⁵ *Principles* (AT VIII, 327; CSM, 289-290).

knowledge, sufficient for "matters relating to the conduct of life which we never normally doubt."⁶

Considering that knowledge must either be metaphysically or morally certain, Descartes must be referring to morally certain knowledge when he praises the potential of optical instruments.⁷ I argue that it is problematic for Descartes to hold that a belief is morally certain if and only if it is beyond all reasonable doubt, and that beliefs formed on the basis of optical instruments are morally certain. Given the state of telescopes and microscopes in the early modern period, I argue that Descartes would have significant reasonable doubt undermining beliefs formed on the basis of optical instruments. It follows that beliefs formed on the basis of early seventeenth-century optical instruments are not morally certain for Descartes. I then explain how the *Optics* can respond to this objection by establishing that a limited range of optical instrument observations can yield morally certain knowledge. The science of the *Optics* is at best partially satisfactory, however, because it can only eliminate reasonable doubts from a limited range of observations. I show that this limited range includes only observations that are clear and self-evident or can be confirmed by some other means. Consequently, it follows that beliefs based on observations beyond that limited range are still subject to reasonable doubt, and therefore do not classify as morally certain knowledge for Descartes.⁸

⁶ *Principles* (AT VIII B, 327; CSM, 289, fn. 2). Serjeantson (1999, 197, fn. 13) notes that "[t]he notion of moral certainty was not particularly English, as is sometimes implied [...]."

⁷ Scholars in the early modern period, including Rodrigo de Arriaga used a three-fold distinction that also included *physical certainty*, but Descartes only recognizes metaphysical and moral certainty (Ariew, 2010, 40ff). Hatfield (2014, 319-321) discusses the differences between metaphysical and moral certainty.

⁸ Scholars have addressed aspects of Descartes's discussions of telescopes and microscopes, but Descartes's epistemic commitment is normally not the focus. For instance, Locy (1923) discusses Descartes's explanations for how to construct microscopes. Wilson (1995) provides a comprehensive discussion of the role of microscopes in early modern philosophy, including Descartes's contributions, but Descartes's potential epistemological problems are peripheral to the larger discussion. Burnett's (2005) book provides a historical tracing of Descartes's attempts to design a lens-grinding machine, but he does not address any epistemological commitments to the telescope or microscope in and of themselves. Notably, Ribe (1997) argues that the *Optics* is Descartes's attempt to master vision so that it can be improved beyond a means of self-preservation to an instrument of scientific knowledge. I agree that the *Optics* attempts to improve optical instruments as a way to perfect vision, but I find that Descartes's epistemology undermines the possibility that optical instruments could provide morally certain scientific knowledge for Descartes except under very limited conditions.

2. Moral Certainty

Descartes, like other early modern scholars, ascribed to a gradable epistemological continuum.⁹ Descartes's continuum can be broken into two broad categories—that which classifies as (i) *belief* and that which is (ii) *knowledge*. The lowest form of belief is (i.a) *mere opinion*, a belief that does not have much justification or evidence in its favour. The highest form of belief is that which is (i.b) *highly probable*, and in between (i.a) *mere opinion* and (i.b) *highly probable* include uncategorized beliefs that are held based on increasing probability. It is worth noting that the concept of probability for Descartes and other early modern thinkers was not associated with the statistical likelihood that we now tend to associate with the term.¹⁰ Rather, in the first half of the seventeenth century, the notion of probability was focused on the amount and quality of evidence in favour of a belief as well as the objectivity of the observer.¹¹ What this reveals is that highly probable beliefs must rise to a high standard of proof; however, we also know that, despite the high standard of proof, Descartes was unwilling to classify highly probable beliefs as knowledge. Consider, for instance, how Descartes explains his use of the phrase “easy to believe” in the *Optics*. He writes:

⁹ See Schachter (2005, 20) for a comprehensive illustration of Descartes's epistemological continuum. Schachter's continuum also goes from *mere possibility* to *highly probable* to *moral certainty* to *metaphysical certainty*. Schachter's article focuses on the role God's guarantee plays in Cartesian knowledge so he utilizes a two-dimensional continuum. For my purposes, a one-dimensional continuum is sufficient.

¹⁰ Daston (1998, 1109) notes that the early seventeenth-century notion of probability “in no way implied a role for chance in the world.” Furthermore, there was “very little connexion between the probabilities of belief and statistical frequencies” prior to 1660 (1114-1115).

¹¹ Shapiro (1983, 140) writes “[...] the term ‘probably’ was losing its rhetorical sense of the merely plausible and taking on the connotation of statements made on the basis of good evidence. [...] Conclusions drawn from investigation of historical and physical phenomena might be highly probable, reaching moral certainty, or they might be less probable, being little more than opinion. What was critical to the elevation of historical and natural findings from mere opinion to moral certainty was the quantity and quality of the evidence and the credibility and impartiality of the investigator or observer.” Hacking (2006, 11) notes that the modern mathematical conception of probability came into being in 1660.

I consider almost as false whatever is only a matter of probability; and when I say that something is easy to believe I do not mean that it is only probable, but that it is so clear and so evident that there is no need for me to stop to prove it.¹²

Descartes's disparaging of probability is not surprising as it is commonly held that Descartes's philosophical and scientific enterprises were focused on attaining *certain knowledge* and not *probable beliefs*.¹³ Descartes has two categories of knowledge, that which is (ii.a) *metaphysically certain* and that which is (ii.b) *morally certain*. The best approach to understanding Cartesian knowledge is to contrast *certainty* with *doubt*. Descartes's route to describing *morally certain knowledge*, which is the type of knowledge of primary interest to this essay, begins by first describing *metaphysically certain knowledge*. Descartes writes, "there is conviction when there remains some reason which might lead us to doubt, but knowledge is conviction based on a reason so strong that it can never be shaken by any stronger reason."¹⁴ Here, Descartes links his concept of *knowledge* directly to the absence of doubt and the presence of certainty. In the *Meditations*, Descartes writes:

Reason now leads me to think that I should hold back my assent from opinions which are not completely certain and indubitable just as carefully as I do from those which are patently false. So, for the purpose of rejecting all my opinions, it will be enough if I find in each of them at least some reason for doubt.¹⁵

In the *Discourse*, Descartes reiterates his method of hyperbolic doubt; he writes, "I thought it necessary to [...] reject as if absolutely false

¹² Descartes to Mersenne, 5 October 1637 (AT I, 450-451; CSMK, 74). Descartes is referring to a passage in the *Optics* where he explains how light rays travel in straight lines but could be deflected or weakened when intersecting with certain bodies (AT VI, 88; CSM, 155).

¹³ Ayers (1998, 1015) notes that Descartes "assigns little worth to belief which falls short of knowledge, whether natural perceptual belief or probable speculation. In general, probable opinion appears neither as a stage on the way to knowledge nor as an acceptable alternative to it, but rather as a distraction to be set aside in case we confuse it with knowledge." Shapiro (1983, 38) also confirms that Descartes was not interested in a probabilistic natural science. Hacking (2006, 46) further corroborates when he notes that Descartes's science "had no room for probability."

¹⁴ Descartes to Regius, 24 May 1640 (AT III, 65; CSMK, 147). Please note that the terms *conviction* and *belief* are synonymous in this paper.

¹⁵ *Meditations* (AT VII, 18; CSM, 12).

everything in which I could imagine the least doubt, in order to see if I was left believing anything that was entirely indubitable.”¹⁶ These passages reveal that if there is reason to doubt, then one cannot be certain; whereas, if one has actively searched for reason to doubt and has not found any, then one is certain. I believe that Descartes reiterates his method of hyperbolic doubt in the *Discourse* because it clearly shows the polar relationship between doubt and knowledge and how Descartes’s scientific principles will ultimately classify as a form of knowledge, namely morally certain knowledge.

Descartes holds that a belief that cannot be undermined by any doubts, even extravagant sceptical doubts, is a metaphysical certainty. The prime example of a metaphysical certainty is Descartes’s *cogito* argument. Since Descartes is unable to undermine the belief that he exists, even after attempting to raise the most extreme sceptical doubts, he finds that his belief that he exists is metaphysically certain knowledge. Descartes considers metaphysical certainties to be the strongest form of knowledge or *scientia*.¹⁷ In brief, metaphysically certain knowledge is indubitable *tout court*.

In Descartes’s scientific practices, he uses empirical approaches that fall short of metaphysical certainty; however, he maintains that sound scientific practices can reveal morally certain knowledge.¹⁸ Descartes writes:

For although we have a moral certainty about these things, so that it seems we cannot doubt them without being extravagant, nevertheless when it is a question of metaphysical certainty, we cannot reasonably deny that there are adequate grounds for not being entirely sure about them.¹⁹

The notion of moral certainty is notoriously unclear, and issues of clarity extend to Descartes’s usage as well.²⁰ Descartes describes moral certainty as “sufficient to regulate our behavior, or which measures up to the certainty we have on matters relating to the conduct of life which we never

¹⁶ *Discourse* (AT VI, 31-2; CSM, 127).

¹⁷ Sorrell (2016, 423-424).

¹⁸ Clarke (1992, 275-276) notes that Descartes “sometimes claims that his explanations are certain; [...]. At the same time he recognizes that they are not absolutely certain, that they do not enjoy the type of certainty that can be realized in mathematics, that they are only morally certain or as certain as one could hope to be in this type of enterprise.” See also Garber (2001, 128-129).

¹⁹ *Discourse* (AT VI, 37-38; CSM, 130). In the passage, Descartes is referring to the existence of external objects, for instance, the earth and the stars as well as the existence of his own body.

²⁰ Morris (2002, 401) notes that the concept is not well understood in the literature.

normally doubt."²¹ In this passage, Descartes says that morally certain knowledge must measure up to the sorts of everyday beliefs that we ordinarily never doubt.

Descartes's quotidian description of moral certainty is useful but misleading. Based on his description, it might seem as if all common observations and equivalent beliefs that are acceptable to everyday living can be classified as morally certain; however, there is reason to doubt this reading. In terms of certainty and strength of knowledge, morally certain knowledge lies between beliefs that are highly probable and knowledge that is metaphysically certain. Given Descartes's contrast of probability with knowledge, it follows that morally certain knowledge must attain something greater than high probability.²²

Assuming that Descartes's understanding of *probability* was equivalent to seventeenth-century scholarly use, we can understand Descartes's use to mean that there is strong evidence that supports the belief. Furthermore, as the quality and quantity of available evidence increases, the rationale justifying the holding of the belief increases until the belief becomes highly probable. With this understanding of *highly probable* in mind, as well as its distinction from *moral certainty*, it follows that *moral certainty* requires more than strong evidence. In other words, the difference between a highly probable belief and morally certain knowledge is not simply that morally certain knowledge has more high-quality evidence in its favour.

The key to understanding the difference between moral certainty and probability is the presence of applicable doubt. Descartes consistently contrasts his two forms of knowledge with doubt as a way to establish the limits of both types of knowledge. For instance, Descartes writes that we cannot doubt morally certain knowledge "without being extravagant."²³ In essence, the difference between a highly probable belief and morally certain knowledge is that it is still reasonable to doubt a highly probable belief. There may be strong evidence in favour of the belief but there remains applicable reason for doubt, and therefore one cannot be certain about the belief even if it is highly probable.

Considering that Descartes consistently contrasts knowledge with doubt, I propose that the best way to understand his use of *moral certainty* is that it is

²¹ *Principles* (AT VIII B, 327; CSM, 289, fn. 2).

²² Baker and Morris (2004, 26, fn. 3) in their description of moral certainty note that "[i]t would be entirely misleading to gloss this by saying that moral certainty is 'only' high probability). What is in this sense 'highly probable' is 'beyond all reasonable doubt'—though not of course beyond metaphysical reasons for doubt, ones that would in the conduct of civil life be deemed unreasonable."

²³ *Discourse* (AT VI, 37-38; CSM, 130).

a belief that is beyond all reasonable doubt.²⁴ Descartes required a significant quantity and quality of evidence for moral certainty in scientific contexts; however, his strong focus on certainty meant that morally certain knowledge must also be free of applicable doubt.

There is at least one exception between Descartes's use of *moral certainty* and the common seventeenth-century usage. Certain types of evidence that would be acceptable to the larger scientific community would be unacceptable to Descartes. For instance, Barbara J. Shapiro notes that, for seventeenth-century scientists and philosophers, "natural phenomena and processes were to be verified by experiment, observation, and the testimony of observers."²⁵ Descartes's scientific endeavours relied on both experiment and observation; however, it is unlikely that Descartes would base morally certain knowledge on the testimony of others.²⁶ Descartes is quite clear in the *Discourse* that the observations of others should not be trusted.²⁷ Also, in a letter to Mesland, Descartes notes that authoritative testimony is insufficient for knowledge of the natural world. He writes:

The moral error which occurs when we believe something false with good reason—for instance because someone of authority has told us—involves no privation provided it is affirmed only as a rule for practical action, in a case where there is no moral possibility of knowing better. Accordingly it is not strictly an error; it would be one if it were asserted as a truth of physics, because the testimony of an authority is not sufficient in such a case.²⁸

²⁴ This definition of moral certainty is not my original idea. Morris (2002, 409), writes, "Finally, what is morally certain is 'beyond all *reasonable* doubt (it can be called into doubt only by an 'absolute' reason for doubt) and involves principles backed up by God's justice." Morris (2016, 100-101) notes that the "courtroom flavor of this phrase is intentional [...]. Even now, American juries are often instructed to seek verdicts 'beyond a reasonable doubt and to a moral certainty.'" See also Baker and Morris (2004, 39). Shapiro (1986, 159) notes, with italics added for emphasis, "[d]epending on the quality and quantity of the evidence produced by these methods, one might reach findings of fact and sometimes even conclusions *that no reasonable person could doubt*."

²⁵ Shapiro (1986, 159).

²⁶ Baker and Morris (2004, 25ff) notes that Descartes's use of the term *testimony* is in reference to the testimony and subsequent reliability of one's cognitive faculties.

²⁷ See *Discourse* (AT VI, 73; CSM, 148). Shapin (1994, 205) writes "[a]s for experimental communications from others, it was probably not worth the philosopher's time soliciting and evaluating them: [...]. Cartesian rationalism could tolerate—even require—that degree and quality of skeptical individualism."

²⁸ Descartes to Mesland, 2 May 1644 (AT IV, 115; CSMK, 233). Further to the point, Coady (2002, 12) notes that Descartes had an individualist ideology and neglected testimony.

Descartes is willing to accept testimony when it regards practical action; however, he is unwilling to accept the testimony of others as *knowledge*. This unwillingness is directly tied to the importance of certainty. Descartes cannot be certain that the authority in question took the proper precautions in his or her experiment or observation. For instance, while praising certain aspects of Galileo's *Discourses and Mathematical Demonstrations Concerning Two New Sciences*, Descartes is also critical of Galileo's general method. Descartes writes:

[...] he continually digresses, and he does not take time to explain matters fully. *This, in my view, is a mistake: it shows that he has not investigated matters in an orderly way, and has merely sought explanations for some particular effects, without going into the primary causes in nature; hence his building lacks a foundation.*²⁹

In effect, Descartes's focus on certainty excludes the possibility of accepting testimony from members of the scientific community as morally certain knowledge.³⁰

For something to be beyond all reasonable doubt, there must be evidence in favour of the belief and there cannot be appropriate doubts that the belief may be false. For example, Descartes explains that one can be morally certain that Rome is a city in Italy even if one has never been to Rome.³¹ Descartes finds his belief about Rome's location to be morally certain because the strength of the evidence favours the belief and there are no appropriate doubts that can undermine that evidence. To elaborate, consider the type of doubt necessary to undermine the belief that Rome is in Italy. Descartes writes that "<[t]hus those who have never been in Rome have *no doubt* that it is a town in Italy, even though it could be the case that everyone who has told them this has been deceiving them.>"³² To doubt this belief would require believing that all the sources that testify in favour of Rome being in Italy are false.³³ This doubt,

²⁹ Descartes to Mersenne, 11 October 1638 (AT II, 380; CSMK, 124). Italics added for emphasis. See Galilei (1890-1914, vol. VIII).

³⁰ Ranea (2002, 317ff) argues that Descartes does not credence the idea that the certainty of knowledge can be grounded on the word of a "gentleman." Ranea (2002, 322) further notes, "Descartes was faced with similar troubles each time his correspondents gave him an account of what they had seen or heard. As in the later British debate, the role of witnessing in providing the foundation of knowledge was at stake in many of Descartes' letters."

³¹ *Principles* (AT VIII B, 327; CSM, 290).

³² *Principles* (AT VIII B, 327; CSM, 290). Italics added for emphasis.

³³ Not only false but also *intentionally* misleading as Descartes alludes to in the above passage.

however, is simply unreasonable because it favours believing a grand conspiracy over every source that testifies that Rome is in Italy. In the same principle, Descartes further explains morally certain knowledge by using an example of decoding a cipher. He writes:

Suppose for example that someone wants to read a letter written in Latin but encoded so that the letters of the alphabet do not have their proper value, and he guesses that the letter B should be read whenever A appears, and C when B appears, i.e. that each letter should be replaced by the one immediately following it. If, by using this key, he can make up Latin words from the letters, he will be in no doubt that the true meaning of the letter is contained in these words. It is true that his knowledge is based merely on a conjecture, and it is conceivable that the writer did not replace the original letters with their immediate successors in the alphabet, but with others, thus encoding quite a different message; but this possibility is so unlikely <especially if the message contains many words> that it does not seem credible.³⁴

In the above example, Descartes finds it inappropriate to doubt the possibility that a decoded cipher could be incorrect if the decoded message is comprehensible. The longer the decoded message, the more incredible it is to doubt the authenticity of the decoded message.³⁵ It is just too inconceivable that the comprehensible message revealed could be the result of an erroneous key.

On the other hand, if *reasonable doubt* is present, then one cannot have morally certain knowledge. Unfavourable perceptual circumstances, for example, can provide enough reasonable doubt to undermine moral certainty. Consider Descartes's example of the square tower that looks round from far away.³⁶ Despite having a sense perception of what appears to be a round tower, Descartes holds that the circumstances of the perception, namely being too far away, is a source of reasonable doubt that undermines the possibility of having moral certainty about the shape of the tower.³⁷ In the *Replies*, Descartes further clarifies his position; he writes:

³⁴ *Principles* (AT VIII B, 327-328; CSM, 290).

³⁵ Descartes would be far more dubious if the cipher was only one word, and he would not attribute moral certainty to a single decoded word since there are innumerable equally likely possibilities.

³⁶ *Optics* (AT VI, 146-147; CSM, 175); *Meditations* (AT VII, 76; CSM, 53).

³⁷ Hatfield (1988, 257-259) notes that Descartes held we could visually determine certain characteristics of bodies, but only when the conditions are favourable. Hatfield (1988, 257) also notes, with italics added for emphasis, "Descartes was prepared to allow that, *when sufficient care is taken*, sensory observation can yield certainty."

[...] although there is deception or falsity, it is not to be found in the senses; for the senses are quite passive and report only appearances, which must appear in the way they do owing to their causes. The error or falsity is in the judgement or the mind, which is not circumspect enough and does not notice that things at a distance will for one reason or another appear smaller and more blurred than when they are nearby, and so on. Nevertheless, when deception occurs, we must not deny that it exists; the only difficulty is whether it occurs all the time, thus making it impossible for us ever to be sure of the truth of anything which we perceive by the senses.

[...] I will simply say that it seems to be quite uncontroversial that when we look at a tower from nearby, and touch it, we are sure that it is square, even though when we were further off we had occasion to judge it to be round, *or at any rate to doubt whether it was square or round or some other shape*.³⁸

In the above passage, Descartes communicates two important points. First, Descartes declares that the senses are not to blame for deception because the senses merely report appearances; rather, the error lies in the mind assenting to dubious sense perceptions. Second, Descartes alludes that, although the universal doubts raised in the *Meditations* regarding the trustworthiness of the senses need no longer be considered, the senses will on occasion relay appearances that are inaccurate. The occasional inaccuracy of the senses gives us reason to be cautious and to doubt at least some of our sense perceptions. In other words, it is not the case that Descartes absolves sense perceptions of all doubt by the end of the *Meditations*. Rather, he shows that we can generally rely on sense perceptions to yield morally certain knowledge in favourable perceptual circumstances.

In fact, Descartes's focus on certainty reveals that what is perceived should always be carefully considered, such as the straight stick that appears to be bent in water.³⁹ Despite having a sense perception from a clear proximity that there is a bend in the stick, Descartes is not morally certain that the stick developed a bend when submerged just because he perceives a bent stick by way of his generally reliable sense perceptions. Descartes's knowledge of refraction and the properties of matter serve as enough reasonable doubt to reject believing that the stick is truly bent.⁴⁰ In brief, beliefs that are subject to reasonable doubt

³⁸ *Replies* (AT VII, 332-333; CSM, 231-232). Italics added for emphasis.

³⁹ Baker and Morris (2004, 38) note, "[t]he senses, however, *at best* yield moral certainty. We know already that they are sometimes untrustworthy, in the senses of offering conflicting testimony. This unreliability is ineliminable; the mechanics of vision, for example, imply that (e.g.) a stick in water will appear bent to sight though it appears straight to the touch."

⁴⁰ *Replies* (AT VII, 333; CSM, 231); see also *Meditations* (AT VII, 89; CSM, 61).

are not morally certain.⁴¹ With the above considerations in mind, an optical instrument observation may be able to lead to morally certain knowledge for Descartes, but only if these observations are beyond all reasonable doubt.

3. The Significance of Optical Instruments

Descartes is clearly interested in the possibility of using optical instruments to expand the range and scope of our experience. For example, in a letter attempting to recruit Jean Ferrier to help craft a lens-grinding machine, Descartes writes, “if you have a year or two to apply yourself to all that is necessary, I would hope that we might see, by your efforts, if there are animals on the moon.”⁴² Also, in the opening line of the *Optics*, Descartes writes: “The conduct of our life depends entirely on our senses, and since sight is the noblest and most comprehensive of the senses, inventions which serve to increase its power are undoubtedly among the most useful there can be.”⁴³ Now, consider how Descartes describes the importance of telescopes. He writes:

[...] it is difficult to find any such inventions which do more to increase the power of sight than those wonderful telescopes which, though in use for only a short time, have already revealed a greater number of new stars and other new objects above the earth than we have seen there before.⁴⁴

Since Descartes finds that our sight is capable of leading to morally certain knowledge, it stands to reason that by increasing the power of sight, telescopes should also be capable of leading to morally certain knowledge as well. Furthermore, Descartes’s confidence in telescopes is straightforward and explicit. As previously noted, he writes: “Carrying our vision much further than our forebears could normally extend their imagination, these telescopes seem to have opened the way for us to attain a knowledge of nature much greater and more perfect than they possessed.”⁴⁵ Also, Descartes does not call them by name, but he implies that microscopes are more important than telescopes. He writes:

⁴¹ A belief that is subject to reasonable doubt may not be morally certain, but it could be highly probable. For example, Descartes might wager with a traveling companion that the tower in the distance is round based on its appearance and the testimony of someone walking by, but he would not claim to be certain that it is round.

⁴² Descartes to Ferrier, 13 November 1629 (AT I, 69; Burnett, 2005, 1).

⁴³ *Optics* (AT VI, 81; CSM, 152).

⁴⁴ *Ibid.* Furthermore, Burnett (2005) reveals the time, intellectual energies, and patronage that Descartes committed to the crafting of a lens grinding machine capable of crafting precise hyperbolic lenses. (Burnett’s whole book reveals important historical details, but pages 41-72 are especially relevant.)

⁴⁵ *Optics* (AT VI, 81; CSM, 152).

I wish to advise you that although at first their use is not as attractive as that of those others [i.e., telescopes] [...], I nevertheless judge them much more useful, because by means of them [i.e., microscopes] we will be able to see the diverse mixtures and arrangements of the small particles which compose the animals and plants, and perhaps also the other bodies which surround us, and thereby derive great advantage in order to arrive at the knowledge of their nature.⁴⁶

In the preceding two passages, Descartes is explicit that telescopes and microscopes could yield knowledge of nature. As noted in Section I, for Descartes to classify these observations as leading to *knowledge* is significant. At the time of the *Discourse*, which was published simultaneously with the *Optics*, Descartes still focused on achieving certain knowledge in his scientific enterprises.⁴⁷ Considering this, he must be referring to morally certain knowledge of nature when writing about telescopes and microscopes. It is unclear, however, that these instruments can yield morally certain knowledge according to Descartes's standards.⁴⁸

Though Descartes thinks that the senses can be trusted if there is no reasonable doubt present, he also recognizes that the senses can be deceptive. Descartes writes: "[...] from time to time we have caught out the senses when they were in error, and it is prudent never to place too much trust in those who have deceived us even once."⁴⁹ By noting that the senses are in error from time to time, he indicates that the senses are not universally trustworthy. Since they are at times liable to lead us to assent to false judgements, we must take care not to simply assent to all of our sense perceptions. Descartes reiterates this point in *The Search for Truth*, when he writes:

I find it strange that men are so credulous as to base their knowledge on the certitude of the senses, when everyone knows that they are sometimes deceptive, and that we have good reason always to distrust those who have deceived us even once.⁵⁰

Descartes's recommendation to be cautious serves to reemphasize the role and importance of reasonable doubt as previously discussed. The senses are undoubtedly fallible and can relay false appearances to the mind in certain circumstances. Considering this, Descartes must have certainty that the senses are relaying accurate information to the mind before he can assent to what he

⁴⁶ *Optics* (AT VI, 81; CSM, 172). Bracketed text added for clarity.

⁴⁷ Garber (2001, 128).

⁴⁸ This question is no small issue. For instance, van Fraassen (1980) questions the epistemic commitment we should have to many types of scientific instruments, including microscopes.

⁴⁹ *Principles* (AT VIII A, 6; CSM, 194).

⁵⁰ *Search* (AT X, 510; CSM, 407).

perceives as morally certain knowledge of nature. For instance, in the *Optics*, he notes “how easy it is to make mistakes” when attempting to judge distance.⁵¹ Consequently, if considerable care is taken and there is no reasonable doubt, then the senses can lead to morally certain knowledge. In contrast, if there is reasonable doubt about a given sensory perception, then any belief based on the doubtful sense perception cannot be considered morally certain.

There is indication that, despite his keen interest in optical instruments, Descartes knew all too well that telescopes and microscopes were problematic. Descartes writes:

Inventions of any complexity do not reach their highest degree of perfection right away, and this one is still sufficiently problematical to give me cause to write about it. [...] I shall give a detailed account of how vision comes about; and, after noting all the things which are capable of making vision more perfect, I shall show how they can be aided by the inventions which I shall describe.⁵²

Put simply, one of the stated goals of the *Optics* is to *perfect* optical instruments so that they rise to the standard necessary to yield morally certain knowledge of nature. In essence, if optical instruments could perfect vision so that what is perceived is “so clear and so evident,”⁵³ then there would be no reason to doubt what is being observed, which in turn would lead to morally certain knowledge of nature.

Based on the above considerations, it follows that the presence of reasonable doubt will undermine the ability of optical instruments to lead to morally certain knowledge. In the following section, I show that early modern telescopes and microscopes were subject to significant reasonable doubt.

4. Reasonable Doubt

Descartes recognizes that our sense perceptions can be mistaken and, in certain circumstances, relay incorrect information to the intellect. This recognition leads him to caution against assenting to sense perceptions when reasonable doubt is present. This same line of reasoning should also apply to optical instruments. Before moving to the science of the *Optics* in Section V, consider the following five reasonable doubts that plagued early optical instruments.

4.1 Instrument Quality

Galileo wrote to Clavius that he was not surprised that the Jesuits of Collegio Romano were unable to observe the moons of Jupiter because one needed an “exquisite instrument” to replicate his (i.e., Galileo’s) observations. Because of

⁵¹ *Optics* (AT VI, 147; CSM, 175).

⁵² *Optics* (AT VI, 82-83; CSM 152).

⁵³ Descartes to Mersenne, 5 October 1637 (AT I, 451; CSMK, 74).

this, Galileo urged Clavius to build a sturdy mount for his telescope because even the small shaking caused by the observer's pulse and breathing was enough to disrupt an observation.⁵⁴ Galileo's recommendation to Clavius reveals just how sensitive these early optical instruments were, and how they required a high degree of quality for accuracy.

4.2 Image Quality

Despite his expertise with the telescope, some of Galileo's careful telescope observations lead to false beliefs. For instance, Galileo observed that the diameter of Mars varied with each of his telescope observations, leading him to conclude that the planet was not round.⁵⁵ It is now easy to understand how Galileo could have come to this erroneous conclusion about the shape of Mars. The quality of the glass and the lens-grinding techniques in the seventeenth century lead to significant aberrations even in expertly crafted lenses. At the time, both spherical and chromatic aberrations were prevalent.⁵⁶ Spherical aberration causes light rays further from the optical axis to converge outside the focal point. Chromatic aberrations result from the component colour wavelengths of white light refracting differently, which causes colours to blur.⁵⁷ Simply stated, aberrations cause optical instrument images to be unclear and distorted, even to the point that a spherical object can appear as if it were not round.

Descartes would not have had a theory that explained the visible aberrations when making an observation of Mars with an early modern telescope. However, Descartes would have been aware of the lack of clarity and distinctness in the images that appear in the telescope. Practically speaking, a lack of clarity and distinctness is how aberrations present themselves to observers. The presence of aberrations or the lack of clarity and distinctness in the telescope images reveals significant reason for Descartes to doubt optical instrument observations.⁵⁸ If Descartes had made similar observations of Mars, his expectation of nothing less than certainty would not have allowed

⁵⁴ Galileo to Clavius, 17 September 1610 (Galilei, 1890-1909, vol. X: 391, 431-432). Found in Biagioli (2001, 286).

⁵⁵ Galileo to Castelli, 30 December 1610 (Galilei, 1890-1909, vol. X: 447, 503).

⁵⁶ According to Hacking (1985, 138-139), there are eight chief aberrations in optical systems.

⁵⁷ In their examination of a seventeenth-century telescope, Miniati, Greco, Molesini, Quercioli (1994, 682) note that "[i]n operation, it is expected that the performance of the telescope is mostly limited by chromatic aberration."

⁵⁸ Wilson (1995, 82) notes that Descartes knew of the optical blurring caused by spherical aberration, and that aberration could not be corrected for microscope lenses in the seventeenth century. See *Optics* (AT VI, 198ff; Olscamp, 152ff).

him to draw conclusions about the shape of Mars due to the presence of considerable reasonable doubt. This same doubt holds true for the microscope as well, but to an even greater degree.⁵⁹

4.3 *Augmentation*

Descartes maintained that vision perception occurred by way of an instantaneous motion that the nerves of the eyes received. Descartes writes:

I would again have you consider the reasons why [vision] sometimes deceives us. [...] because the impressions which come from outside pass to the 'common' sense by way of the nerves, if the position of these nerves is changed by any unusual cause, this may make us see objects in places other than where they are. [...] And if our eyes see objects through lenses and in mirrors, they judge them to be at points where they are not and to be smaller or larger than they are, or inverted as well as smaller (namely, when they are somewhat distant from the eyes). This occurs because the lenses and mirrors deflect the rays coming from the objects, so that our eyes cannot see the objects distinctly except by making the adjustments necessary for looking towards the points in question.⁶⁰

The above passage shows that, for Descartes, we can be deceived by our senses if the image is augmented before it appears to our eyes. Knowing that optical instruments function by manipulating light rays to form a new image should serve as significant reasonable doubt in these instruments. In other words, these instruments could be creating deceptive images.

4.4 *Theory-Ladenness*

Antoni van Leeuwenhoek, a proponent of preformationism, believed that humans were fully formed at conception. His preformationist beliefs led him to observe in human spermatozoa features that a preformed human would have. For instance, he wrote that he observed in human spermatozoa "all manner of great and small vessels, so various and so numerous that I have not the least doubt that they were nerves, arteries and veins."⁶¹ The example is significant because he notes that he had not the least doubt in what he was observing. It is unclear what he was observing that allowed him to believe that he saw nerves, arteries, and veins, but he does later acknowledge his error. In addition, about a century later both Georges-Louis Leclerc and Lazzaro Spallanzani make similar

⁵⁹ According to Turner (2003, 525), the microscope was not regularly relied upon for serious scientific work until the nineteenth century because the quality of the glass and the small lenses led to images being "marred with aberrations."

⁶⁰ *Optics* (AT VI, 141-143; CSM, 172-173).

⁶¹ See van Leeuwenhoek to Brouncker, November 1677, located in van Leeuwenhoek (1941, vol. 2, 293-295).

false observations while using their microscopes.⁶² The possibility of observations being affected by an observer's theoretical commitments, or theory-ladenness, was known to Descartes. He writes that other scientists' observations would "be so badly explained or indeed so mistaken—because those who made them were eager to have them appear to conform with their principles [...]."⁶³ Since optical instrument observations could be influenced by one's already held principles and theories, this serves as reasonable doubt that one's observations may be affected by theory-ladenness.

4.5 Interpretation

Descartes's contemporary, Margaret Cavendish, was highly critical of optical instruments because understanding an observation made through an optical instrument involves a considerable amount of interpretation.⁶⁴ Based on this, it is possible for two observers peering through the same instrument to draw different conclusions about what they are seeing. Cavendish wondered how an observation made with an optical instrument could be considered scientific if what is viewed is not self-evident and could have a variable interpretation. The interpretation doubt is closely related to the other doubts listed, and the above examples of Galileo and van Leeuwenhoek misinterpreting what they observed reinforce Cavendish's argument. These careful scientists definitively misinterpreted what they observed while using their optical instruments. Descartes would undoubtedly have had the same concern in any optical instrument observation that was not rendered as clear and evident.

The five types of doubt I list are by no means extravagant or hyperbolic; they are ordinary and applicable reasons to doubt optical instrument observations. I contend that the above examples and considerations serve as enough reasonable doubt to undermine the ability of optical instruments to lead directly to morally certain knowledge for Descartes. Considering this, Descartes needs a science of explanation that can eliminate reasonable doubt. In the following section, I consider how the *Optics* is supposed to eliminate reasonable doubts.

5. Establishing Moral Certainty

I have shown that early optical instruments are subject to reasonable doubts that would undermine their ability to lead to morally certain knowledge for Descartes.

⁶² Castellani (1973, 40).

⁶³ *Discourse* (AT VI, 73; CSM, 148).

⁶⁴ *The Description of a New World, Called the Blazing-World* contains Cavendish's most comprehensive criticism. See also *Observations upon Experimental Philosophy* (Cavendish, 2001, 50-53). Turner (2003, 525) notes that another reason that the microscope was not popular until the nineteenth century was because observers had difficulty identifying and communicating what they were seeing.

Considering this, Descartes needs a way to eliminate the reasonable doubts described in Section IV for optical instrument observations to lead to morally certain knowledge in at least some circumstances.⁶⁵ The first reasonable doubt about instrument quality is not overly problematic and can be addressed by relying on expertly crafted high-quality instruments.⁶⁶ The other doubts, however, are more problematic. Moving forward, I begin by reconstructing an argument from the *Optics* based on Descartes's technique for crafting telescope lenses.

5.1 Similarity Argument

In the *Optics*, Descartes carefully studies the anatomical structure of eyes and notes the similarities between eyes and optical instruments. Descartes describes how the shape of the eye can affect vision quality, such as longer and narrower eyes causing nearsightedness. Descartes explains that the shape of the eye causes light rays to converge on different parts of the optic nerve.⁶⁷ It is partially through studying the eyes that Descartes understands how to redirect light rays. With that knowledge, he describes optical instruments as artificial versions of our eyes with alterations that augment images in a determined way. See Figure 1. For instance, Descartes writes:

There remains but one other means for augmenting the size of images, namely, by causing the rays that come from the diverse points of the object to intersect as far away as possible from the back of the eye; [...]. For it is the only means which can be used for inaccessible objects, as well as for accessible ones, and its effect has no limitations; thus we can, by making use of it, increase the size of the images indefinitely.⁶⁸

The similarity argument attempts to show that if optical instruments are modeled on the eye, then we can be as confident in optical instruments as we are in eyes. This argument could potentially eliminate the image quality and augmentation doubts that Descartes would have; however, on its own, this argument is insufficient. For instance, because optical instruments use glass and because the angle of refraction determined by the Snell-Descartes law depends on the medium that refracts the light, the image quality and

⁶⁵ Arguably, Descartes's fruitless effort to develop an automatic lens-grinding machine was an attempt to make perfected lenses that were not subject to the reasonable doubts I share in Section IV.

⁶⁶ For instance, by only relying on instruments that are exceptionally sturdy and anchored to a solid and undisturbed surface.

⁶⁷ *Optics* (AT VI, 128; Olscamp, 116); *Optics* (AT VI, 146; CSM, 174).

⁶⁸ *Optics* (AT VI, 155; Olscamp, 119-120).

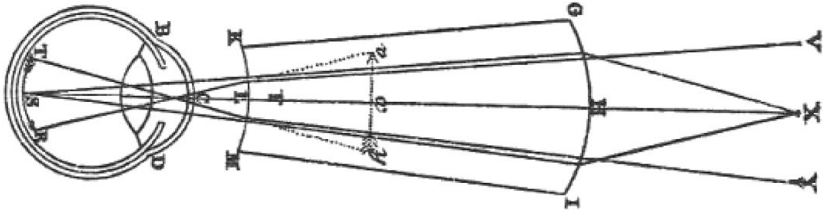


Figure 1 Illustration of Light Rays Focusing in a Telescope and a Human Eye Seeing the Focused Light Rays.⁶⁹

augmentation doubts still stand. To illustrate, picture a stable light source that emits light rays at a set angle toward an arm that holds different lens attachments. With no lens attached, the light appears straight, but as one progresses to denser lenses, the experiment shows that the angle of refraction increases relative to the density of the lens. For example, a diamond lens will cause a greater refraction than a clear glass lens of the same shape and thickness.

In the *Optics*, Descartes notes that the eye contains no less than three refractive mediums. See Figure 2. He writes:

[...] experiment shows that the one in the middle, *L*, which we call the crystalline humor, causes almost the same refraction as glass or crystal, and that the other two, *K* and *M*, cause slightly less, about the same as ordinary water, so that the rays of light pass more readily through that of the middle than through the two others, and yet more easily through these two than through the air.⁷⁰

Descartes is aware that different mediums cause different refractions. Furthermore, the similarity between the eye and optical instruments is only approximate. Descartes describes the crystalline humor as refracting *almost the same* as glass, and the other two refractive surfaces share similarity to ordinary water. Since ordinary water causes a significant refraction, as is evidenced by the straight stick appearing bent in water, and because most optical instruments have no water element to them, this indicates that optical instruments and the human eye are fairly different.

Any variation in the structure and refractive mediums could cause significant differences between the refraction of light in an optical instrument and the refraction of light through the crystalline humor. In essence, the similarity argument is unable to eliminate both the image quality and augmentation doubts. To elaborate, reasonable doubt remains because there is enough

⁶⁹ *Optics* (AT VI, 159, Fig. 30). The image has been rotated 90°.

⁷⁰ *Optics* (AT VI, 106; Olscamp, 84).

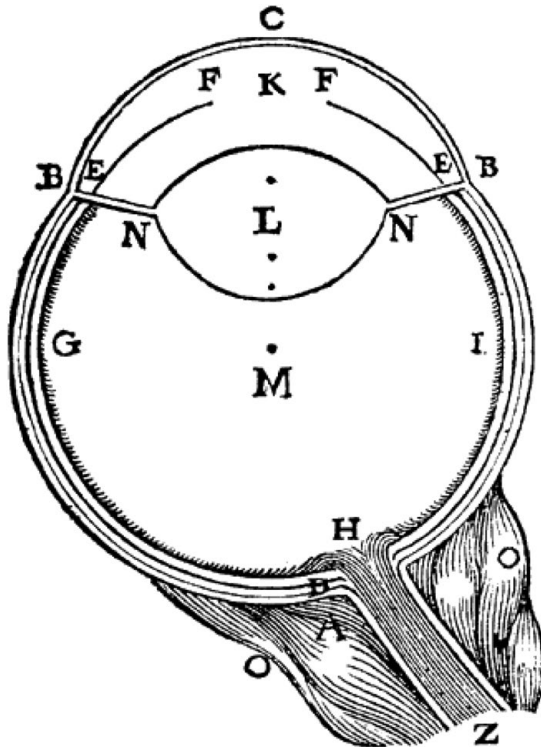


Figure 2 Illustration of the Human Eye and Its Refractive Mediums.⁷¹

variation between optical instruments and eyes for Descartes to see that there is the potential for deception to occur in those differences. Descartes would be unable to rely on the similarity argument to justify that optical instruments lead to morally certain knowledge. An additional argument is needed to show that no deception occurs in the differences between these two similar yet clearly distinct systems.

5.2 Refraction Correction

A supplemental argument is found in Descartes's description of an invention to aid lens grinders. Descartes designs an apparatus that allows a roughly cut lens to slide back and forth along a plane until light refracts to a designated point. When the light refracts to the designated point, the proper angle to finely cut the lens is revealed to the lens grinder. This trial and error technique uses

⁷¹ *Optics* (AT VI, 106, Fig. 13).

naked eye sense perceptions to determine the correct angle of refraction.⁷² Descartes describes this technique using language that affirms his confidence in his invention. He writes:

Although we need to refer to experience in order to determine their quantity, in so far as it depends on the particular nature of the bodies in which they occur, nonetheless we can do this easily enough and with sufficient certainty since all refractions are reduced in this way to a common measure. In fact, to discover all the refractions occurring at a given surface, it suffices to examine only those of a single ray, and we can avoid every error if in addition we examine the refractions in several other rays. [...] Then, if we suspect we have failed in this experiment, we must determine the refraction in several other rays [...] and if we find the same proportion [...], we shall have no further cause to doubt the truth of our observation.⁷³

By using the naked eye to determine the proper way to cut the lens, Descartes's technique assures that the glass lenses are cut so that they refract in accordance with how the naked eye determines they should refract. Basically, Descartes's invention bridges the gap between the refractive differences in the eye and the glass. By examining the refractions of several rays, Descartes's technique can effectively reduce spherical aberrations, diminishing the image quality doubt.⁷⁴ Also, because Descartes's technique requires confirming with the naked eye that light rays passing through the lens refract to a designated point, he can be sure that the refractions are determined, eliminating the augmentation doubt. By using the naked eye, Descartes's trial and error lens-crafting technique is supposed to assure that there is no disparity between the refractions of the optical instrument and the refractions of the eye.⁷⁵

D. Graham Burnett speculates on Descartes's reasons for designing a lens-grinding machine; he writes:

⁷² See Clarke (1982, 21).

⁷³ *Optics* (AT VI, 102; CSM, 162).

⁷⁴ Unfortunately, unbeknownst to Descartes, his lens-grinding method would be unable to resolve chromatic aberrations; I address this at the end of Section V. King (1979, 48) writes that "Descartes failed to differentiate between [spherical aberration] and chromatic aberration and overlooked the physical principles involved."

⁷⁵ Descartes does not provide a similar account for crafting microscope lenses but because the technology is similar, there would likely be a parallel between Descartes's method for crafting telescope lenses and any potential method for crafting microscope lenses.

[h]ere the essential quality of an epistemological problem is presented in terms of mechanical making. [...] Can the lens making machine be thought of, in a sense, as an *epistemological* instrument: a tool for making tools; a tool that guarantees that your tools will work?⁷⁶

I agree with Burnett's speculation, and I further believe that the lens-grinding machine was supposed to be a guaranteed method to craft trustworthy—aberration free—lenses that could lead to morally certain knowledge. Descartes likely believed that lenses crafted from his method would eliminate the instrument, image, and augmentation doubts due to the science of the *Optics*. Also, if there were no reasonable doubts, and the observation was logically consistent with Cartesian first principles, then doubting an observation based on theory-ladenness would likely not be an issue for Descartes so long as there were no equally viable alternative explanations.⁷⁷ Lastly, Descartes held that the interpretation doubt would not apply to observations made using his lenses because he thinks that his lenses would both improve the power and quality of vision. Recall that he described the telescope as an invention that increases the power of sight and is capable of making vision more perfect.⁷⁸ In other words, he believed that observations made using telescopes fashioned with lenses crafted by his method would be clear and self-evident and therefore would not require any interpretation.

5.3 *Limits Considered*

The arguments I reconstruct from the *Optics* are supposed to eliminate aberrations and in turn could diminish the reasonable doubts that undermine moral certainty; however, Descartes has further issues. Burnett writes:

Not until Newton's investigations of the nature of color in the late 1660s (which resulted in part from his foray into lens grinding) did the possibility of chromatic aberration arise, at which point another fundamental limitation on the potential of the uncorrected glass lens was revealed.⁷⁹

⁷⁶ Burnett (2005, 132). Burnett (2005, 19) also notes that Descartes saw the lens grinders' hands as sources of error.

⁷⁷ By contemporary standards, however, Descartes's overconfidence in his first principles and their connection to the natural world are ripe for theory-ladenness objections.

⁷⁸ *Optics* (AT VI, 81-83; CSM, 152).

⁷⁹ Burnett (2005, 17). Also, Van Helden (1974, 45) notes that Descartes's method for grinding lenses "would in fact not have eliminated the problem of *chromatic* aberration (not treated until 1672), lens grinders in those days were not up to such a task—indeed, they never were in the seventeenth century."

Descartes did not have the necessary theoretical framework to attempt a correction of chromatic aberration, so his spherically corrected lenses would always be plagued with chromatic aberrations. Because chromatic aberrations cause blurred images, reasonable doubt would still be an issue for many optical instrument observations.⁸⁰

Despite the presence of chromatic aberrations, Descartes may still be able to claim moral certainty for observations that fall within a limited range. To begin, consider his explanation from the *Meditations* for why we can generally trust sense perceptions. He writes:

I can almost always make use of more than one sense to investigate the same thing; and in addition, I can use both my memory, which connects present experiences with preceding ones, and my intellect, which has by now examined all the causes of error. Accordingly, I should not have any further fears about the falsity of what my senses tell me every day; [...].⁸¹

Also, Descartes notes in the *Principles* that we should not question the size and shape of external bodies because “we can detect these facts not just with one sense but several.” However, he goes on to write:

[...] the same cannot be said of other characteristics like colour, sound and the rest, each of which is perceived not by several senses but by only one; for the images of them which we have in our thought are always confused, and we do not know what they really are.⁸²

The above passages show that any sense perception that can be confirmed in more favourable perceptual circumstances, by another type of sense perception, by memory, or through a logical coherence where active Cartesian scepticism returned no reasonable doubt, then even those perceptions that are not initially clear and evident can lead to morally certain knowledge.

Descartes's rationale explains why everyday sense perceptions are not plagued by reasonable doubts. Most sense perceptions are beyond reasonable

⁸⁰ The effects of chromatic aberration can be reduced by increasing the focal length of the telescope. In simple terms, this means that a more powerful telescope requires an impractically long tube to counter chromatic aberration. For example, according to Kingslake and Johnson (2010, 162-163), a 10-centimeter aperture would need a greater than 40-meter focal length telescope tube to negate chromatic aberration with seventeenth-century lenses. According to Turner (1969, 69), telescopes with extremely long focal lengths of 150 feet or more became common in astronomical study in the latter half of the seventeenth century.

⁸¹ *Meditations* (AT VII, 89; CSM, 61).

⁸² *Principles* (AT VIII A, 324; CSM, 286).

doubt because (i) if the circumstances are favourable, then what is perceived is clear and evident and there is no reason to doubt them, and (ii) if the circumstances are unfavourable, then we can usually investigate and confirm what we perceive. Furthermore, because we have experience interacting with perceptible objects, disagreements and different interpretations are uncommon. If there is disagreement, however, consensus can usually be found by utilizing other types of sense perceptions and undergoing a more thorough examination of the object.

Many of the observations that are made possible by telescopes and microscopes, however, cannot be confirmed in the same way that naked eye sense perceptions can be. Descartes's explanations for why we can trust our sense perceptions suggests that any object that is only perceptible in a telescope or microscope is, to use Descartes's phrase, *always confused*. If an optical instrument observation is confused, then the reasonable doubts of theory-ladenness and interpretation would have to apply to those observations. To explain, for Descartes, when something is *clearly and distinctly perceived*, it is self-evident. In comparison, when something is confused, it is not self-evident.⁸³ If an observation is not self-evident, then the observation could be influenced by an observer's already held principles. Furthermore, interpretation is necessary to understand what one is observing. It follows that a confused observation is susceptible to both the theory-ladenness and interpretation doubts. Without further confirmation, there is no way for a confused observation to lead to morally certain knowledge because there is reasonable doubt.

To elaborate on this point, consider Ian Hacking's explanation for why we can trust what we observe in modern microscopes. Hacking writes:

[...] we have by and large got rid of aberrations; we have removed many artefacts, disregard others, and are always on the lookout for undetected frauds. We are convinced about the structures we seem to see because *we can interfere with them in quite physical ways*, say by microinjecting. *We are convinced because instruments using entirely different physical principles lead us to observe pretty much the same structures in the same specimen.*⁸⁴

Hacking argues that we can have faith in observations made through modern microscopes (and presumably through telescopes) because we have both eliminated aberrations from our instruments and developed the experience needed to understand what we are observing. The necessary experience is acquired by using different sorts of instruments and by interacting with what is observed. In the early seventeenth century, however, there were no telescopes and

⁸³ See Lennon (2016, 119 and 121).

⁸⁴ Hacking (1985, 152). Italics added for emphasis. Hacking is rebutting van Fraassen's anti-realism, but his point is applicable here as well for illustrative purposes.

microscopes that used means other than optical refraction, such as radio telescopes and electron microscopes.⁸⁵ Furthermore, the ability to interact with microscopic objects would be extremely limited and ineffective for early modern observers, and there would be no way of interacting with celestial phenomena seen through telescopes. Without the ability to confirm an observation with different types of instruments and without the ability to interact with what is being observed, the possibility of reasonable doubt still stands.⁸⁶

In situations where optical instrument observations are not self-evident and cannot be confirmed by some other means, then Descartes cannot claim to have morally certain knowledge about what is observed. He may strongly believe what is seen through the optical instrument and may even find what he observes to be highly probable, but reasonable doubt would have to apply and therefore moral certainty could not be attained.

The science of the *Optics* and Descartes's explanation for why we can trust the senses assures that ordinary sense perception, including those sense perceptions aided by eyeglasses and magnifying glasses, can lead to morally certain knowledge. However, optical instrument observations of objects that are too remote or too small still admit of reasonable doubt because these observations cannot be confirmed by something other than a refracting telescope or microscope. Considering this, if an optical instrument observation cannot be confirmed, then the observation cannot lead to morally certain knowledge; however, it may classify as a highly probable belief. Though the tools and techniques necessary will eventually come to be, they were unavailable to Descartes, which should preclude talk of optical instruments revealing knowledge of nature when what is observed cannot be confirmed. Without the possibility of confirmation, the most interesting observations made through telescopes and microscopes, such as observations of mountains on the moon and the crystalline structure of salt, are subject to reasonable doubt and cannot lead to morally certain knowledge.⁸⁷

To illustrate, consider the following example. Imagine that Descartes makes two sets of observations using a telescope that was crafted following his specifications. The first observation is of a faraway steeple on a building that he has never seen before. He observes through the telescope a blurred image of a

⁸⁵ Mersenne had an idea for a reflecting telescope, but Descartes discouraged him from moving forward on the construction. See King (1979, 48-49).

⁸⁶ It may be countered that introducing Hacking is an anachronistic attack against an early modern thinker; however, there is nothing in what Hacking says that Descartes has not considered.

⁸⁷ The problem here is somewhat related to Hatfield's (1988, 257) point that achieving certainty about hypotheticals might be possible for Descartes with extensive experimentation. Experimentation serves as a way to eliminate alternative possibilities so that any possible explanation that remains can become certain.

cross on top of the steeple. Intrigued, he walks toward the steeple before making his second observation. From close by, he can confirm his telescope observation. Since he explains that our sense perceptions can be trusted in favourable perceptual circumstances, his belief about the steeple is morally certain. Furthermore, if he found some reason to doubt his naked eye sense perception, he could investigate by climbing the steeple and touching the cross. After returning home, he then points his telescope toward space. Using the telescope, he believes he is observing a blurred image of Ganymede, the largest moon of Jupiter. Descartes has no other instruments at his disposal that can confirm his observation, and he finds that Ganymede is imperceptible to his naked eye. Because he has no ready means to confirm his observation, he should have reasonable doubt that undermines the possibility of his observation leading to morally certain knowledge.

Perhaps there is another way for Descartes to confirm an optical instrument observation of an inaccessible object. In order of ascending strength, he could (i) repeat his observation using the same optical instrument, (ii) repeat the observation using a different optical instrument of the same type, and (iii) have colleagues repeat his observation using their optical instruments. The first option is insufficient. Descartes could be focused on a speck of dust near the objective lens, a permanent flaw in the lens, or he could have convinced himself that he was viewing Ganymede when he was, in fact, viewing Ceres.⁸⁸ The first option is plagued with the reasonable doubts of image quality, theory-ladenness, and interpretation. The second option would eliminate the specific examples of deception that I mention (i.e., dust on the objective lens or a permanent flaw in the lens), but it cannot overcome the possibility of repeating the original misinterpretation. Galileo's repeated misinterpretations of the shape of Mars and van Leeuwenhoek's repeated misinterpretations of human spermatozoa serve as evidence of this possibility.⁸⁹ Galileo's and van Leeuwenhoek's errors should cast at least some doubt on this method of confirmation. The best option is to have colleagues repeat and potentially corroborate Descartes's observation. The third option could, with time, diminish the theory-ladenness and interpretation doubts through a diversity of observations and community consensus.

Though the community approach to confirmation may be the most fruitful option, it would be an uncharacteristic move for Descartes. To him, science is not a community endeavour.⁹⁰ He writes:

⁸⁸ Ceres is the largest object in the asteroid belt.

⁸⁹ According to Biagioli (2001, 279), Galileo is known to have used many different telescopes. Also, Lane (2015, 6) shows that van Leeuwenhoek had at least 13 microscopes that he used.

⁹⁰ Garber (2001, 314-315).

[...] as for observations that others have already made, [...], they are for the most part bound up with so many details or superfluous ingredients that it would be very hard [...] to make out the truth in them. [...] So if there were someone in the world whom we knew for sure to be capable of making discoveries of the greatest possible importance and public utility, [...], I do not see how they could do anything for him except to contribute towards the expenses of the observations that he would need and, further, prevent unwelcome visitors from wasting his free time.⁹¹

In the above passage, it is clear that Descartes disapproves of relying on and accepting others' observations, effectively eliminating the possibility of confirming optical instrument observations through community and consensus.⁹² Though he could have later changed his mind, there is no evidence that he would be willing to take a consensus approach to confirming an observation.

The argument I offer from the *Optics* cannot, on its own, extend moral certainty to observations made outside of our natural sense perception capabilities because reasonable doubt still lingers. The apparent veracity of observations made through optical instruments does not ensure that these observations directly lead to morally certain knowledge. It follows that what is observed must be confirmed or corroborated through another means in order to eliminate reasonable doubt and allow for the possibility of morally certain knowledge. So, for Descartes, any optical instrument observation that extends beyond our natural sensory limits and is not self-evident or is unable to be confirmed or corroborated by some other means, should be subject to enough reasonable doubt to undermine moral certainty.

Ultimately, this offers a possible explanation for why Descartes never relies on telescope or microscope observations in his published scientific works. Namely, no matter how closely the artisan followed Descartes's lens-grinding method and how well-crafted the lenses were, any observations that extended beyond mundane observations would be subject to enough reasonable doubt to undermine the possibility of having moral certainty. Given that Descartes focused on attaining morally certain knowledge in his scientific endeavours, he could not rely on the most interesting observations made by telescopes and

⁹¹ *Discourse* (AT VI, 73; CSM, 148).

⁹² Coady (2002, 12) writes that Descartes was at odds with "the facts of scientific co-operation and mutual dependency in the uncovering of truths that are (often extremely) difficult to discover." Notably, Gelfert (2006, 628) writes, with italics added for emphasis: "It seems fair to say that, *second perhaps only to Descartes*, Kant has come to be seen as the prototypical example of a philosopher in the 'individualist' tradition—that is, a tradition according to which 'testimony has little or no epistemic importance.'"

microscopes because they did not reveal clear and self-evident images and could not be confirmed by other means.⁹³

Even though optical instrument observations that cannot be confirmed admit of reasonable doubt, it does not follow that these observations must be dismissed altogether or that they are necessarily false. Rather, Descartes could accept these observations as highly probable, that is to say, dubitable but backed by considerable evidence and useful in various regards.⁹⁴ Unconfirmed observations can still be useful if, for example, they are consistent with conjectured beliefs or found to be of instrumental value, but unconfirmed observations that are not self-evident cannot, by Descartes's lights, lead to morally certain knowledge of nature.⁹⁵

6. Conclusion

Telescopes and microscopes could be deceptive in a variety of ways, and I have attempted to show that Descartes should have had significant reasonable doubt in optical instruments. On his behalf, I reconstructed an argument from the *Optics* that explains how optical instruments may reveal morally certain knowledge of nature. I conclude that the observable range that can outright lead to morally certain knowledge is limited. The argument reconstructed from the *Optics* only assures the moral certainty of observations that are "so clear and so evident" that what is being observed cannot be denied or if it is not clear and evident, then what is observed must be confirmable by some other method.⁹⁶ Observations that go beyond the limits of naked eye perception need another means of confirmation that Descartes and his contemporaries did not have at their disposal. So, if an observation made through an optical instrument tells us *X* about an object, then Descartes could classify *X* as morally certain if and only if *X* is either self-evident or can at least be confirmed by a naked sense perception or by a different type of instrument. If *X* cannot be confirmed by something other than a single type of optical instrument, then there is reasonable doubt that undermines the moral certainty of *X*. The need for confirmation means that, for Descartes, optical instruments should be limited; only mundane observations made through optical instruments can outright achieve moral certainty. This outcome makes many of the most interesting optical instrument observations that Descartes could have been capable of making, such as perceiving the moons of Jupiter, the phases of Venus, or the existence of spermatozoa, subject to reasonable doubt and uncertainty.

⁹³ Less discerning natural philosophers and empiricists that were less focused on *certain knowledge*, however, could rely on optical instruments in their scientific enterprises.

⁹⁴ Arnauld and Nicole (1996) argue that probability is the next option when not morally certain.

⁹⁵ See Kuhn (1977, 356-367), Laudan (1984), and Longino (1996, 39-58) for examples of scientific values.

⁹⁶ Descartes to Mersenne, 5 October 1637 (AT I, 450-451; CSMK, 74).

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Abbreviations

AT	Descartes, René. 1964. <i>Oeuvres De Descartes</i> , edited by Charles Adam and Paul Tannery. 11 vols. Paris: Librairie Philosophique J. Vrin.
CSM	Descartes, René. 2009. <i>The Philosophical Writings of Descartes</i> , edited by John Cottingham, Robert Stoothoff, and Dugald Murdoch. 2 vols. Cambridge: Cambridge University Press.
CSMK	Descartes, René. 1991. <i>The Philosophical Writings of Descartes: The Correspondence</i> , edited by John Cottingham, Robert Stoothoff, Dugald Murdoch, and Anthony Kenny. Cambridge: Cambridge University Press.
Discourse	Descartes, René. 1637. <i>Discourse on the Method of Rightly Conducting One's Reason and of Seeking Truth in the Sciences</i> .
Meditations	Descartes, René. 1641. <i>Meditations on First Philosophy</i> .
Optics	Descartes, René. 1637. <i>The Optics</i> .
Principles	Descartes, René. 1647. <i>Principles of Philosophy</i> .
Replies	Descartes, René. 1641. <i>Objections and Replies</i> .
Search	Descartes, René. 1701. <i>The Search for Truth by Means of the Natural Light</i> .

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