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# Why Crucial Experiments Are Not Impossible

Eunice Tse*

**Abstract**

This paper argues that a crucial experiment is not impossible in physics, as long as one takes an instrumentalist perspective. A crucial experiment definitely decides between two competing theories. Although Duhem argues that such experiments are impossible, as there is always the possibility of a third, hitherto unconsidered theory, this paper argues that it is possible to defend crucial experiments from an instrumentalist viewpoint, and furthermore, that such a stance is more desirable as it allows for scientific progress.

## Introduction

A crucial experiment is *not* impossible in physics, from an instrumentalist perspective. After briefly introducing crucial experiments, I will explain Duhem's claim that they are impossible because they assume a false dichotomy, as there may be theories other than the ones considered in the experiment. I will outline an instrumentalist response with reference to the wave revolution in optics and argue that even if there are other theories, a crucial experiment can decide between two of the theories at hand by establishing that one is

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more empirically successful than the other, without pronouncing it as correct. Although this approach may seem to fall short of the crucial experiment's original aim, I will show that it is in fact more desirable as it allows for scientific progress, such as new developments in optics beyond wave theory.

## I. Crucial Experiments and Duhem

A crucial experiment is an experiment that definitely decides between two alternative theories. Its reasoning can be formalised as follows, where $T_1$ and $T_2$ are theories and $O_1$ and $O_2$ are observations:

(P1) Either $T_1$ or $T_2$ are true

(P2) $T_1$ predicts $O_1$ under certain conditions

(P3) $T_2$ predicts $O_2$ under the same conditions

(P4) $O_1$ and $O_2$ are incompatible

(C) If $O_1$ is observed, then $T_1$ should be accepted; if $O_2$ is observed, then $T_2$ should be accepted.

As it stands, the argument is valid. Thus, in order to criticise it, one or more of the premises must be rejected.

Duhem[1] declares that a crucial experiment is impossible in physics by pointing out that it rests on a false dichotomy in (P1): that is, the assumption that only there are only two options available. According to Duhem, one can never be certain that either one of the theories is correct, for there may always be a third theory or more. Hence, even if $O_2$ is observed and $T_1$ negated, it is too rash to pronounce $T_2$ as the correct theory, as it may be the case that neither of them are correct. There may exist a $T_3$, which is inconsistent with $T_1$ and $T_2$, but is in fact correct. Even in the case where there are only two theories proposed, one can't automatically discount the possibility that another theory that may emerge in the future may turn out to be correct instead

[1] Duhem, *The Aim and Structure of Physical Theory* 180-218.

of the current two. Unless one theory is the direct negation of the other ($T$ or $\neg T$), it is always possible that there may be a different theory available, and hence, a crucial experiment cannot confirm that one theory is correct.

## II. An Instrumentalist Response

Instrumentalism can provide a defence for crucial experiments. Instrumentalists consider theories not to necessarily represent reality, but act merely as instruments for deriving correct empirical results. That is, theories are judged by how empirically successful they are. The instrumentalist can agree with Duhem in that a crucial experiment cannot decide definitely which theory *represents reality*, but argue that it can still decide definitely which theory *should be pursued*. This is because a crucial experiment demonstrates that, at one point, one theory is definitely more empirically successful than the other; hence, it is the better instrument for deriving predictions, and should be accepted on instrumentalist grounds. It would not matter if, in the future, another theory were proposed: another crucial experiment could be developed, in order to ascertain which theory is more empirically successful. According to the instrumentalist, whenever a crucial experiment decides between theories, it merely decides on which theory is more empirically successful and should thus be used as the instrument *for the time being*, without a claim about its connection to reality. It does not mean that the theory will be fully empirically successful, and is therefore open to the introduction of newer theories.

In fact, the history of science supports this instrumentalist interpretation of the crucial experiment well. Consider the case of one famous crucial experiment: Young's double-slit experiment, an important step in the wave revolution in optics, when scientific opinion shifted from the particle theory of light (light consists of particles) to the wave theory of light (light consists of waves). Prior to the double- slit experiment, both theories could explain much of the same phenomena, e.g. refraction. So in order to decide between them, Young devised conditions under which the two theories would differ in

their predictions, hence satisfying (P4). The set-up was simple: a single light source was shone through a plate with two slits onto a screen behind it, and the pattern of light on the screen was observed. The two theories predicted different patterns. Particle theory predicted that there would be two clusters of light on the screen corresponding to the shape of the slits, analogous to the pattern that would be made by spray-painting the plate. Wave theory, on the other hand, predicted that there would be an interference pattern: that is, alternating strips of light and dark.[2] The two observations are clearly incompatible. As a matter of fact, in the experiment, an interference pattern was observed, and hence, the wave theory of light became accepted.

So far, both the realist and instrumentalist interpretations of a crucial experiment fit the example. However, although wave theory of light was accepted at the time, nowadays, many physicists believe in a theory of light that combines characteristics of both waves and particles, known as wave-particle duality. Here, instrumentalism provides a better explanation than either the realist interpretation of a crucial experiment or Duhem's complete rejection of it. The realist interpretation would have accepted wave theory as the correct theory following Young's crucial experiment, and would have run into trouble trying to explain how the new theory could be correct instead. In fact, the existence of wave-particle duality may seem to support Duhem's criticism: it represents a 'third theory' that prevents wave theory from being automatically accepted after particle theory is falsified. However, Duhem's criticism fails to account for the general acceptance of wave theory following the crucial experiment. Since Duhem completely rejects crucial experiments, one may expect such experiments to produce no impact on the scientific community;

[2] This is due to waves having alternating peaks and troughs. As the light goes through two slits, there are two sets of alternating peaks and troughs that meet. When peaks and peaks meet or troughs and troughs meet, constructive interference occurs, producing the strips of light. But when peaks and troughs meet, destructive interference occurs and they cancel each other out, resulting in the strips of dark. Due to the alternating patterns of waves, constructive and destructive interference occur alternatively, resulting in strips of light and dark.

but history proves quite the opposite. An instrumentalist interpretation avoids both these faults: it explains the acceptance of wave theory *and* allows for its eventual displacement by wave-particle duality.

## III. A Possible Criticism

At this point, Duhem may respond by saying that the instrumentalist's concept of a crucial experiment falls short of its original aim, and is too weak. The instrumentalist's crucial experiment can only produce a tentative conclusion, a temporary acceptance of a theory. Indeed, the instrumentalist's understanding of a crucial experiment is less dramatic, and if what Duhem means by a crucial experiment being impossible were that the powerful conclusion that the experiment seems to entail is impossible, then the instrumentalist would agree. After all, the instrumentalist does not make any claims about whether or not a theory represents reality. However, this doesn't mean that the concept of a crucial experiment should be abandoned altogether: the double-slit experiment played an important role in the wave revolution of optics, and the instrumentalist's position is able to explain this in terms of preference due to empirical success. I would go further to argue that the instrumentalist's concept of a crucial experiment is preferable to the stronger, correct theory claim: whereas the former allows for future scientific progress, the latter limits it. If a crucial experiment were supposed to result in a completely correct theory, as Duhem's criticism of it implies, then there wouldn't be any new theory on the matter following a crucial experiment. Progress would be limited to merely expanding the scope of the accepted theory, but it would not be possible to displace the theory entirely. Under the realist interpretation, it would not be possible to accept wave-particle duality, given that wave theory had already been accepted and the two are clearly incompatible. In fact, if scientists believed that crucial experiments served this powerful purpose, they would be discouraged from searching for new theories; wave-particle duality may not even have been proposed. Even realists who believe that theories represent reality would want the possibility of new theories that better

match reality. The instrumentalist's concept of a crucial experiment allows for progress, because it only chooses between the two theories at hand which to prefer, without declaring that either must be absolutely correct. In fact, it paves the way for progress, by pointing out which theory scientists should focus on, whilst allowing it to be eventually displaced. Hence, the instrumentalist's interpretation of a crucial experiment is more desirable.

**Conclusion**

In this paper, I have first explained Duhem's claim that a crucial experiment is impossible in physics due to its assumption of a false dichotomy. I have then defended the crucial experiment from an instrumentalist perspective: although neither of the theories may be totally correct, one is still shown to be more empirically successful than the other and should be accepted for the time being, until a new theory is developed. I have shown that the instrumentalist interpretation aligns well with the history of science, by examining the wave revolution in optics. I have considered a further criticism that the instrumentalist misunderstands the concept of a crucial experiment, and argued that although the instrumentalist's conception is indeed different, it is preferable, because it allows for scientific progress. Thus, a crucial experiment is *not* impossible in physics – as long as it is understood in instrumentalist terms.

**References**

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**Eunice Tse** is a BSc Philosophy, Logic and Scientific Method student at the London School of Economics (2013-2017). Her main fields of interest are political philosophy, logic and existentialism. She hopes to enjoy her forthcoming year abroad, after which she will hopefully know what she actually wants to do. You can contact her at [y.tse3@lse.ac.uk].