Journal for General Philosophy of Science (2021) 52:493–499
https://doi.org/10.1007/s10838-021-09560-8

BOOK REVIEW

Arnon Levy, Peter Godfrey-Smith (Eds.): *The Scientific Imagination: Philosophical and Psychological Perspectives*

Oxford University Press: Oxford 2020, 344 pp., £55.00 (hardcover), ISBN 9780190212308

Michael T. Stuart[1,2,3]

Published online: 8 July 2021

The imagination is a mysterious thing. We criticize some people for having too much of it, and others for not having enough. Without imagination, there would be no art, no science, and perhaps no meaningful thought at all. But it is notoriously hard to define, extremely variable between individuals, and entangled with so many similar cognitive processes that it often seems impossible to say anything specific about it at all.[1] Given these theoretical difficulties and a historical aversion in philosophy of science to anything psychological, it is not surprising that the role of imagination in science has gone mostly unremarked until recently.[2] Nevertheless, thanks to new work in philosophy of science, philosophy of mind, psychology and epistemology (not to mention the cognitive and social science of science and science education studies), we are now in a position to investigate the supermassive black hole at the center of scientific practice. What is scientific imagination? How, if at all, does it differ from non-scientific imagination? When is it deployed, and for what purposes? What justifies its use? What are its epistemic outputs? How is it taught, evaluated, and understood by scientists? Can it be improved or calibrated? How is it enhanced by collaboration and computers? How can imaginative biases be overcome? Who gets to do the imagining in science? These are questions we are now beginning to answer.

The Scientific Imagination, edited by Arnon Levy and Peter Godfrey-Smith, seeks "to provide a comprehensive and exciting picture of the scientific imagination" (book jacket), and "to showcase current thinking ["the role and character of imagining within science"] and try to organize it into a coherent research agenda" (p. 1). There are thirteen chapters and an introduction. Ten are written by philosophers, and three by cognitive scientists. Of

[1] For example, Stevenson (2003) gives 12 characterizations of imagination, and there is very little in common across all of them. See also the frustration expressed by Walton and Strawson quoted in Liao and Gendler (2020).

[2] Notable exceptions include Vico (1730), Hadamard (1945) and Holton (1978; 1996).

✉ Michael T. Stuart
mike.stuart.post@gmail.com

[1] Department of Philosophy, University of Tubingen, Tübingen, Germany

[2] Department of Philosophy, University of Geneva, Geneva, Switzerland

[3] Centre for Philosophy of Natural and Social Science, London School of Economics, London, UK

the philosophical chapters, nine are primarily or significantly concerned with scientific models (the exception is Sheredos and Bechtel). This is to be expected, given the popularity of the "models-as-fictions" account in philosophy of science, according to which scientists create models in the same way that novelists create fictions. On this account, scientists learn from fictions by playing a game of "make-believe": they take the model's assumptions to be true, they find out what else is true in the model, and this tells them about reality if the model is a faithful representation of it (Frigg 2010; Frigg & Nguyen 2016; Godfrey-Smith 2006; Levy 2012; Toon 2012). The chapters by Thomasson, Thomson-Jones, Friend and Weisberg present strong new arguments against aspects of this view. And Friend and Yablo both question the relevance of fictionalist metaphysics for the epistemology of scientific model-use.[3]

The three chapters written by cognitive scientists present rich and interesting data that is relevant to questions about scientific imagination, though most of it is drawn from studies performed on non-scientists. It is safe to assume that scientific imagination is at least continuous with non-scientific imagination, and so these results are clearly informative. Still, it is possible that decades of scientific training might alter the functioning of imagination in the context of daily scientific work, and I am sure we all look forward to more direct psychological evidence on how scientists imagine.

All of the chapters present thought-provoking new ideas. And while the philosophical focus is mainly on models, we also learn about thought experiments, metaphors, diagrams, and the family of representational devices Camp calls "frames." Each chapter is written at a level that would be appropriate for advanced undergraduate or graduate students. Overall, I have no doubt that it will serve as a beacon, attracting many new scholars to the topic.

However, since this is a philosophical book review, I had better criticize something. In that case, my main complaint would be that I think the book could have focused even more than it does on the imagination. To provide a silly example, the editors do not mention the word "imagination" (or any of its cognates) in their summaries of the chapters by Thomasson, Thomson-Jones, Yablo, or Weisberg. And indeed, they do so without misrepresenting those chapters.[4] More to the point, the imagination simply is not the primary focus of at least half of the chapters. There is only one in-depth case study of scientists using imagination (by Sheredos and Bechtel), and only two chapters that try to say something about what scientific imagination might be (Salis and Frigg and Sheredos and Bechtel). In many of the cases where an author writes about imagination, other terms—like supposition, conception, inference, or even simply "thought"—could be substituted without loss of meaning.[5]

To be fair, the lack of a more direct and sustained focus on imagination might only be due to the fact that this volume was in preparation for almost five years (I know because I

[3] For a recent defense of this view, see Frigg and Nguyen (2020).

[4] To get a better idea of how much this book focused on imagination, I found myself looking for some figures. Not including references or the index, the word "imagination" can be found 339 times in the book. 85% of these are located in the introduction (11%) and three chapters: Salis and Frigg (37%), Sheredos and Bechtel (11%), and Skolnick Weisberg (17%). Compare this to "model," which can be found 1485 times (not including references or the index). Looking to the index, we find 54 subentries for "model" (24 for "imagination"), and "model" also shows up in 78 other index entries (15 for "imagination").

[5] For recent work on the distinction between these (and other) states, see, e.g., Arcangeli (2017), Balcerak Jackson (2016), Langland-Hassan (2020), and Sinhababu (2013). Of course, we might hold that all of these states or processes mentioned are subtypes of imagination, but an argument must be given for that. And even among those who do hold broad, cognitively unifying views of imagination, there are still good reasons to discuss the subtypes separately (see, e.g., Abraham 2020).

could not wait to read it), and an incredible amount of work has transformed the study of imagination during that time. Thus, several new and interesting topics do not make it into the book, including: scientific creativity and imagination; the ethics of scientific imagination; the prevalence and importance of aphantasia, hyperphantasia and prophantasia in science; the embodiment of scientific imagination; distributed scientific imagination; the logic of scientific imagination; imaginative resistance in science; the epistemology of scientific imagination; scientific imagination as a skill; and imagination in science education.

Ultimately, the book fails to provide a comprehensive picture of the scientific imagination. The good news is that this goal is not met because it is no longer possible to do that in a single book—which is exciting. In the spirit of collaboration then, I will try to summarize the major insights on imagination contained in this book, and highlight the important questions they raise for future work.

Starting with the question of what scientific imagination is, Salis and Frigg outline what is sure to become an influential taxonomy of kinds of imagination (see their Fig. 1.1, 26). It begins by differentiating objectual and propositional imagination. Objectual imagination comes in two varieties: imagistic and non-imagistic,[6] while propositional imagination subsumes counterfactual reasoning, dreaming, supposition, and make-believe. Salis and Frigg argue that imagistic imagination is neither necessary nor sufficient for modelling or thought experimenting in science, and then employ this result to strike a middle-path between those who underplay the role of imagination in science (e.g., Norton), and those who overplay it (e.g., Nersessian and Gendler). Norton's impulse to eliminate imagination from the epistemology of science is deemed correct insofar as it is directed toward imagistic imagination, while Nersessian's and Gendler's enthusiasm for imagination is deemed incorrect insofar as it is directed toward the same.[7] Importantly, Salis and Frigg only argue that imagistic imagination is neither necessary nor sufficient for thought experiments or model-use, so imagistic imagination might still be epistemically relevant in these and other cases (cf. Sheredos and Bechtel, this volume; Kind 2001; Murphy 2020).

Of the sub-types of propositional imagination, Salis and Frigg highlight "make-believe" as one that is particularly apt for the epistemology of scientific thought experiments and modelling. Make-believe is analyzed as a mental state that is free (i.e., we can decide what to imagine), obeys the same inferential processes as belief, does not guide action in the real world, is social, involves Waltonian props, and has a normative component (i.e., to make-believe that p means that, given the choice, it is to be imagined that p). Weisberg's chapter might be taken to suggest that this characterization is too inclusive. Weisberg argues that imagination is not the right mental state to have toward the content of models, because some models cannot be imagined. For example, computational models "are capable of

[6] See Arcangeli (2020a, b) for arguments that complicate this distinction.

[7] I do not think Norton underplays the importance of imagination. In fact, as long as we understand it as obeying a logic (as many do, see, e.g., Canavotto, Berto, and Giordani 2020; Berto 2017; Casas-Roma, Rodríguez, and Huertas 2019), he would straightforwardly accept it. And it is not clear that Norton would want to eliminate imagistic imagination either, because for him, images can express propositions which obey logic (see, e.g., Norton 2004, 58). With respect to Nersessian, her position is that thought experiments are manipulations of iconic mental models, which may include propositions as amodal iconic representations (2008, 98). On her account, it is possible to manipulate a mental model without any imagery: "manipulation of [a modal iconic] representation is likely to involve perceptual and motor processing, whereas an amodal representation is typically held not to involve such processing" (2008, 98). So, it does not seem right to attribute to Nersessian the view that imagistic imagination is necessary for mental modelling. Still, even if Norton's and Nersessian's positions are more flexible than presented, the positions Salis and Frigg juxtapose are still reasonable positions that someone might try to defend, so the argument is instructive.

representing multiple target scenarios, abstracting over details of these scenarios, and even compressing multiple scenarios into a single model. On the other hand, fictional scenarios [which we *can* imagine] are concrete and singular" (228).

On Salis and Frigg's notion of make-believe, we are nevertheless able to imagine such models because we can act socially as though the assumptions of the model are true in a game of make-believe. McLoone (2019) claims that such a view of the imagination tells against Weisberg's unimaginability claim. But Weisberg (or someone else who is sympathetic with imagination as involving mental imagery) might reply that such a view is simply too broad: if imagination is to be a useful term for philosophers it should be a rich psychological state (and not merely a kind of social behaviour). At the very least, it should not capture all thinking about model systems. This is, of course, a very open question.

Sheredos and Bechtel focus on imagination not as a mental state, but as a kind of reasoning. This already raises an important question. Even without a definition of imagination, what sort of thing should we focus on when we do philosophy of scientific imagination? Godfrey-Smith names imagination as a psychological faculty. Camp considers imagination in the Kantian transcendental sense, again as something like a faculty. Thomson-Jones sees imagination as an act of "fiction-making." Several authors associate imagination (or the imaginary) with being false, not-real, or as having idealized content. Collecting the views, one important open question is whether imagination is best approached philosophically as a *mental state* (Salis and Frigg), a cognitive *faculty/ability* (Camp, Skolnick Weisberg, Godfrey-Smith), or a cognitive *act/process* (Thomson-Jones, Sheredos and Bechtel).[8]

In any case, the kind of imaginative reasoning Sheredos and Bechtel highlight has four features: it is free, imagistic, it focuses on objects not presumed to be actual, and it is creative. They show how previous work on imagination by philosophers and cognitive scientists can be captured using their characterization, and then they provide a well-chosen and in-depth case study to illustrate the relationship between imagination and diagram-use. Identifying and understanding the mechanism(s) that generate circadian rhythms in cyanobacteria requires scientists to balance several constantly-changing factors, including background theory, existing data, and cognitive constraints. Hypothesizing a possible mechanism for a complex phenomenon like circadian rhythms, which meanwhile accommodates all the above factors, is very difficult. When achieved, this should be counted as a kind of "imaginative success" (179), *even if the hypothesis proves to be incorrect*. Imaginative success is sometimes achieved through the use of diagrams, which enable scientists to imaginatively animate a mechanism-sketch and thereby understand the proposed mechanism. But some mechanisms involve non-linear behaviours that are connected in complex ways, so mental animation will not always be possible. In such cases, scientists invent hybrid diagrams that include graphs and other kinds of representation, combining and bending diagrammatic conventions for epistemic profit. Scientific imagination is therefore empowered by, but also required for the creation of, good scientific diagrams.

Both Salis and Frigg and Sheredos and Bechtel characterize the imagination as free. Skolnick Weisberg's chapter points out that even if this is true in principle, we do not often take advantage of that freedom: people simply imagine what they know, or what they are used to. She worries about the consequences this might have for scientific creativity and progress. Skolnick Weisberg thus inverts the task set by many epistemologists and philosophers of mind who claim that we must find the proper constraints to put on imagination in

[8] For an argument that these different approaches are mutually consistent, but that we should neverthless focus our attention on scientific imagination as an act/process, see Stuart (2019).

order to make it reliable (Currie 2016; Kind 2018; Kung 2016). A new question, therefore, is to enquire how scientists ensure the proper *breaking* of constraints.[9]

More generally, if obeying certain constraints is not always what makes the imagination epistemically acceptable, what features *can* we point to that indicate an epistemically good use of imagination? Lombrozo gives an intriguing answer in her chapter: an act of imagination is epistemically good insofar as it participates in a process that *eventually* leads to true beliefs (see also Aronowitz & Lombrozo 2020). In other words, Lombrozo (like many scientists), is an *epistemological consequentialist*. Is this the right metaepistemological framework for scientific imagination? Why not think that a good use of imagination is one that respects certain principles of good reasoning (deontic epistemology), or one that is performed by a virtuous reasoner with a well-trained imagination (virtue epistemology)? This is a fascinating issue, especially as the debate between these metaepistemological frameworks is still fairly new.

All of this raises the question, what epistemic contribution, if any, does the imagination *itself* provide? Answers will depend on the kind of epistemic desideratum we are interested in. For example, various authors in the book allow that imagination might produce *knowledge* (Bascandziev and Harris, Friend), *new justified beliefs* (Bascandziev and Harris), *understanding* (Levy), *how-possibly accounts* (Sheredos and Bechtel), or *hypotheses* (Salis and Frigg, Sheredos and Bechtel). Others take imagination to "shed light on the world" (Camp), or help us *learn* (Lombrozo, Friend, Yablo, Godfrey-Smith, and Bascandziev and Harris).

Whatever the epistemic output, we want to know how much the imagination itself contributes to its production. One option is: nothing. For example, on the Waltonian models-as-fictions accounts, scientists discover what follows from a set of model assumptions by using so-called "principles of generation," which are (implicit or explicit) rules that determine what is to be imagined in a game of make-believe. As Friend argues in her chapter, inferring what holds in a fiction is to discover what we are prescribed to imagine about the model. But at no point do we ever have to actually imagine anything. What is true in the model "is not determined by the inferences scientists actually make but by the inferences that are licensed by the model specification and principles of generation" (p. 114). In other words, it is not clear that acts of imagination need to play any role at all in learning what follows from a model. And even if it did, one could easily reply that what is really doing the epistemic work is not the imagination but the background knowledge, model assumptions, and principles of generation. Likewise, in Godfrey-Smith's chapter, models "export" conditionals whose antecedents are the model assumptions and whose consequents are a summary of the model's behaviour. In the end, what justifies these important conditionals for Godfrey-Smith does not seem to be imagination, but case-specific skills and robustness analysis (p. 169). The problem generalizes: if we believe that imagination "works" in science when it is well-constrained, a critic can always reply that it is the constraints that are doing the epistemic work, not the imagination. Can anything be said on behalf of those who believe that imagination itself is sometimes responsible for epistemic progress? Epistemologists and philosophers of mind have argued affirmatively (see e.g., Kind 2018; Williamson 2016), but perhaps it is time for philosophers of science to see if the special context of science provides any new reasons to believe this.[10]

Many philosophers became interested in scientific imagination given the role it seems to play in certain accounts of models. Many chapters in this book highlight that specific

[9] See Stuart (2020) for a discussion.

[10] For reasons to be skeptical about this project, see (Levy and Kinberg 2021).

reason for looking at imagination in science, but others demonstrate that it is not the only one: theorizing about thought experiments, scientific narratives, metaphor, analogy, modal epistemology, or the aesthetics of science are all good entry points. In a sense, it was overdetermined that we would need a philosophy of scientific imagination. Since our discipline began, we have looked more and more carefully at actual scientific practice, including its psychological and sociological aspects. Bringing together all the available resources to study the imagination will require expertise across many disciplines, but we have time. In fact, we are still just getting started.

Acknowledgements I would like to thank Steven French, Peter Godfrey-Smith, Arnon Levy, Alice Murphy and James Nguyen for feedback on a draft of this review.

Funding Open Access funding enabled and organized by Projekt DEAL.

References

Abraham, A. (2020). Surveying the imagination landscape. In A. Abraham (Ed.), *The Cambridge Handbook of the Imagination* (pp. 1–10). Cambridge: Cambridge University Press. https://doi.org/10.1017/9781108580298.001.

Arcangeli, M. (2017). *Supposition and the imaginative realm: A philosophical inquiry*. London: Routledge. https://www.routledge.com/Supposition-and-the-Imaginative-Realm-A-Philosophical-Inquiry/Arcangeli/p/book/9781138223042.

Arcangeli, M. (2020a). The two faces of mental imagery. *Philosophy and Phenomenological Research, 101*(2), 304–322. https://doi.org/10.1111/phpr.12589.

Arcangeli, M. (2020b). The conceptual nature of imaginative content. *Synthese*. https://doi.org/10.1007/s11229-020-02930-7.

Aronowitz, S., & Lombrozo, T. (2020). Learning through simulation. *Philosopher's Imprint, 20*(1), 1–18.

Balcerak Jackson, M. (2016). On the epistemic value of imagining, supposing, and conceiving. In A. Kind & P. Kun (Eds.), *Knowledge through imagination.* Oxford: Oxford University Press.

Berto, F. (2017). Impossible worlds and the logic of imagination. *Erkenntnis, 82*(6), 1277–1297. https://doi.org/10.1007/s10670-017-9875-5.

Canavotto, I., Berto, F., & Giordani, A. (2020). Voluntary imagination: A fine-grained analysis. *The Review of Symbolic Logic*. https://doi.org/10.1017/S1755020320000039.

Casas-Roma, J., Rodríguez, M. E., & Huertas, A. (2019). A common frame for formal imagination. *Minds and Machines, 29*(4), 603–634. https://doi.org/10.1007/s11023-019-09510-w.

Currie, G. (2016). Imagination and learning. In A. Kind (Ed.), *The Routledge Handbook of Philosophy of Imagination* (pp. 427–439). London: Routledge.

Frigg, R. (2010). Models and fiction. *Synthese, 172*(2), 251–268.

Frigg, R., & Nguyen, J. (2016). The fiction view of models reloaded. *The Monist, 99*(3), 225–242.

Frigg, R., & Nguyen, J. (2020). *Modelling nature: An opinionated introduction to scientific representation*. Cham: Springer. https://doi.org/10.1007/978-3-030-45153-0.

Godfrey-Smith, P. (2006). The strategy of model-based science. *Biology and Philosophy, 21*(5), 725–740. https://doi.org/10.1007/s10539-006-9054-6.

Hadamard, J. (1945). *The mathematician's mind: the psychology of invention in the mathematical field*. Princeton: Princeton University Press.

Holton, G. (1978). *The Scientific Imagination - Gerald Holton*. Cambridge, MA: Harvard University Press. https://www.hup.harvard.edu/catalog.php?isbn=9780674794887.
Holton, G. (1996). On the art of the scientific imagination. *Daedalus, 125*, 183–208.
Kind, A. (2001). Putting the image back in imagination. *Philosophy and Phenomenological Research, 62*(1), 85–109. https://doi.org/10.1111/j.1933-1592.2001.tb00042.x.
Kind, A. (2018). How imagination gives rise to knowledge. In F. Macpherson & F. Dorsch (Eds.), *Perceptual imagination and perceptual memory.* Oxford: Oxford University Press.
Kung, P. (2016). Imagination and modal epistemology. In A. Kind (Ed.), *The Routledge Handbook of Philosophy of Imagination.* (pp. 427–439). London: Routledge. https://doi.org/10.4324/9781315657905-47.
Langland-Hassan, P. (2020). *Explaining imagination*. Oxford: Oxford University Press.
Levy, A. (2012). Models, fictions, and realism: two packages. *Philosophy of Science, 79*(5), 738–748. https://doi.org/10.1086/667992.
Levy, A., & Kinberg, O. (2021). *Knowledge via the imagination: Routes and roadblocks. The Junkyard: A scholarly blog devoted to the study of imagination*. https://junkyardofthemind.com/blog/2021/1/22/knowledge-via-the-imagination-routes-and-roadblocks.
Liao, S., & Gendler, T. (2020). Imagination. In E. N. Zalta (Ed.), *The Stanford Encyclopedia of Philosophy* (Summer 2020). Stanford: Metaphysics Research Lab, Stanford University. https://plato.stanford.edu/archives/sum2020/entries/imagination/.
McLoone, B. (2019). Thumper the infinitesimal rabbit: A fictionalist perspective on some "unimaginable" model systems in biology. *Philosophy of Science, 86*(4), 662–671. https://doi.org/10.1086/704976.
Murphy, A. (2020). Towards a pluralist account of the imagination in science. *Philosophy of Science*. https://doi.org/10.1086/710620.
Nersessian, N. J. (2008). *Creating scientific concepts*. Cambridge, MA: MIT Press.
Norton, J. D. (2004). Why thought experiments do not transcend empiricism. In C. Hitchcock (Ed.), *Contemporary debates in the philosophy of science* (pp. 44–66). Malden, MA: Blackwell Publishing.
Sinhababu, N. (2013). Distinguishing belief and imagination. *Pacific Philosophical Quarterly, 94*(2), 152–165. https://doi.org/10.1111/j.1468-0114.2012.01449.x.
Stevenson, L. (2003). Twelve conceptions of imagination. *The British Journal of Aesthetics, 43*(3), 238–259. https://doi.org/10.1093/bjaesthetics/43.3.238.
Stuart, M. T. (2019). Towards a dual process epistemology of imagination. *Synthese*. https://doi.org/10.1007/s11229-019-02116-w.
Stuart, M. T. (2020). the productive anarchy of scientific imagination. *Philosophy of Science, 87*(5), 968–978. https://doi.org/10.1086/710629.
Toon, A. (2012). *Models as make-believe: Imagination, Fiction and Scientific Representation*. Chippenham: Palgrave Macmillan UK. https://doi.org/10.1057/9781137292230.
Vico, G. (1730). *The new science of Giambattista Vico: Unabridged translation of the third edition (1744) with the addition of "Practic of the New Science"* (T. G. Bergin & M. H. Fisch, Trans.). Ithaka: Cornell University Press. https://www.jstor.org/stable/https://doi.org/10.7591/j.ctt20d89gr
Williamson, T. (2016). Knowing by imagining. In A. Kind & P. Kung (Eds.), *Knowledge through imagination.* Oxford: Oxford University Press.