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## Thought Experiments



Michael T. Stuart

Department of Philosophy, University of Geneva,  
Geneva, Switzerland

### Keywords

Thought experiment · Imagination ·  
Possibility · Epistemology of imagination

### Overview

Thought experiments – like Schrödinger’s cat and the trolley problem – are a way for inquirers to focus the power of the imagination. What makes a thought experiment different from fantasies and daydreams is that they aim to produce new knowledge, wisdom, understanding, illumination, or something like that. They typically also have a narrative structure, with a beginning, middle, and end. Usually there are several phases in a thought experiment: one in which we set up some imaginary scenario, another in which we “see” what happens in that scenario, and, finally, one in which we draw some conclusions. At this level of description, thought experiments are like laboratory experiments, except they are carried out in the imagination.

This entry will consider what thought experiments are, who performs them, how they have

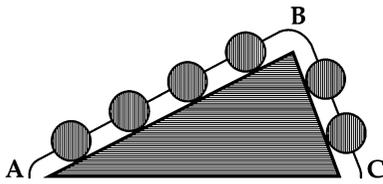
been investigated, what they aim to do, how they work, and how they connect to the possible.

What is it to be happy? Perhaps being happy is just feeling pleasure, like resting your legs after a long day’s work, or listening to a favorite song. Robert Nozick presents a thought experiment to test this view (Nozick 1974). Suppose there was a machine you could enter, which would attach itself to your brain, and stimulate it so that you felt you were experiencing all the pleasures you’ve always dreamed of: the best food, fame, meaningful work, true love, etc. You would have no memories of entering the machine or of your previous life, and you must enter the machine for the rest of your life or not at all. Would you?

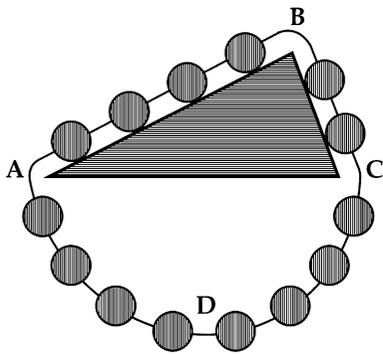
If pleasure is all there is to a happy life, we should all want to enter the machine. But the majority of people would refuse (Hindriks and Douven 2018). Why? Perhaps it is because there is more to happiness than pleasure. Maybe connections to real events and people matter too.

One thing that makes this a thought experiment is that when we begin, we don’t know what will happen. We use our imagination, and we learn something new.

Here is another. Imagine a frictionless triangular prism with a chain draped over it, as in the picture below (see Stevin 1586, 183–187; Mach 1905).



How will the chain behave? Perhaps we think the chain will slide toward A or toward C. Okay. But now, what if the chain is connected around the bottom, like this?



Well, in this case, if the chain slides toward A, it will slide that way forever, and we will have a perpetual motion machine. Same for C. In fact, the slightest motion in either direction will cause a perpetual motion machine. But perpetual motion machines are impossible. So then, what happens? The only other option is that the chain is still. In this case, there is no perpetual motion machine. But what, if anything, does this tell us about the first set-up, where the chain wasn't in a loop? Well since the link of chain at the bottom is a perfect semicircle, it exerts equal downward force on A and C. So removing it will not impact the balance of forces in the system. We therefore have the same balance of forces in both pictures. Thus, because the chain in the second picture must be still, the chain in the first picture must also be still. With this thought experiment, we've just learned something interesting about how chains behave when draped atop frictionless prisms in gravitational fields.

These are thought experiments. They are crucial for many disciplines, including philosophy,

physics, engineering, and law. Paradigm examples in philosophy include Hume's missing shade of blue (and invisible gardener), Mengzi's child at the edge of a well, John Searle's Chinese room, Hilary Putnam's Twin Earth (and brain in a vat), Avicenna's falling man, John Rawls' original position, Frank Jackson/Daniel Dennett's color scientist, Judith Thomson's violinist, David Chalmers's zombies, Plato's cave (and Ring of Gyges), Donald Davidson's Swampman, and Philippa Foot's trolley problem.

Well-known thought experiments in science include Maxwell's demon, Laplace's demon, Einstein's elevator (and train), Schrödinger's cat, Isaac Newton's bucket (and cannonball), Heisenberg's microscope, Galileo's falling bodies (and pendulums, inclined planes, and ship cabin), the Turing test, and the prisoner's dilemma.

We find thought experiments in mathematics, especially concerning difficult concepts like infinity. We also find them in art. For example, philosophers have argued that *Huckleberry Finn*, *To Kill a Mockingbird*, *Oedipus Rex*, *Lolita*, *Henry V*, *King Lear*, *Hamlet*, *Animal Farm*, *Uncle Tom's Cabin*, *The Matrix*, and *2001: A Space Odyssey* all might count as thought experiments.

Thought experiments are also used in therapy to help people cope with phobias (Gendler 2004, 1160), in law to help judges make decisions (Maks del Mar forthcoming), in theology to help interpret scripture (Fehige 2018), and in computer science to help design morally responsible artificial intelligence (Awad et al. 2018). The only field in which thought experiments are claimed not to exist is chemistry (Snooks 2006), but this has recently been shown false (Stuart manuscript).

## Definition and History

The term "thought experiment" was coined by Hans Christian Ørsted (1811) as a label to describe some of Immanuel Kant's work.<sup>1</sup> After Ørsted

<sup>1</sup>Similar notions (under different names) were in circulation before Ørsted. For example, we find some of these in the work of Georg Christoph Lichtenberg, Novalis, and Immanuel Kant (see Schildknecht 1990; Daiber 2001; Fehige and Stuart 2014).

coined the term, the first seminal writing on the topic was Ernst Mach's in 1905. This drew the attention of Moritz Schlick (see Dohrn 2018), Alexius Meinong (1907), and Pierre Duhem (1914; see Buzzoni 2018a). In the 1960s, many of the most influential philosophers of science began to write about thought experiments, including Karl Popper (1959), Thomas Kuhn (1977), Imre Lakatos (1976), and Paul Feyerabend (see Arthur 1999, Stuart 2020).

The literature expanded greatly starting in 1986, the *annus mirabilis* of thought experiments (Fehige 2020). In this year, James R. Brown first laid out his controversial epistemology of thought experiments, and the first conference on thought experiments was held at the University of Pittsburgh (the proceedings were later published in Horowitz and Massey 1991). A number of important monographs and papers quickly began to appear, including Brown (1991a), Sorensen (1992), Häggqvist (1996), Gendler (2000), Kühne (2005), Swirski (2007), Ierodiakonou and Roux (2011), and Frappier et al. (2013). Historical studies have since been produced on, for example, thought experiments in the presocratics (Ierodiakonou 2005, 2011, 2018; Rescher 2005, ch. 4); Plato (Becker 2018); Aristotle (Corcilius 2018); Ibn Sina, Ibn al-Haytham, and Abu Hamid al-Ghazali (McGinnis 2018);<sup>2</sup> Galileo (Koyré 1968; Palmerino 2011; Palmieri 2003, 2018); Newton and Leibniz (Arthur 2018); Kant (Buzzoni 2008, Fehige and Stuart 2014); Hegel and Wittgenstein (Westphal 2018); Ragnar Frisch (Herfeld 2019); Einstein (Norton 1991; Schlesinger 1996, 473–76); Maxwell (Krimsky 1973, Myrvold 2011, Stuart 2016a); Heisenberg (Popper 1959, Van Dyck 2003, and Camilleri 2007, Stuart 2016a); and many others. And now there are also broad, discipline-focused overviews of thought experiments in physics (Peacock 2018), biology (Schlaepfer and Weber 2018), politics

(Miscovic 2018), theology (Fehige 2018), ethics (Brun 2018), economics (Schabas 2018), and mathematics (Starikova and Giaquinto 2018).

Despite all this, there is no agreement about how to define a thought experiment. As we will see, thought experiments have been characterized as fictions, arguments, models, intuition pumps, and much else. Geordie McComb claims that they are best conceived as having only a “family resemblance” in common with each other (2013).

So, there is no agreed-upon definition. But maybe we can define the *performance* of a thought experiment. This is the proposal of Tamar Gendler, who claims that performing a thought experiment is reasoning about a particular set of circumstances that are accessed via the imagination. It must have the purpose of confirming or disconfirming a hypothesis or theory. And the particular circumstance imagined must be more specific than the conclusion of the thought experiment (Gendler 2004, 1155).<sup>3</sup> This last requirement is what gives thought experiments their *experimental* flavor: laboratory experiments derive general conclusions from specific circumstances and events, so thought experiments should as well.

However, there are thought experiments that pose questions rather than offer answers (like the Ship of Theseus<sup>4</sup>). And some thought experiments do not even pose a question: instead they aim only to illustrate a theory or theoretical claim (Brown 1991a, 32; Peacock 2018; Schabas 2018), “exemplify” properties (Elgin 2014), or provide “hypothetical explanations” (Schlaepfer and Weber 2018).

To make matters worse, there is also no agreement on how a thought experiment works. For example, some philosophers argue that a central

<sup>2</sup>Did all of these people *really* conduct thought experiments? As James McAllister (2018) argues, the term “thought experiment” includes the modern Western concept of scientific experiment, which arguably did not exist before Galileo. When it is legitimate to attribute a thought experiment to a historical figure? This is an open question.

<sup>3</sup>Gendler's definition takes elements from John D. Norton's earlier definition (see Norton 1991, 129).

<sup>4</sup>According to Plutarch, Theseus returned to Athens on a ship. This famous ship became a tourist attraction, and had its planks replaced, one by one, as they decayed. The question is, if all the parts are replaced with new ones, is this still Theseus's ship? If not, at what point does it cease to be the same ship? This thought experiment has developed over time, and there are now many more elaborate versions.

feature of thought experiments is that they produce an intuition, which then serves as evidence for a claim (Brendel 2004, Brown 1991a, Dennett 2013, Mišćević 2018). Others disagree. For example, John D. Norton argues that thought experiments are just logical arguments, and thus whether they produce intuitions or not is largely irrelevant.

Perhaps we could proceed along the *via negativa* and try to distinguish thought experiments from what they are not. One obvious place to start is their context. Consider the following schema inspired by Brown (2007, 158)<sup>5</sup>:

Theory & Background → Mental Experience  
 → Interpreted Result

Using this, we can distinguish between what Brown calls narrow and broad conceptions of thought experiments. On the narrow conception, the thought experiment is simply what happens in the mind: it is what we “see” happen in the imagination. It is not the background or the interpretation. On the broad conception, a thought experiment includes all of the above: it begins with the theoretical background and the question to be answered, includes the mental experience, and ends with an interpretation of the mental experience as an answer to our initial question. However, the cogency of this distinction would be rejected by those who hold that thought experiments are merely arguments (e.g., Norton 1996). On this view, all that matters for identifying a thought experiment are the premises, conclusion, and mediating inferences. There can therefore be no narrow conception of a thought experiment, because elements of background theory will be premises in the argument, and therefore they cannot be separated from the thought experiment without eliminating it. Likewise, the interpreted result is the conclusion of the argument, which also cannot be separated from the thought experiment.

In addition to the above disagreements, there is also no settled taxonomy of thought experiments. For some attempted taxonomies of thought experiments, see Popper (1959), Brown (1986, 1991a), and Boniolo (1997).

Because of these difficulties, some philosophers have judged it best to specify in advance a particular class of thought experiments they are interested in, in order to make more piecemeal progress (e.g., Häggqvist 2009, Cohnitz and Häggqvist 2018). Others try to use evidence about the use of thought experiments (e.g., in science or philosophy), to convince others that there really is a single nature or function for all thought experiments. We will focus on this latter strategy first.

One of the most discussed problems about thought experiments is how thought experiments are able to lead to new knowledge or understanding, despite not requiring new experience. James R. Brown’s answer is that performing a thought experiment produces a new phenomenon in the mind (1986, 1991a, 1991b, 1992, 2004, 2007). This phenomenon can serve as “fairly conclusive” evidence for a theory (2011, 43).

John D. Norton (1991, 1993, 1996, 2004a, b) has been Brown’s main foil. He argues that thought experiments are nothing but arguments. We gain new knowledge from thought experiments only by rearranging or logically extending existing knowledge. For Norton, all thought experiments succeed or fail only insofar as they instantiate logically good arguments.

Several accounts attempt to mediate between Brown and Norton. These accounts all argue that thought experiments are more than mere arguments, but less than sources of knowledge derived from pure reason. Perhaps the most popular account is one that draws on cognitive science and was proposed independently by Nenad Mišćević and Nancy Nersessian in 1992. The idea here is that thought experiments are “mental models.” In other words, the narrative presentation of a thought experiment triggers the creation of a mental model, which is “a structural, behavioral, or functional analog to a real-world phenomenon” (Nersessian 2018, 311). The mental model is analogous to a real-world phenomenon

<sup>5</sup>Something like this distinction was first made by Hans Radder (1996) when discussing laboratory experiments. It was then applied to thought experiments by Sören Häggqvist (1996) and Tim De Mey (2003).

in the sense that it accurately represents it, including the constraints on it. Mental models typically embed a specific and personal point of view, tend to be visual or quasi-visual, and are justified by drawing on embodied knowledge (Nersessian 1992).

Another account might be called “experimentalist.” This kind of account focuses on the relation between thought experiments and laboratory experiments. Roy Sorensen (1992), postulates that thought experiments are on a continuum with laboratory experiments. For him, thought experiments perform one of the functions that laboratory experiments can perform, namely, finding and eliminating inconsistencies in our theories. Gooding (1992) emphasizes the embodied nature of thought experiments, in order to explain a sense in which they are like real experiments. And Stuart (2016b) argues that the epistemology of laboratory experiments can be used to evaluate the epistemic value of thought experiments: specifically, the principles for effective laboratory experiments can also be usefully applied to thought experiments. Finally, Marco Buzzoni has pointed out that there are different senses in which thought experiments can relate to laboratory experiments (Buzzoni 2008, 2018b): in one sense, thought experiments are necessary for laboratory experiments, because an imagined experiment must always precede a laboratory experiment. In this sense, thought experiments are a condition for the possibility of laboratory experiments. On the other hand, experiments of all kinds ask questions to nature and attempt to provide answers, so in this sense, thought experiments and laboratory experiments are just the same.

There is also a fictionalist view of thought experiments (Meynell 2014, 2018; Salis and Frigg forthcoming). On this account a thought experiment is a fiction, and our role as thought experimenters is similar to the role of children playing a game of cops and robbers: we set some things as true in the fiction and use props to focus our imaginations. For example, in a game of cops and robbers, sticks might be guns, a set of rocks might be a jail cell, and if you are a robber and you are touched by a cop, you go to jail. The description of the thought experimental scenario plus

some implicit or explicit rules of reasoning tell us what we must imagine and what we are allowed to do in the game. The rest is up to us. By reasoning through the imaginary scenario in accordance with the rules, we learn what else is true or false in the scenario. This enables us to learn from thought experiments, insofar as these tell us what things would be like in a given hypothetical world, which is significant because in some cases, that hypothetical world turns out to be the actual world. For example, in a series of famous thought experiments, Galileo asked what the world would be like if Aristotle was wrong about motion, and this enabled Galileo to make progress (since Aristotle *was* wrong).

### Criticism of Thought Experiments

Some thought experiments seem too far-fetched to draw conclusions about the real world (Wilkes 1988). Some of them seem to promise necessary truth, which is something they might be unable to provide (Thagard 2010, 2014). They employ abstract situations, when what we often want are concrete details (Dancy 1985). And they rely on cognitive systems evolved for everyday scenarios, which can be inappropriate for complicated scientific systems (Bokulich 2001). For scientists these criticisms are more or less easily resolved, since mathematical derivations and laboratory experiments can be appealed to when we want to settle disagreements. However, such recourse is not usually available for philosophers. Given that thought experiments appear to be a central part of the philosophical method, criticisms of the use of thought experiments must be taken seriously. The greatest modern challenge comes from what is called “experimental philosophy.” Beginning in the early 2000s, this movement has led to a methodological crisis that is still developing (for overviews see Knobe and Nichols 2017, Sytma and Buckwalter 2016, Machery 2017, Stich and Tobia 2018).

Philosophers want to know about things like knowledge, love, happiness, and justice. They produce theories and test them using thought experiments. Experimental philosophers typically

present short thought experiments to people, collect the responses, and analyze the data statistically. Some of the results suggest that the intuitions resulting from thought experiments are not shared among different groups of people, and they can be influenced by irrelevant factors including age, gender, culture, native language, level of education, religious belief, and ambient sights, smells, and sounds. We trust our vision because everyone agrees that an apple is an apple, regardless of age, sex, culture and sensory context. If we assume that the nature of knowledge, truth, justice, etc., are objective (like apples), then our intuitions about them appear only to reflect our subjective opinions, not objective facts (Sinnott-Armstrong 2008, 67; Stich and Tobia 2018, 374).

One response to this problem denies the diversity of intuitions. For example, a study by Machery et al. (2015) shows that intuitions about a particular thought experiment *are* shared by people in Brazil, India, Japan, and the USA, despite the fact that earlier studies claimed to show that they varied according to cultural context.

Another response has been to claim that intuitions resulting from thought experiments are informative, but only when the intuitions are *carefully considered* and when they are the intuitions of *experts* (Williamson 2007; Ludwig 2007, 2018). We should not be surprised that the intuitions that regular people have about quantum mechanics are easily manipulated; what matters are the intuitions of professional physicists. In reply, experimental philosophers have produced evidence that (they claim) shows that professional philosophers have corruptible and unstable intuitions too, even when it comes to philosophical topics (e.g., Schwitzgebel and Cushman 2015; Tobia et al. 2013; Schulz et al. 2011).

A third response to the challenge of experimental philosophy argues that the real job of philosophy is to tell us how we *should* characterize things. Thus, even if everyone had different intuitions about justice, this would not prevent us from fashioning a *better* concept of justice, one that people *should* possess. However, if

philosophers still need thought experiments to generate and test their normative accounts, and these are fundamentally unreliable, the problem remains.

Experimental philosophy originally cast doubt on the use of thought experiments. But these days it also invents and employs its own thought experiments to identify new connections between philosophically relevant concepts. For example, here is a thought experiment created by experimental philosopher Joshua Knobe (2003) to test the influence of ethical judgments on attributions of intentionality:

The vice-president of a company went to the chairman of the board and said, 'We are thinking of starting a new program. It will help us increase profits, but it will also harm the environment.' The chairman of the board answered, 'I don't care at all about harming the environment. I just want to make as much profit as I can. Let's start the new program.' They started the new program. Sure enough, the environment was harmed.

Knobe asked participants whether the chairman *intended* to harm the environment. 82% of participants said he did. Now, and here is where it gets interesting, if you give the participants the exact same scenario but replace "harm" with "help," 77% of participants say that the chairman did *not* intend to help the environment. This result seems to imply that there is an important (and previously unrecognized) connection between ethical judgements and judgments about which actions are done intentionally. This finding has now been extended from judgements about intentionality to judgements about what people want, desire, decide, advocate, oppose and know (see Pettit and Knobe 2009, Guglielmo and Malle 2010, Beebe and Buckwalter 2010).

In sum, thought experiments appear central to the methodology of philosophy, but their appropriateness and effectiveness have been challenged, and it is an open question how to respond. To muddy the waters further, the source of the challenge (experimental philosophy) now uses thought experiments as well.

## Thought Experiments and Pedagogy

Because thought experiments are rhetorically and epistemically powerful, they are often used by educators. Their narrative structure, for example, makes them easy to remember. And the fact that they are open-ended requires students to think through complex issues on their own, which can stimulate learning and the development of new skills.

In support of claims like this, there are several social scientific studies which have been performed on students. Gilbert and Reiner (2004) found that students as young as 12 were competent with thought experiments. Others have shown that students resort to thought experiments on their own when faced with difficult conceptual problems (Köseme and Özdemir 2014, see also Reiner and Gilbert 2000, 502). Thought experiments are used effectively by educators to elicit tacit beliefs (Reiner and Burko 2003, 380), to effect conceptual change (Helm et al. 1985), and to help students learn from performances of laboratory experiments (Matthews 1994). Yannis Hadzigeorgiou summarizes the general pedagogical benefits of thought experiments as helping students in (a) developing a creative imagination, (b) developing logical arguments and creative thinking, (c) developing problem-solving skills, (d) learning how to effectively modify laboratory experiments, (e) clarifying concepts, and (f) changing concepts (2016, 24).

This research on this topic is still growing, and there are many possible directions for it to go. For example, are thought experiments equally useful in all fields and for all kinds of student? How do the spontaneously created thought experiments of young students differ from those of professional researchers? And are there ways to make educational thought experiments more effective?

## Thought Experiments and the Possible

Thought experiments focus the imagination like telescopes focus light. This means that they connect to “the possible” in many of the same ways that imagination connects to the possible: by

exploring possible worlds, possible selves, possible pasts, possible futures, and possible theories (see Glăveanu 2018). It is taken for granted by many philosophers that thought experiments can provide a window into the possible. For example, because Descartes can imagine that all of his beliefs are the product of a malignant demon’s deceptions, he takes it to be possible that this is the case.

Some argue that if we can imagine a scenario in some detail, this gives us a reason to believe that it is possible. However, we appear able to imagine impossible things. For example, it is easy to imagine things that are nomologically impossible (i.e., inconsistent with the known laws of nature, e.g., the gravitational constant being slightly stronger), although it is very difficult to imagine things that are logically or conceptually impossible (e.g., a circular square). Thus, some philosophers claim that imaginability should only be used as a *guide* to possibility, at best (Yablo 1993; Gendler and Hawthorne 2002). But why should it even be a guide?

This is an open question. Some argue that the mind evolved to imagine certain things accurately, because it benefited our early ancestors (Williamson 2016, Sorensen 1992). Thus our imaginations tell us whether and how fast we could climb a certain tree if a nearby wild animal were to charge, because that is something that could save our life. But in this case, we should expect our thought experiments not to be useful in telling us what a quantum system will do (Bokulich 2001). And yet many scientists use thought experiments to make great leaps of understanding concerning what is possible in very “unintuitive” scientific systems, including quantum ones. One way to explain this is by reference to constraints: scientists learn the constraints on systems of interest, and they use these to constrain their imaginations in thought experiments (Kind 2018, 244) This might be a plausible explanation for many thought experiments, but not for those which purposely break reasonable constraints and still make scientific progress despite, or because of, breaking the constraints (Stuart forthcoming).

Another connection between thought experiments and the possible is a special use of thought

experiments, favored by Kant, Hegel, and Wittgenstein especially, which we might call “transcendental” (see Westphal 2018). These thought experiments ask us to imagine something, and we find that we cannot. From our failure, we draw an inference about the limits of the human mind or our theories. For example, in his discussion of space and time, Kant asks us to imagine various things that are not in space or time. We can imagine space without objects in it and times in which nothing happens, but we can’t imagine, for example, an apple that does not exist in space or time. Kant uses this to conclude that space and time aren’t things in themselves, but concepts that we use to organize our experience (Critique of Pure Reason, A24-31/B38-46). Einstein does something similar with his chasing a lightbeam thought experiment against Maxwell’s theory of light (see Norton 2013). This kind of thought experiment is interesting because it uses our *inability* to imagine something as evidence in support of claims about the limits of our minds and conceptual frameworks, and perhaps also about the world itself.

## Summary

Thought experiments are tools of inquiry that use imagination in order to gain insight. Through them, we seem able to get glimpses of how the world is, how it could be, and how it could not be. Philosophers, cognitive scientists, and social scientists are concerned with how they do this and what roles are played by things like logic, intuition, imagination, idealization, and images. Since they are a fundamental part of philosophical methodology, the fact that they have recently come under scrutiny has been and will remain a central question until it is (re)solved. Some open questions include whether it’s possible to give a satisfying definition or taxonomy of thought experiments, and how thought experiments relate to fiction, art, imagination, and emotion.

## Cross-References

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