Erkenn (2013) 78:1109–1132
DOI 10.1007/s10670-012-9390-7

ORIGINAL ARTICLE

Theory Choice, Good Sense and Social Consensus

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Received: 13 December 2011 / Accepted: 18 August 2012 / Published online: 8 September 2012

Abstract There has been a significant interest in the recent literature in developing a solution to the problem of theory choice which is both normative and descriptive, but agent-based rather than rule-based, originating from Pierre Duhem's notion of 'good sense'. In this paper we present the properties Duhem attributes to good sense in different contexts, before examining its current reconstructions advanced in the literature and their limitations. We propose an alternative account of good sense, seen as promoting social consensus in science, and show that it is superior to its rivals in two respects: it is more faithful to Duhemian good sense, and it cashes out the effect that virtues have on scientific progress. We then defend the social consensus account against objections that highlight the positive role of diversity and division of labour in science.

1 Introduction

There has been a significant interest in the recent literature in developing a solution to the problem of theory choice which is both normative and descriptive, but agent-based rather than rule-based. Such a solution goes back to Pierre Duhem's notion of 'good sense'. It was recently revived by David Stump, because of the crucial role that intellectual and moral virtues play in it, and has since attracted significant attention. Duhem defined good sense as what guides scientists facing the problem of theory choice—that is, who have to choose between theories equally compatible with the data. Nevertheless, he never provided a full account of good sense. Recent papers have tried to fill this gap by reconstructing good sense and explaining how

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exactly it solves the problem of theory choice. However, these reconstructions are unsatisfying for a number of reasons. First, it is doubtful that they are faithful to Duhem's concept. Indeed, some properties that Duhem attributed to good sense seem to be left out in these reconstructions, whereas some other properties they focus on are taken out of their original context. Moreover, these reconstructions disagree with respect to the central characteristics of good sense. Second, it is also doubtful whether these accounts provide adequate solutions to the problem of theory choice. For instance, none of them explain how an agent-based account can guarantee that good sense is reliable. Neither do they explain how an agent based approach could function in situation of underdetermination in order to lead to a conclusive choice. As a consequence, it is unclear whether good sense should, or even can, be a solution to the problem of theory choice.

In this paper, we explore whether such a middle solution, between purely normative and purely descriptive accounts, is tenable. We develop an alternative reading that manages to accommodate all the properties attributed to good sense. In Sect. 2 we introduce the problem of underdetermination and theory choice, as well as its traditional solutions and their weaknesses. Section 3 presents Duhem's agent-based solution to theory choice by discussing how he described the properties of good sense and its different contexts of use—in empirical sciences, mathematics and history. In particular, we explain how good sense is supposed to solve the problem of theory choice. In Sect. 4 we present the current reconstructions of good sense, developed by Philippe Mongin (2009), David Stump (2007), Milena Ivanova (2010), Abrol Fairweather (2011), and evaluate them in terms of the properties Duhem ascribes to his notion of good sense. In Sect. 5, we discuss several conceptual issues faced by these accounts, independently of their faithfulness to Duhemian good sense. In Sect. 6, we develop a novel reconstruction of good sense, seen as a social consensus smoothing device, which we argue best fits the properties of good sense and explicitly cashes out the effect that virtues have on scientific progress.[1] In Sect. 7, we discuss further objections for the social choice account, and explain why they do not have any bite.

2 The Problem of Theory Choice

The problem of theory choice arises because more than one theory can accommodate the available data at a given time. When multiple theories equally accommodate some body of evidence,[2] we need some kind of justification for preferring one of the theories and discard the other. One can, of course, deny that the problem of underdetermination entails theory choice by claiming that there is no fact of the matter as to which theory is superior (or which one is more likely to be true). But it is philosophically interesting to investigate what considerations enter

[1] Here, effects on scientific progress should not be understood in terms of truth acquisition, but of speed of convergence, for reasons that will become clear later.

[2] Which can range from one given observation to the total set of present evidence, or even to the set of all possible evidence. The wider the set, the stronger the underdetermination. Duhem refers to underdetermination with respect to present evidence.

into justifying preference towards an individual theory, given the observation that hesitation does not persist in scientific practice and that scientists often do have preferences towards one of the rival theories. How are we to choose between theories that fit the evidence equally well? Can we justify our preference for one theory within a set of empirically equivalent ones?

To decide between evidentially equivalent theories, one solution is to resort to non-empirical criteria and compare the simplicity, unity, fertility, etc. of the theories. Other things being equal, one theory may be simpler, more unified or have made more novel predictions than its rivals, and be favoured for this reason. This is the well-known point that *empirical* equivalence does not imply *evidential* equivalence: even if several theories are on a par with regard to empirical data, one may fare differently on some other properties and for this reason we may consider it as confirmed to a higher degree.

The claim that theoretical virtues resolve theory choice can be seen both as a descriptive claim and as a normative claim. It could be argued that the history of science shows that scientists do resolve theory choice based on a list of theoretical virtues. A stronger claim is to argue that theory choice should be resolved by employing theoretical virtues, in which case some kind of algorithm needs to be constructed which allows a rule-based solution to theory choice.

However, choice from super-empirical criteria faces two serious problems, which undermine a rule-governed solutions based only on these criteria. First, different criteria may lead to inconsistent or conflicting preferences. For instance, theory A may be simpler than theory B, but be less unified. In order to choose between them, some criteria should either receive relative weights so we can calculate the overall score of every theory, or be ranked according to a lexicographic order.[3] However, there is no scientific consensus on (or plausible epistemic justification of) any such weighting or ranking. Moreover, the importance of super-empirical criteria seems to vary over time (Duhem 1954; Kuhn 1977).

Secondly, the interpretation of super-empirical criteria is subjective to a certain extent. They are many ways in which a theory can be deemed simple or fruitful. As a result, different scientists may disagree as to which theory they should prefer, even if they agree that the simplest one should be favoured.[4]

As Kuhn famously remarked, these two problems of inconsistency and subjectivity of super-empirical criteria explain the lack of a rational algorithm for theory choice. As there is no way to devise a logical or rational method which would always allow us to choose a theory when we face an underdetermination problem, it is natural that additional factors, for instance psychological or sociological ones, explain how scientists manage to make such choices in practice.

The recently developed agent-based accounts are aimed to avoid the problem faced by the rule-based solutions to theory choice. They aspire to provide a solution that does not dictate rules but can nevertheless justify the outcome of theory choice

[3] That is, we could decide that simplicity always matters most, that equally simple theories should then be assessed according to their scope, and so on.

[4] For instance, both the Ptolemaic and the Copernican theory can be considered as simpler than the other, depending on how simplicity is defined (Kuhn 1977).

by imposing a normative dimension to the agents making the choice. The idea goes back to Duhem's notion of good sense. The function of good sense is to resolve theory choice given the inconclusiveness of theoretical virtues. According to Duhem, only evidence can rationally compel us to adopt or reject a theory. However, when evidence is not enough, good sense steers us towards the most reasonable option. Now the question becomes: on which basis can good sense discriminate between empirically equivalent theories?[5]

Before we discuss in detail the recent reconstructions and provide our own understanding on how such an agent-based solution to theory choice can be articulated, we present the properties attributed to good sense and how Duhem believes it can serve as a solution to theory choice.

3 Duhem's Good Sense

Despite the fact that Duhem's notion of good sense is known for being employed as a solution to the problem of theory choice, Duhem discusses good sense in three different contexts throughout his writing.[6] In his (1954) he mostly discusses good sense in the context of experimental physics and the problem of theory choice, while in his (1991) the notion is used in the contexts of mathematical and historical sciences. We discuss good sense in the context of theory choice first and then also describe the properties of good sense when employed in mathematics and history. Our aim is to examine all the properties attributed to good sense in order to determine which ones *exactly* are relevant to theory choice and to provide an exclusive list of properties, mentioned by Duhem, which any future account of good sense should recover.[7]

3.1 The Role of Good Sense in Experimental Science

According to Duhem, one starts an experiment or observation with a preconceived idea of what its outcome should be; if the observed outcome is different, then it is good sense that leads the scientist to decide how the experiment should proceed—whether more tests should be done, whether modifications of the initial assumptions and conditions should be made, whether the working hypothesis should be changed or abandoned completely. As Duhem argues in his (1954), one can choose a 'timid'

[5] Note that underdetermination is a normative problem, as it implies the absence of a rational, principled way of choosing between empirically equivalent theories. But in the context of good sense, it is also a descriptive problem: we have to understand how scientists often manage to make this choice nonetheless. This in turn leads to a normative assessment again: we may thus be in a position to suggest how scientists could make better choices. This is what Duhem does when he recommends that one be faithful and impartial (1954, 218). In principle, understanding good sense would allow one both to accurately describe and to guide scientific activity.

[6] For an introduction to Duhem's philosophy of science see Martin (1991). For his motivations in developing the concept of good sense and its place in Duhem's overall philosophy of science, see Stump (2007) and Ivanova (2010).

[7] Although this paper does not aim to provide a full-fledged analysis of Duhem's various uses of good sense, our discussion must be detailed enough to establish an exhaustive list of properties.

move and keep the working hypothesis by modifying the initial conditions or auxiliary assumptions, or one can choose a 'bold' move and change the theory. This for Duhem leads to underdetermination: an observation can be consistent with distinct sets of hypotheses and assumptions.[8]

Duhem felt the need to account for the fact that situations of underdetermination do not seem to last in science and thus there must be some faculty that is employed and can explain how scientists reach consensus and resolve theory choice. Good sense is an attempt for Duhem to develop a middle-ground position which is both descriptive but also, as we will see throughout this paper, has a normative dimension. It is not reduced to rules but could potentially be fruitful for scientific progress.

Duhem argues that in situations of underdetermination, no strict rules can be employed: "no absolute principle dictates this inquiry, which different physicists may conduct in very different ways without having the right to accuse one another of illogicality." (Duhem 1954, 216) Both the 'timid' and 'bold' moves are justifiable on the grounds of experience and none of them is disallowed nor dictated by logic. However, good sense comes into justify one of these alternative paths by providing reasons for it, that is, judges the choice of one theory as the reasonable choice.

In his later writings, he further explains that:

> [T]he rules of syllogistic logic are not adequate. They must be assisted by a certain sense of soundness that is one of the forms of good sense […] good sense will intervene at the moment at which one realizes that the consequences of a preconceived idea are either contradicted or confirmed by the experiment. […]
> What a delicate task, concerning which no precise rule can guide the mind! It is essentially a matter of insight and ingenuity! (Duhem 1991, 23–25)

Duhem admits that in cases of underdetermination one appeals to super-empirical virtues of the theory. However, there are not always sufficient in resolving the problem and more considerations should be employed:

> No doubt the physicist will choose between these logically equivalent theories, but the motives which will dictate his choice will be considerations of elegance, simplicity, and convenience, and grounds of suitability which are essentially subjective, contingent, and variable with time, with schools, and with persons. (Duhem 1954, 288)

As a consequence, it is not always straight-forward which 'path' needs to be taken. Scientists can disagree as to which theory should be chosen because good sense is not equally present in everyone:

> [T]hese reasons of good sense do not impose themselves with the same implacable rigour that the prescriptions of logic do. There is something vague

[8] It is important to note that Duhem believed that scientific theories are tested holistically—they are sets of hypotheses and auxiliary assumptions—and as a consequence we can always cultivate empirically equivalent rival theories by modifying the auxiliary assumptions. In the modern literature the problem of underdetermination is treated separately from holism; modification of auxiliary assumptions does not necessarily entail empirical equivalence.

> and uncertain about them; they do not reveal themselves at the same time with the same degree of clarity to all minds. (Duhem 1954, 217)

Nevertheless, Duhem argues that good sense does eventually lead to unique choices.

> [T]his state of indecision does not last forever. The day arrives when good sense comes out so clearly in favour of one of the sides that the other gives up the struggle even though pure logic would not forbid its continuation. (ibid.)[9]

Duhem also suggests that despite the fact good sense is "vague and uncertain" (ibid. 217), we do have some hints of what properties would hinder it. He stresses the importance of impartiality and objectivity and argues that in order for one to have good sense, judgement should not be the product of one's interests and passions.

> [N]othing will delay the decision which should determine a fortunate reform in a physical theory more than the vanity which makes a physicist too indulgent towards his own system and too severe towards the system of another. (ibid. 218)[10]

This reveals a relation between virtues and acceleration. Indeed, Duhem suggests that good sense is cultivated with practise and should be developed *in order to accelerate scientific progress*:

> Since logic does not determine with strict precision the time when an inadequate hypothesis should give way to a more fruitful assumption, and since recognizing this moment belongs to good sense, physicists may hasten this judgement and increase the rapidity of scientific progress by trying consciously to make good sense within themselves more lucid and more vigilant. (ibid., 218)

To our knowledge, so far this accelerating property has not been mentioned in the literature; but it will be crucial in our analysis below, and so will be the virtue-acceleration link.

3.2 Good Sense in Mathematics and History

In his (1991) Duhem starts the discussion on the role of good sense in mathematics by equating it with common sense. Here, good sense is described as a 'feeling for the truth', 'natural instinct', 'ability to discern true from false' and its role is to 'sense' the truth of mathematical axioms, which are self evident (1991, 6–11).[11] Duhem compares the two types of scientific method: the intuitive and the deductive. While the intuitive method has the 'depth' to establish quickly fundamental truths, the deductive method establishes truth by applying the strict rules of logic.

[9] Duhem discusses the example of Biot, who abandoned the emission hypothesis after Foucault's experiments showed that light travels faster in air than in water. That was not an example of a crucial experiment which supported wave optics, however, Duhem argues, it would have been lack of good sense if Biot continued to resist wave optics.

[10] The role of intellectual and moral virtues in scientific judgement is discussed further in his (1991).

[11] The majority of citations in this paper are from the English translations of Duhem's work as we have not found substantial limitations in comparison to the French originals.

> Good sense, which Pascal calls "the heart" here[12], for the intuitive perception of the obviousness of the axioms, and the deductive method to arrive by the rigorous but slow progress of discourse at the demonstrations of the theorems: there we have the two means that human intelligence uses when it wishes to construct a science of reasoning. (ibid., 8)

According to Duhem both methods have their advantages and shortcomings. While the intuitive mind can seize truth quickly, it can also be hasty and fall into error. The deductive mind establishes truths that are secured by the 'slow and prudent procedure', but are not always in agreement with common sense. These two faculties can be co-present in agents but more often one of them is dominant and this is clear by the development of different schools of thought.[13] For example, for Duhem the French school of thought exemplifies the intuitive method, while the German exemplifies the deductive one.[14]

> The extreme vigour of one faculty is often paid for by the enfeeblement of another. Those whose lively good sense allows them to seize upon the truth an intuition as quick as it is accurate are sometimes also those who have the hardest time submitting themselves to the prudent discipline and rigorous deliberateness of the deductive method. On the other hand, those who follow most minutely the rules of the deductive method frequently fail through lack of common sense. (ibid., 11)

Put differently, the ability to 'feel' and anticipate, or accelerate the results of deduction, is a crucial feature of good sense in the context of mathematics.[15]

Duhem first explicitly links good sense to intellectual and moral qualities of agents when he discusses the role of good sense in history. Duhem argues that:

> In the realm of every science, but more particularly in the realm of history, the pursuit of truth not only requires intellectual abilities, but also calls for moral qualities: rectitude, probity, detachment of all interests and all passions. (Duhem 1991, 43)

Duhem once again stresses that good sense belongs to the intuitive mind[16] and suggests it is applied in areas where there can in principle be no systematic method of enquiry. History is one of the sciences that cannot have a method:

[12] Duhem is referring to Pascal's famous claim that "We know truths not only by reason, but also by the heart".

[13] Good sense could in principle conflict with common sense. In particular, Duhem argues that unlike common sense, good sense is acquired with scientific practice, can be developed by experience, and scientists should aim to sharpen it in order to fasten scientific progress.

[14] Only in his (1991) though. It is interesting to note that in his (1954), he distinguishes between the 'focused', 'narrow' and 'deep' French mind, and the 'ample', 'broad' and 'shallow' English mind. Here, the French seem to exemplify the deductive method and the English the intuitive one.

[15] In mathematical science, good sense also allows theorists to choose true axioms. Although this use will not concern us here, for the sake of exhaustivity note that it has other properties in this context. It is equivalent to common sense; it is an ability to 'see' self evident truths; it is possessed by all agents; and it is not cultivated or sharpened by experience.

[16] Here, once more, he is influenced by Pascal: "Historical work essentially requires the intuitive mind for its accomplishment". It is appropriate that one can say of such research that its "principles are found

> There is not, there cannot be, any historical method. Whoever says method says 'a manner of procedure traced with precision, which is capable of leading without deviation from one limit to another'. (ibid., 45)

Duhem argues that most sciences as well as the arts do possess a method. This is not so in the case of history, where no method in principle can be formulated due to the fact that history is not a deductive science. It is in history that good sense receives most attention, since it is the only capacity which can guarantee, for Duhem, the acquisition of truth.

Crucially, the important properties of good sense, when applied in the context of history, are intellectual and moral qualities, where impartiality—'detachment from all interests and all passions'—receives central attention.

3.3 Properties of Good Sense in Theory Choice

We have examined the qualities of good sense employed in theory choice and contrasted it with that in mathematics and in history. In addition to the importance of impartiality, we have seen that underdetermination does not last indefinitely because good sense always ends up favouring a theory; good sense is cultivated with experience and practice; it is an 'innate feeling' or an intuition which guides scientists in their choices; and its presence in individuals is a matter of degree. As in history, it is linked to intellectual and moral virtues. As in mathematics, good sense can accelerate scientific progress; it can lead faster to results which would take longer to be reached. For that reason good sense has a normative dimension, as its cultivation promotes scientific progress.

It must be clear now that the solution that good sense offers to the problem of theory choice is consistent with the contemporary formulation of the problem, described in Sect. 2. It is motivated by the lack of a rule-based solution, or algorithm, based on the super-empirical virtues of theories, and in that anticipates Kuhn's later analysis[17]; and it suggests a solution at the level of personal passions and interests, that is, in terms of additional criteria.[18]

Footnote 16 continued
in common use and are open to the scrutiny of everybody. One has only to look, and no effort is necessary; it is only a question of good eyesight" (ibid, 44). Duhem often equates good sense with the intuitive mind (Duhem 1991, 24).

[17] This is echoed by the fact that Duhem only provides examples of theories being *eliminated* by good sense (Duhem 1954, 218)—either of scientists clinging for too long in the face of disconfirming evidence, or embracing a new theory too swiftly. This emphasis on negative examples makes clear that fully understanding how good sense operates is at the very least difficult, at worst impossible. One solution could be that even if good sense amounts to a formula based on super-empirical criteria, this formula may change as the context varies. Again, this is consistent with Kuhn's remark that the relative weights attributed to super-empirical criteria evolve over time, which Duhem also anticipated.

[18] Personal interests and passions may correspond to psychological factors (when one tends to prefer her own theory), and to sociological ones (when one prefers a theory because it is widely favoured, or rejected, by the scientific community). More generally, they include preferences for theories stemming from the identity of their authors and supporters.

We can now summarise the characteristics of Duhem's good sense that are relevant to the context of the underdetermination problem[19]:

1. it is partly based on some super-empirical criteria.
2. it is hindered by passions and interests, and can best be attained by striving for impartiality and faithfulness.
3. it cannot be reduced to an algorithm or a list of criteria.[20]
4. it always ends up favouring one theory (given enough time).
5. it fastens scientific progress.
6. it is cultivated by scientific practice.
7. it is not logical but reasonable.
8. it is a cluster of moral and intellectual properties.
9. it is not equally instantiated in all agents.[21]

Note that the accelerating property, although never acknowledged in the literature, is a central property of good sense. It is present both in experimental science and in mathematics, just as the moral/intellectual virtues are present both in experimental science and in history. Also note that these properties are deemed consistent by Duhem, as they are all mentioned (even if briefly) in his (1954). In his later writings (1991) Duhem does not seem to add new properties to good sense as employed in theory choice but does expand its application to other areas.[22]

We now turn to several recent reconstructions of good sense, to argue that each of them fails to accommodate at least one of the above properties.

4 Good Sense Reconstructed

Duhem's good sense has attracted significant attention in the recent literature on theory choice. We start with Mongin's minimal reconstruction of good sense, then describe Stump's virtue epistemology account, before we consider Ivanova's objections and Fairweather's further defence of Stump's reading. Our aim is to show that neither account manages to fully capture all the properties we have examined in the previous section.

4.1 Mongin's Temporal Account

Although most of the recent literature on Duhem's good sense, discusses below, highlights the role of moral and intellectual virtues, a more restricted reading is

[19] Let us mention that in the context of experimental science, good sense is not only used to evaluate hypotheses but also to formulate them. (Duhem 1991, 24) However, here good sense is not attributed additional properties.

[20] Having a list of criteria is necessary but not sufficient to having an algorithm.

[21] One interesting question which arises from considering all the properties of good sense is whether any of them should be regarded as more important or bear any priority over other properties. Duhem does not seem to address this issue. In Sect. 6 we discuss the relationship between different properties and show certain tensions that appeal if one tries to accommodate them into the same account.

[22] As we discussed in Sect. 2, the properties and role of good sense vary dependent on the subject to which it is applied.

possible if one prioritises the temporal aspects of good sense. Mongin (2009) proposes a "time-based interpretation" (p. 314)[23]: if, following Duhem's examples, scientists can lack good sense either in being to hasty, or too obstinate, this is because theories should neither be abandoned too early nor adopted too soon:

> The conservative physicists becomes unbearable only when he repairs the existing theory *over and over*, and the radical is unpalatable only when he strikes *too early*. (Mongin 2009, 314)

In other words, when evidence accumulates, having good sense amounts to feeling the right moment when it becomes unreasonable to cling to a theory. However, identifying this moment is just as difficult as it is to determine the number of similar observations that make an inductive inference reasonable.

This temporal account captures the fact that good sense varies in individuals and is hindered by passions and interests—a scientist would tend to cling longer to his favoured theory. As good sense dictates when the right moment to leave a theory is, after the accumulation of data, it partly accommodates the accelerating property.[24]

A worry for this account is that it does not explain why super-empirical criteria would make us abandon a theory earlier or later than another. Worse, if such criteria mattered, nothing prevents that there exist an algorithm that makes the right moment depend on (say) the complexity of a theory. It also does not accommodate the property that good sense always chooses a theory.

4.2 Stump's Virtue Epistemological Account

The first systematic attempt at understanding the notion of good sense was given by Stump (2007). Stump argues that Duhem's good sense can best be understood from a virtue epistemological perspective. Virtue epistemology, like virtue ethics, shifts the focus of analysis from beliefs, or actions in the case of ethics, to the agent who forms the beliefs or performs the actions. Virtue epistemologists define knowledge as the belief which a virtuous agent would hold. Stump notes some significant similarities between virtue epistemologists and Duhem's notion of good sense:

> Like contemporary virtue epistemologists, Duhem also takes knowledge to be dependent on the virtues of the knower. Scientists must have intellectual and, indeed, moral virtues in order to reach scientific knowledge, especially when choosing between empirically adequate theories. (Stump 2007, 150)

Stump argues that Duhem's notion of good sense and Linda Zagzebski's understanding of virtue epistemology share 'an ethical vocabulary of epistemic norms' (ibid., 152), and more importantly, they are both attempts at establishing that neither morality nor theory choice can be seen as rule-governed. No algorithm can be constructed to determine the outcome of moral choice in a situation of a moral

[23] Mongin's interpretation is made briefly, as it is not crucial to his paper, which does not concern good sense directly. By mentioning and later discussing it, we merely intend to illustrate a way in which good sense can be minimally interpreted; this does not impinge on the general purpose of Mongin's paper.

[24] To accommodate it fully, it would have to suggest the abandonment of a theory as quickly as possible, ideally after a unique experiment.

dilemma nor can an algorithm be constructed to give an outcome when choosing between empirically equivalent rival theories.

According to Stump:

> In Duhem's account of scientific theory choice, there is openness, since strict rules do not apply, but also objectivity. The source of this objectivity is the epistemic agent—the scientist who acts as an impartial judge and makes a final decision. (Ibid., 155)

Stump believes that connecting Duhem's concept of good sense to virtue epistemology can be informative and help us understand how a theory of non-rule governed rational choice can be constructed.[25] The idea is that the agent is the source of justification of theory choice. The agent possessing good sense, that is, the agent exemplifying all the relevant intellectual and moral qualities, will be the source of justifying why preference should be given to a particular theory. What is of particular importance in Stump's reading is that moral qualities are given primary importance and "scientific judgement is subordinated to moral conditions" (Stump 2011, 15). On Stumps reading, good sense should be seen as a normative property, imposing a choice without the appeal to any rules.

The advantages of this account are that it recovers the no-algorithm property of good sense, since agents are the source of justification of theory choice and good sense is a normative property; moreover it explains the need to stay away from passions and interests, since knowledge is reached only by intellectually and morally virtuous agents.

The disadvantages of this account are that if moral qualities are of primarily importance to theory choice, then no room is left for super-empirical virtues. Also, it does not explain why moral virtues would accelerate scientific progress, neither does it account for good sense' ability to always determine a choice.

4.3 Ivanova's Middle-Way Account

In her (2010) Ivanova argues that Duhem should not be seen as a virtue epistemologist because there are essential differences in application of epistemic virtues between Duhem and virtue epistemologists.[26] She nevertheless agrees with Stump regarding the content of good sense—it is a cluster of intellectual and moral virtues relevant in solving the problem of theory choice. Ivanova believes that Duhem understands good sense as a property fully present in an idealised agent. She points at Duhem's discussion of a perfect theory (Duhem 1996, 68), which he took to be a helpful idealisation in promoting scientific progress, and his discussion of

[25] Kidd (2011) has also supported Stump's reading by claiming that good sense is a responsibilist virtue epistemological notion. Some concerns with this defence are given in Ivanova (2011). Fairweather (2011) argues that good sense is compatible with both reliabilist and responsibilist virtue epistemology. In any case, a responsibilist account fits a strictly smaller number of properties of good sense than a reliabilist one (as it focuses primarily on moral virtues), which is why we do not consider it here.

[26] Ivanova argues that Duhem and virtue epistemologists differ in their epistemic aims and, most importantly, that Duhem had very different motivations to virtue epistemologists in developing the concept of good sense and making relevant the role of moral and intellectual virtues.

scientists who exemplified properties of good sense (Duhem 1991, 71). She argues that Duhem took good sense to be fully exemplified in an ideal scientist, a construction, which can be reached by idealisation and abstraction from actual scientists. Ivanova argues that for Duhem good sense is as normative a construction as the idea of a perfect theory is—it can guide scientists in their decisions by excluding some possibilities but cannot impose any specific rules or outcomes of choice. It is also a descriptive notion, since it is constructed by idealisation and abstraction of actual scientific practice.

The central difficulty for good sense, according to Ivanova, is to know who has it. Duhem himself suggests that 'battles' of good sense are not rare in theory choice (Duhem 1954, 217). Every scientist can insist they have good sense. However, what Duhem takes to settle this battle is new empirical evidence favouring one of the theories and discarding the other. Ivanova notes that if new evidence only can resolve the issue, then good sense is justified post hoc and becomes redundant.[27] This can lead to the claim that good sense has good 'track record', since it is always justified post hoc by further evidence, and as a consequence is reliable. However, the problem of providing ways to compare good sense in agents and deciding who exemplifies it in situation of theory choice remains unsolved, making good sense an unsatisfying solution to theory choice.

This account accommodates the role of super-empirical virtues and the no-algorithm property. However, it does not explain why having moral virtues is central to good sense. It could also potentially lead to violation of Duhem's desire for impartiality as other virtues, and even vices, might prevail over it. For Ivanova, such violation would still count as an exemplification of good sense, since the only criterion of judging good sense is that it chooses a theory that is supported by future evidence and becomes a more fertile research project. It also fails to accommodate the accelerating property of good sense and does not account for its ability to always determine a choice.

4.4 Fairweather's Hybrid Account

Fairweather (2011) argues that the best way to understand good sense is by taking elements from both Stump's and Ivanova's readings. He argues that two factors are central to the evaluation of good sense as a virtue epistemological notion: (1) see whether Duhem has a reversed order of analysis; and (2) see whether good sense satisfies the 'success from ability' criterion. The first has to do with the relevant shift promoted by virtue epistemologists in analysing beliefs in terms of agents and not vice versa. The second has to do with whether the employment of good sense is responsible for epistemic success.

Stump's account satisfies both of the criteria—agents are the source of justification and good sense confers uniqueness in theory choice. Ivanova's account, on the other hand, does not take good sense to be able to determine the outcome of choice nor does it give epistemic standing to the theory it chooses.

[27] She has also argued (Ivanova, forthcoming) that good sense cannot solve theory choice because it is not possible to provide unique ordering of 'good sense' and conclude uniquely who exemplifies it.

While it could in principle explain convergence of opinion in theory choice, only the availability of new evidence could justify one outcome and dismiss another.

Fairweather's proposal is to see good sense as an ability employed in different epistemic situations. He suggests that we should distinguish between non-underdetermination situations and underdetermination situations, which lead to theory choice, and recognise the application of good sense only in the latter case. Fairweather's reading captures Duhem's claim that in non-underdetermination situations, scientists follow the hypothetico-deductive method and need to employ good sense only when faced with empirically equivalent rival theories. On his account, scientists mostly engage in rule governed procedures which results in their developing and shaping their cognitive abilities and skills that are later employed in underdetermination situations.

Fairweather suggests that both Stump's and Ivanova's readings of good sense have some limitations. Ivanova's reading suggests that good sense is not capable of justifying a unique outcome of choice and only empirical evidence can determine and justify the choice of a theory from a set of rivals. It does not confer to the theory any epistemic standing and uniqueness of choice. Contrary, on Stump's account, good sense is sufficient to confer uniqueness. Fairweather argues that Ivanova's reading cannot explain how theory choice becomes determinate in light of new evidence, since any new empirical evidence can in principle be accommodated within the empirically equivalent rival theories. Thus, given that no new evidence can really favour one theory, the essential role of good sense is to provide a unique choice.

Fairweather's hybrid account of good sense combines elements of both Stump's and Ivanova's readings. The bottom line of his account is that good sense alone is not sufficient to confer epistemic standing to the chosen theory but nevertheless is necessary to confer uniqueness, which stops the underdetermination that would be faced otherwise.

Fairweather's account overcomes some limitations of Stump and Ivanova. It accommodates the role of super-empirical criteria, the impartiality characteristic, the desire to stay away from interests and passions and only it presupposes that good sense always ends up choosing a theory.

However, it is at odds with the fact that good sense is supposed to merely accelerate scientific progress. For Fairweather, good sense has a specific function—namely, to lead to a unique theory—which makes it necessary for scientific progress. Note that only Fairweather's account helps understanding why good sense always ends up favouring a theory. However, as we will see, this is actually a problematic property of Duhemian good sense.

4.5 Taking Stock

In Table 1 we summarise how the four accounts accommodate the main properties of Duhemian good sense.[28]

[28] We have left out some properties of good sense that we presented in Sect. 3 because they are accommodated by all accounts.

Table 1 Assessment of the reconstructions of good sense

Good sense	Mongin	Stump	Ivanova	Fairweather
Super-empirical criteria	**No**	**No**	Yes	Yes
Impartiality/passions and interests	Yes	Yes	**No**	Yes
Not an algorithm	**Maybe**	Yes	Yes	Yes
Accelerates science	**Partly**	**No**	**No**	**No**
Always ends up choosing	No	No	No	**Yes**

Bold characters indicate the problematic characteristics of the accounts

As the table makes clear, no account perfectly fits Duhem's good sense; in particular, note that none accommodates the accelerating property. Note that this is not an attack on these reconstructions. Although it may be the case that none of these reconstructions are satisfying, it may also be the case that Duhem's concept of good sense is inconsistent to begin with, if understood as possessing all the aforementioned properties. Duhem only devoted a couple of pages of his main book to good sense in experimental sciences, in which the characteristics listed at the end of Sect. 3 are all mentioned (before making more general remarks in his 1991, mostly in the context of mathematics). Maybe Duhem's hunches as to how underdetermination is solved in practice were no more than hunches that cannot be recovered by a more careful analysis. However, Sect. 6 will show that the properties are not inconsistent by offering an alternative reading of good sense that accommodates them all, including the accelerating one.

Even if Duhemian good sense is a consistent concept, it may not be the one we need. That the existing accounts mentioned above fail to be faithful reconstructions dismisses them as attempts to salvage Duhem's concept, but not necessarily as adequate solutions to the problem of theory choice.[29] The next section discusses whether they may provide a solution after all, regardless to their relation to good sense.

5 Virtues, Reliability and Acceleration

One of the problematic properties of good sense is that the claim that it always ends up allowing one to make a choice appears to be a descriptive claim and is not about good sense itself as a normative notion. One could perfectly imagine sequences of observations and experiments that equally favour several theories, or successively favour each of them. It might also be argued that not all examples of underdetermination have been indeed resolved. It is currently an open issue whether Bohmian mechanics or Everettian quantum mechanics, or collapse interpretations of quantum mechanics, will prevail and lead to a sound quantum

[29] One may still argue that Duhemian good sense can be satisfactorily defined by a subset of the properties we highlighted, for instance by providing reasons why Duhem considered some of them as more or less important than others—although we have found no such reasons. One of the existing reconstructions may also well end up providing a better account of the general role of intuition in science; but this topic goes beyond the scope of this paper.

field theory. Moreover, one can claim that the resolution of underdetermination has nothing to do with good sense but with the emergence of a new theory. In the case of underdetermination between the special theory of relativity and Lorentz' ether theory, what resolved the dispute had nothing to do with theoretical or moral virtues[30] but with the fact that the former theory served as a stepping stone to the general theory of relativity, leading to significant novel predictions and richer empirical content. Overall, what we are left with is an empty claim that good sense always resolves theory choice, which is not always descriptively correct.

The property could be weakened by arguing that good sense always ends up leading to a choice in favourable conditions—for instance when successive observations consistently favour one theory among all. In other words, if one theory is better than the others (more empirically adequate), good sense will end up favouring it. This is especially consistent with Mongin's account, and also with Ivanova's account of good sense being judged post hoc.[31] However, this is not Duhem's understanding, which thus seems to make a claim about the world (evidence always ends up favouring one of our theories) rather than about good sense. This is why we take the fact that Fairweather's account accommodates this claim as problematic.[32]

Another problem for the concept of good sense is that there is a deep tension between the accelerating property, on the one hand, and the moral/intellectual virtues and the no-algorithm property on the other hand. For either these virtues are valued for themselves, which grants the no-algorithm property but does not guarantee that good sense accelerates scientific progress; or they are valued for their possible products (e.g. accelerating science or leading to truth) in a given context (e.g. the social environment), which could make good sense compatible with an algorithm based on this context's parameters.

The virtue epistemological reading of good sense also needs to address how exactly we can understand the property of reliability of good sense. It is not clear whether reliability is a property of good sense. While Duhem does not mentioned this property, the virtue epistemology accounts consider it as necessary. Ivanova's criticism of good sense shows that the post hoc judgement of good sense leads to the claim it is reliable, but that just illustrates how problematic the notion is. It is difficult to defend the role of good sense when trying to cash out how we judge its reliability. The virtue epistemology accounts have not defended the claim of reliability of good sense and have not offered a way to avoid the post hoc nature of

[30] Theoretical virtues do not resolve the problem of underdetermination because they are inconclusive. Lorentz' theory exemplifies the virtue of conceptual continuity, since it does not revise the concepts of space and time, while Einstein's exemplifies the virtue of ontological simplicity, since it eliminates the ether.

[31] The social consensus account may seem to escape this dependence on conditions. Some convergence or washing out results in Bayesian confirmation theory establish that any sequence of evidence, regardless of which theory every piece of evidence confirms most, tends to bring individual degrees of belief closer than they were in the outset (De Finetti, 1974). However, these degrees do not have to be 0 or 1; in cases of conflicting evidence, scientists may agree that they cannot decide. So in unfavourable conditions, good sense will be stuck under the social interpretation as well.

[32] See Table 1, last row.

good sense. In any case, none of the accounts (including the one we develop below) makes clear why good sense could be considered as reliable.

One last worry for the virtue epistemology reading stems from Fairweather's claims that good sense has a very specific application—it is employed only in theory choice—and does not play any epistemic role in non-underdetermination situations. This claim avoids one of Ivanova's objection to Stump's virtue epistemological reading—that it is not representing Duhem's motivation of employing the notion of good sense. Stump's reading implies that epistemic and moral virtues are relevant for the acquisition of knowledge as a whole, while Duhem holds that in the construction and evaluation of theories scientists must follow the deductive-nomological model. As such, Duhem's application of epistemic and moral virtues is much more limited than what a virtue epistemological reading of good sense would imply. While Fairweather's reading stays true to Duhem's motivation, it does not explain why virtue epistemology can play such a dual role in scientific enquiry. It is problematic that epistemic and moral virtues are employed only in a very specific limited domain, while it is recognised that they are epistemically irrelevant in most epistemic situations where knowledge is acquired by following strict rules without the employment of epistemic virtues. This implication is problematic for any virtue epistemologist, since it implies that there are other relevant factors for the acquisition of knowledge apart from epistemic and moral virtues and seems to undermine their aim to define knowledge uniquely in terms of the agent's cognitive character.

Having examined the four recent reconstructions of good sense and their limitations, we now offer an alternative reading of good sense which fits all of the properties listed in Sect. 4, including the accelerating one. We believe that by expanding the domain of application in which good sense is considered—from an individual to a social level—we can provide a reading which manages to accommodate all of the properties of Duhemian good sense and thus illustrates how a normative but non rule-governed account of theory choice can be defended.

6 Good Sense as Promoting Social Consensus

This section presents a way to recover all the properties of good sense and to justify the effect of intellectual virtues on scientific progress, by considering how good sense functions at the social level, although this analysis does not capture Duhem's motivation in developing the concept of good sense, which exclusively functions at the individual level. As we argue below, it appears that good sense can be interpreted from the role it plays in a social context. As seen in Sect. 2, the idea that sociological factors can play a role in theory choice has been familiar at least since Kuhn. Even after every scientist made her choice, there may still be no general consensus as to which theory is preferable. In other words, collective choice can be problematic even if individual choices are not. On the other hand, collective processes can generate a unique choice despite individual disagreement.

We suggest that having good sense can be interpreted as choosing a theory so as to smooth the scientific consensus building process. Of course, what good sense

exactly amounts to naturally will depend on the process by which the scientific community reaches a consensus. Still, even this admittedly vague definition allows us to recover all the Duhemian properties of good sense.

It is already apparent that by design, good sense understood as social smoothing accommodates its accelerating property. If theory choice is partly accomplished at the social level, then anything that accelerates the social decision process does also accelerate the choice between rival theories. The real questions are to elucidate how exactly good sense accelerates consensus building, and whether some additional Duhemian properties can also be accommodated. So what kind of choice should good sense prescribe in order to have the *acceleration* property? Although some options are available, none of them seems satisfying.

First, suppose that good sense prescribes to prefer whatever theory one predicts the majority will end up choosing. Agents would estimate around what option the final consensus is likely to solidify, and then anticipate the result by choosing the option. Of course, it is extremely unlikely that scientists even reason in such a way; but this should not impinge on a normative analysis of good sense. Although this would certainly accelerate consensus building, it would make good sense entirely social, disconnected not only from super-empirical criteria but also from any evidence whatsoever, which is at odds with what scientific practice should be.

Secondly, suppose that good sense accelerates consensus building in virtue of prescribing a purely strategic choice. A strategic choice would be for a scientist who favours theory A—whereas most scientists favour theory C—to defend theory B instead of A because it increases the chances that the scientific community ends up adopting A. This could happen if B is more similar to C than A; or if A is a highly unorthodox theory supported by some evidence E, if choosing B makes the community more sensitive to E, which in turn increases A's appeal. Even if such scenarios seem convoluted, they are merely instances of a simple principle: when wanting to convince people holding widely opposed opinions, it is more efficient to drag them to a middle ground first.

However, if good sense only amounted to such strategic choices, the role of moral virtues could not be accommodated. Moreover, it is not obvious what the accelerating property could be either: preferring B to A may increase the chances that A ends up being adopted by the scientific community while making the process take longer.

We should not be surprised that it is difficult to determine the nature of the choice that good sense prescribes, as it is supposed to escape any rule-based procedure. But maybe we do not need to. Whatever process determines social choice, one of its crucial characteristics is that the more diverse the scientists' choices are, the longer it takes to reach a consensus. This characteristic is intuitive: the influence of scientists' individual biases should be reduced by the conservation of identical evidence (that is, if scientists care about evidence at all). It also derives from results in Bayesian epistemology, called convergence or washing out theorems.[33] They show that regardless of the differences in their prior beliefs regarding the truth of

[33] For introduction to such results, see Gillies (2000), Joyce (2009). The first technical theorems are due to De Finetti and Doob.

various hypotheses, any sequence of common evidence will lead the agents' beliefs to end up being arbitrarily similar in the long run.[34] The crux of the matter is the general fact that common evidence tends to bring agents' beliefs closer. As a result, the closer prior beliefs are, the earlier posterior beliefs will reach a given degree of proximity.

As a consequence, *whatever makes individual opinions more similar* would smooth out the social decision process. The ideal solution would be for everyone to make an identical choice; however, this is impossible given the necessary subjectivity in the interpretation of super-empirical criteria (see Sect. 2). No attitude could possibly make scientists' priors identical in all contexts. A better solution is to minimise the *variance* between opinions. Surprisingly, this seems to be what good sense as described by Duhem accomplishes, precisely because virtues are crucial components.

As seen earlier, there is a tension between the accelerating property of good sense and the fact that it is hindered by passions and interests. When one theory is obviously better than its rivals, being biased in its favour would accelerate its adoption.[35] How can we reconcile the fact that passions and personal interests are the bigger obstacles to good sense while being biased may sometimes accelerate science?

The problem vanishes once the social dimension is introduced. Indeed, passions and personal interests are personal, that is, they are not shared. If a scientist who has to choose between theories is influenced by her personal interest, then her choice is more likely to differ from that of others. The presence of passions and personal interests increases the chance that a population manifests a wide variety of individual opinions. This is why impartiality and faithfulness are important: everyone's being impartial will decrease the variation between everyone's judgments and thus accelerate the choice of a theory. According to this argument, personal interests and passions are problematic not because they are moral vices, but because they increase the variance among beliefs within the scientific community.

By contrast, the problem of the subjective appreciation of super-empirical criteria cannot be solved in such a principled way. This is partly because, as Kuhn observed and as recalled in Sect. 2, the list of relevant super-empirical criteria and their respective importance is typically time-dependent, even if it evolves more slowly than scientific theories are modified.[36] As a result, no general algorithm based on super-empirical criteria could regiment theory choice: it also depends on what beliefs are held in the scientific community. Typically, scientists should assess empirically equivalent theories in function of super-empirical criteria, while ignoring all reasons to choose that do not directly stem from scientific practice, that is, all reasons that are unlikely to be shared by other scientists. Good sense makes scientists' opinions as similar as possible, but not to the extent that they should

[34] Such results of course depend on technical assumptions, which do not matter to our discussion.

[35] Stump (2007) notices that good sense cannot be reduced to reliability of the choice process, or else being biased towards the best theory would count as an example of good sense.

[36] For instance, Kuhn noted that accuracy slowly became a relevant criterion as science took the contemporary we are familiar with; but it was not regarded as highly centuries earlier.

always agree on what constitutes a good theory. Overall, if we interpret good sense with respect to its smoothing role in the context of social consensus building, Duhem was right to deem passions and interests as the main obstacles to good sense: although not the only ones, they are the only ones that can—and should—be overcome.

The above analysis vindicates the social interpretation of good sense, as only it accounts for several of its key features from the current alternative readings: it accelerates the evolution of science while being mostly hindered by passions and interests (for it reduces the disparities between scientists and makes their beliefs converge faster); it is context dependent and thus not readily reducible to an algorithm[37]; and it accounts for the role of super-empirical criteria. This shows that the key properties of Duhemian good sense can be accommodated simultaneously, and thus that the concept is not inconsistent.[38]

Still, the social interpretation faces several issues. We now briefly mention three minor objections; the next section will discuss a more important problem.

One advantage of the social construction account is that it is capable of overcoming Ivanova's main objection to good sense—judging who has it. Recall her objection to good sense being judged post hoc, namely that good sense cannot solve theory choice because there is no way to determine who has good sense. On the social reading this objection can be overcome because good sense smoothes up convergence in a social group. However, convergence does not guarantee getting things right and is not even linked to confirmation of the chosen theory, which Duhemian good sense requires. As Ivanova argues, because of the post hoc justification of good sense, it always gets things right. Just like the other accounts, the social choice account cannot guarantee such a link.[39]

A further problem with the social choice interpretation is that it does not intrinsically rely on moral virtues such as faithfulness and impartiality; they are only favoured because of their effects on the social choice process, which would displease the defenders of the virtue epistemology account. But even for Duhem, passions and interests hinder good sense because of the biased choice they lead to. Faithfulness and impartiality are not to be praised for their intrinsic value, but for the effects they have.

A final worry for the social choice reading is that it could be reduced to an algorithm after all. That it is context-dependent means that there could be no such algorithm merely based on super-empirical criteria. Still, given a scientist's

[37] Recall that it *might* be unable to accommodate the no-algorithm property; however, the account would have to be fleshed out significantly in order to support this claim.

[38] Note that although the social consensus account fits the properties of Duhemian good sense, the the fact that good sense functions at a collective level was never explicit in Duhem's understanding of good sense.

[39] The social consensus account may appear to escape this dependence on conditions. However, even if individual degrees of beliefs converge to a given limit, this limit does not have to correspond to a degree 0 or 1—that is, to certainty that a hypothesis is true or false. Indeed, in cases of conflicting evidence, scientists may agree that they cannot decide. So even under the social interpretation, good sense may be stuck if conditions are unfavourable.

subjective appreciation of super-empirical criteria *and a social context*,[40] may not the optimal choice be computable? It may, but Duhem's no-rule property arguably encompasses only algorithms based on properties of the theories, not of people's beliefs and preferences about them—precisely because Duhem never assigned good sense any social dimension.[41]

7 Uniformity or Diversity?

Thus far, only the social consensus account explains how good sense accelerates scientific progress: it promotes convergence of opinion in the scientific community. However, as seen above, it does so at the possible cost of the no-algorithm property—which is difficult to establish given how vaguely the social decision process has been defined.

Nevertheless, even in its sketchy state, there is a much more serious worry with the social consensus account, or even more fundamentally with the reason why it works: it is at odds with some prevalent analyses of the social structure of science. Recall that according to the social choice account of good sense, a scientist should keep her beliefs as far as possible from the extremes (to a certain extent, since idiosyncratic preferences for some super-empirical criteria are allowed). More generally, any attitude that reduces divergences between individual opinions would have an accelerating effect; ignoring passions and personal interests is but one way to cause such a reduction. At bottom, the explanatory work is done by the increased similarity between scientists, or by their greater conformity. Indeed, any rule whatever that prescribes a unique choice would best accelerate scientific progress; the absence of a principled way to arbitrate between super-empirical virtues is what renders complete uniformity unfeasible. In any case, constrained maximization of uniformity among scientists provides the fundamental justification for the social consensus account.

However, this analysis seems to fly in the face of much recent philosophical work, according to which the success of scientific activity crucially relies on diversity rather than on uniformity. During the last four decades it has become increasingly clear that science works well partly because it has a distributed structure; a scientific community that enjoys a huge variety of beliefs is not only viable but also more successful. Hull (1988) argues that the goals of science can be compatible with, and explained by, scientists' individual desires for recognition,[42] and also insists that roles should be distributed. In particular, individuals need not be impartial with regard to their own work.[43] This mitigates the importance of virtues

[40] That is, the set of the other scientists' beliefs and a description of the social decision process.

[41] Duhem did hold that different societies (such as the English, the French or the German) exemplified different kinds of intuition or reasoning. This shows that he acknowledged that social factors can be detrimental to the use of good sense. Still, it does not mean that he considered good sense itself, or some properties thereof, as stemming from, or constituted by, effects at the social level.

[42] Merton (1973) was the first to understand recognition as the main motivational source for scientists.

[43] As Godfrey-Smith suggests "Hull argues that there is no need for individual scientists to take a cautious and sceptical attitude toward their *own* work; others will do this for them" (2003, 165).

in general (and thus indirectly the relevance of good sense in science), as well as that of conformity between scientists. The strength of Hull's analysis is that it is descriptive and normative: it emphasizes the importance of recognition as a motivation for scientists as well as certain key characteristics of science (descriptive part), but also explains how the former justifies the latter (normative part).

The combination of private motives and diversity of choices appears with Kitcher (1993) and later Strevens (2003), who emphasize that scientific success would be fostered by allowing scientists to work simultaneously on *different* theories. Often, the optimal scheme scientific resource allocation would not be a unique allocation of all scientists on a unique research project, but a bet-hedging strategy that allocates scientists to different projects depending on their chances of being successful. The virtue of these results is that they establish not only that the bet-hedging strategy can often be collectively preferable, but also that the nature of the scientists' individual rewards is such that bet-hedging may naturally emerge from individual choices. In other words, it might be preferable for a scientist to be dogmatic and work on a generally neglected theory, because of the greater reward if it succeeds; as the reward is cashed out in terms of prestige, it depends on the number of other scientists working on the same program, which is why different scientists may rationally choose to work on different programs.

These results threaten the relevance of good sense in scientific practice, and in particular our social consensus reconstruction. For although the above authors give very different accounts of what science is and why it is by and large successful, they agree that it is improved by diversity, and at least entirely compatible with the lack of moral and intellectual virtues.

In other words, the diversity of scientists' beliefs is currently considered as a *positive* feature of science.[44] By these lights, it is odd that good sense is supposed to make them as similar as possible. Note that this is not only a problem for the social account of good sense. Duhem holds that perfect science would be characterized by everyone exercising good sense. However, this cannot be expected from a wildly diverse group of scientists, including some dogmatic ones. If scientific progress is improved, or accelerated, by such diversity, then it cannot be because everyone is reasonable in a similar way, and even less by everyone exemplifying the same virtues. Dogmatism, as long as it is distributed in the population, not only can but does contribute to scientific progress.

Still, despite the fact the above works strongly suggest that diversity of beliefs benefits science, they do not prove it—they are based on models, that depend on technical assumptions, and as a result only show that it is *possible* for diversity to benefit science.

By contrast, according to Kuhn (1962) conformity too is important in science. In normal science, scientists must be partial to the paradigm in which they are working—they must be dogmatic to some extent so as to be able to develop it

[44] This is not to say that scientists' beliefs are not also similar to each other to a great extent, especially in natural science. For instance, scientists typically agree on the importance of empirical accuracy. But they agree mostly on how scientific theories or hypotheses should be assessed in principle. The diversity of beliefs emphasized here concerns beliefs as to what hypothesis or theory is true rather than how to assess this truth in general.

regardless of early anomalies, and importantly they must all be dogmatic towards the same paradigm. So one can resist the diversity argument and, based on Kuhn's defense of conformity, defend the social choice account of good sense.

However, even Kuhn allows for diversity in revolutionary science, as scientists may develop several pre-paradigmatic alternatives to the current paradigm. Moreover, conformity is important in normal science only because Kuhn does not allow the possibility of simultaneous fully formed paradigms. In later accounts of scientific change, such as Lakatos' (1970) and Laudan's (1977), research programmes/traditions are allowed to compete. As a result, diversity rather than conformity appear to benefit science.

The previous arguments suggest that diversity, rather than uniformity, both is and should be a feature of scientific activity. However, we do not think they pose a serious threat to the social consensus interpretation of good sense, for the following reasons. The social consensus account emphasizes the positive effect that the similarity of *beliefs about the truth of theories* has on reaching a consensus about theory choice. Recall that the problem is to justify a choice between theories that enjoy equal empirical success; good sense solves it by bringing beliefs about the truth of theories closer.

By contrast, Kitcher and Strevens' results highlight the positive effect of cognitive division of labour for scientific success. Here the problem is to maximize the chances that a successful theory is developed; the solution is to have scientists work on, or *pursue*, different theories.

As a consequence, the seemingly contradictory diagnoses are not opposed. First, they suggest solutions to different problems—that of *assessing and comparing* equally satisfying theories, and of *obtaining* a satisfying theory to begin with. Second and more importantly, their solutions, although respectively based on uniformity and diversity, do concern different attitudes, respectively belief and pursuit. As a matter of fact, it is well-known, at least since Laudan's (1977) famous analysis, that the *acceptance* and the *pursuit* of theories are distinct attitudes, for a scientist may well accept one theory (as the best theory available) yet pursue another one, for instance because it is promising despite its current lack of success.

Consequently, the arguments based on good sense and on division of labour in science do not lead to two competing views of science. There is no conceptual obstacle to the possibility that members of a scientific community agree on what counts as the best available theory while different members strive to develop different other theories.

To summarize, the social account provides the best fit to Duhem's description of good sense,[45] and escapes the criticism based on Kitcher and Strevens' results, according to which what most benefits science is the diversity of individual attitudes. Still, this by no way proves that the social consensus account is correct. It remains under the threat of a theory that would manage to justify the positive effect of diversity of *beliefs* on scientific activity.

[45] Understood as the conjunction of properties mentioned in Sect. 3.

8 Conclusion

In this paper, we have assessed recent solutions to the problem of theory choice that originate from Duhem's concept of good sense. We have argued that the current reconstructions of good sense have limitations insofar as they do not accommodate all the properties Duhem attributed to good sense. We have proposed an account of good sense as a social consensus soothing attitude that, we argue, is the most faithful reconstruction of Duhem's good sense. Even though it expands Duhem's original analysis, it fits all the required properties and at the very least shows that it is a consistent concept. We have argued that the failure of the current reconstructions to solve the problem of theory choice is due to their lacking justification of the effect that intellectual and moral virtues have on scientific progress. We have also defended the social consensus account against apparent objections stemming from recent results that highlight the importance of division of labour in science. Still, we have not proved that it escapes all possible objections based on diversity, and so leave it open that a sound critique of social choice could be developed in the future. In general, it is difficult to assess the success of Duhemian good sense as a solution to the problem of theory choice, as all existing reconstructions only manage to make sense of it by impoverishing or enriching it.

Acknowledgments We thank Samir Okasha, David Stump and participants to the 2012 BSPS conference and to the Bristol Work in Progress Philosophy Seminar for their useful comments. Milena Ivanova would like to acknowledge the financial support of The Royal Institute of Philosophy.

References

de Finetti, B. (1974). *Theory of probability*. New York: Wiley.

Duhem, P. (1954 [1906]). *The aim and structure of physical theory*. Princeton: Princeton University Press.

Duhem, P. (1991). *German science: Some reflections on German science: German science and German virtues* (John Lyon, Trans.). La Salle, IL: Open Court (First published 1915).

Duhem, P. (1996 [1893]). Physics and metaphysics. In R. Ariew & P. Barker (Eds.), *Pierre Duhem: Essays in the history and philosophy of science* (pp. 29–50). Indianapolis: Hackett.

Fairweather, A. (2011). The epistemic value of good sense. *Studies in the History and Philosophy of Science Part A, 43*(1), 139–146.

Gillies, D. (2000). *Philosophical theories of probability*. Routledge: Psychology Press.

Godfrey-Smith, P. (2003). *Theory and reality: An introduction to the philosophy of science*. Chicago: University of Chicago Press.

Hull, D. L. (1988). *Science as a process: An evolutionary account of the social and conceptual development of science*. Chicago: University of Chicago Press.

Ivanova, M. (2010). Pierre Duhem's good sense as a guide to theory choice. *Studies in the History and Philosophy of Science, 41*, 58–64.

Ivanova, M. (2011). 'Good sense' in context: A response to kidd. *Studies in the History and Philosophy of Science, 42*(4), 610–612.

Ivanova, M. (forthcming). Is there place for epistemic virtues in theory choice? In A. Fairweather (Ed.), *Virtue Scientia: Bridges between virtue epistemology and philosophy of science*. Synthese Library, Dordrecht: Springer.

Joyce, J. (2009). The development of subjective Bayesianism. In D. Gabbay, S. Hartmann S., & J. Woods (Eds.), *Handbook of the history of logic* (Vol. 10). Inductive Logic.

Kidd, I. J. (2011). Pierre Duhem's epistemic aims and the intellectual virtue of humility: A reply to Ivanova. *Studies in the History and Philosophy of Science* (electronic version).

Kitcher, P. (1993). *The advancement of science: Science without legend, objectivity without illusions*. Oxford: Oxford University Press.

Kuhn, T. (1962). *The structure of scientific revolutions*. Chicago: University of Chicago Press.

Kuhn, T. (Ed.). (1977). Objectivity, value judgment, and theory choice. In *The essential tension: Selected studies in the scientific tradition and change* (pp. 320–353). The University of Chicago Press.

Lakatos, I. (1970). history of science and its rational reconstructions. In I. Lakatos & A. Musgrave (Eds.), *Criticism and the growth of knowledge* (pp. 91–136). Cambridge: Cambridge University Press.

Laudan, L. (1977). *Progress and its problems: Toward a theory of scientific growth*. Berkeley: University of California Press.

Martin, R. N. D. (1991). *Pierre Duhem: Philosophy and history in the work of a believing physicist*. La Salle, IL: Open Court.

Merton, R. (1973). *The sociology of science: Theoretical and empirical investigations*. Chicago: University of Chicago Press.

Mongin, P. (2009). Duhemian themes in expected utility theory. In A. Brenner & J. Gayon (Eds.), *French studies in the philosophy of science*. Berlin: Springer.

Strevens, M. (2003). The role of the priority rule in science. *The Journal of Philosophy, 100*(2), 55–79.

Stump, D. (2007). Pierre Duhem's virtue epistemology. *Studies in History and Philosophy of Science, 38*, 149–159.

Stump, D. (2011). The scientist as impartial judge: Moral values in Duhem's philosophy of science. New perspectives on Pierre Duhem's. *The aim and structure of physical theory (book symposium) Metascience, 20*, 1–25.