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Scientists Are Epistemic Consequentialists about Imagination

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Abstract

Scientists imagine for epistemic reasons, and these imaginings can be better or worse. But what does it mean for an imagining to be epistemically better or worse? There are at least three metaepistemological frameworks that offer different answers to this question: epistemological consequentialism, deontic epistemology, and virtue epistemology. This paper presents empirical evidence that scientists adopt each of these different epistemic frameworks with respect to imagination, but argues that the way they do this is best explained if scientists are fundamentally epistemic consequentialists about imagination.

1. Introduction

What makes an imagining good? There are many ways to be good, or more technically, to have value. And the question, "what makes an imagining good?" may be asked with respect to all kinds of value, including ethical and aesthetic value. This paper is concerned with how an act of imagination can have *epistemic* value, or in other words, how it can be *epistemically good*.

There are several ways to understand epistemic value. This paper will discuss three, inspired by epistemological consequentialism, deontology, and virtue theory. These approaches are historically associated with ethics, but they need not be. Consequentialism's central claim is just that "certain normative properties depend only on consequences" (Sinnott-Armstrong 2019). If we take those normative properties to be moral, we have the beginnings of ethical consequentialism. But the normative properties could be epistemic instead. Likewise, deontic epistemology, like deontological ethics, focuses on the properties of actions over states of affairs. Here, acts of imagination can be good or bad depending on how well they conform to epistemic norms, regardless of the consequences. Finally, virtue theory centers the agent, focusing on virtues. These can be understood as character traits or dispositions that are epistemically or ethically valuable.[1]

[1] For a history of how this tripartite distinction has been adopted in epistemology, see Axtell (1997).

The tripartite distinction between consequentialism, deontology, and virtue theory hasn't played much of a role in philosophy of science yet.[2] This paper will apply it to the case of scientific imagination. To motivate it briefly, philosophers often claim that imagination is epistemically efficacious when it is constrained, that is, when we use it in a way that respects certain norms of good reasoning. This sounds deontological. Other philosophers, however, emphasize the epistemic importance of imagination for breaking constraints. This could be because a virtuous scientist is one who possesses the right amount of skepticism about dogma. Or perhaps it is because breaking a particular constraint at a particular time had positive epistemic consequences, and that is what matters. Each framework plausibly sheds some light on the epistemology of (scientific) imagination.

In the case of imagination, historical records are unlikely to reveal which frameworks are actually employed or endorsed by scientists in their everyday work. As Alan Rocke puts it, "scientists in later life rarely recount their work-related imaginative peregrinations, and virtually never do they do so at or near the time of the event." This makes things difficult for scholars interested in scientific imagination because

> the usual sources upon which one relies, namely, the books, journal articles, laboratory records, and correspondence written by our subjects, rarely mention such mental details. In the rare instances when historians do encounter such recollections by their protagonists, the evidence must necessarily be viewed skeptically. Not only might our protagonist be shading the truth or even prevaricating for ulterior reasons, he or she also may well simply be remembering inaccurately. And it is understandably difficult—impossible, in a strict sense—for the historian to get a second source for any given mental event, in order to triangulate toward historical truth. (2010, 327–28)

To overcome these limitations, real-time qualitative research should be used to help reveal the cognitive activities and social patterns of scientific practice, through carefully interpreted observations and interviews (Nersessian and MacLeod 2022). The present paper presents the results of such a study, beginning in 2016 and still ongoing. It focuses on the principal investigators (PIs), students, and postdocs of two collaborating systems biology labs (labs A and B), a genetics lab (lab C), two climate science labs (labs D and E), and a physics lab (lab F).[3] All materials were transcribed, coded,

[2] There are several notable exceptions. Catherine Elgin is a deontic epistemologist about scientific understanding (Elgin 2017). Paternotte and Ivanova (2017) apply virtue epistemology to theory choice. The idea of incorporating consequentialism into metaepistemology is relatively recent, although some argue that consequentialism was implicit in reliabilist externalism from the beginning (see Ahlstrom-Vij and Dunn 2014; Berker 2013; Dunn 2021). If that is correct, than reliabilist externalists about science are epistemic consequentialists, though not necessarily: Sylvan (2018) argues that consequentialism is not an ingredient of reliabilist externalism. Separately, one might argue that pragmatists are consequentialists, as "the ground of evaluation of any claim for the pragmatist is not where it comes from but what it does" (Brown 2021, 301). Though I do not know of any explicit connection that has been made between pragmatism and epistemic consequentialism in philosophy of science.

[3] Below, participants will be labelled by the lab and a number. For example, B3 will refer to participant number 3 from lab B. The numbers are only used to differentiate participants and carry no further meaning.

and analyzed using a mix of analytic induction and grounded theory methods. For more details about the methodology, see Stuart (2019b).

2. Scientists are epistemic consequentialists about imagination

According to epistemic consequentialism, states of affairs are the focus of normative evaluation. Right cognitive acts are defined as those that promote (or more strongly, *maximize*) good states of affairs (Ahlstrom-Vij and Dunn 2014; Berker 2013; Goldman 1986; Kagan 1992, 1997). There is no agreement about what exactly the epistemic good is, but a number of authors take it to be accurate belief. On this view, if one can sew in an additional accurate belief into one's doxastic quilt, ceteris paribus, one should. Other options for the epistemic good include true belief and approximately true belief, and plausibly knowledge, understanding, and epistemic ability are also candidates. Epistemic consequentialism goes from a theory about value to a theory about what one ought to do via something like the following norm: We ought to perform whatever cognitive action best promotes the epistemic good.

Just as in ethics, there are two main flavors of epistemic consequentialism: direct and indirect. According to direct epistemic consequentialism, acts are right or wrong depending on how well they promote epistemic value. This is the analogue of act utilitarianism. According to indirect epistemic consequentialism, rules for action (e.g., "be sensitive to evidence!") are right or wrong depending on how well they (tend to) promote epistemic value.

Some reasons exist in the literature for thinking that epistemic consequentialism is a good framework for understanding scientific imagination. In previous work, I have shown that scientists value imagination principally for its role in solving problems (Stuart 2019b). If solving problems is what imagination is "good for," it is natural to think that a specific use of imagination will be valued insofar as it solves a problem, or contributes to solving a problem. This seems to be a straightforward instance of consequentialism, where the desired consequence is the solving of a problem. We can interpret this as a form of *epistemic* consequentialism in at least two ways. First, it might be that scientists value solving problems because they see this as a way to promote the epistemic good, whether that is accurate belief, true belief, knowledge, understanding, or something else. Second, it might be that problem solving itself just *is* the final epistemic good. This is along the lines of what "functional" accounts of scientific progress predict (Shan 2019).

In addition, some scholars have developed epistemological accounts of scientific imagination that seem clearly consequentialist. For example, Tania Lombrozo presents evidence from cognitive psychology about subjects who are asked to explain things to themselves while they are reasoning through a problem (2020). Often their explanations are incorrect. Still, "researchers documented learning benefits for those prompted to explain, *even though the explanations were often incorrect*. [The studies] suggest that generating an explanation 'objectifies' the incorrect commitments it embodies in a way that allows learners to recognize a conflict between those commitments and the accurate text they're simultaneously reading. Recognizing the conflict can, in turn, initiate a process of belief revision" (2020, 242; original emphasis). For Lombrozo, the act of developing possible explanations for a given phenomenon is not epistemically praiseworthy because it respects duties that all good reasoning must

respect, or because it exemplifies particular virtues (though it might also do these things). Rather, it is good because of its consequences: "we can shift from thinking about models as epistemically valuable to the extent they accurately describe or approximately resemble the world to instead considering their epistemic value in terms of their role in supporting the acquisition of true beliefs. A *model* can be false, but a downstream consequence of *engaging in the process of modeling* can be the production of true beliefs" (2020, 245; original emphasis). Lombrozo is claiming that acts of imaginative modelling need not yield true or accurate beliefs to be valuable, as long as they *eventually* lead to such beliefs. This seems clearly to exemplify a consequentialist epistemology of imagination.

The trick that Lombrozo describes, where one profits by explaining something even when that explanation is incorrect, is one that scientists themselves recognize and exploit. For example, I asked a geneticist who was just finishing his first postdoc how he overcomes recalcitrant problems. In reply, he said he would

> give a seminar to the lab or a small working group. The best is to just retell the stuff you are working on to people at different levels: to colleagues in the same field, in different fields. Just try to imagine and to explain to, I don't know, to relatives, someone outside of science ... because you will be really clear .... Just the whole process of defining it will help you to understand why you are stuck, in many cases. (C2, interview, 26/11/2019)

In other words, this scientist recognized the value of trying to explain something, just as Lombrozo would predict, even if their understanding of the phenomenon is mistaken, and even if the act of trying to explain doesn't immediately produce anything valuable. The attempt itself has value insofar as it eventually reveals epistemic gaps or tensions between ideas.

Turning more directly to imagination, many participants did invoke what sounds like consequentialist language in relation to the role of imagination in problem solving. For example, a PhD student in a computational systems biology lab said "There's imagination in finding a solution to a problem. Yeah, definitely. Imagination is important. Because at some point you're just solving problems all the way to a finish line" (A3, interview, 03/01/2016). This notion of "getting to the finish line" was used by several of the participants of that lab, and was echoed in other labs.

How does imagination help scientists get to the finish line? Imagination can be useful in producing testable hypotheses about what might be going on in a system, or what caused an experiment to yield an unexpected result. A genetics postdoc confirms that his project "requires a bit of imagination for sure. You need to be able to think outside the box and get new ideas that then you might be able to test .... Also, if an experiment fails, we try to see why, and so we imagine, for example, the protein binding to the DNA .... We need imagination because otherwise we wouldn't be able to troubleshoot anything" (C3, interview, 05/12/2019). Here, it is clear that imagination is valued for its role in producing testable ideas. Imagination can also be useful in helping scientists to frame their problems: "You need imagination because it [the set of mechanisms for gene expression in yeast] is so complex that if you don't reduce it to a few key points in that system, there is no way you can ever go forward" (C3, interview, 05/12/2019). The language in both cases implies that imagination is

valued for helping the scientist to "move forward" in their attempts at understanding a system. In these cases, the value of imagination is defined instrumentally in terms of its usefulness in helping the scientist achieve a particular goal.

Another common refrain was that imagination is valuable because of its connection to creativity. For example, the PI of a molecular biology lab working on transcription factors said "[Imagination] is extremely important to me. I think it's very important to be creative, and I think imagination is a large part of creativity .... To be creative means, there's something that you want to do or there's something that you just can't immediately go and do, so the imagination is finding a way to make it happen" (B1, interview, 25/04/2016).

The literature on scientific creativity is vast, but there are two things that are almost universally agreed on: First, imagination is a source, vehicle, or sine qua non of creativity (Gaut 2003; Hills and Bird 2019; Stokes 2014), and second, creative ideas are those that are novel and valuable (Gaut 2010; Kieran 2018; Kronfeldner 2018; though for criticial discussion see Hills and Bird 2019; and Sánchez-Dorado 2020). If imagination is valued because it contributes to creativity, then the value of an act of imagination is instrumental, and can be calculated in terms of whether it produces something new and useful. I will illustrate with a few examples.

After responding positively to a question about whether the imagination has epistemic value, the PI of a genetics lab was asked to describe a case where imagination was used well. The PI presented an episode in which a graduate student used imagination "to see why a particular technology is appropriate for what he was doing" (C1, interview, 22/04/2019). The graduate student was working on hybrid proteins. The idea was to use a DNA binding domain from a particular protein to "tether" pieces of a protein to specific regions in the chromosome to investigate their effect. The student realized that the hybrid proteins were interfering with the function of the wild type protein. He didn't know which proteins were the target of this interfering protein, but he happened to read a paper that appeared in *Nature* at that time, which proposed a new method for identifying protein-protein interactions. After reading the paper, the student imagined whether and how he could use this method to figure out which proteins his protein was interacting with. "It took a leap of imagination to think that this might actually work. And he was actually the first person to use this method outside of the lab that had invented it. And he discovered the first novel gene using this method" (C1, interview, 22/04/2019). This use of imagination to explore and motivate the possible adoption of a new methodology was considered one of the best the PI could remember, precisely because of how well it worked out in the end, specifically, in leading to the discovery of a novel gene that played a part in the biological system of interest. There was no mention about this student having any general cognitive virtues that explained the success of this instance. Likewise, no intrinsic features of the imagining were mentioned, such as its respecting particular norms of good reasoning. Immediately after providing the above example, and still thinking about cases in which imagination played an important epistemic role, the genetics PI generalized, saying that "a lot of the progress in biology is driven by progress in technology ... I've been very lucky to have picked up on certain technologies relatively early on. Because they, in many junctures, made a big difference in what I was able to do." In other words, technological innovations are valued for their ability to increase problem-solving power, and we can use imagination to run mental

experiments to test the potential applicability of new methodologies. This enables the successful adoption of new technologies, which leads to epistemic progress in the form of problem solving. Again, it seems to be that the consequences of the act of imagining matter for determining the value of such imaginings.

It is also important to discuss failures of imagination. In response to a question about such failures, the PI of one of the two climate science labs reported that one important function of imagination is generating new ideas for solving difficult problems, especially those that are attractive to funding agencies. A common way for imagination to fail is when "the idea wasn't thought through well enough. You think it's a good idea, but you don't go all the way ... to think about the details that it involves, then it ... it basically fails because some of these details turn out to be major problems" (D1, interview, 19/06/2019). The reason that uses of imagination like these are judged to be epistemically bad is because they didn't have good consequences. How a project pans out retrospectively determines whether the inspiring use of imagination was good or bad, irrespective of any other epistemic qualities of that imagining. The PI regrets that the idea wasn't sufficiently well thought through, which might sound deontic. But the reason she regrets not thinking it through is because if she had, she might not have wasted her time, energy, and resources. Thinking things through, or imagining in more detail, is not necessarily valuable on its own, as the next example shows. Instead, imagining that *particular* idea in more detail would have been better, because neglecting to do this at the time had bad consequences.

When asked for an example where imagination was used poorly, a PI working at the Large Hadron Collider at CERN said: "I had an engineer. We had to produce some equipment, and this guy was always diverging to something that was not useful for the experiment ... I mean, any equipment, a piece of electronics, you can make it do many things. But you have to do the right things" (F1, interview, 08/12/2018). The engineer in question would, for example, deconstruct instruments he was given in order to think about other uses the instrument might have. The PI admitted that this strategy can sometimes pay off, and indeed might be necessary to start thinking about what other uses the Large Hadron Collider could have itself, if no new physics are suggested by its outputs in the next few years. But in this case, despite appreciating the imaginative tendencies of the engineer in general, the PI needed a particular problem to be solved, and anything not furthering that goal was a waste of time. Here, doing the "right thing" is doing whatever leads to the construction of the equipment required for the functional operation of the detector at CERN. There is a desired end goal, and in this case, acts of imagination are characterized as good when they help to achieve that goal, and bad when they interfere, despite whatever other qualities they may have. As he put it, "At the end, they have to solve a problem, how they solve a problem, I don't care" (F1, interview, 08/12/2018).

3. Scientists are deontic epistemologists about imagination

Deontic epistemology does not define right action in terms of consequences. Instead, it defines right action directly. On this account, acts are the primary bearers of epistemic value, and an act is epistemically right when it respects certain epistemic duties or norms. Here are three candidate duties: form a belief that p iff you have

sufficient evidence that *p* (Conee and Richard 2004; Clifford 1877; Feldman 2002); form a belief that *p* iff *p* was produced in a reliable way (Goldman 1979); or, ensure the accuracy of our existing doxastic attitudes (where "ensure" means something like "certify") (Sylvan 2020).

Indirect epistemic consequentialism and deontic epistemology appear similar, as both recommend following a set of rules. They might even recommend the same set of rules. The difference rests in what justifies the rule-following. For epistemic consequentialists, we are meant to follow a rule because of the good consequences that typically follow from behaving in accordance with it. For deontologists, however, we ought to follow a rule because acting in conformity with that rule just is the fundamental epistemic good.

There are also philosophers whose work on the epistemology of imagination seems to take a deontic line. This might include those who claim that an imagining is justified when it is governed by a set of constraints: "It is generally agreed that imagination must be in some way constrained in order to be epistemically useful" (Badura and Kind 2021, vii; Kind and Kung 2016). These constraints fall into two groups (Stuart 2020a). The first are logic-based: Imaginings should have true or likely premises with deductively valid or inductively strong inferences. The second are inspired by the literature on modelling: Imaginings should have accurate representations of a target system, which evolve using a dynamic that mirrors the dynamics of the target system. Perhaps imagining in accordance with these constraints is all there is to imagining well. But it is possible that we should adhere to constraints on imagining because doing so will have the best consequences, epistemologically speaking. In other words, these constraints can also be justified by an indirect epistemic consequentialist.

A clearer example of deontic epistemology of imagination can be found in Sheredos and Bechtel (2020), which explores the role of diagram-use in the imagination-led discovery of mechanisms in biology. Sheredos and Bechtel are interested in the construction of *how-possibly* accounts of a phenomenon, regardless of whether the how-possibly account leads to a *how-actually* account. They write, "Often, scientists advance how-possibly explanations before they are in any position to evaluate experimentally what is actual. Here we provide an account of this epistemic activity" (2020, 179). Specifically, they are interested in how scientists imagine their way to new mechanism-sketches, independently of whether the sketches turn out to be accurate. Instead of leaving the epistemic value of an act of imagination to be determined from a future standpoint in which the consequences are known, they claim that we can tell whether an act of imagination is good or bad, regardless of the consequences. And this is what we would expect from a deontic account.

The kind of imaginative act Sheredos and Bechtel are interested in counts as epistemically good when it sticks its neck out beyond the given data, but still coheres with all or most of the existing data and background knowledge, in a way that provides an account of a mechanism. When this happens, we have an "imaginative success" (2020, 179), which is a kind of success that can be achieved even if the account of the mechanism is false. "A failure to find 'the actual mechanism' is not a failure tout court" (2020, 179).

Imaginative success is "a notable form of ongoing success in scientific research." Why? Because it is

> no simple feat to take a mechanistic model built for one class of organisms, apply it wholesale to another, and provide an articulate depiction of how the resulting hypothetical mechanism could actually be constituted so as to produce the target phenomenon. Likewise, it is no simple feat to adapt such a model in the face of new data. While those initial models proved to be factually inaccurate, we regard the researchers as having attained a kind of imaginative success simply by constructing the diagrams in Figures 7.1 and 7.2. The success consists in integrating known data regarding cyanobacteria, fitting these into a generalized hypothesis regarding TTFLs [transcription- translation feedback loops] as the mechanisms of circadian rhythms, generating a new, specific model of how such a mechanism could work in this case, and identifying the gaps in this new model as a way of driving research forward. (2020, 189–90)

One characterization of deontic epistemology defines right cognitive action as that which respects our epistemic duty to ensure the accuracy of our doxastic attitudes (where "ensure" means something like "certify") (Sylvan 2020). In the example given by Sheredos and Bechtel, we see scientists synthesizing data and organizing it into a new account. It does not matter whether the account is correct. What makes the act of imagination successful is that the scientists have respected their epistemic duty to ensure the accuracy of their doxastic attitudes by working hard to produce a mechanism-sketch that captures all the various kinds of background theoretical knowledge and empirical data. As Sheredos and Bechtel say, this is no simple feat. The very fact that the mechanism-sketch respects all this existing data and theory is enough to make it praiseworthy.

We can also find scientists speaking this way about imagination. Thus, the PI of the genetics lab was discussing a model he had recently developed about a chromatin remodeler in yeast that is required for the yeast to be viable. The model was included in a paper that was under review.

> We had evidence suggesting that this remodeler, in part, operates by recognizing specific short DNA sequence motifs. And we had a bunch of experiments consistent with this idea. And we pushed the idea . . . But we were, I think, appropriately cautious to point out that our data didn't prove that this was the case, and they certainly didn't disprove that this particular remodeler uses other mechanisms to get itself to specific genes.

The PI did not know whether the model would be accepted by others, or experimentally confirmed. To the PI's dismay, the reviewers were not happy with the model. Why?

> Perhaps because there is a certain dogma in the field that these factors are recruited by transcription factors . . . and the idea that it might not be as simple as that, that there may be some remodelers that themselves show DNA sequence specificity, isn't very popular, even though it is well-known that one of the protein components of the remodeler is a DNA binding protein that has a specific

> recognition motif that we had identified, as being linked to the function of the remodeler. So, I couldn't understand how one could argue against this model. (C1, interview, 22/05/2019)

In other words, even though this PI recognized that the model was possibly false, it was *already* epistemically "good," for him, because "even though the information had been floating around for years, people had not managed to put it together in the way we had." So, as the above deontological reading of Sheredos and Bechtel suggests, the new model can be (and is) appraised, independently of its downstream epistemic consequences, by the way it respects existing theoretical knowledge and empirical data. In other words, here is a scientist who seems to be reasoning in a deontological way about a use of the imagination.

Can we be more specific about how, exactly, imagination respects epistemic norms? Sheredos and Bechtel focus on imagistic imagination (2020, 180–81), and so does the PI in question. I asked, "When you're thinking about these remodelers and so on, do you actually *see* anything in your head?" He replied:

> I try to! . . . I think we've gotten to the point where we know that there are these various parts that are interacting at these promoter regions, regions where gene transcription starts. And when you think about it in physical terms, you begin to see that it's hard to imagine all of these parts being there at the same time. So there's some kind of dynamic interplay between these bits and pieces, that is still, rather mysterious. And now I think it's worthwhile to try to imagine physically how the parts would fit together, because there are moving parts to the system. And what we measure by the experiments we do are the average properties of the system. We are unable, so far, to actually take a snapshot of a gene, and see what's there, at any given time, and much less, to be able to see the movie! But I think it's important to imagine what might be going on.

I asked what all of this actually looked liked, for him. He answered,

> For me, it's just cartoon stuff [inspired by the images we find in journal articles and textbooks]. But now that there are 3D structures of a lot of the components, you know, it's still just cartoons on 2D paper or maybe you look on a computer screen and you get some idea of the three dimensionality of it. (C1, interview, 22/05/2019)

This was also reflected in discussions with a postdoc in this lab, who said that he imagines "like in a Pixar cartoon how some process in the cell is happening . . . . You imagine it like in a cartoon, exactly like, the cell is like Shrek or something, and then, you focus on something that's important to you, that you're most interested in, and really try to imagine all the steps or how it would work" (C2, interview, 26/11/2019).

One way to understand these quotations is that an act of imagination can be good in a deontic sense when it respects all the background knowledge and empirical information in a visual episode of imagining, by representing things accurately. They do not have to "look like" the real entities to be accurate, but they should be accurate in the same sense in which an idealized model can be accurate. On this view, imagining

in accordance with a duty of respect is all that is required for it to be epistemically good. Interestingly, the scientists I interviewed only tended to evaluate acts of imagination this way when they were speaking about imaginings that were ongoing; that is, whose consequences were still unknown.

4. Scientists are virtue epistemologists about imagination

Virtue epistemology tends to shift the evaluative focus to the properties of *agents*, either the agent as a whole, or their defining character traits, dispositions, or other features. A virtuous agent is one who possesses a preponderance of virtues. And an agent can be virtuous even if they sometimes do "wrong" things, or if their actions have bad consequences. Epistemically good imaginings will be those that manifest the virtues of an agent.

There are at least two ways to think about scientific imagination in a virtue-theoretic way. One is to consider the imagination itself as a virtue. On this view, epistemically right acts of scientific imagination will be those that manifest the virtue of a well-trained or reliable scientific imagination. Another option is to deny that imaginativeness is, itself, a virtue, but claim that acts of imagination can nevertheless manifest *other* epistemic virtues. In what follows I will focus on the stronger claim—that imagination can itself be a virtue.

Historically, there are philosophers who have portrayed imagination as a virtue. For example, Peter Adamson identifies al-Kindī and al-Fārābī as arguing that imagination is an epistemic virtue (Adamson 2015). Timothy Chappell argues that imagination is a key moral virtue (2014). Noël Carroll discusses imagination as an aesthetic virtue (2002). It has at least been suggested that an overactive imagination is part of the tendency toward conspiratorial thinking (Swami et al. 2011), which has been portrayed as an epistemic vice (Cassam 2016).

Why think of imagination as an *epistemic* virtue? When used for epistemic purposes, imagination (as a character trait) does seem to admit of a golden mean between head-fully-in-the-clouds and head-fully-in-the-box. And imagination seems to fit with both of the two main kinds of virtue emphasized by virtue epistemologists. *Virtue reliabilists* focus on those virtues that are mostly products of evolution. For example, good perception, intuition, and memory are virtues in this sense. *Virtue responsibilists* focus on those virtues that are acquired through hard work and exposure to exemplary role models. These kinds of virtue include conscientiousness, open-mindedness, intellectual humility, intellectual courage, and intellectual determination. Obtaining these virtues through effort is praiseworthy.

We could understand imagination as a virtue in either or both senses. In previous work, I have argued for a dual systems account of imagination that considers imagination as an ability that can be exercised in an automatic and unconscious way, or in a conscious and controlled way (Stuart 2019a). We might frame automatic, unconscious imagination as the first kind of virtue. Along these lines, Timothy Williamson argues that imagination is a cognitive capacity that has evolved to help us come to know modal facts that are relevant for our survival (Williamson 2016). We don't know how imagination tells us that we'll make it if we try to jump over some particular stream, but it does, and it generally does so reliably. Controlled, conscious imagination would more clearly correspond with the second kind of virtue, in the sense that

we can learn to use it carefully and correctly. A well-trained imagination in this sense is praiseworthy. An example of a philosopher who might be a virtue theorist about imagination is Amy Kind, who has recently been arguing that imagination is a skill. Kind (2020) presents an extended discussion of what skills are, why we should think of imagination as a skill, how we can evaluate various strengths of this skill, and how all of this relates to existing discussions of imagination and the epistemology of imagination.

Kind doesn't explicitly claim that imagination is a virtue. And it is not clear whether skills and virtues are the same thing (for some history on this question, see Bloomfeld 2000; Annas 1995; Stichter 2007). Carlotta Pavese defines "reductive virtue epistemology" as those brands of virtue epistemology that define knowledge in terms of skill (2016), and identifies Ernest Sosa, Christoph Kelp, John Greco, Duncan Pritchard, John Turri, and Linda Zagzebski as proponents of this view. Reductive virtue epistemologists take the relevant cognitive skills to be related to the disposition to believe truly, and when Kind is discussing the skill of imagination, she is discussing what she calls "instructive imagination," which is the kind of imagination we use "to try to figure out how the world works, or at least, how some aspect of the world works" (Kind 2020). So perhaps Kind would be at home with a kind of reductive virtue epistemology.[4]

In any case, even if virtues aren't (only) skills, they are closely related to skills (Stichter 2013). So, I will treat Kind's discussion of imaginative skill as an instance of a virtue theoretic approach to epistemology of imagination. Kind presents "expert imaginers" like Nikola Tesla, Temple Grandin, and Satoshi Kamiya, all of whom have been able to use their imaginative capacities to impressive effect. Kind argues that this skill can be developed through practice and training, and as we will see, scientists agree.

When asked about improving imagination, most scientists spoke in clearly virtue-theoretic terms. For example, how can you help a student to imagine more effectively if they were stuck on a problem? The PI of the genetics lab answered:

> I mean, primarily I think just by suggesting that they try this that or the other thing. But to be honest with you, I often just leave students on their own. I'm always very happy to talk to them if they have ideas or results, but I don't like so much to tell students what to do. Because I think, too much of that stifles their imagination ... But I think it's a bit tricky, the job of the lab head, because science is a creative activity, and if the only creator is the PI, that's not very good. Even if the PI is super creative, if that person essentially inhibits the creativity of others, then that might be negative. (C1, interview, 22/05/2019)

For this PI, it is important to let people develop their own powers of imagination. If there is too much guidance from the boss, students might turn off their imaginations.

[4] Sarah Wright argues that imagination is only a skill for virtue reliabilists, not for virtue responsibilists (2018), which chafes against my classifying Kind as a virtue responsibilist. However, this distinction has been understood in different ways. For example, Heather Battaly portrays virtue reliabilists as those who claim that virtues can be "hard-wired faculties ... acquired skills ... or even acquired character traits," while virtue responsibilists (like Zagzebsky, Montmarquet, and Baehr) focus mainly on character traits (Battaly 2018, 2). On this telling, Kind could be a reliabilist.

According to virtue epistemologists who focus on skill, this is good advice: Skills can only be acquired through the effort of the agent. Virtues cannot be gained through testimony alone.[5]

Of course, students require *some* guidance. But what guidance can you give to improve the imagination? After all, a scientific mentor cannot directly observe and evaluate a student's performance and give feedback (Kind 2020). The PI working at CERN addressed this worry by insisting that imagination should be trained in a problem-focused way: "I lead them with problems to solve. And I don't try to solve the problem for them" (F1, interview, 08/12/2018). This partially addresses the issue of skill transmission: While you can't give someone a more skillful imagination by telling them what to do, you can provide open-ended prompts that cause someone to imagine (using things like problems, metaphors, puzzles, and thought experiments), which, over time, eventually improve their skills in imagining (Stuart 2017, 2018).

Another strategy is to help students improve related character traits and abilities that are useful for gaining skill in imagination. A PI in climate science notes that conversations about imagination only naturally arise, in her experience, around the transition from PhD to postdoc, when budding scientists are required to come up with their own fundable projects. These scientists are often "scared that they wouldn't have the imagination to come up with these ideas." To help, this PI would remind students of "examples that illustrate where they have been creative and imaginative, and when they came up with new ways to address a problem, and new questions that they saw as relevant. I try to do that with explicit examples" (D1, interview, 19/06/2019). In other words, to empower the skill of imagination, she first tries to encourage the complementary virtue of intellectual courage, by reminding the students of previous occasions in which those students were skillful in imagination.

The PI of the other climate science lab was also asked how he helps students improve their uses of imagination. He replied,

> It's actually quite hard to teach that! In a way, yes, I tell them how to do it, in a way, but the point is, being now more and more senior, I have a lot of experience. This is what a PhD student or a Masters student, or even an early postdoc does not have, right? So this is something which is then a bit tricky, to say, well, you get that with experience. But what you can teach is, in a way, to be always critical. To not fully believe in either the observation, nor the model output. I still have colleagues who are quite senior who say, 'well this is observation right?' Well yes, but, so what! It's measured, there can be problems! So it's being critical, that's what you can give the young students, with their own results. (E1, interview, 20/06/2019)

Here, the PI tries to help his students develop their imaginations by encouraging them to be critical, to question everything, and to be intellectually curious. Again, we

[5] As Federica Isabella Malfatti writes, "I can give you some advice on how to perform, say, backstroke; I can show you. But you won't learn as long as you sit by the pool. You may even listen carefully to my explanations, understand everything I say and trust me blindly, but you will need to do more than believing me, if you want to get to know how to swim: you need to use the information I gave you—you need to jump in and practice yourself" (Malfatti 2019).

are honing the virtue of imagination by strengthening the surrounding and supporting virtues.

Finally, if imagination is a virtue, then we should expect it to admit of a golden mean between extremes. And indeed, scientists offered numerous accounts of students that were too imaginative, or not imaginative enough. This was sometimes framed as negative because of its negative consequences (as we saw in section 1). But in some cases, the participants would describe people directly as particularly gifted or not-so-gifted imaginers. Interestingly, while scientists agree that overactive imaginations generally need to be pared down, this typically isn't a major concern. Instead, it's the other extreme—the *lack* of imaginative skill—that PIs find more common, and more worrying.

Now, what do these empirical results mean for the epistemology of scientific imagination?

5. Discussion and Implications

5.1 Skepticism about the epistemic value of imagination

Epistemologists and philosophers of science want to know whether imagination has epistemic value, and if so, why. Here is one pointed way to ask this question: For a given use of imagination (e.g., a thought experiment), how much, if any, of the epistemic value of the output of that episode is due solely and wholly to the imagination? This is a difficult question whose answer relies on our explicating the relationships between imagination and other sources of epistemic value, like perception, memory, logic (e.g., Norton 2004), innate structures programmed by evolution (Mach 1905; Sorensen 1992), tacit and nonpropositional knowledge (Miščević 1992; Nersessian 1992, 2018), and rational insight (Brown 2011). Perhaps imagination is partially responsible, in the sense of being an enabling condition for all of those things (Buzzoni 2008, 2018; Stuart 2017). Or we might say that imagination itself is directly responsible (Kind 2018).[6]

This issue can drift into difficult debates about rationalism, empiricism, and naturalism. Perhaps the above-mentioned tripartite distinction can help break the stalemate by drawing attention to how cognitive acts are evaluated in science. For example, if cognitive acts get their epistemic value from their consequences, then an act of imagination can have epistemic value if it promotes epistemically valuable states of affairs. To establish that a given act of imagination has epistemic value, we simply need to show that without it, we would not have gained specific new accurate beliefs, knowledge, or understanding. And certainly, there are imaginings we can credit in this way, however we define imagination, and whatever the states of final epistemic value are.

The same is true if deontology or virtue theory are the correct frameworks. Thus, if cognitive acts get their epistemic value from how well they respect certain epistemic norms, then acts of imagination have value depending on whether they respect those norms. It is not yet settled what these norms are, but if the current literature in metaepistemology is on the right track, they will be things like ensuring the accuracy of our beliefs. As we saw above, we can claim that scientists use their imaginations to

[6] For a recent overview of the options, see Murphy (2022).

produce how-possibly accounts that respect the norm of ensuring the accuracy of existing beliefs by staying coherent with background knowledge and empirical data. As long as these are genuine acts of imagination (and not acts of some other kind), then it will be hard to deny that acts of imagination can have epistemic value in this sense.

Lastly, if cognitive acts are valuable insofar as they manifest certain virtues, then whether an act of imagination has value depends on whether it manifests the virtue of imaginativeness, or some other epistemic virtue(s). And it seems clear that acts of imagination in science can manifest virtues, for example, by imagining in a prudent, well-trained, responsible way.

In sum, the tripartite distinction can helpfully complicate questions about whether and how imagination might count as having epistemic value by providing three specific ways for defending the claim that acts of imagination can have epistemic value.

5.2 What are scientists, really?

We have seen three different ways we might think about the epistemic value of imagination, and scientists seem to adopt all three frameworks. Interestingly, scientists tend to do this depending on the time index. If we are talking about a *past* act of imagination, the act tends to be evaluated as good when it had good consequences. If we are talking about a *current* act of imagination (one where the consequences aren't yet clear), it is more likely to be evaluated as good when it respects certain duties to imagine well. And if we are talking about *future* uses of imagination (or uses of imagination in general), scientists tend to shift to a virtue-theoretic framework.

This seems natural. Consequentialism is most easily applied in cases where we know the consequences. Deontology captures open-ended problem-solving because scientists have developed norms to guide such problem-solving processes. And virtue theory is concerned with forging virtuous scientists able to overcome all kinds of obstacles. Still, it is interesting to consider whether and how we might characterize scientists as more fundamentally committed to just one of these frameworks. One way to do this is to ask whether positing a deeper commitment to one of the frameworks best explains the above data.

If scientists are normative epistemic consequentialists, they should be able to say what a given scientist should do, in a given context, by reference to consequences. In the case of acts of imagination, this is difficult to do. In pedagogical contexts, we might suggest imagining a particular simplification of a system that we know tends to lead to greater understanding. But at the cutting edge, it is hard to anticipate what imaginings will have the best consequences. Probably no one would have recommended that Kekulé imagine snakes, or Maxwell a demon. Instead, consequentialists can recommend a set of rules or attitudes, each of which tend to have the best consequences. Looking back to §3, we saw scientists evaluating and prescribing imaginings in terms of duties or norms. It's possible that they did this, not because obeying those duties and norms is the fundamental epistemic good in science, but because doing so tends to have good consequences. Since scientists often feel comfortable departing from the duties and norms promoted by deontic epistemologists, for

example by generating false but useful explanations, perhaps it is because they are, at heart, consequentialists. In other words, they recommend that imagination respects certain norms in the moment because that is the best they can do in the absence of a time machine that can also visit possible worlds. Thus, it seems that positing an underlying commitment to consequentialism is capable of explaining the remarks that appear deontological.

Similarly, if you ask a consequentialist about how best to act in the future or in general, they could tell you to promote or maximize the good, or to follow the rules, or respect the duties one should always follow because they tend to promote the good. However, imagination might be a special case. Celebrated breakthroughs of imagination do not always come by following rules or respecting duties. What is required for science to do best, in a consequentialist sense, might be to occasionally scorn accepted dogma and established methodological rules (Stuart 2020a). If we want to encourage the next generation of scientists to develop the ability to imagine this way, when appropriate, perhaps the best thing to do is to encourage the development of a set of scientifically valuable character traits (virtues) like imagination, open-mindedness, curiosity, and skepticism. While these character traits can be valued on their own, these traits could also be valued because of their good downstream epistemic consequences. Thus, while scientists sometimes speak as deontic epistemologists and virtue theorists, it is possible to understand them as thorough-going consequentialists.

Can we run the same argument in the other directions? Suppose scientists are "really" deontologists. In this case, their remarks about present episodes of imagination-use are consistent with the data. However, when speaking about past or future imaginings, they should say that an act of imagination was (or will be) epistemically good if it respected (or will respect) the duties that all imaginings ought to respect. There is nothing preventing scientists from doing this. To decide if a given use of imagination was a good one, they would merely have to check whether it respected the relevant duties. But this is not what we find. Instead, scientists talk about consequences and virtues, and they are reluctant to commit themselves to any categorical norms for good imagining. Further, it is difficult for a deontologist to reconcile imaginings that violate epistemic norms but which are nevertheless positively evaluated due to their good downstream consequences.[7]

Now suppose scientists are "really" virtue theorists. In that case, their answers about future imaginings (and imagination in general) are consistent with the data. To imagine well in the future (and in general), one should improve one's intellectual excellence. However, their answers to questions about current and past imaginings are harder to accommodate. When asked to evaluate a current or past episode of imagination, virtue-theoretic scientists should reply by considering whether the act in question manifested the epistemic virtues of the agent. If it did, then it was epistemically good. And again, there is nothing stopping scientists from evaluating all imaginings, past, present and future, in a virtue-theoretic way. But this is not what they do. Instead, they talk about consequences and respecting duties. Finally, it is difficult for the virtue theorist to account for imaginings that manifest vices, like

[7] For examples, see Stuart (2020a).

arrogance or vanity, but which are nevertheless positively evaluated by scientists due to their good downstream consequences.[8]

In sum, to portray scientists as thorough-going deontologists or virtue-theorists about the epistemic value of imagination, we require an error theory that explains why scientists mistakenly present their own evaluations in consequentialist terms. This is not needed for those who portray scientists as thorough-going epistemic consequentialists about imagination. Another option is for deontologists and virtue theorists to build good consequences into their accounts of epistemic value. But in that case, a major concession is being made concerning the fundamental importance of consequences for the epistemology of imagination.

Given the above considerations, perhaps it is best to understand scientists as epistemic consequentialists about imagination. Of course, they might not be epistemic consequentialists about other kinds of scientific activities, for example, experimental design, mathematical reasoning, or collaboration. It could be that imagination is especially suited to a consequentialist framework, given that it can and sometimes should be, literally, unruly.

5.3 Consequences for mainstream epistemology

The correct metaepistemology, whatever it is, must be consistent with scientific practice. Given that imagination is part of scientific practice, then if scientists are consequentialists about imagination, deontic and virtue epistemologists need to explain this away. They could allow that scientists are consequentialists and argue that they shouldn't be, or they could deny that scientists are really consequentialists. I will consider two ways of making this latter move.

First, we might claim that qualitative data about how imagination is used in science does not tell us how imagination is *actually* used in science. While there is certainly some possibility of error when using empirical methods, this objection begs the question against qualitative social scientific methods, which are generally taken to be reliable for extracting information about the cognitive processes and social patterns that underlie complex human behavior. Indeed, there are good reasons for thinking that qualitative methods are especially relevant for analyzing scientific practice and informing philosophical debates (Nersessian and MacLeod 2022).

Second, we might reject the idea that scientists hold any fundamental view about the epistemic value of imagination. Perhaps scientists shift back and forth between consequentialism, deontology and virtue epistemology depending on the context, with no deeper preference. Historically, however, pluralism of this sort has not been attractive for epistemologists. The main question there is how to understand epistemic value, and only one framework can be correct. For instance, metaepistemologists can agree that epistemic pluralism is desirable in the sense that science should promote a diversity of stances or standpoints. But this recommendation will be justified because of its good consequences, or because of its respect for epistemic duties and norms, or because it manifests certain virtues. It will not be justified using a combination of all three frameworks.

[8] An interesting example might be Galileo. For accounts of Galileo's virtues and vices, see Roberts and Wood (2007), Baehr (2021), and Fricker (2021). For more on imagination, creativity and vice, see Kieran (2014a, 2014b, 2018).

And what goes for scientists should also go for epistemologists. We might hold that in epistemology, it is always or generally best for there to be a combination of virtue epistemologists, consequentialists, and deontologists. But here again, the explanation of this value will be consequentialist, deontic, or virtue theoretic. In sum, it is not clear that virtue and deontic epistemologists can use pluralism to deny the above conclusions without embracing normative epistemic pluralism themselves, which they have so far been unwilling to do.

5.4 Consequences for philosophy of science

While epistemologists might reject pluralism at the fundamental level, the opposite seems true in philosophy of science. Pluralism is practically definitive of modern philosophy of science, where pluralism is thought to be required for capturing the complexity of scientific practice (Kellert, Longino, and Waters 2006; Ankeny et al. 2011; Ruphy 2016; Chang 2012). The same argument has been given for scientific imagination: it seems that the great diversity of practices, methods, and stages of evaluation require pluralism (Murphy 2020; Stuart 2020b). But the kind of pluralism usually championed in philosophy of science tends to focus on the aims, methods, and ontologies of science, not fundamental sources of epistemic value. Indeed, it is useful to ask why we think pluralism is a good thing for philosophy of science. Is it because it has the best consequences, because it respects our epistemic duties, or because it manifests virtue? I suspect that many pluralist philosophers of science would be tempted to explain their pluralism by saying that it allows them to best explain the details of scientific practice. If I'm right, this suggests a monist, consequentialist justification for pluralism. While I cannot defend this suggestion in any detail here, it is worth thinking about how philosophers of science do (and should) justify their own pluralism, and whether their pluralism also applies to these three ways of doing epistemology of science.

6. Conclusion

If we define good actions consequentially, then good imaginative acts are those with good epistemological consequences. If we define good actions deontically, then good imaginative acts are those that respect the duties that govern epistemic imaginings. Finally, if we define good actions virtue-theoretically, then good imaginative acts manifest the competencies of virtuous imaginers. I have presented new empirical data to show that scientists employ each of these three metaepistemological frameworks, and have argued that the most natural way to accommodate this data is to claim that scientists are really consequentialists, at least about acts of imagination. Philosophers can be pluralists and use different frameworks to explain different practices; however, if the above arguments are correct, consequences should take up an important part of the center stage for any epistemology of scientific imagination.

Many open questions remain. *Why* are scientists consequentialists about imagination? Is it due to education, funding and publication incentives, hero narratives, societal pressure, epistemological and pragmatic reasons, or something else? What kind of consequentialists are they? For example, are they maximizing or satisficing, internalists or externalists, and what is the epistemic good that acts of imagination should promote (e.g., accurate belief, true belief, more/better knowledge, understanding,

problem-solving ability, or something else)? Also, how should we think about scientific *communities* versus *individuals*? Perhaps different frameworks apply to each. And if scientists instrumentally adopt norms of imagination, what are they? Finally, what does all of this tell us about the scientific *tools* whose roles might be characterized as focusing and amplifying the power of imagination, like thought experiments, diagrams, and models? Are these also evaluable in terms of their consequences?

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