Epistemic Justification in the Context of Pursuit
A Coherentist Approach

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Abstract. The aim of this paper is to offer an account of epistemic justification suitable for the context of theory pursuit, that is, for the context in which new scientific ideas, possibly incompatible with the already established theories, emerge and are pursued by scientists. We will frame our account paradigmatically on the basis of one of the influential systems of epistemic justification: Laurence Bonjour's coherence theory of justification. The idea underlying our approach is to develop a set of criteria which indicate that the pursued system is promising of contributing to the epistemic goal of robustness of scientific knowledge and of developing into a candidate for acceptance. In order to realize this we will (a) adjust the scope of Bonjour's standards –consistency, inferential density, and explanatory power–, and (b) complement them by the requirement of a programmatic character. In this way we allow for the evaluation of the "potential coherence" of the given epistemic system.

Keywords: epistemic justification, coherence, Bonjour, inconsistency, explanatory power

1. Introduction

In this paper we present a coherentist account of epistemic justification suitable for the evaluation of the epistemic pursuit worthiness of scientific theories. We will first motivate our approach and explain its main underlying idea.

1.1. Epistemic Justification of Scientific Theories

Science has many goals. Besides the practical ones, such as improving the life standards of citizens, or providing predictive control of our environment, there are also epistemic goals. Science should provide us with knowledge about the world. It should increase our understanding by providing explanations and accurate descriptions of natural or social phenomena.[1]

Epistemic justification is concerned with the latter type of goals. It is traditionally conceived of as providing standards for the acceptability

[1] Of course, these goals are interwoven. For instance, predictive power is also an epistemic goal. Moreover, they are historically dynamic – see Footnote 27.

of certain beliefs in the knowledge base or the cognitive system of an intelligent agent. Applied to a scientific theory, it provides criteria for its inclusion and acceptance into the grand corpus of our scientific knowledge. It concerns the question as to whether we have good reasons to consider it as being (approximately) truthful, empirically adequate, etc. Hence, epistemic justification is tightly connected to what Larry Laudan calls the context of acceptance, i.e. the context in which scientists choose to accept a theory and thus treat it as if it were true (Laudan, 1977, p. 108).

However, while it is a worthwhile epistemic goal to satisfy the criteria of theory acceptance, it is not the only one. A quick glance at the history of science reveals that scientific knowledge is highly dynamic and we shouldn't be all too assured with the theories we have accepted. Not just is it the case that theories often have to be altered and adjusted, but sometimes they have to be entirely replaced. Under sufficient pressure of anomalies we may be justified in no longer maintaining the belief that these theories are sufficiently good to be considered acceptable. These times of crisis we do not want to face empty-handed.

Therefore, another important epistemic goal of our scientific knowledge is achieving robustness with respect to these perturbations and conditions of uncertainty. If robustness is the ability to maintain performance in the face of perturbations and uncertainty (Stelling et al., 2004), then we can say that the scientific knowledge in a given domain is robust if it is able to maintain its key functions of explaining and helping us to understand the world, by means of avoiding and, if necessary, by overcoming scientific crisis. Clearly, the more robust our theories (in a certain domain) are with respect to these perturbations the more robust is our scientific knowledge base as a whole (in this domain).[2] Although robust theories support this aim, since we cannot be sure that even the best theories withstand a possible future crisis we need more in order to ensure the robustness of the scientific knowledge as a whole. Recall that, as Otto Neurath famously remarked (Neurath, 1983, p. 92), scientists are "like sailors who have to rebuild their ship on the open sea, without ever being able to dismantle it in dry-dock and reconstruct it from the best components". Given the case that the old ship is about to sink and we cannot fix it anymore, we need to have (an)other "backup"-ship(s) available. Similarly, given the fact that even our best theories may fall into crisis, it is supportative of the aim of robustness to have alternative "backup"-theories around.

[2] For an account of the robustness of theories (and/or their constitutive parts) see for instance (Wimsatt, 2007; Calcott, 2011) or (Chang, 2004, p. 51-52). See also Footnote 11.

These theories don't come from nowhere, but have to be thoroughly investigated and pursued.

This opens two perspectives on the composition and structure of scientific knowledge as a whole or in a give domain: (i) the flat perspective under which scientific knowledge is composed of accepted theories and (ii) the entrenched perspective under which scientific knowledge is composed and structured by layers of more and more entrenched theories. The degree of entrenchment may be measured by any standard of epistemic justification (such as for example the degree of coherence). At the most entrenched level we have the accepted theories. At the following levels we have alternative theories that may in times of crisis offer good backups for the accepted theories, or that may under further development eventually surpass the currently accepted theories. Although they do not (yet) suffice the criteria of actual epistemic justification for being accepted (e.g. they are not coherent enough) they are epistemically justified in a different sense since they, on the one hand, support the robustness of scientific knowledge, while, on the other hand, they are promising of developing into candidates for acceptance and in so far they serve the goal of adequacy and accuracy of scientific knowledge. We will thus say that a theory is *potentially epistemically justified* to the extent that it is promising of contributing to the epistemic goal of robustness and of developing into a candidate for acceptance.[3] In the following subsection we will suggest that a theory is epistemically worthy of further pursuit to the extent it is potentially epistemically justified.

1.2. The Context of Pursuit

According to Laudan, in addition to acceptance and rejection, pursuit and non-pursuit are the other two major cognitive stances that scientists can legitimately take towards research traditions (and their constituent theories) (Laudan, 1977, p. 119). The notion of the context of pursuit resulted from the discussion on the traditional distinction between the context of discovery and the context of justification (proposed by Hans Reichenbach in the 30s' (Reichenbach, 1938)) which, in view of many philosophers, needed to be refined by introducing an intermediate step. For example, Richard Tursman speaks of "the logic of pursuit and/or of preliminary evaluation of hypotheses", linking it to Charles S. Peirce's account of abduction as a logic of pursuit, according to which, there is a *prima facie* ground for pursuing a hypothesis which is capable of explaining certain surprising facts, which have

[3] Also Sven Ove Hansson (2003) makes –in reference to David Makinson– the distinction between actual and potential justification of beliefs.

been observed (Tursman, 1987, p. 13-14). Imre Lakatos characterizes his “methodology of scientific research programmes” as consisting of “a negative heuristic”, which tells us what paths of pursuit to avoid, and “a positive heuristic”, which tells what paths to pursue (Lakatos, 1978, p. 47). Ernan McMullin speaks of a “heuristic appraisal”, which regards the research-potential of a theory (McMullin, 1976). Thomas Nickles also discusses “heuristic appraisal” (Nickles, 2006), as well as a “preliminary evaluation”, “plausibility assessment” or “pursuit” as the context which ”requires the comparative evaluation of problem-solving efficiency and promise, not simply the evaluation of completed research”, in contrast to the traditional theories of confirmation (Nickles, 1980, p. 21). Martin V. Curd argues that “not only is the logic of pursuit of more immediate practical relevance to scientific inquiry than the logic of probability but also that it is the only workable notion of a logic of discovery in the sense of a logic of prior assessment that one can formulate” (Curd, 1980, p. 204). Finally, Laudan describes this intermediate step as “the context of pursuit” (Laudan, 1977; Laudan, 1980), and Laurie Anne Whitt as “theory promise” or “theory pursuit” (Whitt, 1990; Whitt, 1992).

Nevertheless, the question of pursuit has often been left out of the accounts of epistemic justification. Even though some of the above mentioned authors discuss the nature of the context of pursuit or the possible logic of pursuit, and even though it has often been pointed out that such a prior assessment already embraces elements of justification (Schickore and Steinle, 2006a, p. viii), there has been little to no consideration of this question in the concrete accounts of epistemic justification.[4] In contrary, pursuit worthiness has been mainly discussed in view of an interwoven set of epistemic and non-epistemic values, the latter referring to social, ethical, or political values or personal interests of scientists (e.g. (Nickles, 2006), (Kitcher, 2001, Chapter 9), (Douglas, 2009, Chapter 5)).

As we have suggested in the previous subsection, the pursuit worthiness is a valid subject of epistemic justification that needs to be addressed in a different way than theory acceptance. Scientific theories clearly do not suddenly come into existence complete and fully equipped with an explanatory apparatus that would satisfy the standards of the-

[4] The closest to an epistemic treatment of pursuit worthiness came Laurie Anne Whitt who, in response to McMullin’s approach, remarked that “There seems to be no reason to accept the stipulation that epistemic appraisals are limited to contexts of acceptance.” (Whitt, 1992, p. 616). See also footnote 15. Also Hasok Chang’s coherentist epistemic iteration addresses some aspects of the context of pursuit even though Chang does not explicitly discuss the notion of pursuit or pursuit worthiness (see also Section 1.3).

ory acceptance. Their origin lies in ideas and hypotheses that have been thoroughly investigated, reformulated, corrected. But at the same time, young theories can be promising of developing into good backups for the currently established theories, and eventually even into acceptable ones. Hence, from an epistemic perspective, what we are concerned with in the context of pursuit is not the question as to whether a theory is acceptable, but as to whether there are good epistemic reasons for its further pursuit. We will say that a theory is *epistemically worthy of pursuit* to the extent that it can be shown to have a promising potential for contributing to those epistemic goals that determine theory acceptance, as well as to the value of robustness of scientific knowledge. In other words, a theory is epistemically worthy of pursuit to the same degree that it is potentially epistemically justified.

To be sure, the evaluation in the context of pursuit, as a part of the scientific practice, is certainly not exclusively epistemic. Many other non-epistemic factors play a role in deciding which problems to tackle, which methodology is ethically acceptable, etc. But this does not imply that epistemic values do not have a place in such an evaluation. In contrary, debates among scientists about the further pursuit of emerging scientific theories are often focused on novel explanations and predictions that the given theory offers, its consistency and compatibility with theories from other scientific domains, etc. Having good epistemic reasons for the further investigation of a theory is an important criterion for deciding about its pursuit, though it is not the only one that is practically relevant.

It is also important to notice that the question of epistemic pursuit worthiness is different from the question: Which theory should an individual scientist actually pursue? Showing that a theory is epistemically worthy of pursuit does not imply that *each* scientist should engage in its actual pursuit, since more than one theory can simultaneously be epistemically worthy of pursuit. The fact that some of them are epistemically worthy of pursuit should not be confused with specific preferences individual scientists may have when choosing which of these theories to work on.[5] A rational division of labor in a given scientific discipline depends on the epistemic status of all available theoretical candidates, as well as on some non-epistemic factors, such as the number of scientists working in the field, the financial resources, personal interests and expertise of the scientists etc. Therefore, an account of the epistemic pursuit worthiness provides tools that (together with some

[5] For the discussion on the criteria in view of which individual scientists choose which theories to pursue see (Whitt, 1990).

other elements) play a central role in determining the rational division of labor in a given scientific community.

In addition to being interested in the epistemic rather than the "practical" pursuit worthiness (which involves both epistemic and non-epistemic criteria), what we are after in this paper is the pursuit worthiness of explanatory theoretical frameworks rather than the pursuit worthiness of scientifically relevant entities (such as the precise measurement of certain physical constants, the invention of measuring instruments, or the discovery of certain phenomena) or technological developments.[6] These two processes are often interwoven, but the criteria applicable to the pursuit worthiness of the former may not necessarily apply to the pursuit worthiness of the latter, and the other way around.

1.3. Coherentist Approach

Among the accounts of epistemic justification that have been applied to the evaluation of scientific theories, coherentist approaches have been scoring fairly better than the foundationalist ones.[7] Thagard's explanatory coherentism has been applied to a number of scientific revolutions (Thagard, 1992), Chang has applied his epistemic iteration to the case of the invention of the concept of temperature (Chang, 2004), while Bonjour's coherentism (Bonjour, 1985; Bonjour, 1989) has been discussed with regard to the problem of theory choice in Kuhn's philosophy of science (Kuukkanen, 2007). Nevertheless, none of these accounts is fully suitable for theory evaluation in the context of pursuit. Thagard's explanatory coherence is primarily concerned with theory acceptance, even when it is applied to the cases of early developments of theories (e.g. see his discussion of Wegener's theory of the continental drift (Thagard, 1992, p. 171)). In contrast, in Chang's epistemic iteration coherence is used "as a guide for a dynamic process of concept formation and knowledge building, rather than strict justification" (Chang, 2004, p. 156). Even though his approach could be seen as addressing epistemic justification in a broader sense of the term, it does not offer any criteria for an assessment of the initial pursuit worthiness of theories, which, as we shall see, is an important part of the evaluation of pursuit worthiness. Bonjour's coherentism offers criteria of epistemic

[6] Martin Carrier makes a similar distinction between "epistemic research" as the search for understanding, characterized by knowledge-guided mode of problem selection, and "application-oriented research" as the search for utility (Carrier, 2010). However, our distinction is different since a scientifically relevant phenomenon does not necessarily belong to a search for utility.

[7] For example, see the discussion in (Kleiner, 2003, p. 513-514) and (Chang, 2004, p. 223-224).

justification as it has been traditionally conceived, that is, regarding the context of acceptance (we will discuss this more in Section 2).

As it has already been mentioned, a theory is epistemically worthy of pursuit to the extent that it can be shown to have a promising potential for contributing to the epistemic goals of the scientific enterprise. In a coherentist framework, we can say that a theory is epistemically worthy of pursuit to the extent that it can be shown to have a promising potential for contributing to a greater coherence and greater robustness of scientific knowledge. Such a character can be manifested in the theory being promising of increasing the coherence of an already existing research tradition (for example, by deepening its explanatory mechanisms), and/or in the theory being promising of developing into a system or a research tradition that is more coherent than the currently established one in the given domain, and/or in the theory being promising of developing into a good backup theory or a research tradition for the currently dominant one.[8] The latter feature is motivated by the epistemic virtue of robustness of knowledge.

The significance of robustness as an epistemic goal becomes even more obvious once we have stepped on the coherentist ground. In order to explain why, let us briefly recall that the main virtue of a foundationalist approach to epistemic justification is the "firm foundation" of knowledge: it is supposed to be not only the basis of epistemic justification, but also to offer robustness to the knowledge, since even if our theories turn out to be wrong, there is always a firm ground to get back to and start building the knowledge all over again. To use again Neurath's analogy , a foundationalist approach presupposes that there is always a dry-dock where the ship can be reconstructed on the basis of its firm components all over again. Needless to say, the idea of such an unquestionable basis of scientific knowledge has by many been regarded untenable, and coherentism stepped in as an alternative. Now, in order to compensate for the lack of a firm foundation, coherentism, applied to scientific knowledge, needs to introduce robustness in a different way, namely, by allowing for developing theories to serve as backups of the currently established ones. In other words, if there is no absolutely certain foundation to which we can always turn to, then the best we can do in order to achieve robustness of the scientific knowledge as a whole with respect to the uncertainty of the future developments, is

[8] In the remainder of the paper we will – for the sake of simplicity – use the terms "cognitive system", "(scientific) theory" or "scientific hypothesis" interchangeably. It is clear though that especially in the early stages of their development, such cognitive structures have neither all the properties of a theory nor all the links which would make them sufficiently systematic, and yet, they can be more than just a hypothesis.

to allow for a pursuit of theories that are alternative to (and possibly incompatible with) the currently established ones.

In summary, our task is to offer the standards on the basis of which it can be judged to which degree a theory is epistemically worthy of pursuit, viz. to which extent it is potentially epistemically justified viz. *potentially coherent*. We will paradigmatically build our framework on the basis of Bonjour's account. The advantage of adjusting an already existing theory of justification is that we can obtain a single unifying (in this case, coherentist) framework of justification, covering both the context of pursuit and the context of acceptance. The reason why we have chosen Bonjour's criteria for this purpose is that, on the one hand, they are concise and simple, which makes them especially suitable for a demonstration of our approach. On the other hand, they are sufficiently similar to other approaches to theory evaluation (such as, for example, Laudan's problem-solving approach (Laudan, 1977) or the approach of Kitcher's explanatory unification (Kitcher, 1989) or Thagard's explanatory coherentism (Thagard, 1992)). This means that our account can be easily adjusted to fit different methodological frameworks. The way we will modify Bonjour's criteria is by adjusting them in such a way that their focus is shifted towards those aspects of theories which point to their epistemic pursuit worthiness.

1.4. Structure of the Paper

The paper is structured as follows. In Section 2 we give a brief summery of Bonjour's system of coherence. In order to see which requirements should be satisfied for an epistemic evaluation to be adequate for the context of pursuit, we will in Section 3 present the main ideas of Laudan's notion of the context of pursuit. In view of Laudan's ideas, we will in Sections 4 to 6 present the criteria of potential coherence, applicable to the evaluation of scientific theories in the context of pursuit. In Section 7 we will give a meta-justification of our framework. Finally, Section 8 brings some concluding remarks.

2. Bonjour's Concept of Coherence

Bonjour defines coherence by means of the following criteria (Bonjour, 1985, p. 95-99):[9]

1. *Consistency:*

[9] For the sake of transparency we will give each criterion (or group of criteria) an appropriate name.

a) *Logical consistency:* A system of beliefs is coherent only if it is logically consistent.[10]
b) *Probabilistic consistency:* A system of beliefs is coherent in proportion to its degree of probabilistic consistency. Probabilistic inconsistency occurs when a system of beliefs contains both the belief that P and also the belief that it is extremely improbable that P. According to Bonjour, probabilistic inconsistency differs from the logical one in two respects: (i) it is extremely doubtful that probabilistic inconsistency can be entirely avoided; (ii) probabilistic consistency (unlike the logical one) is a matter of degree, depending on how many such conflicts the system contains, and the degree of improbability involved in each case.

2. *Inferential density:*
   a) *Presence of inferential connections:* The coherence of a system of beliefs is increased by the presence of inferential connections between its component beliefs and in proportion to the number and strength of such connections.[11]
   b) *A lack of inferential connections:* The coherence of the system of beliefs is diminished to the extent to which it is divided into subsystems of beliefs which are relatively unconnected to each other by inferential connections.
3. *Explanatory power:* The coherence of a system of beliefs is decreased in proportion to the presence of unexplained anomalies in the believed content of the system. Bonjour defines an anomaly as a fact or event, especially one involving some sort of recurring pattern, which is claimed to obtain by one or more of the beliefs in the system of beliefs, but which is incapable of being explained (or would have been incapable of being predicted) by appeal to the other beliefs in the system.

[10] Bonjour remarks that making the criterion for consistency absolutely necessary might be an oversimplification. Moreover, recent research has shown that it is sensible to ask how inconsistent a theory is and that logical inconsistency can be considered to come in degrees as well. In order to measure such degrees syntactic approaches based on minimal inconsistent sets (Hunter and Konieczny, 2008) or maximal consistent sets (Knight, 2002) have been suggested, as well as semantic approaches employing paraconsistent models such as (Hunter, 2002; Hunter and Konieczny, 2005; Grant, 1978; Grant and Hunter, 2006; Grant and Hunter, 2008; Ma et al., 2009).

[11] It is interesting to notice that William Wimsatt emphasizes the role of two more refined notions in scientific theories that are based on the inferential density, namely the robustness and the generative entrenchment of parts of cognitive systems. Given a directed graph of inferential connections "a robust node has multiple inferential paths leading *to* it and resists failure because of its multiple sources of support." and the generative entrenchment of a node is given proportional to the "number of nodes reachable from that node" (Wimsatt, 2007, p. 142).

Conceived in this way, Bonjour's concept of coherence – to which we will refer to as *the actual coherence* – can be used for an assessment of different belief systems, including scientific theories.[12] Nevertheless, in order to be applicable to the evaluation of scientific theories, a few adjustments should be made to Bonjour's criteria:

1. First, Bonjour's unit of appraisal – "belief system" – should be replaced with "cognitive system". The reason for this is that, especially in the context of pursuit, a scientist does not necessarily have to believe in the assumptions constituting her model, but rather take them as provisional descriptions of what is yet to be further investigated. For instance, she may not believe that some concepts used in a certain pursued scientific model refer in a strict sense or that some ad hoc hypotheses are true.
2. Once we have adjusted the unit of appraisal, it becomes clear that the criterion of inferential density should be adjusted as well. In contrast to the inferential density of the belief system of an individual, which also addresses inferential connections between two theories belonging to it, the inferential density of a scientific theory can be seen as consisting of two aspects: the internal one –referring to the inferential connections within the theory itself, and the external one– referring to the connections between the theory and other scientific theories. The standard of inferential density, adapted for the evaluation of scientific theories, is now formulated in the following way:

   > The coherence of the cognitive system is increased by the presence of both, the inferential connections within the system, as well as the connections between the evaluated system and other established scientific systems; and vice versa, the coherence is diminished by the absence of the connections within the system as well as connections with other theories that are considered relevant for it (for example, if they have an overlapping explanatory scope, or if one theory is expected to deepen the other, etc.).

3. For the same reason, we can distinguish between the internal and the external aspects of the consistency criterion. Bonjour's formulation of the standard of consistency can be taken to refer to the internal (logical and probabilistic) consistency,[13] while the standard of the external (logical and probabilistic) consistency is now expressed in the following way:

[12] "By devising a new system of theoretical concepts the theoretician makes an explanation available and thus enhances the coherence of the system. In this way the progress of theoretical science may be plausibly viewed as a result of the search for greater coherence." (Bonjour, 1985, p. 100).

[13] For the precise distinction between the internal and external consistency, see Section 5.3.

> A system of beliefs is coherent in proportion to its logical and probabilistic consistency with other, already established scientific theories.

Even though rooted in a coherentist framework, Bonjour's criteria are similar to some other standard approaches to theory evaluation. For example, Laudan's view on the scientific development as a progress in problem-solving employs similar criteria: explanatory power is expressed in terms of empirical problem-solutions, inferential density in terms of compatibility between theories (the absence of which is a type of external conceptual problems) and a preference for more unifying problem-solutions, while inconsistency falls under internal and external conceptual problems (Laudan, 1977). In a similar vain, it could be argued for the similarity between Kuhn's and Bonjour's criteria. For example, as already mentioned, (Kuukkanen, 2007) suggests that Kuhn's philosophical standpoint could be incorporated into a coherentist epistemology. Furthermore, according to Kitcher, "scientists in the thick of a controversy face two types of predicaments: those of inconsistency and those of explanation." (Kitcher, 2000, p. 31). If we add to that Kitcher's view on the aim of inquiry as "the provision of a maximally unified set of explanatory schemata that will generate the largest possible set of true instantiations" (Ibid., p. 24), we can see a clear similarity between Bonjour's and Kitcher's evaluation criteria. Therefore, rooting our account in a coherentist epistemology and moreover, in Bonjour's notion of coherence, should not prevent it from being relevant for other approaches to theory assessment as well. It should rather be seen as a paradigmatic demonstration of adjusting existing accounts of epistemic justification to the context of pursuit.

3. Laudan on the Context of Pursuit

Laudan distinguishes two contexts in which cognitive appraisals of scientific theories and research traditions are made:

1. *The context of acceptance* is a context in which scientists choose to accept one of the competing theories (and research traditions), thus treating it as if it were true (Laudan, 1977, p. 108).
2. *The context of pursuit* is a context specific for the emergence of a new research tradition, in which scientists begin to pursue and explore it long before it is qualified to be accepted over its older rivals (ibid., p. 110).

By recognizing the context of pursuit, we can explain the historical fact that scientists sometimes, particularly in the time of scientific revolutions, work alternatively in two different, even mutually inconsistent, research traditions:

> I shall suggest that, within each of these contexts of inquiry, very different sorts of questions are raised about the cognitive credentials of a theory, and that much scientific activity which appears irrational – if we insist on a uni-contextual analysis – can be perceived as highly rational if we allow for the divergent goals of the following two contexts: [the context of acceptance and the context of pursuit] (ibid., p. 108).

Thus, accepting one research tradition does not necessarily have to preclude scientists from pursuing alternatives which are inconsistent with it. For example, Galileo's physics was in its early stage much weaker than its primary rival, Aristotelianism:

> Aristotle's research tradition could solve a great many more important empirical problems than Galileo's. Equally, for all the conceptual difficulties of Aristotelianism, it really posed fewer crucial conceptual problems than Galileo's early brand of physical Copernicanism ... Galileo was taken seriously by later scientists of the seventeenth century, not because his system as a whole could explain more than its medieval and renaissance predecessors (for it probably could *not*), but rather because it showed promise by being able, in a short span of time, to offer solutions to problems which constituted anomalies for the other research traditions in the field. (ibid., p. 112, italics in the original).

A similar case is Daltonian atomism. Dalton's early atomic theory was confronted by numerous serious anomalies, and was far from reaching the problem-solving success of its dominant rival – elective affinity chemistry. Still, his system was taken to be promising since, in contrast to its rival, it was able to predict what has later on come to be known as the laws of definite and multiple proportions (namely, that chemical substances combine in certain definite ratios and multiples thereof no matter how much of the various reagents was present (ibid., p. 113)). Dalton's theory was thus acknowledged as worthy of further pursuit mainly because of its scientific promise, despite the fact that it did not (yet) satisfy the standard of theory acceptance.

Taking these examples into account, it is obvious that Bonjour's criteria of coherence aren't suitable for the context of pursuit. Both Galileo's and Dalton's theories were in the early stages of their development less coherent than their dominant rivals. Still, both of them were taken to be worthy of pursuit. An account of epistemic justification applicable to the context of pursuit should be able to offer the standards in view of which we can understand why their pursuit was rational.

Before we present our account of coherence evaluation for the context of pursuit, let us make a critical remark on Laudan's approach. Laudan gives the following criterion for when it is rational to pursue a research tradition: "*it is always rational to pursue any research tradition which has a higher rate of progress than its rivals* (even if the former has a lower problem-solving effectiveness)" (ibid., p. 111, italics in the original). Since only one tradition at the time can have a higher rate of progress than its rivals, Laudan's criterion can evaluate pursuit worthiness of only one tradition in cases in which different rivaling traditions are simultaneously worthy of pursuit. Indeed, if a tradition is worthy of pursuit, that does not imply rejecting its rivals as unworthy of pursuit. There are situations in which it may be rational for a given scientific community to pursue two or more research traditions at the same time. One of these traditions may exhibit a higher rate of progress than its rivals at one point, but soon it may turn out to be the other way around, or they may exhibit similar rates of progress.[14]

Our idea of pursuit worthiness is in this respect more similar to the one developed by Laurie Anne Whitt (1990, 1992), whose indices of theory promise also allow for more than one theory at the same time to be evaluated as being promising of further investigation (Whitt, 1992, p. 632).[15]

4. The Notion of Potential Coherence

In order to clarify the idea underlying our account of potential coherence, let us make an analogy between a scientist pursuing a theory and a painter trying to paint a particular landscape in a more realistic way than other painters have done it so far. Just like the painter will start with a simple sketch, so does the scientist begin with an abstract model. And just like the sketch is far from being the final form of the painting, ready to compete with other already finished paintings, so is the pur-

[14] Alexander Rueger's criticism of Laudan's criterion (Rueger, 1996, p. 267) along the similar lines overlooks the fact that Laudan expresses his criterion only as a sufficient, but not a necessary one. In contrast, according to (Whitt, 1992, p. 616-617), Laudan's criterion is not even sufficient for the evaluation of pursuit worthiness.

[15] Note that even though the criteria constituting our account are similar to those explicated by Whitt, our approaches differ in several key respects. First, our account is formulated in terms of a coherentist account of epistemic justification, while Whitt's approach is rooted in Laudan's (Laudan, 1977) and McMullin's (McMullin, 1976) methodological frameworks. Second, our account introduces a unificatory aspect to the evaluation in the context of pursuit and the context of acceptance by allowing for both to be presented within the same epistemic framework (namely, Bonjour's coherentism).

sued theory in its beginnings not able to compete with its dominant rival with respect to its actual coherence. Nevertheless, the sketch could already show certain strengths due to which we can say that it seems promising of *becoming* as realistic a painting of the landscape as other works, if not even more. For example, even though it is still lacking various nuances of colors, a number of details, etc., we could imagine that the previous painters did not have a technique for representing three-dimensional objects, whereas the new painter develops such a technique and thus introduces a significant novelty allowing for a more realistic depicting of the landscape than it was possible earlier. And so, when evaluating the promising character of this work, rather than criticizing it for being a sketch with many shortcomings compared to the finished paintings, we would focus on its strengths and particularly on those elements which the other paintings have not managed to include. As the painting develops we can evaluate whether it is still promising or whether those initially interesting elements have ceased to be interesting (for example, another painter could have in the meantime incorporated the novelty into an already more realistic painting, while our painter did not manage to improve any other elements of her work.) In a similar way, the criteria of the potential coherence should enable us to judge whether a developing scientific theory is sufficiently promising in spite of its obvious shortcomings.

When we say *potentially* coherent, we are not after a degree of coherence which a theory will certainly have in the future. It is clear that we cannot foresee that with certainty. What we are after are indications which tell us that the theory *might* develop or *is promising* of developing into a powerful scientific system. The fact that we speak here of a possibility, instead of a full guarantee, means that the result of such an evaluation will always include a certain level of chance and risk. We are thus interested in certain properties, a theory can *actually* hold, on the basis of which experts in the given field are able to say whether taking such a risk is epistemically justified or not. In order to account for this we take into account the following two aspects:

1. In order to evaluate the potential coherence of T we need to focus on certain positive features of the theory, which highlight that there are good reasons to consider it an (epistemically) attractive candidate for further pursuit. These are often properties which the dominant rival lacks. The idea is here to restrict the focus of the criteria of the actual coherence (in our case, Bonjour's original criteria, see Section 2) to the particular strengths of the theory, which should serve as indications of whether the theory is sufficiently promising. We will thus assess the *potential* explanatory power of the theory, its *potential* inferential density and its *potential* consistency.

2. Since we cannot expect a theory to be fully developed right from the start we should not be too critical of the various shortcomings that it faces. However, we should also not turn a blind eye on them since we want to evaluate if the theory in question is promising of overcoming these problems. What we expect instead is that T offers a *programmatic character*, i.e. methodological and heuristic means to tackle these problems in its further development.

The diachronic character of pursuit points to two distinct questions concerning the assessment of pursuit worthiness. First, we may ask whether a theory is *initially* worthy of pursuit. The importance of this question can easily be seen in the case of assessing new research proposals with which scientists apply for funding. Even though certain non-epistemic factors also play a role in such an assessment, proposals for the research of new scientific theories should, in principle, be attractive from an epistemic perspective as well. In other words, we are usually interested in financing the research of theories that are epistemically worthy of pursuit. However, even if a theory is initially promising, that does not guarantee that it will also remain worthy of further pursuit. Therefore, we will show how our criteria of the potential coherence are applied when evaluating theories in these two respects.

The *initial* pursuit worthiness will be assessed by means of the following criteria:

C1. Potential Explanatory Power
C2. Potential Inferential Density
C3. Potential Consistency
C4. Programmatic character.

For an assessment of the *successive* pursuit worthiness, we will use the same set of criteria, but in addition, the criteria will require a gradual strengthening, which takes into account our expectations concerning the growth of the theory.

It is important to notice that even though it is difficult to pinpoint the exact moment when a theory should be subjected to the evaluation of its initial pursuit worthiness, principally speaking, we are referring to the moment when it enters the discourse of the given scientific community (for example, by being presented in a publication or at a scientific conference). This may also be a time period during which the idea has been proposed and has received the initial criticism. Moreover, the distinction between the initial and the subsequent pursuit worthiness has to be done in view of the specific historical and scientific context. For example, the subsequent pursuit worthiness could refer to the subsequent models of the given theory, or the subsequent theories in the given research tradition.

In the following two sections we will introduce each of the above mentioned criteria. We will then in Section 7 give a meta-justification for them. While the aim of Bonjour's meta-justification is to show that his system is truth-conducive, the task of our meta-justification is to show that our criteria are conducive – as much as that is possible in the context of pursuit – of the actual coherence and the epistemic goal of robustness explicated in Section 1.

5. Initial Pursuit Worthiness

The initial pursuit worthiness is assessed in terms of the criteria C1–C4. Since we are interested in possible future developments of a theory and possible ways in which it can contribute to the development and robustness of our scientific knowledge as a whole, the evaluation of the pursuit worthiness of a theory needs to be done in view of already established scientific findings. In other words, the theory is to be evaluated against the *cognitive horizon* characterized inter alia by the more entrenched theories of its time, which it may in part inherit and in part challenge. The cognitive horizon includes, for instance, questions such as what is considered as an explanandum in the given domain, what are important problems, what is a proper methodology for the research in the given domain, etc.

5.1. Potential Explanatory Power

We begin by discussing first Bonjour's criterion regarding explanatory connections in the evaluated system of beliefs. According to Bonjour's requirement, the coherence of the system is decreased in proportion to the presence of unexplained anomalies. However, as we have seen in Section 3 (for example, in the case of Galileo's physics and Dalton's chemistry), what we need to focus on in the context of pursuit is what the system can actually explain or predict[16] and on the question of how significant those explanations and predictions are, in spite of there being a number of unexplained anomalies. Therefore, we need to introduce a weaker version of the requirement for explanatory power:

> *Potential Explanatory Power*: The potential coherence of a cognitive system is increased by the presence of explanations that are con-

[16] Since Bonjour treats explanations and predictions as involving the same sort of inferential relations (see (Bonjour, 1985, p. 240, Note 15)), we will do the same. It would be possible, of course, to introduce a separate criterion for the predictive power of a theory.

sidered to be significant at that point of the scientific development. An explanation[17] is significant if:

a) it addresses the phenomena for which the established or other pursued rivals have either no explanation, or have explanations which are weak (a weak explanation would be, for example, an explanation that introduces new conceptual problems);
b) it addresses certain benchmark problems or questions in the given scientific domain in a novel way.

For example the fact that classical thermodynamics could not solve the problem of the blackbody radiation, made explaining this phenomenon significant. Or, for instance, during the development of Galileo's physics a number of anomalies appeared for the Aristotelian framework. Even though the proponents of the latter one offered explanations of these phenomena, they "smacked of the artificial and the contrived" (Laudan, 1977, p. 112). Finally, Copernicus' heliocentric system provided an explanation (or rather a prediction) of planetary movements from the assumption of a non-stationary Earth. In this case, the explained phenomena were not observations that were unexplained in the Ptolemaic system.[18] Rather, Copernicus offered a new way of explaining some of the most important phenomena in the sixteenth century astronomy.

Let us conclude this section by discussing the epistemic status of explanations in young theories. Explanations offered by young pursued theories have often a certain *prima facie* or hypothetical character which may be, for instance, due to their idealized nature, due to imprecision of the measurement of data supporting them, or due to the fact that the epistemic status of (some of) the evidence supporting the explanations is itself in need of investigation. In contrast, although we probably never reach a state in scientific development in which explanations are final and "all-things-considered", the explanations of an accepted theory are "enough-things-considered" so that we characterize

[17] Even though we are not here discussing the notion of a scientific explanation, it is the task of an account of explanation fitting our account to be able to dismiss spurious explanations as non-scientific (e.g., if someone offers to "explain" all the phenomena by claiming that they occur because god wanted them that way). For instance, in view of a causal-mechanical account, most of spurious explanations can be rejected due to the fact that they do not offer any underlying causal mechanism.

[18] As Friedel Weinert remarks: "Copenicus' observations do not establish any *new* facts. . . . It is therefore fair to say that from an observational point of view, the Copernican and Ptolemaic systems were equivalent." (Weinert, 2009, p. 24-25, italics in original).

them as epistemically justfied, together with the theory to which they belong.[19]

For instance, Miller (2002) argues that a certain ignorance concerning observational inaccuracies in experiments or experimental data is sometimes fruitful for the explanatory strength and growth of young scientific theories. As an example he brings Galileo's thought experiment according to which, when a stone is dropped from a moving ship, it will drop directly under the person who has dropped it. Such a conclusion was in disagreement with Aristotelian assumptions. But had Galileo "extremely precise measuring instruments" (Miller, 2002, p. 36), then an empirical experiment would not have had the predicted outcome. Various forces (such as the Coriolis force, the centrifugal force, etc.) would have interfered Galileo's idealized setting based on an inertial reference system and a free fall through vacuum. Similarly was Einstein's special theory of relativity based on the idealized assumption "of an inertial reference system in the sense that it only deals with measurements made in such systems, which Einstein himself took to be its 'logical weakness'" (ibid., p. 37).

Another example is the case of Galileo's telescope, which allowed for important discoveries and an increase in the explanatory power of the heliocentric view. Initially there was no theory of lenses available to epistemically justify the evidence gained by means of telescopes. Only later, around 1610, did "Kepler [...] have a knowledge of optics [...] which enabled him to [...] investigate the *theory* of the telescope." (van Helden, 1974, p. 40).[20] However, as van Helden points out, "the importance of the new discoveries [by means of telescopic observations] was tremendous", they " were bombshells indeed" and although "the opposition was powerful, and the instruments were very poor", "the time it took Galileo to convince all reasonable men was astonishingly short" (ibid., p. 51). One reason was that Galileo was able to significantly improve the telescopes (see (ibid., p. 52)). Moreover, telescopic observations were objective in the sense that they were reproducible. Additionally "the telescope was instrumental in the growth of the idea that the laws of nature apply everywhere equally [...] everywhere in the universe" (ibid., p. 57) and thus it contributed to a more unifying scientific worldview.

The fact that idealized settings, though being "less accurate" in terms of data, are "more informative" often serves as a catalyst for a further fruitful development in which the empirical precision step by step gets improved by more and more accurate models. The same

[19] Of course, "How much is 'enough'?" is one of the essential questions of epistemic justification in the context of acceptance.

[20] We are indebted to Steffen Ducheyne for suggesting van Helden's paper to us.

goes for ad hoc hypotheses, arguments by analogy, the (temporary) acceptance of inconsistencies (see Section 5.3) and similar epistemic tools that are often useful to master early obstacles of theory building. Only later in Einstein's general theory of relativity the approximative character of his earlier model has been overcome by allowing for accelerating reference systems. Similarly, Galileo's discoveries served as a catalyst for the study of lenses which "became an important part of optics" (ibid., p. 52), and which in the long run deepened his cognitive system by epistemically justifying the evidence gained by means of telescopes.

5.2. Potential Inferential Density

The potential inferential density is evaluated in terms of the potential internal inferential density and the potential external inferential density.

5.2.1. *Potential Internal Inferential Density*

It is easy to notice that the more phenomena can be explained by the same set of hypotheses, the more unifying the system gets. For example, the underlying idea of Kitcher's account of explanatory unification is that the same argument pattern is to be used in the derivation of a wide range of explananda (Kitcher, 1981, p. 512). In a similar way Thagard suggests that "we should prefer theories that generate explanations using a unified core of hypotheses." (Thagard, 1992, p. 67). Now, to ask how inferentially dense a system is, is in fact to ask, how unified it is (Bonjour, 1985, p. 97). Therefore, if a theory which is being evaluated for its potential coherence, has a more unified core of hypotheses than its rivals, this will contribute to its potential inferential density. More precisely:

> *Potential internal inferential density:* The potential coherence of the cognitive system is increased by the presence of a unified core of hypotheses.

For example, during the revolution in the geological sciences, Hess' theory of seafloor spreading which explained the mechanism of the continental drift – offered a highly unified explanation of the phenomena relevant to the ocean basins. Hess' main hypothesis could account for a wide range of phenomena, in contrast to permanentist and contractionist theories that required additional ad-hoc hypotheses to explain the same set of explananda (Le Grand, 1988, p. 198).

There are different accounts of explanatory unification (e.g. (Friedman, 1974; Kitcher, 1981; Weber, 1999)) that could be applied for a more precise assessment of unifying properties of scientific theories.

5.2.2. *Potential External Inferential Density*

If the theory in question shows certain inferential connections with other established or pursued theories this will speak in favor of its potential coherence. An example of such inferential connections would be analogical relations between theories: one theory can develop using an analogy between its explananda and the explananda of another, already developed theory. According to Laudan, analogy is, in fact, the most common form of mutual reinforcement between theories (Laudan, 1977, p. 230). For example, Huygens used the analogy between the familiar phenomena of water and sound waves and the hypothetical phenomena of the light waves to explain the nature of the latter ones (Thagard, 1981, p. 249). Moreover, if the theory establishes inferential connections with theories with which the dominant rival has not managed to connect so far, this will increase its potential inferential density. In this way a young theory shows the promise of contributing to the aim of robustness: it points out some of the advantages it can introduce in case the dominant rival turns out to be a weak theory after all. We can thus formulate the following criterion:

> *Potential external inferential density:* The potential coherence of a cognitive system is increased by the presence of significant inferential connections between this system and other established or pursued scientific theories. The connection is significant if:

a) it links the system to a theory with which the dominant or a pursed rival has not managed to connect so far, or
b) it links the system to a theory that is itself considered established.

For example, the fact that Galileo's physics, in contrast to Aristotelian/Ptolemaic research tradition, had inferential connections with Kepler's astronomy and Copernicus' heliocentric system, contributed to the promising character of all three theories.

5.3. Potential Consistency

Finally, the criterion of consistency needs to be modified. In order to get a better grip of this criterion, let us first distinguish between different types of inconsistencies. First of all, if we make a distinction between a theoretical framework and observations, we can make a difference between, on the one hand, inconsistencies within a theory or between theories, and on the other hand, inconsistencies between a theory and observations (see (Priest, 2002, p. 122)).

We first discuss those within or between theories. Taking into account the place in the theoretical framework where the inconsistency appears, we can distinguish between:

1. *Internal inconsistency*, which concerns inconsistencies within the theory. We say that a theory[21] is *logically* internally inconsistent if it contains a proposition and its negation. Using Bonjour's notion of probabilistic inconsistency (see Section 2), we can say that a theory is *probabilistically* internally inconsistent if it states P and also that it is highly improbable that P.
2. *External inconsistency*, which concerns inconsistencies (logical or probabilistic) between the evaluated theory and other, already established theories. We say that a theory is *logically* externally inconsistent if it contains a proposition, while some other established theory contains the negation of this proposition. A theory is *probabilistically* externally inconsistent if it states P while some other established theory states that it is highly improbable that P (or the other way around). We can further make a difference between two types of external inconsistencies:
   a) a theory T_1 is inconsistent with a rival theory T_2;
   b) a theory T_1 is inconsistent with an a non-rival theory T_2.

In the reminder of this section we will present the criteria of potential consistency in view of the above types of inconsistencies, namely, the potential internal consistency, the potential external consistency with established or pursued non-rival theories, and the potential consistency with observations. Note that we will skip the inconsistencies with rivals. This type of inconsistencies have often been a reason for suspicion towards the former one. Just take the example of Copernicus or Galileo whose theories had some major inconsistencies with assumptions of the Aristotelian/Ptolemaic physics, which caused a serious resistance of the scientific community towards the acceptance of the new framework. Rejecting a pursued theory on the basis of such inconsistencies would make our assessment too conservative in character. Moreover, if the

[21] We take a theory to consist of a certain set of propositions and all their consequences. We restrict the latter to the consequences which are known at the given time point since the coherence evaluation can only take into account the known consequences and thus the inconsistencies known at that time point. On the basis of new consequences it may turn out that a seemingly consistent theory is in fact inconsistent. Two other remarks are important at this point. First, we are of course aware of the fact that the language of propositional logic is rather suboptimal for the task of a proper formalization of scientific theories. We use it as a simplification (and so does Bonjour). It is an open question what formal language is best for this task, and if there is any one (!) such language at all. Second, it is often the case that especially (but not only) immature theories contain contradictions. To speak about consequences of such systems in terms of classical logic is not very helpful, since in face of contradictions classical logic derives anything. Logicians have developed various ways to cope with such situations by use of paraconsistent logics (see e.g. (Béziau and Carnielli, 2006; Batens et al., 2000)).

evaluated theory has a high potential explanatory power, it might very well turn out that it could one day become more (actually) coherent than its rival. In this case, the assumptions of the latter one would cease to belong to the accepted scientific views, and consequently, these inconsistencies would become irrelevant. That is why inconsistencies of this type do not necessarily have to be resolved by reconciling the opposing theories, but they could instead become obsolete, due to the "winning" of one of the rivals. Therefore, they should not be burdening for a theory which is assessed in the context of pursuit.

5.3.1. *Potential Internal Consistency*

It is important to notice that it is an oversimplification of the scientific practice to treat the criterion for consistency as absolutely necessary (see (Bonjour, 1985, p. 247), as well as Footnote 10). The higher the potential explanatory power of a theory is, the more forgiving we are towards possible inconsistencies in it. More precisely, by temporarily accepting certain inconsistencies, we may enhance the overall potential explanatory power of the system. As Thagard points out: "It may turn out at a particular time that coherence is maximized by accepting a set A that is inconsistent, but other coherence-based inferences need not be unduly influenced by the inconsistency, whose effects may be relatively isolated in the network of elements." (Thagard, 2000, p. 74-75).[22] In a similar vain, Lakatos suggests that "it may be rational to put the inconsistency into some temporary *ad hoc* quarantine, and carry on with positive heuristic of the programme. This has been done even in mathematics, as the examples of the early infinitesimal calculus and of naive set theory show" (Lakatos, 1978, p. 58).

Another example is Bohr's theory of the atom, which included both classical electrodynamic principles as well as quantum principles, which were mutually inconsistent. Bohr's idea was to temporarily ignore this inconsistency and to proceed on the inconsistent foundations (Lakatos, 1978, p. 55). However, the developing theory was not abandoned due to this: "Though the theory was certainly considered as problematic, its empirical predictions were so much better than those of any other theory at the time that it had no real competitor." (Priest, 2002, p. 123).

[22] Even though Thagard doesn't clarify what he means by an inconsistency being *isolated* in the network of elements, he probably refers to avoiding the explosion which is inevitable in terms of classical logic. Some logics that are able to deal with inconsistencies block problematic applications of certain rules, such as disjunctive syllogism, to inconsistent formulas while at the same time allowing for the full classical derivative power for the consistent parts of a theory (see (Batens and Meheus, 2006; Batens, 1999)). In this sense they isolate inconsistencies since they prevent them from spreading.

Thus, we should not consider it an initial drawback if a young research is still burdened by internal inconsistencies. However, since we strive for a high actual coherence in the long run, it is a positive property of a cognitive system if it provides means to tackle these problems in its further development (see Sections 5.4 and 6). Of course, in the fortunate case that a young theory is internally consistent, this contributes to its attractiveness as does any problem that is avoided in first place and hence does not have to be tackled in the further development. Thus, we can formulate the following criterion:

> *Potential internal consistency:* The potential coherence of the cognitive system is increased if the system is consistent.

5.3.2. *Potential External Consistency*

Let us now take a look at the second type of external inconsistencies – those between two non-rival theories. First of all, the fact that a pursued theory is inconsistent with some other scientific systems is not a sufficient reason for saying that it has a low potential coherence. For example, even though quantum mechanics and general relativity are mutually inconsistent, neither has been considered unworthy of pursuit due to this inconsistency.

However, if a pursued theory turns out to be consistent with an established or pursued non-rival theory with which the dominant rival is inconsistent, this will speak in favor of its promising character. For example, if quantum mechanics had a rival theory T which were consistent with general relativity, the potential external consistency of T would be increased. Similarly to the case of the external inferential density, consistency with such theories indicates that the pursued theory is promising of contributing to the robustness of scientific knowledge in the given domain. We can thus formulate the following criterion:

> *Potential external consistency:* The potential coherence of a cognitive system is increased if the system is consistent with significant theories. A theory is significant if:
>
> a) it is a theory with which the dominant or a pursued rival of the evaluated theory is inconsistent, or
> b) it is an established non-rival theory.

Just like in the case of internal inconsistencies, the (temporary) acceptance of external inconsistencies may be fruitful. For example, Adam Smith's economic theory was considered to be incompatible with the Newtonian thesis of a balance of forces in nature, since on the one hand, it relied on a general Newtonian balance of nature, while on the other hand, it postulated forces of economic motivation (e.g. self-interest) which were seemingly incompatible with such a balanced system (Laudan, 1977, p. 230). Nevertheless, this inconsistency did not lead to the rejection of Smith's account, since the explanatory power of the theory was sufficiently high. In fact, the inconsistency became obsolete due to a conceptual change in view of which the notion of a force in economics became distinguished from the one used in physics. As a contrasting example, take Velikovsky's explanation of some historical events (such as the reported parting of the Red Sea for Moses), which was based on the hypothesis that Venus passed near the Earth some 5000 years ago. Velikovsky's theory was rejected not merely due to its inconsistency with Newton's law of motion (Thagard, 1992, p. 91), but because it did not exhibit a high potential explanatory power. The phenomena it attempted to explain (namely, mythological events) could not even be considered as historical explananda in the proper sense. Furthermore, it did not have a sound and systematic methodology (see e.g. (Fitton, 1974)), which would allow for an adequate programmatic character (see Section 5.4). Therefore Velikovsky's theory did not have the properties that could compensate for its external inconsistencies, and which would render it worthy of pursuit.

5.3.3. *Potential Consistency with Observations*

Finally, let us have a look at (in)consistency of a theory with respect to observations. Observational inconsistencies may be viewed as being addressed by the explanatory properties of a theory (see the discussion at the end of Section 5.1). For instance, according to Graham Priest, inconsistencies of this type are viewed as explanatory anomalies (Priest, 2002, p. 122), which is also the case according to Bonjour's definition of anomalies (see Section 2). When we talk about observations with which the theory is consistent then we restrict the focus on relevant observations: of course, in the majority of cases it is not of epistemic interest whether a scientific theory is consistent with contingent facts such as the fact that we are right now working on this paper. Of epistemic interest are here, for instance, observations that are relevant for the evidential support for the theory in question, such as observations of successful predictions. We have already mentioned that Bonjour treats these as being part of the explanatory scope of a theory (see footnote 16). Another type of relevant observations are those of successful predictions of other theories with which our theory is inferentially connected. This type of observations is accounted for by our criterion of the potential external inferential density. Hence, this type of (in)consistencies is already addressed by our criteria.

5.4. Programmatic Character

So far we have presented adjusted versions of all three Bonjour's criteria, suitable for the evaluation of the initial potential coherence of a theory T. These criteria highlighted attractive features of T with respect to the criteria that constitute Bonjour's notion of coherence.

But in which way can we assure that a theory, which, for instance, offers certain significant explanations, but is at the same time facing some difficult explanatory anomalies, a lack of inferential connections or certain inconsistencies, is still worthy of pursuit?

First of all, it is important to notice that the fact that the theory cannot solve such anomalies at the moment, does not mean it cannot work towards finding the solutions. Especially in the early stages of a pursued theory, models are still highly idealized and outline only the main features and ideas of the young program. Thus, for instance, the empirical accuracy might in many ways still be suboptimal. Only an iterative process of gradual refinement can successively reduce the abstract character and fine-tune the models. What needs to be assured then is that there are certain ways in which the given theory can further be investigated. This is the purpose of our next criterion.

> *Programmatic character of a developing theory:* The potential coherence of a cognitive system is increased to the extent to which the system has a programmatic character and decreased to the extent it lacks one. A cognitive system has a programmatic character if it is embeded in a theoretical and methodological framework which allows for the further research of the system to proceed in spite of the encountered problems, and towards their systematic resolution.

The shortcomings of the theory that the programmatic character is to address may be explanatory anomalies, the lack of unifying power, the lack of inferential connections (especially with well entrenched non-rival theories), the lack of internal consistency, and the lack of external consistency (especially with well entrenched non-rival theories).

Such a character of a cognitive system can be explicated by an example from science policy. If we are to finance a new scientific project which offers some significant explanations, but at the same time faces certain anomalies, what we would expect from the scientists arguing for its epistemic pursuit worthiness is to show that their further research can proceed in spite of these anomalies, as well as towards their systematic resolution. In other words, a theory should exhibit an adequate perspective of the problem horizon into which it is embedded and provide the heuristics capable of guiding the research towards a possible resolution of the key problems with which the theory is currently confronted. As Kitcher points out: "to defend a particular proposal for modifying consensus practice, one must show, constructively, that it has *the potential to find solutions* to the predicaments that it faces" (Kitcher, 2000, p. 31, italics added). So, even if the theory does not exhibit a high *actual* explanatory power (and/or some other virtues regarding the inferential density or consistency) at the early stages of its development, if the scientists show that they are capable of proceeding with the further research, there is a good reason to think that the project has a certain level of resilience concerning the current anomalies. And even though we cannot be absolutely certain that the research will have a successful outcome, such a programmatic character should give us a reason to make a leap of faith.[23]

For example, we have already mentioned Bohr's theory of atom as based on inconsistent assumptions. However, the theory showed not only an explanatory significance, but also a methodological plan for introducing gradually improved models (Lakatos, 1978, p. 63). In that way, the programmatic character gave credibility and a *rationale* to an inconsistent program (ibid., p. 64).

Another example is Wegener's theory of the continental drift. The theory had high potential explanatory power since it provided explanations for the phenomena (such as paleontological similarities between the continental regions on the opposite sides of the ocean), for which its rivals only had weak explanations (for instance, in order to explain such similarities they had to introduce the hypothesis of land bridges between the continents, which was inconsistent with the theory of isostasy). Nevertheless, many geologists regarded Wegener's theory as incapable of accounting for its main element – the mechanism of drift. Not only was it unclear which forces could be responsible for continental drifting, but according to some, any conceivable mechanism of the drift seemed to conflict with the physical theory, since continents couldn't simply plough through the hard ocean floor ((Le Grand, 1988, p. 129); (Laudan, 1981, p. 230)). Nevertheless, Wegener's theory, already in its early stages had a programmatic character. Using the measurements obtained by others, Wegener estimated that the oceanic crust was no more than 5 km thick in contrast to continental blocks, the average thickness of which was taken to be around 100 km. Consequently, in Wegener's model continents moved mainly through the fluid substrate, and had only a thin semi-rigid oceanic crust in their way. In reply to the objection that such a plow would result in deformations of the ocean floor, Wegener called upon isostasy which precluded the formation of significant elevations in the seefloor (Oreskes, 1999, p. 78-79).

[23] Similarly, Whitt speaks of "programmatic research directives" that are provided by the heuristic of a theory (Whitt, 1992, p. 621); also see (Whitt, 1990, p. 472-473).

Thus, as Naomi Oreskes explicates, even though Wegener's model may seem completely wrong from a nowadays geological perspective, in the 1920's it was consistent with the available understanding of terrestrial kinematic properties. And even though the model was based on hypotheses which could not be proved, it showed that the problem of the mechanism could in principle be resolved. Moreover, it pointed to the problem-field that required further investigation: isostasy and the nature of the substrate, which seemed to be directly related to the question of the mechanism of drifting. Thus, it gave a programmatic character to the theory of continental drift with respect to this issue.

6. Successive Pursuit Worthiness

So far we have explicated the notion of the initial pursuit worthiness. However, as the research of a young scientific theory continues, these criteria alone cease to be sufficient for answering the question, whether the theory has remained worthy of pursuit. What we expect from a young theory in order to remain worthy of pursuit, is also to show an improvement in its epistemic properties. The successive pursuit worthiness evaluates whether a theory has remained worthy of pursuit.

We have already seen that Laudan emphasizes the link between pursuit worthiness and "the rate of progress" (see Section 3). Similarly, for Lakatos each step of a research programme should be consistently content-increasing, constituting thus a consistently progressive theoretical problem-shift (Lakatos, 1978, p. 49). A developing research programme "is planted, as it were, in an inimical environment which, step by step, it can override and transform" (Lakatos, 1978, p. 55). Such a diachronic element is rooted in the dynamic character of pursuit itself: while both the actual coherence and the potential coherence evaluated for the initial pursuit worthiness capture the epistemic state of the system at a particular time point, the potential coherence regarding the successive pursuit worthiness takes into account both the development of the system, as well as its potentials for the future endeavor. It evaluates whether the system is on its way to overcome its shortcomings and to fulfill its promising aspects that are e.g. indicated by its programmatic character. In this way we check whether we have been justified in giving a leap of faith to the theory and hence in taking the risk that comes with it.

Of course, we expect our theory to still fair well with respect to the criteria that were so far introduced. Hence, when we evaluate whether a theory remains worthy of pursuit we again apply our four criteria C1–C4. However, our evaluation should get increasingly more critical as time goes by in the sense that we expect the theory to live up to its promise and to exhibit growth in (at least one of) two respects:

1. *Theoretical Growth:* A cognitive system should exhibit a theoretical progress. Such a progress can be obtained, for instance, by applying the programmatic aspects of the theory and hence gradually overcoming problems such as explanatory anomalies, inconsistencies, etc.
2. *Growth of the Programmatic Character:* Problems that have not yet been addressed by the programmatic character of the theory should gradually become addressed by it.

Hence, these two aspects of a theoretical development function as *constraints* posed on C1–C4. A theory should either fulfill the promises that were indicated by its programmatic character and thus exhibit a theoretical growth, or at least improve the programmatic character itself. How do these two aspects influence the evaluation of pursuit worthiness in terms of our four criteria?

Let us first take a look at the theoretical growth. As time goes by we expect that progress is made, for example, concerning the issues that have been addressed by the programmatic character of the theory. For instance, if scientists manage to get results by making use of the heuristics provided by it then this in turn serves as a positive feedback for the programmatic character and gives us reasons to firm our leap of faith in the theory. Fulfilling the promises indicated by the programmatic character should result in a theoretical growth in one or more of the following ways:

1. the growth of the explanatory power: by introducing additional explanations or improving already existing explanations (by refining or deepening them, by introducing new evidence, etc.);
2. the growth of the internal, resp. external inferential density;
3. the growth of the internal, resp. external consistency.

In other words, the more promises (announced by the programmatic character) the theory manages to fulfill, the better it becomes with regards to its potential coherence. Moreover, if the scientists manage to have a high rate of progress, this will boost our trust in the theory even more. After all, if the heuristics and methods are demonstratively applicable in a smooth way this provides an index of the accuracy and adequacy of the theory and indicate that the theory is on its way towards satisfying our epistemic goals. Note that such a theoretical growth can also result from the improvements that were not announced by the programmatic character, for instance from parallel developments in other scientific theories (e.g., an external inconsistency with an established theory from a different domain may be resolved by the developments in that domain alone).

However, should the scientists not manage to make any progress by means of the heuristics, this will decrease its potential coherence. The reason is parallel to our argument above: if the work along the methodological and heuristic outline of the programmatic character proves to be rather tenacious or stopped entirely then this is a good reason to evaluate the programmatic character worse than initially. This will especially be the case if no alternative heuristics or methods are available, since the theory then seems to be on the wrong path. Moreover, the unresolved anomalies that were supposed to be resolved, will lower the score of the theory in the other criteria. For instance, if the programmatic character was initially meant to address certain explanatory anomalies, the fact that this plan did not show any progress will in turn lower the potential explanatory power of the theory.

The second constraint which is relevant for the assessment of the successive pursuit worthiness is the growth of the programmatic character itself. The more time goes by the more we expect the scientists to provide theoretical and methodological means to address open questions that have not been addressed by the programmatic character thus far. This may concern the explanatory anomalies, (internal or external) inconsistencies, or the (external or internal) inferential density the theory displays.

The main underlying idea of our evaluation of the potential coherence regarding the successive pursuit worthiness is that the problems addressed by the programmatic character move to the set of resolved problems, while the (old or new) problems that have neither been resolved nor addressed by the programmatic character become addressed by it.

Let us look at an example. In the case of the pursuit of the theory of continental drift, Wegener's model, which as we have seen gave a programmatic character to his theory, was further improved. For instance, Arthur Holmes proposed a model, according to which the continents were displaced by convection currents in the earth's mantle, generated through radioactivity (Frankel, 1979, p. 68). This model was inferentially connected with the theory of radioactivity, with which the rivals of the theory of continental drift were not connected. Moreover, even though Holmes' hypothesis of convection currents could not have been substantiated at the time, it pointed to a possible path towards a resolution of the problem of the mechanism of drift, and offered heuristics for its further investigation (such as the examination of the presence or indices of the presence of convection currents in the interior of the earth).[24] In addition, the number of significant explanations was increased as well through the work by Alexander du Toit, who found various similarities between the South African and the South American coastlines on the opposite sides of the ocean (Oreskes, 1999, p. 157-166).

It is important to notice that the successive potential coherence depends also on some non-epistemic criteria, such as the number and the expertise of scientists working on the theory or the appropriate funding that allows for the required resources. Hence, when evaluating the successive potential coherence, and the *satisfactory* rate of growth, these factors should be taken into account as well. For instance, even though Wegener's theory of continental drift exhibited a theoretical growth throughout the 1920s and 1930s, in the 1940s hardly anyone was working on it. Hence, it is not surprising that the theory did not exhibit any significant growth in this decade.

7. Meta-Justification

In this section we will give a meta-justification of our criteria for the pursuit worthiness of a theory. The goal is to argue that following the lead of our criteria is indeed conducive of epistemic aims of science. In Section 1 we have specified two major epistemic goals of science: (a) to gain adequate and accurate knowledge about the world and (b) scientific knowledge should be robust, i.e. the scientific knowledge base as a whole should be able to avoid and/or withstand perturbations. One may view science as a long-winded dialogue with nature with the final aim to come to an agreement.[25] Robustness concerns the situation when nature answers "No" to our arguments: in these cases we want to be able to respond. Sometimes it is enough to adjust some of our arguments viz. theories, but sometimes – if nature's "No" is too plentiful – it is more promising to come up with new argumentative strategies viz. theories and to give up on the old one. The central question in this paper has been: when are we justified to pursue a new cognitive system T judged by its epistemic virtues? In view of our dialogue with nature this is so if T is promising of strengthening

[24] This was precisely the outcome of the expeditions conducted in the early 1930s, which included Dutch geologist Vening Meinesz and North American geologists Richard Field and Harry Hess. The results of their investigation confirmed an uneven distribution of radioactive constituents and thermal properties in the earth, which made Meinesz conclude that "in the actual earth there can be no doubt that convection currents must develop" (quoted from (Oreskes, 1999, p. 248)).

[25] Pera rightly pointed out that it is more accurate and awarding to view science as a discourse between multiple agents and nature (Pera, 1994) . However, in order to make our point it is fine to simplify matters.

our repertoire of argumentative moves to dodge nature's "No"'s. More precisely, in view of our epistemic goals and the coherentist perspective adopted in this paper this is the case if T is promising of growing into a theory that is (a) highly actually coherent and (b) that strengthens the robustness of our scientific knowledge as a whole. It is promising of the latter in case it is promising of growing into a backup candidate if the dominant rival falls into crisis. Of course, since T is in its development or yet to be elaborated further we can only talk about its epistemic promise or potentials. This comes with an essential risk and it is a worthwhile goal to control and reduce the latter as much as possible. Hence, we are interested in indices of the epistemic promise of theories. The epistemic justification in the context of pursuit can then be carried out by evaluating and comparing theories with respect to these indices.

Two indices of epistemic promise are central to our approach: (i) the focus on *significant aspects* concerning criteria of coherence and (ii) the *programmatic character* and the focus on *developmental aspects* that comes with it.

Let us first discuss point (i). Take for instance the potential explanatory power (see Section 5.1). Here the focus was on *significant explananda*. On the one hand, we have pointed out crucial and benchmark problems. In order for a theory to be epistemically attractive, i.e. to provide an adequate grip on its subject matter, it should be able to tackle these problems (or at least provide a perspective for tackling them, see (ii)). On the other hand, some of these are phenomena for which the dominant rival does not offer a (satisfactory) explanation. In view of the robustness of scientific knowledge we are interested in tackling these problems. After all, these (and other) anomalies may very well be deficits of the dominant rival that may eventually be a part of the factors responsible for its downfall.[26] In this case we need backup theories that can fill this lacuna and offer alternative argumentative strategies to the "No"'s of nature that produced them.

A similar situation occurs with respect to consistency and inferential density. In case the dominant rival is inconsistent with another established theory, or it does not offer inferential connections with it, this again may be an index of its deficiency. Hence, in order to gain a robust scientific knowledge base we are again interested in theories that are able to fill these gaps.

Since we are evaluating the pursuit worthiness of theories it is natural to also address developmental aspects. This brings us to point (ii). Theories in the context of pursuit are suboptimal in various respects:

[26] There may of course be more than one dominant rival. In this case our discussion can easily be adjusted accordingly.

they are burdened with explanatory anomalies, they may have to deal with inconsistencies, etc. Hence, the only way to compensate for these shortcomings is to offer a programmatic character, i.e. heuristics for how to proceed further and how to eventually overcome (some of) them. The programmatic character indicates that a theory has the potential to grow into a richer and more (actually) coherent one.

Of course, as time goes by we expect from a theory to actualize these promises given by its programmatic character and also to widen the programmatic character to address formerly unaddressed problems. These aspects are taken into account in our evaluation of the successive potential coherence (see Section 6). Our criteria require from a theory to exhibit a theoretical growth or at least to develop its programmatic character. In this way we make sure that the unresolved anomalies (that is, explanatory anomalies, the lack of a unifying core of hypothesis, the lack of inferential connections with other established theories, the lack of internal consistency, or the lack of consistency with other established theories) are either resolved by the theory or addressed by its programmatic character. Moreover, they make sure that as time goes by, these anomalies become more urgent to be resolved, and that the epistemic status of the theory is developing, or shows promising of developing, towards a higher actual coherence.

8. Conclusion

In this paper we have presented an account of epistemic justification suitable for the evaluation of theories in the context of pursuit. We have built our model paradigmatically on the basis of an account of epistemic justification based on Bonjour's concept of coherence. By adjusting the criteria of his concept of coherence and by complementing them with the requirement for a programmatic character we gave an account of what we have dubbed *the potential coherence* of a cognitive system. This enabled us to judge whether the theory is sufficiently promising to be further investigated.

In this conclusion we want to point out a specific contextual character of our framework. Many notions constituting our criteria have been left undefined in any strict manner. For example, what counts as a scientific explanation, what counts as a benchmark problem in the field, what counts as a unified core of hypotheses, etc. – have been intentionally left unspecified. The meaning of these notions needs to be obtained in view of the specific conceptual framework characterizing the cognitive horizon of the time. However, such an approach introduces the problem of relativism: if the criteria of potential coherence can be interpreted in different ways, doesn't that mean that a theory may be evaluated as worthy of pursuit in view of one interpretation, and not worthy of pursuit in view of another? How can we avoid such a relativistic outcome in cases of scientific controversies, in which, for example, the new theory may challenge the traditional views on what counts as a valid standard of scientific explanation or what counts as a valid explanandum in the given field? A detailed analysis of this problem would have to take into consideration not only the change in the interpretation of the standards and in the weighting that are placed on them, but also the change in more general goals of science.[27] In such cases, pursuit worthiness is to be evaluated not only as the question: "Is this theory worthy of pursuit?", but also as the question: "Are there good epistemic reasons to allow for a different set of epistemic standards for theory evaluation?". Taking into account the epistemic aim of robustness of scientific knowledge may be helpful in resolving this type of disputes and may motivate a (soft?) methodological pluralism However the precise nature of such a meta-evaluation, which criteria it consists of, how object-level arguments interplay with meta-level arguments, etc. requires a discussion of its own that goes beyond the scope of this paper.[28]

It is also important to point out that we have built our account *paradigmatically* on the basis of Bonjour's coherentism. Bonjour's criteria may be suboptimal in certain respects when applied to the evaluation of scientific theories,[29] but they were sufficiently simple for demonstrating our approach. Our main aim was to show how the standards of epistemic justification suitable for the context of acceptance can be modified and adapted for the context of pursuit. Indeed, by modifying Bonjour's account or by replacing it with some other set of criteria, we could in an analogous way obtain alternative frameworks of epistemic justification, suitable for the evaluation of pursuit worthiness.

[27] For instance, McMullin shows how the focus on prediction, which was characteristic for Babylonian astronomy, and on explanation, characteristic for Greek astronomy, conjoined into the complementary goals of the new science of the seventeenth century (McMullin, 1984, p. 48).

[28] McMullin (1984) as well as Laudan (1984) argue that shifts in standards of theory evaluation are based on epistemic reasons as well.

[29] For instance, it could be argued that the criterion of predictive power is insufficiently represented in Bonjour's account, or that the virtue of robustness of theories and theoretical entities – although indirectly addressed in terms of inferential density – could be presented in a more elaborated way (see footnotes 7 and 11).

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