Chapter 6
Quantification and Certainty

Abstract In this chapter, I examine the context in which Sanctorius presented his measuring instruments in his publications. In difference to previous studies, which often have focused solely on the *Commentary on Avicenna*, this being the only work in which Sanctorius included illustrations of his instruments, I analyze the measuring instruments in the light of all that Sanctorius published. Furthermore, I scrutinize the relation of the various instruments to each other and discuss Sanctorius's possible complementary use of them. Of particular interest in this context is the role of the *De statica medicina*, which has become a keyword for Sanctorius's quantitative approach to physiology. These considerations will serve as an introduction to an in-depth study of Sanctorius's measuring instruments in Chap. 7, and reveal the agenda behind his quantification efforts—to enhance certainty in medicine. Given that the degree of conjecture in medicine was a contested issue in traditional introductory discussions in contemporary works on medicine, I examine Sanctorius's claim to enhance certainty through quantification, measurements, and instruments against the backdrop of the prevailing discourse(s) therein. While it is immediately obvious that Sanctorius departed from traditional views by introducing new quantitative procedures into medicine, the investigation of the roles that he assigned to logical reasoning, on the one hand, and to experience, empirical knowledge, and his new methods of quantification, on the other, draws a more complex picture regarding the combination of theory and practice in his works.

Keywords Certainty · Experience · Experiment · Quantification

Before analyzing Sanctorius's individual measuring instruments in more detail, in the following chapter, I will examine, more generally, the context in which Sanctorius presented these devices in his works. Since he published illustrations of them (and indeed of all of his instruments) exclusively in the *Commentary on Avicenna*, and only occasionally and superficially referred to them in his other books (Sect. 4.2), previous studies on Sanctorius's measuring instruments have

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often focused on this work.[1] In contrast, I shall consider the measuring instruments in the light of all of Sanctorius's published work, noting not only their mention, but also their omission. Moreover, I will scrutinize the relation of the various instruments to each other as well as Sanctorius's possible complementary use of them. In this context, the role of the *De statica medicina*, having become a keyword for Sanctorius's quantitative approach to physiology, is of particular interest. These considerations will serve as an introduction to an in-depth study of Sanctorius's measuring instruments in Chap. 7 and reveal the agenda behind his quantification efforts—to enhance certainty in medicine.

6.1 Measuring the Quantity of Diseases: Four Instruments

The four of Sanctorius's instruments to have received the most scholarly attention are: the *pulsilogium*, the thermoscope, the hygrometer, and the weighing chair that Sanctorius used to observe insensible perspiration.[2] In the secondary literature, they are often mentioned in connection with the sixth question (*quaestio*) of Sanctorius's *Commentary on Avicenna*, which discusses why the medical art is conjectural.[3] Sanctorius stated:

> The medical art is conjectural because of the quantity of diseases, of remedies, of virtues, because of idiosyncrasies or properties of nature and because of the individual conditions [of patients]. The reason why the quantity is conjectural is because in the first book of *Ad Glauconem*, at the beginning, and in the third chapter of the third book of *Methodi* Galen says *that the quantity of each thing can neither be written nor said*. With regard to the quantity of diseases, Galen states in the fifteenth chapter of the ninth book of *Methodi* that *in order to apply a remedy, not only the type of the disease must be known, but also its quantity*, which, according to the fourteenth chapter of the ninth book of Galen's *Methodi is a certain measure of the quantity of the deviation (recessus) from the natural state and this quantity can only be known by conjecture*. We have pondered for a long time, how that quantity of diseases can sometimes be partially known. We have invented four instruments (Sanctorius 1625: 21).[4]

[1] See e.g., Mitchell 1892, Miessen 1940, Guidone and Zurlini 2002: 129–133. Important exceptions are Bigotti and Taylor 2017, Bigotti 2018.

[2] Sanctorius usually refers to methods of measuring the humidity of air rather than to the two hygrometers he devised (Sanctorius 1612b: 105, 229 f., Sanctorius 1614: 20v–21r, Sanctorius 1625: 7, 522, Sanctorius 1629a: 24). The fact that he first mentions and illustrates these devices in the *Commentary on Avicenna* implies that he developed them in the period between his publication of the *De statica medicina* in 1614, and of the *Commentary on Avicenna* in 1625 (Sanctorius 1625: 23 f., 144, 215, 305). For the sake of simplicity, I subsume under the term "hygrometer" both the methods of measuring air humidity and the two instruments Sanctorius developed for this purpose. Distinctions between the instruments and the methods as well as their relation to each other are explored in Sect. 7.4.

[3] E.g., Ettari and Procopio 1968: 88, Grmek and Gourevitch 2001: 2010 f., Sanctorius and Ongaro 2001: 24 f., Bigotti 2016: 4 f.

[4] "Ars medica est coniecturalis ratione quantitatis morborum, remediorum, virtutis, ratione idiosyncrisiae, i. proprietatis naturae, & ratione conditionum individuantium. Ratione quantitatis est

From this citation it seems that the four measuring instruments constituted a coherent program of measurements, which were developed in response to Galen's assertion that it was impossible to detect the quantity of a disease, that is, the measure of divergence in a body from its natural state. Accordingly, historians have interpreted them as interdependent devices, used complementarily by Sanctorius.[5] Yet, perusal of all the passages in which Sanctorius referred to his measuring instruments reveals a more ambiguous relation between the instruments and their use. Around two hundred pages after the quoted citation, Sanctorius mentioned only the *pulsilogium*, the thermoscope, and the hygrometer, in a discussion that touched on the same aspects as the sixth question referred to above. Sanctorius here again explained that he had invented instruments to determine the "certain measures of the affections of the body" (Sanctorius 1625: 214 ff.). Moreover, a hundred pages later still, Sanctorius referred only to two instruments: the thermoscope and the hygrometer. By means of these two devices, he explained, it was possible to discern a balanced and an imbalanced complexion. Interestingly, in his description of the weighing chair, with which he conducted his static observations, Sanctorius made no mention of any other device (Sanctorius 1625: 304 f., 555–8).

In the *Commentary on Hippocrates*, he grouped the four instruments together differently again. While he dealt with the question of why the medical art was conjectural in almost the same manner as in the *Commentary on Avicenna*, referring therefore to all four of the measuring instruments, in a later passage of *Hippocrates*, Sanctorius spoke of the *pulsilogium*, the thermoscope, and the weighing chair as the three instruments that served his pursuit of a "certain knowledge of the quantity of the vital virtue" (Sanctorius 1629a: 23 ff., 136 f.). A look into the *Commentary on Galen* shows that here, too, Sanctorius discussed the measuring instruments in various combinations. Published in 1612, two years before the *De statica medicina*, 13 years before the *Commentary on Avicenna*, and 17 years before the *Commentary on Hippocrates*, the work already contains all of the four instruments and yet does not present them together as a group.[6] In the discussion of the possibility of measuring deviations from the balanced complexion, which Galen had considered impossible, Sanctorius suggested three instruments: the thermoscope, the *pulsilogium*, and the hygrometer. A few chapters later, however, writing on this same topic, he referred to the thermoscope, the *pulsilogium,* and the weighing chair, but not to the

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coniecturalis: quia Galenus primo ad Glauconem in principio, & 3. meth. 3. dicit, *quod nec scribi, nec dici potest de unoquoque, illud esse quantum*. Ratione quantitatis morborum: Galenus enim 9. Meth. 15. dicit, *ut verum exhibeatur remedium, non solum oportet cognoscere morbi speciem, sed etiam eius quantitatem, quae ex Gal. 9. Meth. 14. est certa mensura quantitatis recessus à naturali statu, quae quantitas solum coniectura haberi potest*. Nos diu cogitavimus, quomodo illud quantum morborum aliqua ex parte aliquando cognosci possit. Excogitavimus quatuor instrumenta." See: Sanctorius 1625: 21. Original emphasis.

[5] E.g., Ettari and Procopio 1968: 88, Grmek and Gourevitch 2001: 2010, Bigotti 2016: 5.

[6] In Sanctorius's first published work, *Methodi vitandorum errorum*, reference is made only to the *pulsilogium* and it can be assumed that Sanctorius had not yet developed either the thermoscope or the hygrometer. But according to his own testimony, he must already have been engaged in the weighing procedures whose results he later published in the *De statica medicina* (Sanctorius 1603: 109r–109v) (Sect. 2.2).

hygrometer (Sanctorius 1612b: 229 f., 374 ff.). Contrary to this, in the *De statica medicina*, published 2 years after the *Commentary on Galen*, Sanctorius mentioned the hygrometer and the thermoscope, but did not allude to the *pulsilogium* (Sanctorius 1614: 20v–21r).

Thus, Sanctorius's varying grouping of the four measuring instruments calls into question whether he really conceived of them as complementary parts of an overall program geared to the quantification of physiological parameters and fundamental to his novel doctrine of static medicine—the *Ars de statica medicina*. As has become apparent, the different combinations do not stem from the chronological development of his instruments, or medical theory, as different combinations can be found in the same work, even in Sanctorius's last book, the *Commentary on Hippocrates*, published in 1629.[7] In the following, a closer examination of the theoretical context in which Sanctorius presented the measuring instruments in his different books will shed more light on their relation to each other and, more generally, on Sanctorius's quantification efforts.

6.1.1 Galen's Latitude of Health Quantified: The Measurement of Disease, Virtue, and Humors

Sanctorius presented his measuring instruments in his published works mostly in relation to the question of the quantity of diseases, which was taken to mean a deviation (*recessus*) from the natural state of a body, i.e., from its temperate, balanced complexion. Sanctorius presented his measuring instruments as a direct advancement of Galenic medicine, as a solution to a problem that Galen had been unable to resolve. According to the Greek physician, so Sanctorius, it was impossible to determine quantity in medicine and medicine therefore had a conjectural character. In Chap. 5, it has been outlined that Galen tried to classify the complexion of drugs and of human bodies along ranges, or latitudes, which permitted of degrees. These degrees were, however, not expressed in numerical values and so remained conjectural, as, according to Galen, the intensity of a drug and likewise the complexion of a patient could be detected only by touch (Sect. 5.2). This is where Sanctorius stepped in. Sanctorius thought it possible to establish the norm for individuals, i.e., their natural state, and to measure deviations from that norm by measuring various parameters, such as the pulse and respiration, the heat of the body, and its parts, as well as the surrounding air, perspiration loss, and the humidity and dryness of the air. Doing so would enable him to put numerical values to the gradual differences that occurred in health and disease in the complexions of bodies. How Sanctorius conceived of this in detail and how he put this into practice with regard to the respective measuring instruments will be considered below.

[7] As mentioned earlier, Sanctorius published the *Commentary on Hippocrates* together with another work entitled *De remediorum inventione*, which, however, contains no reference to his measuring instruments (Sect. 2.6 and 5.2.4).

Browsing through the different passages in which Sanctorius mentioned his measuring instruments, the theoretical context is more or less identical to the one just portrayed. Hence, the differing groupings of the four devices are not connected to the specific text in which they appear. Yet, two passages deserve further mention, as they diverge slightly from the others. As stated above, in the *Commentary on Hippocrates*, Sanctorius mentioned the *pulsilogium*, the thermoscope, and the weighing chair in relation to his efforts to determine the quantity of the vital virtue and not, as was otherwise the case, with regard to the natural state of a body and the deviation (*recessus*) from it (Sect. 6.1). According to Galenic medicine, the vital spirits conveyed vital virtue, a power which ensured that life itself was maintained. This vital virtue manifested itself in the rhythms of heartbeat, pulse, and respiration. Thus, its relation to Sanctorius's *pulsilogia*, which served to measure pulse and respiration, is clear. Furthermore, the principal product of respiration was thought to be heat, generated and distributed by the heart as well as the arteries. Given that the arteries contained blood mixed with vital spirit, which in turn conveyed vital virtue, it is understandable why Sanctorius employed the thermoscope, too, in order to measure the vital virtue of a body.[8] He explained, for example, that, in acute diseases, a large increase in heat over a period of a few days indicated that the vital power was steady. In addition, heat was crucial for the digestive process. As insensible perspiration resulted from the processes of respiration and digestion, the connection between the quantification of the vital virtue and Sanctorius's observations with the weighing chair is also clear.[9] However, here again, the question remains: Why did Sanctorius, in omitting the hygrometer, fail to mention all four of his measuring instruments? Since the vital spirits were generated from inhaled air, the humidity or dryness of the air must have been important to the vital virtue. Moreover, as shown above (Sect. 3.3.1), air was thought to be the most important factor of the six non-natural things and the quality of air had a considerable effect on insensible perspiration. Therefore, Sanctorius's reasons for excluding the hygrometer, when seeking to determine the quantity of the vital virtue, remain obscure (Sanctorius 1629a: 136 f.; Siegel 1968: 163; Siraisi 1990: 107 ff.).

Taking all the aspects into consideration, it seems that Sanctorius considered the power of the vital spirits, the vital virtue, to be one of the various parameters that indicated how much a body deviated from the normal, healthy condition. Earlier in the *Commentary on Hippocrates*, he wrote that the vital virtue was robust only in those whose four humors were "in symmetry" and whose body parts were "optimally uniform." Hence, measuring the robustness of the vital power enabled one to determine the humoral balance, i.e., the health of a patient (Sanctorius 1629a: 86).

The second passage that differs a little from Sanctorius's usual presentation of his measuring instruments is the description of the weighing chair in the *Commentary on Avicenna*. Instead of referring to the measurement of the natural state of a body,

[8] The connection between Sanctorius's use of thermoscopes and Galenic concepts of fever will be considered below, see: Sect. 7.3.2.

[9] For more information on the generation of the vital spirits and the processes of respiration and digestion, see Sects. 3.2.5 and 3.2.6.

he included the explanation of his large steelyard in a discussion of the signs that indicated the quantity of humors necessary to preserve health. Sanctorius explained that, according to Avicenna, not only the proportion of the four humors in the body was important, in order to preserve health, but also their quantity. However, Avicenna did not teach how to determine this quantity and Galen held it impossible to gain knowledge of it, per Sanctorius. He continued: "But after having thought about this for a very long time, we invented static medicine, in which we declared when the quantity and proportion of the humors can be found in our body" (Sanctorius 1625: 555).[10] With reference to Galen's teachings, Sanctorius argued that the quantity of the humors could be determined by measuring the ratio between ingestion and excretion. If the intake of nutrition corresponded to the output of sensible and insensible evacuations, the humors would be balanced, quantitatively and proportionally, and health would be preserved. It is to be recalled here that, according to Galenic physiology, the humors were generated during the digestive process from the ingested nutrition. Thus, Sanctorius measured the quantity of the humors only indirectly, by observing the equilibrium between the substances the organism consumed and those it rejected. A lack of equilibrium in this regard indicated an imbalance in the humors and hence a deviation from the natural healthy state (Sects. 3.1.2 and 3.2). Accordingly, like the robustness of the vital virtue, the quantity or, rather, the balance of the humors, measured via intake and output, was another parameter that helped Sanctorius determine the natural state of a body (Sanctorius 1625: 555 f.).

In this context, it is interesting to note that Sanctorius referred in his discussion of how to determine the quantity of humors not only to Avicenna and Galen, but also to another physician: Jacques Despars (ca. 1380–1458). The French doctor was famous for his commentary on Avicenna's *Canon* and this is the work that Sanctorius mentioned here. He explained that Despars, in dealing with the same issue, had written that the quantity of the humors must be equivalent to the release (*resolutio*) from the body parts and the spirits. But according to Despars, so Sanctorius, these daily evacuations could not be quantified, since a lot of them were released insensibly. Hence, Despars had already related the determination of the quantity of the humors to the measurement of insensible evacuations, but considered the latter impossible. Furthermore, he had already noted the great quantity of these excretions. This implies that Despars's commentary on Avicenna's *Canon* was a source of inspiration for Sanctorius's proposal to determine the balance of the humors by measuring insensible perspiration (Sanctorius 1625: 555 f.; Jacquart 1980).

As indicated above, Sanctorius did not point to any of the other measuring instruments in his description of the weighing chair in the *Commentary on Avicenna*. Even though the humors were directly linked to the primary qualities and to the individual complexion of a body and thus to its natural state, Sanctorius specifically and exclusively related the determination of the quantity of the humors to the weighing chair and to his measurement of insensible perspiration. This further calls into

[10] "Nos autem hoc diutissimè excogitando adinvenimus staticam medicinam, in qua declaravimus, quando in corpore nostro, & quantitas, & humorum proportio reperiatur." See: Sanctorius 1625: 555.

question the role of the *De statica medicina* as an overall framework for Sanctorius's quantification of physiological parameters by means of his four measuring devices. The fact that Sanctorius related his weighing procedures to the preservation of health, namely to the question of how to find the quantity of humors that was needed to preserve health, underscores the orientation of the *De statica medicina* toward individual hygiene and its dietetic handbook character (Sect. 4.1). Yet, in view of the strong connection of his other measuring instruments to the six non-natural things, such as the thermoscope and the hygrometer, the context of the preservation of health does not set the *De statica medicina* apart. Why then did Sanctorius not mention here the other measuring devices? And why did he point in only one of the many aphorisms of the *De statica medicina* to the thermoscope and the hygrometer, and not at all to the *pulsilogium*? To explore these questions, I shall take a closer look at Sanctorius's representation of the *De statica medicina* in his published works. Consideration of the different contexts in which Sanctorius mentioned the work will enhance understanding of the role that Sanctorius assigned to the *De statica medicina* and its relation to the other measuring instruments.

6.1.2 *The Relation of the* De statica medicina *to the Measuring Instruments*

Sanctorius first mentioned the *De statica medicina* in the *Commentary on Galen*, which was published 2 years earlier than the aphoristic treatise. In most instances, Sanctorius referred to the *De statica medicina* in the context of the measurement of insensible perspiration, and more generally, of bodily evacuations, sometimes in connection with the digestive process. Moreover, he included references to his weighing procedures in discussions of the non-natural things and at times highlighted their importance for the preservation of health. The same picture emerges with regard to his other two commentaries—the *Commentary on Avicenna* and the *Commentary on Hippocrates*.[11] In the few passages in which Sanctorius grouped the *De statica medicina* together with other measuring instruments, the context is, as outlined above, the determination of the deviation of a body from its natural healthy state and the measurement of the quantity of the vital virtue.[12] Hence, Sanctorius usually presented his weighing procedures in isolation from his other quantification efforts. If he did mention the *De statica medicina*, i.e., the weighing chair, in

[11] In his two other published books, *Methodi vitandorum errorum* and *De remediorum inventione*, Sanctorius does not refer to the *De statica medicina*. For Sanctorius's references to the *De statica medicina* in his three commentaries, see: Sanctorius 1612a: 139, 348, 352 f., 358, 447, 496, 756 f., 759, 761, Sanctorius 1612b: 4, 40, 48, 71 f., 84 f., 87, 95, 198, 342, 357, 374 f., Sanctorius 1625: Ad lectorem, 7, 23 f., 27 f., 60, 68, 81, 157, 161, 264, 373, 375, 394, 522, 555 ff., Sanctorius 1629a: 23 f., 70 f., 78, 137, 204, 207, 210, 276, 291, 300 f., 309 f., 367, 381 ff., 429, 469.

[12] The text passages in which Sanctorius connects the *De statica medicina* with other measuring instruments are Sanctorius 1612b: 374 ff., Sanctorius 1625: 21–5, Sanctorius 1629a: 23 ff., 136 f.

connection with some of his other measuring instruments, then not in isolation, but ranked among the other devices. This reinforces the impression that static medicine was not a sort of superstructure for Sanctorius's physiological measurements, but rather served to determine certain parameters that, together with his other quantitative examinations, indicated to him the quantity of disease. In the preface to the *Commentary on Avicenna*, when Sanctorius proclaimed his new approach to the teaching of theoretical medicine, he wrote of his "instruments and static experiments"—a statement that highlights the specificity of the weighing chair and its differentiation from Sanctorius's other instruments.

Interestingly, apart from the description of the weighing chair in the *Commentary on Avicenna*, Sanctorius never referred to the actual instrument with which he conducted his observations of insensible perspiration. Instead, he wrote of his "static medicine" (*statica medicina*), "static experiments, experiences, and observations" (*staticis experimentis*, *staticae experientiae*, *staticis observationibus*), or simply "our statics" (*staticis nostris*). At this point it should not be forgotten that Sanctorius expressly gave his aphorisms the title ***Ars*** *… de statica medicina* and also repeatedly wrote in his commentaries about his "static art" (*statica ars*). As elucidated in Chap. 3, static medicine was about much more than a steelyard and other weighing measurements. It also comprised Sanctorius's new interpretation of the doctrine of the six non-natural things, which he considered apparently to be a whole new medical art, in which the instrument was but a means to achieve the ultimate goal: the exact measurement of insensible perspiration. Indeed, the *De statica medicina* contains neither an illustration nor a description of the weighing chair. Only to later editions published after Sanctorius's death in 1636 were an illustration and a description of the steelyard sometimes added, reproduced from the *Commentary on Avicenna*. Thus, the focus of static medicine was not the weighing chair and its use, but rather the results of the weighing procedures and the conclusions that Sanctorius drew from them.

While the further implications of Sanctorius's labelling of static medicine as an art are explored below, what is of interest here is that Sanctorius seemingly distinguished this static art from his use of other measuring devices. The equal ranking of the *De statica medicina* and his other instruments stands in stark contrast to the importance that Sanctorius occasionally assigned to static medicine, namely that healing and preserving health was impossible without a knowledge of the quantity of insensible perspiration in patients (Sect. 5.4.1). In view of this, it is curious that Sanctorius did not always mention the *De statica medicina*, i.e., the weighing chair, when dealing with the measurement of how much a body deviated from its natural state (Fig. 6.1). Moreover, in the passages in which he grouped the weighing chair together with other measuring devices, he did not emphasize the former's relevance, which suggests that all of the measurements to which Sanctorius referred were of equal importance to him. Contrary to the thermoscope and the *pulsilogium*, whose complementary use Sanctorius explicitly described in the *Commentary on Avicenna*, as will be shown later, Sanctorius did not allude to any similar interrelated use of different instruments with regard to his weighing chair and the observation of insensible perspiration. In the aphorism of the *De statica medicina*, in which he

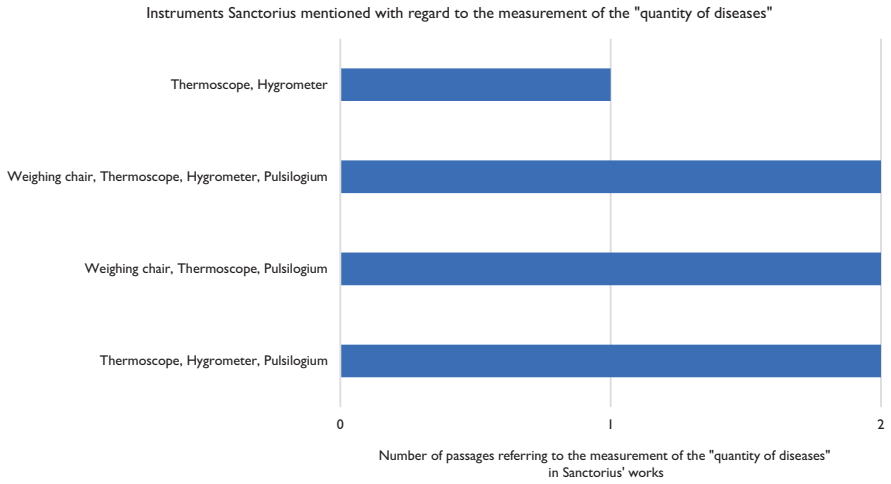

Fig. 6.1 Different combinations in which Sanctorius mentioned his instruments with regard to the measurement of the "quantity of diseases". (Sanctorius 1612b: 229 f., 374 ff.; 1625: 21–5, 214 ff., 304 f.; 1629a: 23 ff., 136 f.)

mentioned the hygrometer and the thermoscope, he did so in the section on the non-natural pair air and water, discussing how to determine the "weight of the air" (Sect. 5.3.2). The relation to insensible perspiration was thereby only indirect, since Sanctorius described the harmful effects of "heavy" air on insensible perspiration only in a later aphorism. Hence, the measurements that Sanctorius conducted with the thermoscope and the hygrometer seem not to have been included in his newly formulated rules of health that revolved around insensible perspiration and constituted for Sanctorius a new medical art. Concerning the *pulsilogium*, the fact that Galen's work *De pulsibus ad tirones* (On the Pulse for Beginners) was one of the sources for the doctrine of the six non-natural things, a work Sanctorius was very familiar with, and in which Galen used the expression "non-natural" when referring to the causes of alterations in the pulse, makes it even more obscure why Sanctorius did not refer to his *pulsilogia* in the *De statica medicina* (Sect. 3.1.1) (Sanctorius 1614: 20v–21v; 1625: 24, 76 ff., 219–22, 346).

Hence, it has become apparent that static medicine cannot be identified as an overall program of measurements conducted with various measuring instruments. Instead, the quantification of insensible perspiration by means of a weighing chair was only one of several means that helped Sanctorius quantify diseases, i.e., determine any deviation from the natural state of a body. Thus, there is a tension between the importance that Sanctorius ascribed to the *De statica medicina* and the rather minor role he gave to it when he mentioned the work together with the other measuring instruments. Furthermore, despite the strong relations between the six non-natural things and the thermoscope, the hygrometer, the *pulsilogia* and, as will be seen below, also the two steelyards that Sanctorius built to measure climatic conditions (Sect. 7.1), none of these instruments was integrated into the measurement of

insensible perspiration. These conclusions mirror those formulated in Chap. 3, where it was stated that static medicine cannot readily be identified as the overall framework of Sanctorius's works (Sect. 3.3.7).

6.2 The Question of Certainty in Medicine

The only two text passages in Sanctorius's works in which he mentioned his four measuring instruments together as a group are connected to the discussion of the same question: whether the medical art is conjectural. This was a standard question which featured in the traditional introductory discussions of medical knowledge and the place of medicine among the arts and sciences included in the opening sections of medical commentaries as well as in general works on medicine. In his discussion of these topics, Sanctorius argued that certainty in medicine could be greatly enhanced through the use of his weighing chair, *pulsilogium*, thermoscope, and hygrometer. In order to better understand this important feature of Sanctorius's four measuring instruments and, more generally, his integration of quantitative methods and instruments into the discussions of the conjectural character of medicine and the related aim of enhancing certainty in medicine, I will briefly outline the main issues that were at play and Sanctorius's stance on them.

6.2.1 Medicine—ars *or* scientia*?*

The authoritative differentiation of art (*ars*) and science (*scientia*) with regard to disciplines derives from Aristotle. Thus, in the discussions of the status of medicine as either an art or a science, the basic understanding of terms was Aristotelian. As Nancy Siraisi aptly summarized:

> *Scientia* is usually assumed to offer certain knowledge about universal truths arrived at by demonstration (that is, syllogistic reasoning) from generally accepted principles, and to be pursued for the sake of truth. Different *scientiae* are distinguished by their subject matter. … And *ars* is a rationally organized and transmitted body of knowledge or skill resulting in a product (not necessarily a material one) (Siraisi 1987: 226).

Hence, *scientia* was understood as a theoretical discipline concerned with the knowledge of universal causes that were hidden from the senses and could be perceived only by the mind. *Ars*, on the contrary, referred to practical skill and ordered knowledge. It was associated with empirical and individual aspects, with particulars perceived by the senses. While *scientia* offered certain knowledge, *ars* always involved conjecture. Medicine with its ambiguous position, swaying between the university classroom and the sickbed, was not easy to fit into either of the categories. In the Middle Ages and the Renaissance, academically educated physicians usually wanted at least some aspects of medicine to qualify as science, not least in

order to guarantee its high status as a core university subject. However, they also readily admitted that much of it belonged to the kind of knowledge identified as art. Without delving into the depths of the topic, which have been explored elsewhere, I shall focus here on Sanctorius's answer to the question.[13] His answer was clear and unambiguous: medicine is an art and not a science. In his three commentaries, he put forward several reasons why "medicine could by no means be *scientia*" (Sanctorius 1612a: 74). He thereby refuted not only the teaching of Avicenna—who considered medicine to be both a science and an art—and the academic medical convention of the fourteenth and fifteenth century, which upheld the latter's view, but also the opinions of those sixteenth-century medical commentators who claimed medicine for *scientia* alone.[14] Contrary to these authors, Sanctorius, in identifying medicine as an *ars*, saw himself in the tradition of Hippocrates, Aristotle, Galen, and Averroes. While a detailed analysis of Sanctorius's argument lies beyond the scope of the present work, certain statements deserve further consideration, as they help us appreciate Sanctorius's conception of medicine and medical knowledge.[15]

In the *Commentary on Galen*, Sanctorius explained that Aristotle had described arts as productive sciences (*scientias effectivas*). He thereby referred to the Aristotelian tripartite division of human knowledge, which was oriented to the purposes this knowledge served: speculative (i.e., theoretical), practical (related to leading a good and useful life), or "factive" (related to the production of things in the arts and trades). According to Sanctorius, it was clear that medicine was not a science, as the purpose of *scientia* was knowing (*scire*), while the purpose of medicine was operating (*operari*). However, this did not mean that medicine, as an art, concerned solely practical aspects or necessarily entailed the habitual practice of it. The habitus of an art could be acquired either from repeated activities (*iteratis actibus*) or from a master, explained Sanctorius in the *Commentary on Avicenna*, and it was hence possible to speak of "excellent theoretical and practical physicians [*medici theorici* and *practici*] who never exercised the art" (Sanctorius 1625).[16] Thus, on the one hand Sanctorius's clear identification of medicine as an art suggests that he highlighted the practical dimensions of medicine related to the senses and to utilitarian knowledge. On the other hand, he did not dismiss the intellectual dimensions of medicine, but, quite on the contrary, considered them of integral importance to the art. This ambiguous attitude toward the role of the senses and the

[13] For an account of the debates concerning the status of medicine as an art or a science, see: Siraisi 1981: 118–37, Ottosson 1984: 68–74, Siraisi 1987: 226–38.

[14] "… medicina nullo modo potest esse scientia, …." See: Sanctorius 1612a: 74.

[15] In the *Commentary on Avicenna* and in the *Commentary on Hippocrates*, Sanctorius discusses the question of whether medicine is an art or a science in separate *quaestiones*. See: Sanctorius 1625: 28–37, Sanctorius 1629a: 18–23. In the *Commentary on Galen*, Sanctorius refers to the issue in discussions about both the subject of Galen's *Ars medica* and definitions of medicine. See: Sanctorius 1612a: 9–15, 63–7. For an account of Sanctorius's arguments in the *Commentary on Avicenna*, see: Siraisi 1987: 236 f.

[16] "Respondemus dari duplicem habitum, vel acquisitum ex iteratis actibus, vel à magistro: hac enim ratione possunt dari optimi medici theorici, & practici, qui nunquam artem exercuerint, …." See: Sanctorius 1625: 29. The English translation is based on Siraisi 1987: 236.

role of the mind in gaining medical knowledge relates to the ambiguous relation between theory and practice that is found in Sanctorius's works. As was mentioned earlier, Sanctorius rejected the division of medicine into theory and practice in the university curricula, on the grounds that medicine, contrary to theory and practice, was a "factive" or operative art, meaning that its purpose was neither truth, as in the case of theory, nor action, as in the case of practice, but instead, operation, i.e., the preservation and restoration of health (Sect. 4.3) (Sanctorius 1612a: 64; Park and Daston 2006: 6).

With his strong emphasis on the nature of medicine as an art, Sanctorius was in line with a general trend at the beginning of the seventeenth century, namely to pay far greater attention to the status of medicine as an art. In conjunction with the revaluation of practical medicine, starting from the fifteenth century, the practical and social dimension of medicine was increasingly stressed, a development that, according to Ian Maclean, can be associated with the rising value attributed to therapeutics, to clinical precepting, and to the design of hospitals at this time (Maclean 2002: 70–5). Yet, there is one feature that distinguishes Sanctorius's concept of the "art of medicine" considerably from the conventions of Latin academic medicine and this was his quantitative approach to medicine and attendant use of instrumentation.

6.2.2 Enhancing Certainty in Medicine through Quantification

Contrary to the common Aristotelian understanding of *ars* as knowledge that offered no prospect of certitude, Sanctorius thought it possible to enhance or even to gain certainty. In a letter to his friend Senatore Settala (life dates unknown), in 1625, the year he published the *Commentary on Avicenna*, he stated:

> I send his Lordship the two books on Avicenna's text, as He wrote me, and I pray His Lordship to read them carefully, because He will read new thoughts, which are, however, based on the authorities of Hippocrates and Galen with regard to practice and experience. … Besides, He will frequently see the advantages which one can gain from the use of the static, invented by me, which one can certainly call mathematical medicine (*mathematica medica*) as it adds so much certainty to medical things (Castellani 1958: 5).[17]

Hence, according to Sanctorius, the *De statica medicina* increased the certainty of medicine to such an extent that it could be termed "mathematical" medicine. While the reference to mathematics certainly pointed to the quantitative method on which Sanctorius allegedly based his aphorisms, it also had other connotations. Based on

[17] "Mando a V.S. li 2 libri sopra la parte di Avicenna secondo mi ha scritto et prego V.S. che li lega con diligenza perchè legerà pensieri nuovi fondati però nella autorità di Hippocrate et Galeno, nella pratica et nella esperienza. … Di più vedrà spesso li benefitij che cavar si può dal uso della statica inventata da me la qual certo si può chiamar mathematica medica tanto ci fa certi nelle cose di medicina." See: Castellani 1958: 5. The translation is based on Bigotti 2016: 1.

the authority of Aristotle and of Averroes (1126–1198), mathematics was traditionally considered as the demonstrative science (*scientia*) par excellence, which thus provided knowledge with the highest degree of certainty.[18] By comparing his static medicine to mathematics, Sanctorius therefore made a very strong statement for the certainty of his newly invented art. In doing so, he claimed that it was possible for an art to achieve a degree of certainty comparable to that accomplished in the sciences and indicated that this certainty was attained by using the subject of mathematics, namely quantification. Along the same lines, in the *Commentary on Galen*, Sanctorius termed his aphoristic treatise "static theorems" (*staticis theorematibus*) and explained that his weighing procedures (*staticis experimentis*) were in the first degree of certainty. It seems, thus, that he thought that from the *De statica medicina*, understood as an art, knowledge of universal causes could be gained and that it was therefore possible to achieve certain knowledge from particulars by means that did not refer to deductive reasoning but to the senses—to the observations and experiences (*experimenta*) that he made with his weighing chair. This interpretation is reinforced by the fact that in the *Commentary on Hippocrates*, Sanctorius explicitly stated that the theorems (*theoremata*) of medicine were most certain (*certissima*), since, following Galen, the universal precepts of medicine had most certain and eternal truth (Sanctorius 1612b: 71, 95; 1629a: 23).

However, Sanctorius's claim to certainty in medicine was not limited to the *De statica medicina*, but also included some of his other measuring instruments. Coming back to the citation quoted at the beginning of this chapter (Sect. 6.1), in the discussion of the conjectural character of medicine, Sanctorius made it clear that elements of uncertainty could be greatly reduced not only by static medicine, but also through the use of his *pulsilogium*, thermoscope and hygrometer. In Sect. 6.1, I have outlined that Sanctorius usually presented these instruments, in varying combinations, as a solution to one aspect that made the medical art conjectural: the quantity of diseases. In this connection, he also frequently stressed the certainty that the use of his measuring devices provided. In the *Commentary on Galen*, he explained for example that the *pulsilogium* enabled one to know, not by conjecture but with the most certain knowledge (*scientia*), how much the movements of the pulse of a patient deviated from its natural state. Around a hundred pages later, Sanctorius similarly proclaimed that his four measuring instruments ascertained (*reddimur certi*) the quantity of the deviation from the natural state. In the *Commentary on Avicenna*, he wrote: "But we find out the quantities or certain measures of the affections with various instruments" (Sanctorius 1625: 215).[19] By means of the thermoscope and the hygrometer, Sanctorius maintained in the *Commentary on Galen*, one could exactly perceive the furthest degrees of active and

[18] The issue of the certainty of mathematics gained considerable attention in the second half of the sixteenth century, when a dispute arose over the question of the causes and foundations of this certainty and the way in which it was interpreted. For more information on Renaissance debates on the *certitudine mathematicorum*, see: De Pace 1993.

[19] "Nos verò instrumentis varijs adinvenimus quantitates sive certas affectuum mensuras …." See: Sanctorius 1625: 215.

passive qualities. He thereby alluded to the four primary qualities, which, according to Galenic medicine, could be divided into active qualities (hot and cold) and passive qualities (wet and dry) in accordance with the Aristotelian distinction between the active and the passive pair amongst the four elements. As the mixture of these primary qualities in the body, the so-called complexion, was the decisive factor for the body's state of health, measuring them was crucial, per Sanctorius, in order that deviations from the balanced complexion, i.e., from the natural, healthy state of a body, could be determined. The thermoscope and the hygrometer not only enabled him to *exactly* measure the primary qualities, but also to determine their "furthest degrees," as he explained. Referring to the Galenic concept of the latitude of qualities, this implies that by using the two instruments, extreme deviations from a healthy state could be measured (Sanctorius 1612b: 105, 229, 374).

In order to guarantee that the measurements provided certainty, some other factors had to be considered, too. The instruments needed to be used repeatedly in sickness and in health, the measuring results had to be carefully recorded, and even minor variations noted. In the *Methodi vitandorum errorum*, Sanctorius stated:

> … only from this comparison [of the pulse of the previous attack of disease and the present pulse] can we obtain a certain and infallible judgement on whether the patient is in a better or worse condition (Sanctorius 1603: 109r).[20]

In the same vein, Sanctorius described in the *Commentary on Avicenna* that the use of his thermoscope allowed one to compare febrile heat from 1 day to another, or from one paroxysm to another. On this basis, the physician could infer with certainty, so Sanctorius, whether the febrile heat increased, or decreased, and to what degree. An important point in this regard was that the instruments aided the physician's memory. According to Sanctorius, "no physician is provided with such ingenuity and memory as to be able, without the *pulsilogium*, to keep in mind the minimal differences of the movement and rest of the artery" (Sanctorius 1625: 222).[21] Therefore, Sanctorius continued, other physicians determined the pulse by conjecture, whereas he, by using his *pulsilogium*, could instead gain infallible knowledge (*cognitionem infallibilem*) of it. Hence, the measuring instruments not only served to quantify and to record a patient's state of health, but also helped the physician compile accurate data sourced from medical practice. Memorizing by heart the details of patients' histories also assured greater certainty in diagnosis. It is interesting to recall here that Sanctorius's choice of the *De statica medicina*'s form and structure was likewise informed by the wish to makes its content easier to memorize (Sect. 4.1.1). This testifies again to Sanctorius's strong concern for medical practice and his awareness of the pitfalls that a physician daily encountered at

[20] "… solum ex hac collatione certum & infallibile iudicium colligemus, an aeger sit in meliori, vel deteriori statu; …." See: Sanctorius 1603: 109r. The English translation is taken from: Bigotti and Taylor 2017: 87.

[21] "… nullus Medicus sit tam faelici ingenio, & memoria, qui posset sine pulsilogio tenere memoria minimas differentias motus, & quietis arteriae: …." See: Sanctorius 1625: 222. The English translation is taken from: Bigotti and Taylor 2017: 94.

the bedside. In this spirit, Sanctorius intended his measuring instruments, just as his other devices, to facilitate the work of practicing physicians and to improve therapeutics. What set the *pulsilogium*, the thermoscope, the hygrometer, and the *De statica medicina* apart was their ability to enhance the certainty of medical knowledge and thereby to improve the physician's judgment, his diagnosis. Notwithstanding that Sanctorius still adhered to the Aristotelian definition of *scientia* and thus placed his measuring instruments at the service of *ars*, he claimed that he could bring to the medical art a new precision which would, if not achieve absolute certainty, then in any case approximate it in a way never before believed possible. An epitome of Sanctorius's ambiguous concept of the status of medical knowledge can be found in the preface to the *Commentary on Avicenna*, where he explained that "through the long use and trial of all these things [healing, experiments, instruments, and static art], I found out that they can make this medical philosophy clear and manifest" (Sanctorius 1625: Ad lectorem).[22] Similarly to his description of the *De statica medicina* as a mathematical medicine, Sanctorius seemingly contradicted here his clear identification of medicine as an art. In naming the subject matter of medical theory "philosophy," he implied that he conceived of it as having the same status as philosophy, which was commonly assumed to be a science. What is more, he maintained that his medical approach, which was based on experience, observation, and the use of instruments, could enhance the clarity of this "philosophy" (Sanctorius 1625: 222; Siraisi 1987: 237 f.).

However, this is but one side of the coin. Along with the insistent claims as to the certainty of medicine, brought about by his new approach to the art, Sanctorius also repeatedly qualified his statements. An example of this can be seen in the citation quoted above, when he declared that he had "pondered for a long time, how that quantity of diseases can sometimes be partially known" (Sect. 6.1). In the *Commentary on Galen*, after having presented his *pulsilogium*, thermoscope, and hygrometer, he explained that these instruments enabled him to approximate the quantity of diseases to the greatest possible extent (*quammaxime*). This implies that, according to Sanctorius, a true, mathematical knowledge of this quantity could not be gained. In a later passage of the same work, Sanctorius made this even more explicit. He stated:

> … along with Galen at the start of the first book of [*De methodo medendi*] *ad Glauconem*, however, I shall admit that it is impossible that the ultimate and specific quantity will be fathomed by the physician, and so Galen rightly states that: "if I knew that quantity of action, I would consider myself to be as people say Asclepius was" (Sanctorius 1612b: 376).[23]

[22] "Hippocrates enim 2. Aphorismorum 17. vult, quod sanatio indicet morbum: Ego quoque Divini Senis imitation dico, quod & sanatio, & experimenta, necnon etiam instrumenta, & statica ars; quae omnia longo usu, & periclitatione adinveni, hanc medicam philosophiam reddere possint claram, & manifestam." See: Sanctorius 1625: Ad lectorem.

[23] "… quamvis fatear cum Galen 1. ad Glauc. in principio esse impossibile, ut illud ultimum & specificum quantum à medico penetretur: meritoque ibi dicit: si ego scirem illud quantum agendum, talem me reputarem, qualem fuisse ferunt Aesculapium." See: Sanctorius 1612b: 376. The English translation is based on: Bigotti 2018: 97.

Hence, in striking contrast to his insistent claims as to the certainty of medicine and his ability to achieve this certainty, Sanctorius apparently also had his doubts. In his last published commentary, the *Commentary on Hippocrates*, he cautiously wrote about the "quantity of diseases" which "might be occasionally perceived," and that he had invented four instruments for this purpose. Consequently, Sanctorius questioned the certainty with which the quantity of diseases could be determined in all three of his commentaries. In my opinion, it is significant that he did so in the two passages of his commentaries in which he explicitly dealt with the question of whether the medical art is conjectural—in the *Commentary on Avicenna* and in the *Commentary on Hippocrates*. Interestingly, these are also the only two instances in which he presented all four of his measuring instruments together as a group (Sanctorius 1612b: 230; 1625: 21–5; 1629a: 23–6).

To further blur the picture, when Sanctorius discussed the conjectural character of medicine, he did not only refer to the quantity of diseases, but also to other quantities that, following the Galenic teachings, made medicine uncertain: the quantity of remedies and the quantity of virtues. Moreover, idiosyncrasies and individual conditions of patients also added to the uncertainty of medicine, so Sanctorius (Sect. 6.1). Remarkably, while describing in some detail how the quantity of diseases could be ascertained by means of his instruments, Sanctorius offered hardly any solutions as to how to make these other conjectural factors more certain. Concerning the quantity of remedies, Sanctorius simply quoted various writings of Galen that relate to the latter's pharmacological theory and to the concept of the latitude of qualities (Sect. 5.2.2). From these, Sanctorius concluded that it was impossible to know with absolute certainty the strength of a remedy, i.e., its degree of intensity. In the *Commentary on Galen*, he explained that he used the weighing chair, the thermoscope, and the *pulsilogium* to determine the dosage of remedies, but this statement was followed by the assertion quoted above, that it was impossible to know the "ultimate and specific quantity." With regard to the quantity of virtues, matters are more ambiguous. I have shown above that Sanctorius held that he could gain certain knowledge of the quantity of the vital virtue by using three of his measuring instruments (Sects. 6.1 and 6.1.1). However, in discussing the question of the conjectural character of medicine, he made no reference to this solution, but briefly explained that it was necessary to know the quantity of the virtue in order to determine the quantity of remedies, both of which quantities remained conjectural, according to him. Thus, from today's standpoint, Sanctorius is once again equivocal, leaving one to wonder about his actual concept of medical knowledge and the status he assigned to his instruments and quantitative observations (Sanctorius 1625: 24, 215 f.; 1629a: 24 f.).

In contrast, on the question of the indeterminable nature of idiosyncrasies and individual conditions Sanctorius was clear: it was impossible to ascertain these two factors. Referring to Galen, he explained that it was necessary for the physician to know not only the common nature, but also individual natures, since there were, for example, people who had an idiosyncrasy that made them suffer so much from the smell of roses, or from eating cheese, as to fall at times into syncope (*lipothymia*). However, these properties of nature were as diverse as individuals and so

innumerable as to be hidden (*occultae*) from the physician. Even in the *De statica medicina*, described elsewhere by Sanctorius as a mathematical medicine, he included an aphorism that says:

> The quantity of insensible perspiration varies according to the differences of natural properties, of regions, of seasons, of ages, of diseases, of food, and of the other non-natural things (Sanctorius 1614: 2v).[24]

Thus, according to Sanctorius, the influence of individuals' peculiar nature, or constitution on their state of health could not be determined with any certainty, and this made individuals incomprehensible to the physician. However, he did tone down this element of uncertainty in medicine a little, by maintaining that the task of the physician was not to treat individuals but to treat specific diseases. Accordingly, he understood an effective medicine to be one that cured the same disease in any number of different people. This added a universal aspect to therapy and weakened the argument that medicine was conjectural because it dealt so largely with particulars and thus did not arrive at general truths (Sanctorius 1625: 25, 214 f.; 1629a: 25 f.).

What to make now of these noticeable ambiguities in Sanctorius's work? All things considered, it seems Sanctorius was convinced that his instruments provided certainty, since he often referred to the values gained with them as being "most certain" or even as having "mathematical certainty." However, when it came to determining quantity in medicine and, more generally, to those five factors that made the medical art conjectural—the quantity of diseases, remedies, and virtues, as well as idiosyncrasies and individual conditions—Sanctorius was no longer so sure. While he was often quite confident about reducing, or even eliminating conjecture with regard to the quantity of diseases, he was strikingly reluctant to suggest solutions to making the other factors more certain. He appears to have been of the opinion that not all quantities in medicine could be determined and that, owing to the individuality of patients, medicine always would include a conjectural element. While his measuring instruments, when used alone, provided reliable and certain findings, their combined use in the quantification of disease might still leave room for uncertainty and provide only an estimate of the patient's state of health. Sanctorius's doubts in this regard might also explain the ambiguous relation between the measuring instruments and his varying grouping of them, analyzed above. And yet, despite all the equivocations, it is important to stress that Sanctorius's conception of the medical art as being able to approximate certainty, and his recourse to instruments and quantitative observation in order to enhance this certainty, clearly demonstrate his marked departure from tradition. From today's perspective, Sanctorius was at the threshold of a new understanding of medical knowledge and, more generally of *scientia*, according to which certainty would lie in the observation and experience of material things rather than in causal first principles. In this period of transition, Sanctorius proposed a specific approach: quantitative observation by means of instruments.

[24] "Quantitas perspirationis insensibilis aliquam varietatem patitur pro varietate naturae, regionis, temporis, aetatis, morborum, ciborum, & aliarum rerum non naturalium." See: Sanctorius 1614: 2v.

6.2.3 *The Role of Reasoning and the Method of the Six* Fontes

The preceding paragraphs disclosed the complex constellation in Sanctorius's works of traditional ideas on medical knowledge, his reinterpretation of them, and his introduction of new procedures based on quantification and instrumentation. However, these procedures were not the only means by which Sanctorius claimed to enhance certainty in medicine. Notwithstanding that Sanctorius's identification of medicine as an art stressed its practical and empirical dimensions, reasoning still played an important part for him in the purview of medicine. As mentioned above, Sanctorius did not consider it strictly necessary for a physician to actually exercise the art, which, he felt, could also be learned from a master alone, by using the mind rather than the senses (Sect. 6.2.1). Moreover, Sanctorius argued that anatomists could obtain mathematical certainty in their inquiry into disease and its causes by emphasizing that anatomical studies were not based on the senses alone, but involved reasoning, too (Sect. 4.2.1). This implies that, in the case of anatomy, it was the intellectual activities involved rather than anatomical practice and experience which made this field of medicine certain for him. In fact, already in his first publication, Sanctorius presented his doctrine of six *fontes* (sources), based on Aristotelian syllogistic logic, as the most certain of the, as the title says, "Methods to avoid all errors occurring in medical art" (*Methodi vitandorum errorum omnium qui in arte medica contingunt*). Without going into the details of this method, which have been outlined elsewhere, I will only briefly summarize its main features.[25]

Sanctorius's six *fontes* method was based on the collection of signs or symptoms (*per syndromen signorum*) and their progressive analysis. He identified six sources (*fontes*) of diagnostic signs that he considered would suffice to remove all ambiguity and uncertainty from diagnostic conclusions.[26] These were: external (procatarctic) causes, like bitter foods or remedies, the disposition of the patient; internal efficient causes, like bitter humors, symptoms, affected parts; and those things which aggravate or alleviate the condition.[27] According to Sanctorius,, the physician following this method could overcome the problem of the idiosyncrasy of patients as well as the problem of diseases having contrary symptoms but the same cause, or,

[25] For accounts of Sanctorius's method of six *fontes*, see: Wear 1973: 173 ff., 214 f., 238 f., 243, Maclean 2002: 162, 285, 288, 300 f., 336 f., Poma 2012: 222 ff.

[26] Ian Maclean argues that Sanctorius's determination of six as a sufficient number of sources is a mathematical and not a logical claim and can be related to the trend toward computation mentioned in Sect. 5.2.1 (Maclean 2002: 162).

[27] The term "procatarctic causes" refers to a specific Galenic doctrine of causes based on Galen's treatise *De causis procatarcticis* (On Procatarctic Causes), which differentiates between *causa continens*, usually taken to mean "sustaining," "internal," "material," "remote," or "occult," and *causa procatarctica* which can be described as "preliminary," "external," "material," "proximate," or "efficient" and involved the six non-natural things. For more information on this doctrine and on Renaissance debates about the issue, see: ibid.: 146 f., 262–5, Galen and Johnston 2016: xxxv–xxxvi. Efficient causes form part of the Aristotelian doctrine of the four causes and are described by Aristotle as "the primary sources of the change or rest." See: Falcon 2019.

at an early stage, almost indistinguishable symptoms. In brief, Sanctorius suggested the six *fontes* as a means to apply to the fundamentals of medicine, i.e., to the established universal causes or categories, those particulars encountered in medical practice and perceived by the senses. In developing his own sign theory, Sanctorius was following a trend toward the reorganization of the medical field of semiology, which had begun in the late sixteenth century. As Ian Maclean has argued, the doctrine of signs grew in importance at this time, and Renaissance physicians put forward very different versions of sign theory. While Sanctorius's interest in semiology was thus in line with contemporary tendencies, his claim to have identified *the infallible* method that guaranteed a certain diagnosis was remarkable.[28] It shows that, according to Sanctorius, the means by which the physician could solve the problems and uncertainties that occurred in medical practice by no means related only to the senses, to experience, instrumentation, and quantitative observation, but also to mental procedures in the form of a logical methodology focused on categories and causes as well as on theories and reason. Hence, in the quest for certainty in medicine, Sanctorius did not only suggest his novel quantitative approach, but also drew on traditional sign theory (Sanctorius 1603: esp. 8v–9v; Maclean 2002).

To get a clearer picture of the significance and status that Sanctorius assigned to his two methods for enhancing certainty in medicine—the logical method set out in the *Methodi vitandorum errorum* and the practical and quantitative procedures set out mainly in the *De statica medicina* and the *Commentary on Avicenna*—it is instructive to compare how he referred to them in his other published works. Contrary to the instruments and quantitative measurements which, as was stated above, Sanctorius repeatedly mentioned in his three commentaries, he rarely mentioned the six *fontes* method in these works.[29] However, in discussing the second part of Galen's work *Ars medica*, which deals with semiology, Sanctorius, in his *Commentary on Galen*, frequently emphasized the importance of sign theory in diagnosis and the necessity of detecting a syndrome of signs. In this context he often mentioned the work *Methodi vitandorum errorum* (Sanctorius 1612a: e.g., 322, 335–9, 344 f., 499 f., 634). What is more, in 1630 Sanctorius published a revised version of this book, which implies that he still considered its content and the six *fontes* method significant.[30] In the same year, he also released a second edition of his *Commentary on Galen*, to which he added, among other things, a fairly lengthy passage outlining Galen's sign theory in more detail (Sanctorius 1630a: 854–67). This shows that, late in life, he still saw semiology based on logic and reasoning as a topic worthy of further discussion. Besides all this, as noted earlier, Sanctorius's work *De remediorum inventione*, that dealt with finding the correct remedies, was

[28] For more information on medical semiology, see: Maclean 2002: esp. 276–332.

[29] The only references by Sanctorius to his six *fontes* method that I can find in his commentaries are in the *Commentary on Galen*, see: Sanctorius 1612a: 170 f. [erroneously paginated 174 instead of 170], 308.

[30] I did not check all the revisions that Sanctorius made for the second edition of the *Methodi vitandorum errorum*, but only looked at the passage in which he presented his six *fontes* method, which remained unchanged. See: Sanctorius 1630b: 33–8.

based on syllogistic logic and focused on a method for identifying the specific differences between diseases which Sanctorius had presented in the *Methodi vitandorum errorum* (Sect. 5.2.4). Directly at the start of the work, Sanctorius stated: "The reason why physicians very rarely find the proper and particular remedy is their ignorance of the art of medicine, of philosophy, and of logic" (Sanctorius 1629b: 1).[31] Thus, even though Sanctorius propounded the use of instrumentation and measurements in order to improve the work of the physician, he still held that logic and philosophy were essential foundations of medicine, as was common among contemporary learned physicians.

All in all, given the minor role that the method of the six *fontes* plays throughout the whole of Sanctorius's works, it appears that this approach was less important to him than his instruments and measurements, which he mentioned more often. In the 1630 edition of the *Commentary on Galen*, Sanctorius not only dwelled longer on Galen's sign theory, but also included references to some of the devices that he had presented 5 years earlier in the *Commentary on Avicenna*.[32] In view of this, it is conceivable that Sanctorius developed and presented the six *fontes* method in his first publication, the *Methodi vitandorum errorum*, due to strategic considerations. Since sign theory was very popular at the time, he might have seen this as a way to promote his career. Being aware of its lack of originality, he later no longer emphasized his six *fontes* method. And yet, even after he had become professor at the University of Padua, Sanctorius still held that sign theory, more generally, and likewise syllogistic reasoning were highly relevant for gaining medical knowledge and for the success practice of medicine. And so, he did not tire of repeating that, in order to determine the complexion of a patient, it was necessary to consider a collection, or syndrome of signs. It is striking that Sanctorius did not weigh the two procedures against each other, but dealt separately in his works with sign theory and logical method on the one hand, and instruments and measurements on the other. Despite the eminent practical orientation of two procedures that ultimately fulfilled the same purpose, namely to determine the complexion of a patient, Sanctorius never sought to systematically merge them. In this context, it is interesting to note that Sanctorius considered semiology as an important means to aid the memory of the physician—a function fulfilled, too, as we have seen, by his *pulsilogium* and the *De statica medicina* (Sect. 6.2.2). This notwithstanding, Sanctorius connected his quantitative approach to physiology to the Galenic concept of the latitude of health and to Galenic pharmacological theory, and not to sign theory. It remains thus an open question how, for example, Sanctorius's strong emphasis on the importance of insensible perspiration in diagnosis and therapy relates to his declared necessity of always observing a collection of signs, or symptoms when making a diagnosis. A manifestation of the rather independent existence of the two procedures in

[31] "Causa, cur medici admodum rarò verum & proprium remedium inveniant, est artis medica, Philosophiae, & Logicae imperitia …." See: Sanctorius 1629b: 1.

[32] To his second edition of the *Commentary on Galen*, Sanctorius added references to the thermoscope, the hygrometer, the *pulsilogium*, the clyster (*mitrenchyta*) and to the instrument to quench the thirst of fever patients. See: Sanctorius 1630a: 262 f., 594, 693, 762, 807 f.

Sanctorius's works and probably also in his concept of medicine is his last publication, *De remediorum inventione*, which focuses on a logical method for finding the correct remedies without any reference to measuring instruments or quantification. More pointedly, Sanctorius's concurrent but independent use of mental and sensuous, or experiential procedures with the aim of enhancing the certainty of medicine and of improving diagnosis and treatment reflects the complex relations between the empirical and rational parts of the discipline of medicine and coincides with the ambiguous relation between theory and practice found in his works (Sect. 4.3). In order to better understand these relations, it is pertinent to now take a look at the other side of the spectrum and to examine more closely Sanctorius's notions of the role of experience and empirical knowledge in medicine (Sanctorius 1612a: 335 f.; 1630a: 854; Poma 2012: 218).

6.2.4 The Role of Experience and Empirical Knowledge

In his first publication, *Methodi vitandorum errorum*, released in 1603, Sanctorius wrote:

> From this nature of tastes and colors, as explained so far, those mixtures of the humors, which are manifest to the senses, can be gathered. In order to fully know, however, the [mixtures] which are in the most inner parts of the body, where neither the tongue, nor the eyes can go, there are methods proposed in the sixth book that can teach every of the predominant humors and consequently any of their mixtures (Sanctorius 1603: 149r).[33]

Hence, Sanctorius pointed here clearly to the limits of experience and the use of the senses. According to him, the only way for the physician to penetrate into the depths of the body was to use his mind and thereby apply the method of a syndrome of signs that he had presented in the sixth book of his *Methodi vitandorum errorum*. Accordingly, sign theory was the means by which the physician could gain knowledge of things that were not accessible to the senses. In another passage of the same work, Sanctorius stated that not even "millions of thousands of particulars" (*milliona millia particularia*) could produce a universal. According to him, no universal cause could be derived from the experience of single events and he argued that one would need an infinite number of instances in order to logically produce a universal from particulars—an undertaking that was impossible for mortal man. Consequently, neither experience nor experiments—Sanctorius used both words indiscriminately in this context—could ever provide certain knowledge, since they were concerned only with particulars. As medicine, in the words of Sanctorius, "centered on universals and not particulars," the physician needed to know universal causes and thus

[33] "Ex hac natura saporum, & colorum hactenus explicata illae humorum misturae, quae sensibus sunt manifestae, colligi possunt: Quomodo verò pernoscantur, quae sint in penitissimis corporis partibus, in quas neque lingua, vel oculi penetrare possunt, traditae sunt in 6.lib. Methodi, quae possunt docere omnes praedominantes humores, & per consequens quamlibet eorum miscellam: …." See: Sanctorius 1603: 149r.

use other means than experience and the senses to gain this knowledge, namely Aristotelian syllogistic reasoning and sign theory (Sanctorius 1603: 188v; 1612a: 90).

Nonetheless, there still was a connection for Sanctorius between particulars and universals and in this regard, experience could be useful. He explained:

> We do not deny, however, that induction or experiments can contribute toward knowing a universal; because as Boethius said in [his commentary on Aristotle's] *Categories*, experience is the collection of examples, and after the collection, the intellect is urged on by its own light to separate the natural universals from the individual, for the whole universal nature is in any individual (Sanctorius 1603: 189v–190r).[34]

From this citation, it is clear that Sanctorius held, even while admitting that experience might help the physician arrive at universal truths, that there was no infallible way or method to proceed from personal experience to universals, and that it was ultimately the mind that gleaned universal truths from appearances, "by its own light." The perception of particulars triggered the mind to identify the correct cause of the perception. Thus, Sanctorius adhered to the Aristotelian theory of knowledge and its division into sensory experience and intellection (Sect. 6.2.1). His association of Galenic semiology with Aristotelian scientific methodology in order to explore the possibilities of induction, i.e., the methodological derivation of knowledge from particulars, reflects a development that Per-Gunnar Ottosson detected in medieval and Renaissance commentaries on Galen's *Ars medica*. Moreover, as Andrew Wear has shown, Sanctorius's view of the role of experience in medicine was influenced also by contemporary discussions on medical method, which stressed an a priori type of knowledge, according to which theory preceded action, explained the action, and gave it its sense.[35] Notwithstanding that the physician first examined the patient by looking for symptoms and relating these to the possible cause of the disease, the investigation of symptoms and signs would have been pointless, had the causes of the signs not previously been known. As Sanctorius explained in the preface to the *Commentary on Avicenna*, when discussing the division of medicine into theory and practice, the physician first explored the truth and then directed it to action, that is, to the preservation or restoration of health. Along the same lines, Sanctorius's new approach to the teaching of medical theory aimed to confirm theory a posteriori, by means of practice, and to corroborate practice a priori, by means of theory (Sect. 4.3) (Ottosson 1984: 196).

Thus, Sanctorius's critical opinion of sensory experience and his emphasis on reason as the preferable means to gain knowledge about universal truths, show him to be very traditional and conform with contemporary views. In light of this,

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[34] "Non tamen negamus inductionem, vel experimenta conferre posse ad cognoscendum universale: quia, ut dicit Boetius in praedicamentis, experientia est exemplorum collectio, post quam collectionem intellectus à proprio lumine excitatur ad separandam naturam universalem ab individuali; tota enim natura universalis est in quolibet individuo, …." See: ibid.: 189v–190r. The English translation is taken from: Wear 1981: 255.

[35] For accounts of Sanctorius's views on medical methods, see: Wear 1973: esp. 210–56, Wear 1981, Poma 2012. See also Sect. 4.1.1, fn. 2.

Sanctorius seems far removed from the figure of the ingenious innovator who pioneered a new medical science. Yet, as one might guess after having read the previous chapters, things are not always quite as simple as they seem at first glance. Eleven years after the publication of the *Methodi vitandorum errorum*, Sanctorius wrote in the preface to the *De statica medicina* that "not only do the mind and the intellect perceive sincere and pure truth, but also the eyes and the hands virtually palpate it" (Sanctorius 1614: Ad lectorem).[36] This fits with Sanctorius's description of the work as "mathematical medicine" or "static theorems" (Sect. 6.2.2) and implies that he did, after all, believe it possible that knowledge of universal causes could be gained from particulars by means of the observations and experiences that he made with his weighing chair. The contrast with his statements in the *Methodi vitandorum errorum*, outlined above, is immediate and striking. Curiously, in the first edition of this work, a chapter title stated that "induction gives sufficient proof" (*probatur inductione sufficientissima*), which suggests that Sanctorius was not as convinced of the impossibility of induction as it might seem from his other statements in the book. But in the second edition of the *Methodi vitandorum errorum*, published 27 years later, Sanctorius deleted the "sufficient" from the chapter's title. Hence, despite his bold claim in the *De statica medicina* that eyes and hands could feel truth, he seems still to have been in doubt about the possibility of induction as late as 1630.[37] Similarly, a year earlier, Sanctorius wrote in his book *De remediorum inventione* that "without reason and the advice of Galen or Hippocrates, experience cannot be trusted" (Sanctorius 1629b: 11).[38] In fact, as Elaine Leong has pointed out, such a pairing of experience with reason was ubiquitous and enduring in medieval and Renaissance learned medical writings. It served to distinguish the Hippocratic-Galenic medical sect (usually referred to as dogmatic, or rational sect) against the rival empirical sect, which Galen had so fiercely attacked in his works and whose members relied, according to the Greek physician, on experience alone. By emphasizing the need to always couple experience with reason, learned physicians tried to distance themselves from the practices of unlearned healers, and invoked a picture of an acceptable empiricism that was backed up by medical learning. A loyal Galenist, Sanctorius's ambiguous attitude toward the role of experience and empirical knowledge was certainly influenced by Galen's dislike of the empirical sect and by the anxiety of being perceived as an adherent of this medical school. The statement quoted above is preceded by Sanctorius's warning that one should not listen to

[36] "… veritatem ipsam sinceram ac puram putam non solum animo & intellectu percipiant, sed oculis etiam ac ipsis quasi manibus palpent, …." See: Sanctorius 1614: Ad lectorem.

[37] Ian Maclean pointed out this change in the chapter title in Sanctorius's *Methodi vitandorum errorum*. However, Maclean did not consult the first edition of the work, and therefore assumed—having referred to the second edition published in 1630—that the adjective *sufficientissima* was added only to the 1631 edition of the book. In fact, the 1631 edition of the *Methodi vitandorum errorum*, published in Geneva, was a copy of the original edition of the book from 1603. See: Sanctorius 1631: 162, Maclean 2002: 169, fn. 87.

[38] "Nos verò experientiam, esse concedendam putamus, sed sine ratione, & Galeni seu Hippocratis consilio, credimus experientiae non esse fidendum." See: Sanctorius 1629b: 11.

the Empiricists (*Empirici*), who rejected reason and authority and said that experience was worth more than the philosophies of Hippocrates and Galen. In the same way, Sanctorius frequently attacked present-day Empiricists in the *Methodi vitandorum errorum* and complained in the *De remediorum inventione* about unlearned physicians and surgeons (*medici* and *chirurgi plebei*), who did not properly follow the Galenic teachings. All things considered, Sanctorius undoubtedly assigned an important role to experience and the senses, but was at the same time careful to acknowledge their limitations. According to him, the physician was a "*sensatus philosophus*," who used his mind to derive universal knowledge. However, sometimes he also was a "*sensatus artifex*," who rather used experience and practical skill for the same purpose. Since Sanctorius switched in his works between these two ideas, he appears to have considered the physician to be both—a "sensible" philosopher and a "sensible" artisan (Sanctorius 1603: 7v, 16v–18v, 61r, 170r–170v; 1612a: 107, 117, 123; 1629b: 11, 39, 66; 1630b: 258; French 1994: 322; Maclean 2002: 169–98; Leong and Rankin 2017: 168, 170).

The preceding passages have shown that the question of certainty in medicine was, to be sure, not easily answered. Sanctorius put forward two methods that he believed would make the work of the physician more certain and so reduce the errors committed in medical practice. Whether he really believed that conjecture could be completely eliminated from medicine and absolute certainty achieved remains an open question. The method of the six *fontes*, or more generally, of a syndrome of signs, tied in with contemporary attempts to reorganize the medical field of semiology and adhered to traditional views of the role and limits of experience and the senses. Contrary to this, Sanctorius broke new ground by using instruments in order to enhance the physician's perceptions and so make the medical art more certain. Especially with the *De statica medicina*, Sanctorius attempted to overcome the division made between sensory experience and intellection. The very idea of using a mechanical instrument to render visible an internal and invisible bodily process which was completely hidden from the senses and thereby lay claim to mathematical certainty shows that Sanctorius was prepared to think what was, by earlier Aristotelian-Galenic standards, the unthinkable: namely, that experience and quantification could provide knowledge about universal causes. In doing so, Sanctorius walked a tightrope between the traditional Galenic position, accepted and cultivated at the universities, and the empiricist position, deemed by the learned medical community to be inferior, arbitrary, and even dangerous. Sanctorius left no doubt as to which camp he belonged In. His firm commitment to Galenic medicine can then explain how Sanctorius's attitude toward experience, empirical knowledge, and the use of the senses, which sounds ambiguous and contradictory today, was no contradiction for Sanctorius himself. In his attempt to improve Galenic medicine, he reconsidered the relation between the empirical and the rational parts of the discipline without, however, abandoning the fundamental principles upon which the whole discipline of medicine rested. Sanctorius's thoughts on the roles of experience and reason in medicine also elucidate something about the way in which he conceptually integrated his weighing procedures, and, too, his experiences with the other devices, into a traditional Galenic framework. It should now be clear that, for

Sanctorius, theoretical medical concepts, such as dietetics and the doctrine of the six non-natural things, had necessarily to be the starting point for any inquiry into the uncertainties involved in the medical art. These uncertainties were strongly felt by Sanctorius, who, as a diligent practitioner, was eager to avoid errors in diagnosis and treatment and, more generally, aimed to improve the day-to-day work of the physician. To further investigate Sanctorius's understanding and use of experience, empirical knowledge, and practice, it is pertinent to take a look at the terminology he used to describe these factors in his works.

6.2.5 Experience or Experiment?

In the Middle Ages and the Renaissance, the Latin word *experimentum* was closely aligned to the word *experientia* (experience) and both were usually used indiscriminately, with no systematic distinction between them. Generally, they simply referred to experience of some kind and included a whole range of empirical practices, such as drug testing or dissections. Furthermore, neither *experientia* nor *experimentum* had to result from firsthand experience, but might well be based on others' reports.[39] Perusal of Sanctorius's works suggests that he, too, employed the two words interchangeably, although a systematic analysis of his use of the terms would be needed to confirm this hypothesis, and that is not feasible here. Rather, I want to draw attention to another related Latin term, *periculum*, which can be translated as "trial" or "test" and began to be used in the sixteenth century to designate the deliberate execution of a trial, as in: *periculum facere*, "to put to the test." As Roger French has argued, this phrase alluded to the famous first of Hippocrates's *Aphorisms* that says: "Life is short, the Art long, opportunity fleeting, experiment treacherous, judgment difficult" (Hippocrates and Jones 1931: 99).[40] According to French's research, the phrase *experimentum periculosum* (treacherous experiment) was used consistently in the various Latin translations of the originally Greek aphorism. He concluded that this expression could not signify passive experience, since *periculum* also meant an attempt or trial, including the attendant risks. In his opinion, the Renaissance translators qualified the noun *experimentum* with an adjective derived from *periculum* in order to highlight that what was meant was an active attempt with

[39] The historical development of "experiment" is complex and difficult to pin down, since the roles and functions this notion has had in different contexts and times are manifold. For accounts of early modern understandings of the term, see e.g., Schmitt 1969, Dear 1995, Dear 2006, Leong and Rankin 2017, Steinle et al. 2019. For a study of the various uses of "experiment" in research processes and the understanding of experiment as a means for empirical research, see: Steinle 2005.

[40] Evan Ragland has shown that sixteenth-century writers also referred to other precedents for using the phrase *periculum facere* to mean the conduct of a trial or test. These were taken from classical Latin literature, such as Cicero and the plays of Terence and Plautus. See: Ragland 2017: 511.

uncertain outcome, a clinical or medical trial (French 1994: 320–33; Dear 1995: 13; 2006: 106; Leong and Rankin 2017: 162–70; Ragland 2017: 512).

Interestingly, Sanctorius used the phrase *periculum facere* in the preface to the *De statica medicina*. He wrote: "But I am the first to make the trial [*periculum feci*], and unless I am mistaken I have by reasoning and by the experience [*experientia*] of 30 years brought this art to perfection …" (Sanctorius 1614: Ad lectorem).[41] Hence, following French's interpretation of the expression, this implies that Sanctorius wanted to stress here that he was the first to make a *deliberate* test in order to determine the quantity of insensible perspiration. He evidently considered it important to inform his readers that he gained his information not from passive observation, but from an active, contrived event. He appears, thus, to have had some notion of "experiment" according to which the "experimenter" consciously, and with forethought, attempted to test a particular hypothesis by devising a specific observational situation by which to resolve the question. This understanding of experiment, or rather "putting to the test," is of course very different from modern experimental methods and randomized clinical trials. However, Sanctorius's use of the phrase *periculum fecit* in the preface to the *De statica medicina* shows that he was aware he was presenting a new and different approach to a medical problem, based on a specific empirical practice that might best be described as controlled and deliberate observation. It appears then, that it was this procedure that, according to Sanctorius, enabled the eyes and hands of the physician to feel truth. Remarkably, Sanctorius used the phrase *periculum facere* also in a passage of the *Commentary on Avicenna*, when describing his thermoscopes. He explained that by means of these instruments he "put to the test" whether the heat in children and adolescents was the same (Sanctorius 1625: 357; Schmitt 1969: 105–21).

But there is also another dimension to this. Using the expression *periculum facere* instead of *experimentum* or *experientia* in reference to Hippocrates's first aphorism might simply mean that Sanctorius did not want to risk being regarded as an empiricist. Hippocrates served here as a model for the empirical observer, recording case histories and justifying "experiment" with regard to the patient, and impartially recording empirical data. As mentioned earlier, Sanctorius not only used the phrase *periculum facere* in the preface to the *De statica medicina*, but also presented himself as a follower of Hippocrates, especially regarding the use of the aphoristic form (Sect. 4.1.1). Thus, it is very probable that Sanctorius invoked the Physician of Kos strategically, in order to legitimize his new approach to physiology as an acceptable empiricism. Indeed, this might even have been the reason why he chose to present the results of his weighing procedures in aphorisms. Note that in the preface to the *De statica medicina* Sanctorius again paired experience with reason. What is more, in the preface to the *Commentary on Avicenna* Sanctorius introduced his novel way of teaching medical theory, which, as a direct continuation of the Hippocratic teachings, was based on the use of "experiments [*experimenta*],

[41] "… ego verò primus periculum feci, & (nisi me fallat genius) artem ratione & triginta annorum experientia ad perfectionem deduxi, …." See: Sanctorius 1614: Ad lectorem. The English translation is based on: Foster 1924: 145.

instruments, and static art." Here Sanctorius did not use the phrase *periculum fecit*, but rather the Latin word *periclitatio*, which, like *periculum,* can be translated as "test" or "trial," but also as "danger," "risk," or "hazard." The fact that Sanctorius drew so heavily on the authority of Hippocrates in the introductions to the two publications, in which he mainly set out the practical and quantitative procedures aimed at enhancing certainty in medicine, strongly suggests that he struggled to distance himself from the empirical sect and to emphasize that his novel methods were based on learned medical knowledge. It is easy to understand the importance of this to Sanctorius, if one considers that he was still working as a university professor of medical theory at least at the time when he published the *De statica medicina* (Sanctorius 1625: Ad lectorem; Ramminger; Lewis and Short 1879).

Having said all this, it must be noted nonetheless that what Sanctorius actually practiced might have differed from the words he used and from the methods that he recommended in his books to enhance certainty in medicine. Similarly, the use of the word *periculum*, like that of *experimentum* and *experientia*, does not necessarily imply that Sanctorius performed actual experimental procedures as opposed to hypothetical "thought experiments." It is therefore necessary to finally take a closer look at his measuring instruments in order to further examine Sanctorius's making and doing: his use of experience, observation, quantification, and experimentation in medical practice. In the process, not only will the material dimensions of his endeavors come to the fore, but also the ways in which contemporary technology and craftmanship played a part in Sanctorius's concept of medicine as an art that could, if not attain, then at least approximate certainty (Maclean 2002: 296).

References

Bigotti, Fabrizio. 2016. Mathematica Medica. Santorio and the Quest for Certainty in Medicine. *Journal of Healthcare Communications* 1: 1–8.

———. 2018. The Weight of the Air: Santorio's Thermometers and the Early History of Medical Quantification Reconsidered. *Journal of Early Modern Studies* 7: 73–103.

Bigotti, Fabrizio, and David Taylor. 2017. The Pulsilogium of Santorio: New Light on Technology and Measurement in Early Modern Medicine. *Society and Politics* 11: 55–114.

Castellani, Carlo. 1958. Alcune lettere di Santorio Santorio a Senatore Settala. *Castalia* 1: 3–7.

De Pace, Anna. 1993. *Le matematiche e il mondo: Ricerche su un dibattito in Italia nella seconda metà del Cinquecento*. Milan: Franco Angeli.

Dear, Peter. 1995. *Discipline & Experience: The Mathematical Way in the Scientific Revolution*. Chicago: University of Chicago Press.

———. 2006. The Meanings of Experience. In *The Cambridge History of Science,* Vol. 3: *Early Modern Science*, ed. Katharine Park and Lorraine Daston, 106–131. Cambridge\New York: Cambridge University Press.

Ettari, Lieta Stella, and Mario Procopio. 1968. *Santorio Santorio: la vita e le opere*. Rome: Istituto nazionale della nutrizione.

Falcon, Andrea. 2019. Aristotle on Causality. In *The Stanford Encyclopedia of Philosophy*, ed. Edward N. Zalta. https://plato.stanford.edu/archives/spr2019/entries/aristotle-causality/. Accessed 12 Dec 2019.

Foster, Michael. 1924. *Lectures on the History of Physiology during the Sixteenth, Seventeenth and Eighteenth Centuries*. Cambridge: Cambridge University Press.
French, Roger K. 1994. *William Harvey's Natural Philosophy*. Cambridge: Cambridge University Press.
Galen and Ian Johnston. 2016. *On the Constitution of the Art of Medicine; The Art of Medicine; A Method of Medicine to Glaucon*. Cambridge, MA\London: Harvard University Press.
Grmek, Mirko D., and Danielle Gourevitch. 2001. La maladie mesurée: l'apport de Santorio Santorio. *La Revue du Praticien* 51: 2009–2012.
Guidone, Mario and Fabiola Zurlini. 2002. L'introduzione dell'esperienza quantitativa nelle scienze biologiche ed in medicina Santorio Santorio. In *Atti della XXXVI tornata dello Studio firmano per la storia dell'arte medica e della scienza, Fermo, 16–17–18 maggio 2002,* ed. Studio firmano per la storia dell'arte medica e della scienza, 117–137. Fermo: A. Livi.
Hippocrates, and William Henry Samuel Jones. 1931. *Hippocrates,* Vol. IV. Cambridge, MA: Harvard University Press.
Jacquart, Danielle. 1980. Le regard d'un médecin sur son temps: Jacques Despars (1380?–1458). *Bibliothèque de l'École des chartes* 138: 35–86.
Leong, Elaine, and Alisha Rankin. 2017. Testing Drugs and Trying Cures: Experiment and Medicine in Medieval and Early Modern Europe. *Bulletin of the History of Medicine* 91: 157–182.
Lewis, Charlton T. and Charles Short. 1879. periclitatio. In *A Latin Dictionary*. Oxford: Clarendon Press. http://www.perseus.tufts.edu/hopper/text?doc=Perseus:text:1999.04.0059:entry=periclitatio. Accessed 23 Dec 2019.
Maclean, Ian. 2002. *Logic, Signs, and Nature in the Renaissance: The Case of Learned Medicine*. Cambridge\New York: Cambridge University Press.
Miessen, Hermann. 1940. Die Verdienste Sanctorii Sanctorii um die Einführung physikalischer Methoden in die Heilkunde. *Düsseldorfer Arbeiten zur Geschichte der Medizin* 20: 1–40.
Mitchell, S. Weir. 1892. *The Early History of Instrumental Precision in Medicine. An Address before the Second Congress of American Physicians and Surgeons, September 23rd, 1891*. New Haven: Tuttle, Morehouse & Taylor.
Ottosson, Per-Gunnar. 1984. *Scholastic Medicine and Philosophy: A Study of Commentaries on Galen's Tegni (ca. 1300–1450)*. Naples: Bibliopolis.
Park, Katharine, and Lorraine Daston. 2006. Introduction: The Age of the New. In *The Cambridge History of Science,* Vol. 3: *Early Modern Science*, ed. Katharine Park and Lorraine Daston, 1–17. Cambridge\New York: Cambridge University Press.
Poma, Roberto. 2012. Santorio Santorio et l'infallibilité médicale. In *Errors and Mistakes. A Cultural History of Fallibility*, ed. Mariacarla Gadebusch Bondio, Paravicini Bagliani, and Agostino, 213–225. Florence: SISMEL-Edizioni del Galluzzo.
Ragland, Evan R. 2017. "Making Trials" in Sixteenth- and Early Seventeenth-Century European Academic Medicine. *Isis* 108: 503–528.
Ramminger, J. periclitatio. In *Neulateinische Wortliste. Ein Wörterbuch des Lateinischen von Petrarca bis 1700*. www.neulatein.de/words/0/018468.htm. Accessed 23 Dec 2019.
Sanctorius, Sanctorius. 1603. *Methodi vitandorum errorum omnium, qui in arte medica contingunt, libri quindecim*. Venice: Apud Franciscum Barilettum.
———. 1612a. *Commentaria in Artem medicinalem Galeni,* Vol. I. Venice: Apud Franciscum Somascum.
———. 1612b. *Commentaria in Artem medicinalem Galeni,* Vol. II. Venice: Apud Franciscum Somascum.
———. 1614. *Ars Sanctorii Sanctorii Iustinopolitani de statica medicina, aphorismorum sectionibus septem comprehensa*. Venice: Apud Nicolaum Polum.
———. 1625. *Commentaria in primam Fen primi libri Canonis Avicennae*. Venice: Apud Iacobum Sarcinam.
———. 1629a. *Commentaria in primam sectionem Aphorismorum Hippocratis, & c. … De remediorum inventione*. Venice: Apud Marcum Antonium Brogiollum.

———. 1629b. *De remediorum inventione*. Venice: Apud Marcum Antonium Brogiollum.
———. 1630a. *Commentaria in Artem medicinalem Galeni*. Venice: Apud Marcum Antonium Brogiollum.
———. 1630b. *Methodi vitandorum errorum omnium, qui in arte medica contingunt, libri quindecim*. Venice: Apud Marcum Antonium Brogiollum.
———. 1631. *Methodi vitandorum errorum omnium, qui in arte medica contingunt, libri quindecim … Nunc primùm acceßit eiusdem Authoris De inventione remediorum liber*. Geneva: Apud Petrum Aubertum.
Sanctorius, Sanctorius, and Giuseppe Ongaro. 2001. *La medicina statica*. Florence: Giunti.
Schmitt, Charles B. 1969. Experience and Experiment: A Comparison of Zabarella's View With Galileo's in *De Motu*. *Studies in the Renaissance* 16: 80–138.
Siegel, Rudolph E. 1968. *Galen's System of Physiology and Medicine*. Basel\New York: S. Karger.
Siraisi, Nancy. 1981. *Taddeo Alderotti and His Pupils: Two Generations of Italian Medical Learning*. Princeton: Princeton University Press.
———. 1987. *Avicenna in Renaissance Italy: The Canon and Medical Teaching in Italian Universities After 1500*. Princeton: Princeton University Press.
———. 1990. *Medieval & Early Renaissance Medicine: An Introduction to Knowledge and Practice*. Chicago: University of Chicago Press.
Steinle, Friedrich. 2005. *Explorative Experimente: Ampère, Faraday und die Ursprünge der Elektrodynamik*. Stuttgart: Steiner.
Steinle, Friedrich, Cesare Pastorino, and Evan R. Ragland. 2019. Experiment in Renaissance Science. In *Encyclopedia of Renaissance Philosophy*, ed. Marco Sgarbi, 1–15. Cham: Springer.
Wear, Andrew. 1973. *Contingency and Logic in Renaissance Anatomy and Physiology*. Phd diss., Imperial College London.
———. 1981. Galen in the Renaissance. In *Galen: Problems and Prospects*, ed. Vivian Nutton, 229–262. London: The Wellcome Institute for the History of Medicine.