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Idealization, scientific realism, and the improvement model of confirmation

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Abstract

That many of our most successful scientific theories involve one or more idealizations poses a challenge to traditional accounts of theory confirmation. One popular response amongst scientific realists is the "Improvement Model of Confirmation": if tightening up one or more of the idealizations leads to greater predictive accuracy, then this supports the belief that the theory's inaccuracy is a result of its idealizations and not because it is wrong. In this article I argue that the improvement model is deeply flawed and that therefore idealizations continue to undermine "success-to-truth" arguments for scientific realism.

Keywords: idealization; scientific realism; theory confirmation; bootstrapping; the no miracle argument.†

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1 Introduction

Scientific realists contend that the predictive and explanatory success of a scientific theory is a good guide to believing in its truth or approximate truth. However, many of our most successful scientific theories involve laws with one or more idealizations and are therefore known to be false. Famous examples of idealizations include point masses, rigid rods, infinite densities, and perfect vacuums. A common response among realists is that such theories can still be believed to be approximately true because tightening up one or more of the idealizations leads to greater predictive accuracy. This provides evidence—so the account goes—that a non-idealized true theory exists that our best current theory approximates.

This account, which I will dub the "Improvement Model of Confirmation", is most often associated with Ronald Laymon (1980, 1985, 1989, 1995); but other versions of it can be found in Leszek Nowak (1980), Ernan McMullin (1985), James Derden (2003), Michael Weisberg (2007) and Jose Rolleri (2013). That it continues to go unchallenged is surprising, as it seems to me to be deeply flawed. In this short article I assess the Improvement Model of Confirmation and raise what I take to be its most fundamental difficulties. I start by explaining why well-known approaches to confirmation struggle to accommodate scientific theories with idealizations and outline the most essential features of Laymon's version of the improvement model. I then raise a number of objections to it before considering a potential response courtesy of Clark Glymour's condition for bootstrap confirmation. It will be shown that this addition ultimately fails to save the improvement model. As a result, the fact our most successful theories to date involve idealizations undermines "success-to-truth" arguments and poses a serious challenge to scientific realism.

2 The improvement model of confirmation

Traditional models of confirmation do not fare well in explaining how theories that include idealizations are accepted in scientific practice. This can be illustrated by appealing to a well-known idealized theory: the kinetic theory of gases. At the heart of this theory is the Boyle-Charles law, typically written as:

$$PV = nRT$$

Where P is pressure, V is volume, T temperature, n number of moles of gas and R the gas constant. This law is said to hold true only for gases that satisfy certain idealization assumptions, the most important of which include:

I_1 = The particles of gas are small hard spheres that occupy no volume

I_2 = Each particle collision is perfectly elastic and frictionless

I_3 = There are no intermolecular forces between the particles or long-range forces acting on the particles

I_4 = The gas is homogenous and the particles indistinguishable

As none of these assumptions are true for any empirically observed gas, simple inductive confirmation by instances is ruled-out because—strictly-speaking—there are no instances of gas that satisfy these assumptions. Bayesian confirmation theory also struggles to explain how the theory can be supported by observation. According to Bayesians, prior beliefs in a hypothesis ought to be revised consistently with Bayes' Theorem:

$$P(H/E) = P(E/H) \times P(H) / P(E) \text{ if } P(E) > 0$$

In the theorem, P(H) is a measure of the experimenter's prior probability that H is true. However, if H is a prediction based on an idealized theory, then the experimenter already knows for certain that H is false. In other words, that its prior probability is 0. Regardless of whether E occurs the probability of H given E is also 0 and therefore confirmation by E cannot take place.

The hypothetico-deductive method and its derivatives equally fall silent when it comes to idealized theories. In its simplest form it claims that confirmation is the reverse relation of deduction: if a hypothesis H can be deduced from a theory T using background assumptions and initial conditions, then T receives confirmation provided H is empirically observed. But once again we know that our prediction based on an idealized theory will not match that observed. The only time this might happen is if there is a fortunate cancelling out of idealizations that only an unfortunate practitioner would take as confirmation of their theory.

A staple response among realists is that confirmation of idealized theories can be attained using the methods above if we infer not to the truth of the theory but to its "approximate truth". The world is a complicated and messy place, so they argue, and idealization assumptions are needed to make prediction computationally tractable. Provided the experimental observations do not deviate too much from the theory, then we can say it has been confirmed to be approximately true.

The problems with this reply are twofold. Firstly, a measure of approximate truth has been notoriously difficult to pin down and no widely accepted theory exists that allows us to say just how much truth a theory contains. Secondly, even if such a measure were possible, it raises questions about how much approximate truth is needed for rational acceptance. As Chuang Liu (1999) has made clear, a useful idealization need not always be a good approximation: whilst $sin\theta = \theta$ can be assumed for very small angles in a pendulum, larger angles produce unacceptable deviances. There is only a short range of initial conditions that provide “good enough” predictions from idealized theories; but why should these be said to be supporting evidence when other larger error-inducing setups are ignored?

As a remedy to some of these problems several realist philosophers have proposed that idealized theories can be confirmed if the measure of approximate truth is made *relative* to a non-idealized true theory. I will be focussing here on Laymon's account as he has developed it in the most detail over the past three decades; however, I am confident that the problems inherent in his account carry over to all other versions.

The basic strategy goes that if a perfectly true theory exists with no idealizations, then it stands to reason that another theory (which contains systematic deviances from it) is approximately true relative to that theory. For example, in the case of the Boyle-Charles gas law, the final true non-idealized theory is one that allows for things such as the size of the molecules, their intermolecular forces and energy escaping through their collisions. Of course, in practice, scientists are in the dark about the final true theories, but they do have their idealized theories. If it can be shown that these theories are “in-principle improvable”, so that when their idealization conditions have been removed, we are left only with a perfectly true theory, then we can infer their approximate truth relative to that final theory.

Laymon sums up this intuition in what we might call his “Improvability Principle”:

Improvability Principle: *If a set of fundamental laws is true, then we can make in principle sufficient corrections so as to yield better predictions*. (1989, 359)

The reason why Laymon only calls for “in-principle improvability” is down to the fact that there are limitations to a scientist’s computational and practical resources that make it almost impossible for deidealization to be carried out beyond a few steps. Nonetheless, Laymon argues that even though such improvements are possible in only a small number of cases, this provides inductive evidence that they are fully improvable in principle (1985, 156-157; 1989, 359).

From the Improvability Principle Laymon derives two rules, one for confirmation and the other for disconfirmation:

Rule-1: *A scientific theory is confirmed (or receives confirmation) if it can be shown that using more realistic idealizations will lead to more accurate predictions*.

Rule-2: *A scientific theory is disconfirmed if it can be shown that using more realistic idealizations will not lead to more accurate predictions*. (1985, 155.)

Laymon does not intend these rules to stand alone: they are meant to supplement one's preferred method of confirmation for ordinary non-idealized theories. Nevertheless, as I will now argue, these rules cannot help a realist explain how idealized theories are confirmed in scientific practice.

3 A critique of the improvement model

If the Improvability Principle is correct then finding instances from the history of science that satisfy rules 1 and 2 would provide a good case for arguing that our current theories are approximately true vis-a-vis some unknown true non-idealized theory. But why should somebody already sceptical of realism accept the principle in the first place? At present, scientists have never uncovered a fully de-idealized theory, and so there are no complete examples to support its validity. In fact, I suspect that any intuitive appeal the Improvability Principle has comes not from the existence of true theories discovered by scientists but from a much weaker principle which we might call the “Reverse Improvability Principle”:

Reverse Improvability Principle: *If we can make in principle sufficient corrections so as to yield better predictions, then a set of fundamental laws is true.*

This principle does not beg the question against the antirealist by already assuming the existence of true scientific theories. It also has strong intuitive appeal: if a theory which is false has been corrected, surely this provides evidence that some true theory about the target phenomena exists to be discovered? Imagine I am playing a game of guessing how many sweets are in a jar and my initial guess is 200. Upon being told that I am wrong, I then guess 250. If I have been told that my new guess is false but more accurate, surely this provides reason for thinking that it is only a matter of time before my correction process arrives at the true figure?

Sadly, for the realist the Reverse Improvability Principle lets in too much and is too weak a foundation for realism. To show why, first consider the fact that any false theory T_f can be in principle corrected for to make it true. Even statements of contradiction can be corrected for by removing the offending conjunct. To find inductive evidence that a false theory can in principle be improved is therefore relatively easy. This means almost all false theories approximate some corrected true theory T_t and are therefore approximately true relative to that theory. As a consequence, this has the unhappy result that one can be a realist about almost any theory—provided it has been corrected a sufficient number of times.

Laymon never specifies just how many corrections are sufficient, but going on the historical cases he cites, it does not seem to be that many. A realist about idealized theories might respond by saying that the problem with the argument above is that it does not start with a scientific theory that we *know on independent grounds* to be one that is idealized away from reality. In other words, rules 1 and 2 are not meant to apply to *all* empirically false theories but only to those that have *known idealization conditions*. For example, background assumptions such as those from atomic theory tell us that nature is not made up of point-sized particles and that therefore any falsity produced by this part of the theory is due to idealization. This gives us independent grounds for thinking that the kinetic theory of gases and the Boyle-Charles law are false because of idealization and not for any other reason. Our background assumptions, therefore, can be used to constrain the number of false theories that rules 1 and 2 are meant to apply to.

The problem with this response is that short of knowledge of the final true theory, we cannot say that our current theory is false because it gets things drastically wrong due to 'brute error' or because it is the result of using an idealization. In fact, even if a clear distinction between these two ways in which a theory can be false exists, the problem still stands. Consider the following amendment to the Boyle-Charles law:

$$PV = nRT + k$$

Where k is some additive constant not significantly different in magnitude from the largest error produced by the idealizations. Then this theory, which is a hybrid containing some idealized falsity and some brute-error falsity, has been corrected or improved by scientists the same number of times as the Boyle-Charles law and therefore takes an equal share of confirmation—even though removal of all the idealization conditions to this law would not lead to some, yet undiscovered, true theory.

4 A bootstrapping response?

Laymon considers whether his original Improvement Model can be strengthened with the addition of a bootstrapping condition along the lines of Glymour (1980). This additional condition provides further reason, he argues, that the improvements are due to deidealization and that therefore the underlying theory approximates a true theory:

> Consider a situation where the relative realism of idealizations I_1 and I_2 is unknown or indeterminate with respect to some existing background

> standard...Say that, with respect to phenomenon P, idealization I_2 produces the better prediction. Therefore, assuming the truth of T, our judgement is that I_2 is the more realistic idealization. Now, let it be the case that T, I_1 and I_2 can be brought to bear on some other phenomenon P'. Then the judgement of the relative superiority of I_2 means that T, if true, will produce a better prediction about P' with I_2 than with I_1. If such a better prediction is not produced, we have reason to believe that T is false. The method is appropriately called bootstrapping because we first use the theory to generate an appraisal of relative realism; then we test the theory using that appraisal.
> (Laymon 1985, 166)

The idea seems to be that we rely on our main theory and any other background assumptions to make a prediction about the relative realism of two idealization assumptions. If that prediction is borne out in the experimental data, then we use that better idealization to confirm the approximate truth of the underlying theory. It is an example of bootstrapping because we are relying on the theory to provide an explanation of why one idealization assumption is more realistic than another.

Can the addition of a bootstrap condition like this resolve some of the worries raised in section 3? Let us return to the Boyle-Charles gas law and the underlying kinetic theory of gases and let us compare two different idealization assumptions I_1 and I_2:

I_1 = The particles of gas are small hard spheres that occupy no volume
I_2 = The particles of gas are small hard spheres that occupy n volume where $n > 0$.

These idealization assumptions cannot both be true: either the particles take up space or they do not. Given some experimental setup and observations, we might make two contrasting predictions about the temperature of the gas. The first H_1 predicts a temperature based on the Boyle-Charles gas law and the second H_2 predicts a temperature using a correction for molecular size (as in the van der Waal's equation). If H_2 is closer in value to the actually measured temperature than H_1, then we can say that we have evidence that the error is caused by a genuine idealization and not for some other fault in the theory of gases.

The problem with Laymon's version of the bootstrap condition is that it is too imprecise to provide warrant for the underlying theory. Even if the relative realism predictions pan out across a wide range of experimental setups, the fact Laymon's account does not require a precise match means it can be too easily explained by other means. For instance, just because the use of I_2 gives us a better prediction (in terms of being closer to the actual observed value), this does not provide much evidence for the truth of the underlying theory. Antirealists could agree that using I_2 produces a theory which is more useful or more empirically adequate—but it is a large jump to go from there to the truth of the underlying explanation.

A bootstrap condition closer to what Glymour originally had in mind might do better. Instead of using the background theory to predict the relative realism of two idealizations, what the realist needs is a prediction of the precise value a law will deviate from the values observed. The odds of the size of deviance matching that predicted when the underlying explanation was at fault seems remote and therefore gives significant reason to believe in the truth of the underlying theory. This is more in keeping with Glymour's original account because it requires the theory, idealizations, and observations to be consistent with one another, not just in terms of *best* fit but *actual* fit.

In practice this would require using our theory and idealizations to make a prediction about what the error size would be between our idealized theory and the actual measurement. Of course, for a theory with multiple idealizations it is going to be difficult to confirm the prediction when the observed value will be affected by other perturbing factors not incorporated into the prediction. And here is where a bootstrapping response ultimately comes unstuck. For it to be successful we would need to do either one of two things: (1) make predictions for the errors of *all* the idealization assumptions or (2) screen-off the effects of other perturbing factors. The first of these is not feasible by assumption because we have already seen that scientists lack the computational resources required to deidealize theories in their entirety. The second is also not possible because, as McMullin (1985, 267) reminds us, not all idealization assumptions can be screened-off through good experimental design. If our idealization is that the light waves are passing through a "perfect vacuum", then although we might be able to approach this, we can never truly replicate it. Experiments designed to screen other idealizations such as "the solar system is a two-bodied system" and "the pendulum is infinitely long" are clearly not feasible.

5 Conclusion

The fact a false theory can be improved in practice gives little reason to support the idea that it approximates a true theory. Many false theories can be improved in this way and if this counts as valid confirmation realists would need to accept as true too many false theories. Attempts to limit the falsity to only those that involve legitimate idealizations fails because there is no practical way of knowing whether the deviances in our theory are caused by idealizations or because our underlying theory just happens to be wrong.

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