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Towards a Pluralist Account of the Imagination in Science[1]

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Abstract

Typically, the imagination in thought experiments has been taken to consist in mental images; we visualise the state of affairs described. A recent alternative maintains that it is only the propositional imagination that is necessary for the conduct of a thought experiment (Salis and Frigg *forthcoming).* I set out problems with these monistic accounts, and develop a pluralist stance. Thought experiments appeal to a variety of our imaginative capacities and we ought to focus on the function of particular thought experiments when considering what type of imaginative engagement they invite.

1. Introduction: thought experiments and imagery

Thought experiments are tools of the imagination that have contributed to significant scientific developments. My aim here is to draw on discussions of the imagination in the philosophy of mind to give an account of the nature of the imagination involved in their conduct. I begin by outlining the common view that the imagination in thought experiments is imagistic; that is, when engaging with thought experiments, we form pictures in our mind of the scenario described. I then discuss a recent alternative to this view, Salis and Frigg's

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propositional account, which sets out to demonstrate that imagery plays no important role. After presenting a series of worries with these monistic accounts, I propose that we ought to adopt a pluralist stance when thinking about the type of imagination involved in scientific thought experiments. This best captures the ways in which scientists use thought experiments for a range of purposes.

It is widely recognised that the term ‘imagination’ picks out various acts and is too broad for a single characterisation. Given what Kind (2013) refers to as the ‘heterogeneity’ of the imagination, we can consider what different forms it can take.[2] One way to categorise the imagination, which broadly follows the distinction Salis and Frigg present in their account of the scientific imagination, is to distinguish between 1) ‘propositional imagining’ and 2) ‘non-propositional imagining’. Propositional imagining is a matter of imagining *that* something is the case. I can imagine that there are flowers on my table, for instance. Propositional imagination does not require the use of mental imagery. Non-propositional imagining, on the other hand, can be the following: a) objectual imagining—this involves mental imagery, for example, I imagine flowers on my table by forming an image in my mind of flowers on my table. This is not limited to visual imagery; I can have imagery that correlates with other sense modalities as well. And b) phenomenal imagining—this consists in imagining seeing, hearing, touching and so on, for example, imagining *seeing* flowers on my table, or *hearing* a dog barking, or *feeling* an emotion (Stock 2017, 24). Now that we have an idea of the different forms the imagination can take, we can turn to existing views of the imagination in scientific thought experiments.

[2] As Kind (2013) highlights, distinctions have been drawn, between for example, dramatic and hypothetical, sympathetic and perceptual, and propositional and objectual imaginings.

Although little attention has been paid to the question of what kind of imagination is involved in the conduct of a thought experiment, it has typically been taken to be like forming a picture in the mind's eye; a visual form of imagination.[3] Brown states that 'we typically "see" something happening in a thought experiment' (2004, 25). Similarly, for Gooding, 'the ability to visualize is necessary to most if not all thought experiments' (1992, 285). Miščević and Nersessian utilise the cognitive science literature on mental modelling. For Miščević (1992), thought experiments consist in building a quasi-spatial "picture" of the scenario described. Nersessian's account is slightly different in that it does not involve 'pictures in the mind' (1992, 294); it can be a matter of forming more abstract analogical representations. Yet the reasoning involved is of a non-propositional nature; 'inferences subjects make are derived from constructing a mental model of the situation, rather than by applying rules of inference to a system of propositions representing the content of the text' (*ibid*, 293).[4]

Although there are some thought experiments that employ our other sensory modalities such as Strawson's philosophical thought experiment that asks us to imagine a purely auditory world, the type of imagery relevant to scientific thought experiments is typically taken to be visual. This may be because many have drawn comparisons with ordinary experiment where the primacy of visual perception is typically assumed. For example, Brown states the 'only

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3 This observation has been the starting point for Salis and Frigg, and Arcangeli (2010).

4 The mental model accounts offer important insights on the reasoning involved in thought experiments. However, I leave them to one side and follow Arcangeli (2010) and speak in terms of the imagination and the various forms it can take. This allows us to avoid making a commitment to a specific model of the mind.

difference [between a thought experiment and an ordinary experiment] is that the perception is not a sense perception but, rather, is an intuition, an instance of seeing with the mind's eye' (2004, 35).

We can see, then, that many accounts of thought experiments that highlight a crucial role for the imagination have characterised it in broadly imagistic terms. I'll now turn to a view of the imagination that departs from such accounts.

2. The propositional alternative

Salis and Frigg (*forthcoming*) have developed an account of the scientific imagination that they apply to both scientific models and thought experiments. Although they agree that thought experiments involve the imagination, they propose that imagery (of any sensory modality) is unnecessary for their performance. For them, it is only the propositional form of the imagination that is relevant in the scientific domain.

To demonstrate their view, Salis and Frigg provide an example from Galileo, namely his thought experiment which was used to answer the question: 'is a force required to keep an object moving with constant velocity?' Galileo asks us to imagine a frictionless U-shaped cavity. If a ball is dropped from one side, it will continue to move until it recovers the original height it was dropped from on the other side of the cavity due to the law of equal heights. We then imagine that the second side of the U-shaped bend is flattened, so that the ball is now being dropped from a height and then travels along a straight line. The law of equal heights still applies yet the ball can never recover its original height and so, it will continue moving. This thought experiment exposes a contradiction in Aristotle's theory that moving objects will come to a stop. From this, Galileo establishes the law of inertia; no force is needed to keep an object moving with constant velocity.

Salis and Frigg state that mental imagery is insufficient: ‘When considering Galileo’s cavity we do not seem to have a perception-like representation of the cavity being frictionless or the lack of air resistance’ (*forthcoming*, 17). It seems true that we cannot have a visual image of frictionless, but perhaps Salis and Frigg are mistaken to claim that any kind of mental imagery is irrelevant. A different sensory modality could be more important when detecting friction, and so, we could have a *tactile* image of frictionlessness instead. Or we could think about how we might represent absences in the imagination, in this case, subtract friction from the scenario imagined. In the *Two New Sciences,* Galileo through Salviati, provides descriptions of experiments previously performed to help convince Simplicio that certain mathematical results apply to nature and to make certain theoretical claims plausible. In one section, he describes cutting a channel along a piece of wood and states ‘having made this groove very straight, smooth and polished as possible, we rolled along it a hard, smooth, and very round bronze ball…’ (1914, 178). Here, Galileo helps us imagine the effects of frictionlessness, that is, what it would look or feel like, by providing us with descriptions whereby friction is reduced as much as possible.[5]

Putting to one side issues with this particular example, Salis and Frigg are correct to say that in order for thought experiments to be successful, we must have certain conceptual knowledge and thought experiments are going to include steps that are best captured as

[5] The importance of what Galileo might be asking us to do will become apparent when I outline my pluralist account.

propositional reasoning (see also Arcangeli, 2010)[6]. Further to maintaining that mental imagery is insufficient, Salis and Frigg take it to be unnecessary. They argue that it is a propositional form of the imagination, imagining *that* something is the case, that is necessary for conducting thought experiments, insisting that we ‘need to grasp the relevant concepts, with or without forming a mental image of the objects and the transformations they stand in for’ (*forthcoming*, 18). They generalise this claim to cover all cases of the scientific imagination in modelling and thought experiments.

I agree that the propositional form of the imagination has a place in thought experiments, and Salis and Frigg have mapped out a useful way of categorising the imagination when thinking about its role in the scientific domain. However, I have some worries with their view, and my account developed in the following sections differs in significant respects.

Firstly, there are close connections between a propositional view of the imagination in thought experiments and Norton’s argument view. Norton analyses thought experiments as arguments and maintains that all thought experiments can be reconstructed into argument form without any epistemic loss, and that the ‘actual conduct of a thought experiment consists in the execution of an argument’ (2004, 50). Norton has reconstructed many thought experiments into arguments and holds that there are no examples that cannot be handled in such a way. Consequently, their typical narrative form and any of their creative, or to use Norton’s terminology, ‘picturesque’ qualities, are deemed epistemically redundant.

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[6] Arcangeli states that the imagination in thought experiments is not limited to a pictorial kind, and argues that a broader notion of the imagination is present in the work of Mach.

Salis and Frigg aim to offer an alternative to Norton, arguing that his view misses the importance of the imagination and the use of imagined particulars. They state that characterizing thought experiments as arguments 'presupposes a propositional kind of imagination' (*forthcoming*, 7) and 'the arguments leading to the general conclusions involve imagined scenarios and particulars' (*ibid,* 16). However, it is difficult to see how their account departs in any significant respect from an argument view. In their analysis of Galileo's case, which is the only thought experiment they discuss, they state: 'Galileo deliberately imagines a certain hypothetical scenario, he develops a deductive reasoning leading to a contradiction, and he quarantines its content since he explicitly invites us to imagine a non-actual situation' (*ibid*).

Their view actually comes out stricter than Norton's in certain ways. Norton has expanded his position to allow that the notion of argument involved in carrying out a thought experiment is broad, where valid logical inferences include informal reasoning and even reasoning with imagery, for example, a picture can be a premise in an argument as seen in some mathematical cases. Thought experiments are governed by a 'very general notion of logic' (Norton 2004, 54). There is a worry with Norton's view that the notion of argument becomes so broad that his position ends up trivial—the claim amounting to the idea that there is some reasoning or inference involved (Stuart 2016b). In light of this, I take Norton, as many have done in the literature, to be restricted to a narrower sense of argument.

The worry is that either Salis and Frigg's propositional account, although insisting that there is a role for imagination, is stricter than Norton's (broad) argument view, or it is difficult to see what the distinction between Salis and Frigg's propositional account, and Norton's (narrow) argument view is. A propositional view of the imagination in thought experiments therefore appears to collapse into Norton's (narrow) account.

Salis and Frigg situate their account within a broader view of modelling and representation in general. They endorse the claim that models and thought experiments are examples of make-believe. The idea is that modelling involves engaging with fictions in a way that is analogous to our engagement with fictions in art such as reading literature and watching films. The make-believe view was developed by Walton (1990) in the context of representations in art. Simply put, the view is that models are representations that function as 'props' that prescribe imaginings.

Given my claim that their account is strongly aligned with Norton's narrow view, what is the role for make-believe? And what's the relation between propositional imagination, argument, and make-believe?[7] The problem is that it is hard to see the benefit of treating thought experiments as fictions in the Walton sense over Norton's narrow view if the nature of the imagination is propositional (belief-like) and thought experiments involve deductive reasoning.[8] Meynell gave an earlier account of thought experiments as make-believe, and

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[7] This is not to say that characterising thought experiments as arguments necessarily means that they cannot be fictions in the Waltonian sense. As Friend demonstrates: 'Walton is not interested in our ordinary conception of fiction…On his view, any work that prescribes imaginings counts as fiction' (2011, 164). But if this is all that is meant, what do the advocates of this view think they are getting from treating thought experiments as make-believe?

[8] A parallel worry is raised by French who considers a version of the models as fictions view that takes the imaginings involved to be of a conceptual nature: 'in the context of this review

raises a similar concern. She argues that if we were to maintain that the imaginings prescribed follow the logical form of beliefs, and the relations between beliefs, then it is not clear how they would differ from Norton's background assumptions (2014, 4165).[9]

Secondly, although my focus is on thought experiments, I want to suggest that there are relevant differences between thought experiments and models which may impact the nature and role of the imagination in their conduct and thus, undermine a "one size fits all" account of the scientific imagination. Salis and Frigg are right to stress similarities between thought experiments and models and they show that bringing the two together offers a fruitful way of thinking about the imagination in science. Both involve creating and engaging with idealized hypothetical scenarios, and because of this, some have argued that 'models are often experiments *in thought'* (Cartwright 2010, 19), or that models are cases of "extended cognition" (Thoma 2016). Further, it is often claimed that they share important similarities with experiment: they offer a description of an initial set up which is then manipulated for us to consider what would happen. Yet they each depart from experiment in that they do not involve intervention in the world. Salis and Frigg also acknowledge some distinctions between thought experiments and models, such as the fact that the former does not include the 'formal apparatus', that is, mathematical reasoning to provide a formal proof, which is present in the latter.

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of fictionalism, how is *conceptual imagination* to be demarcated from the kinds of conceptual explorations that advocates of the Semantic Approach or Weisberg's 'mathematical models' approach will also acknowledge?' (French *forthcoming*, 188).

[9] Meynell emphasises the importance of experiential language, and the use of pictures as aids for thought experiments which gives insight into the nature of the imagination involved.

I agree that scientific models involve the imagination in some way, and perhaps refer to imaginary objects or systems, and I do not want to advocate a strict distinction between models and thought experiments. However, I want to note we should attend to their differences when giving an account of the imagination involved in their use: a) imagination is sufficient for carrying out a thought experiment but not a model which has an underlying formal apparatus. No calculations on paper nor a computer are required when we carry out, for example, Galileo's thought experiments. To use Thoma's phrase 'the phenomenon is established purely in the imagination' (2016, 136). Therefore, thought experiments rely on an imaginative process in a way that models do not. b) Additionally, the level of complexity in models is a key difference between them and thought experiments; the latter are typically simple and in fact, much of their value seems to rest on this simplicity. Whereas, as Weisberg highlights, imagery is limited in many cases of modelling: 'it is relatively easy to imagine [to form "mental pictures" of] the content of finite, deterministic, individualistic models like a population of genes undergoing assortment, it is unclear that this could generalize to more complex cases' (2013, 63).

And so, there might be differences with regards to the type of imagination involved in various areas of scientific practice. In the remaining sections, I turn to the varied nature of the imagination across scientific thought experiments.

3. What kind of imagination do thought experiments invite?

So far, we have seen that the imagination in thought experiments has been taken to be imagistic. Salis and Frigg propose a different, propositional view. I agree with Salis and Frigg that the imagination in thought experiments should not always be characterised in terms of imagery, and it can be a matter of entertaining propositions. We can also hold that some aspects of conducting individual thought experiments will not require sensory imagination. But I disagree with the scope of this claim. While we can attempt to rationally reconstruct thought experiments into a propositional or argument form, the idea I wish to defend is that at least sometimes, this will lead us to miss important features involved in their use in scientific practice. This includes the ways in which scientists call upon our imaginative capacities to convince us of an outcome, or help us understand a theory or problem.

Further, it seems plausible that some people will find reasoning via visualising more useful than others, and may even require this form of imagination in order to arrive at an outcome. Whereas for some, accompanying imagery will not or cannot be present, or if it is, it will not always be necessary. Because of this, I want to shift the attention towards a different, but related, issue. This is the question of: What do thought experiments ask us to do? What kind of imaginative engagement do they invite? I draw on Balcerak Jackson who argues that imagining, conceiving and supposing are three different cognitive activities that each play distinct epistemic roles. For example, Thomson's violinist thought experiment invites us to 'vividly represent the scenario from the perspective of the experiencing subject' (2016, 45) whereas supposing that there are say, finitely many prime numbers, does not require us to picture or simulate an experience. Instead, we are asked to use our ability to 'think a thought with a particular content' (*ibid*, 51).[10] I will stick to the broader distinction between

[10] For Balcerak Jackson, Chalmers's zombie thought experiment is a case of conceiving; we simulate what a reasoner would be rationally committed to in the situation described. I am yet to find a scientific case that asks us to "conceive".

propositional and non-propositional imaginings.[11] My aim is to show that in the spirit of Balcerak Jackson's account, different thought experiments invite different types of cognitive activity.

This emphasises the importance of paying close attention to particular examples. Salis and Frigg rely on one case and then generalise to all other scientific thought experiments. Similarly, the mental model theorists often talk in very general terms about reasoning in problem solving contexts to then make claims about scientific thought experiments. I argue for a pluralist view: if we look to a range of cases, and think about what their function is, we can see that there are different requirements of our imaginative capacities when engaging with different thought experiments.

4. Pluralism

Let's begin with a case of a scientific thought experiment that seems to invite us to propositionally imagine only, where any objectual or experiential component is unnecessary. We can look to one of Darwin's "imaginary illustrations" presented in *On the Origin of Species* as an example:

> Let us take the case of a wolf, which preys on various animals, securing some by craft, some by strength and some by fleetness; and let us suppose that the fleetest prey, a deer for instance, had from any change in the country increased in numbers, or that other prey had decreased in numbers, during that season of the year when the

[11] For my purposes, I do not need to address the question of whether supposition or conceiving should be included under the umbrella term "imagination" which Balcerak Jackson denies.

> wolf is hardest pressed for food. I can under such circumstances see no reason to doubt that the swiftest and slimmest wolves would have the best chance of surviving, and so be preserved or selected (Darwin 1964, 90).

The function of the thought experiment is to demonstrate Darwin's theory's explanatory potential, as opposed to provide evidence in support of natural selection (Lennox 1991). Here, it seems that we are not required to picture the wolf and the properties it is described as possessing, nor does the thought experiment ask us to adopt a perspective of the scenario. The language is descriptive, the thought experiment refers to concrete objects and processes, and it is of course possible to visualise aspects of it. But I think a Salis and Frigg-type analysis would be right in this case: to succeed, the thought experiment merely requires that we grasp its propositional content—we imagine *that* there is a wolf and so on, with no mental imagery of a wolf or phenomenal component of seeing or feeling a wolf required.

There have been many candidates of thought experiments, or thought experiment-type reasoning, that cannot be reduced to a (narrow) argument form. For instance, those that involve spatial reasoning such as seeing that a square object will not fit through a circular hole (Cooper 2005, 223) or performing mental rotations of shapes. But I will focus on an example from the scientific domain: Maxwell's demon.

The function of Maxwell's demon is to help us reconcile our belief in the practical inviolability of the second law of thermodynamics—that the entropy of an isolated system cannot decrease—and the in principle violability that is a consequence of Maxwell's theory. It describes a demon who can control a "door" separating a box of hot gas with faster moving molecules, and a box of cold gas with slower moving molecules. The demon can selectively open the door so that heat flows from the cold gas to the hot gas, making the hot side hotter, and the cold side colder. This violates the second law.

The example asks us to adopt the position of the demon who has a capacity greater than our own, and to form a visualisation of the box and the molecules from the demon's perspective. This results in us understanding that the fact that we will not experience violations of the second law is down to our lack of capacity to do what the demon does, that is, track the individual molecules. Stuart states that the example works by relating the second law of thermodynamics to experiences that we already have: 'We may have trouble imagining a being that can see molecules, but if we imagine *ourselves* in an analogous position say, in control of a sliding door, surrounded by molecules which act like medium sized rubber balls, we understand the scenario perfectly' (Stuart 2016a, 27).

The role of thought experiments is not limited to providing us with propositional knowledge—the function of many is to increase our understanding. Understanding is a topic of significant interest in current philosophy of science, and some have drawn links between scientific understanding and visualisation such as de Regt (2017). In the context of theories, he argues that visualisation is an effective way to achieve understanding; scientists tend to prefer visualisable theories over more abstract ones and find pictorial representations helpful in understanding. De Regt states that this is to be expected given that imagining in this way involves well-developed visual capacities that are used every day (*ibid*, 257). Thought experiments are one way in which theories can be made intelligible and it appears that in the demon case, Maxwell deliberately engages our non-propositional imagination to help us understand the second law of thermodynamics.

What other candidates are there for thought experiments that ask us to do more than to consider a set of propositions? That is, those that ask us to put ourselves in a particular situation, visualise a state of affairs, and/or imagine what we would observe. Another example is Einstein's elevator. Here, we have a shift in perspective between two different people, and we think about what they would see. Yet another case from Einstein, the chasing a beam of light thought experiment, is similar: Maxwell's electromagnetism and Newtonian mechanics give different predictions as to what one would observe, and the thought experiment allows us to grasp the force of this tension. Further, Starikova and Giaquinto (2017) discuss how mathematicians imagine using visual mental imagery (that differs from applying mathematical rules) in examples of thought experiments in knot theory, graph theory and geometric group theory, which contribute to mathematical knowledge.

As mentioned, a propositional view of the imagination in science does capture some of the reasoning involved in thought experiments, and a proponent of that view may insist that we could reconstruct all of the above examples within the propositional framework. But it is evident that scientists and mathematicians utilise their visual imaginations while engaging with certain thought experiments and have reason to invite members of the community they are communicating with, whether scientific or public, to do the same. A complete account of the imagination in science needs to accommodate such instances, and a pluralistic view clearly does.

5. Conclusion

We have seen that philosophers have typically taken the imagination in scientific thought experiments to consist in mental images. A recent challenge insists that it is only a propositional form that is required. I have argued that while I think this offers an important insight into how some thought experiments work, or how aspects of thought experiments work, I disagree with the scope of the claim. If we ask: 'what do thought experiments ask us to do?' it becomes evident that they appeal to a variety of our imaginative capacities and some demand a type of imaginative activity that goes beyond the consideration of propositions. Consequently, we should embrace the richness of the imagination and the different resources it can bring into play when thinking about how scientists construct thought experiments for different purposes. I have argued that we should adopt a pluralist stance rather than limiting an account of the imagination in thought experiments to one type, whether imagistic or propositional.

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