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# How to be rational about empirical success in ongoing science: The case of the quantum nose and its critics

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ABSTRACT

Empirical success is a central criterion for scientific decision-making. Yet its understanding in philosophical studies of science deserves renewed attention: Should philosophers think differently about the advancement of science when they deal with the uncertainty of outcome in ongoing research in comparison with historical episodes? This paper argues that normative appeals to empirical success in the evaluation of competing scientific explanations can result in unreliable conclusions, especially when we are looking at the changeability of direction in unsettled investigations. The challenges we encounter arise from the inherent dynamics of disciplinary and experimental objectives in research practice. In this paper we discuss how these dynamics inform the evaluation of empirical success by analyzing three of its requirements: data accommodation, instrumental reliability, and predictive power. We conclude that the assessment of empirical success in developing inquiry is set against the background of a model's interactive success and prospective value in an experimental context. Our argument is exemplified by the analysis of an apparent controversy surrounding the model of a quantum nose in research on olfaction. Notably, the public narrative of this controversy rests on a distorted perspective on measures of empirical success.

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## 1. Introduction

Empirical success is a central criterion for scientific decision-making. Competing models and methods are considered pursuitworthy if they produce tangible and quantifiable results. In this context, empirical success is seen as a necessary if insufficient condition for the truth or, at least, the adequacy of scientific explanations. Advocates of both scientific realism and anti-realism have centered on empirical success as a criterion of the progressiveness of models (Van Fraassen, 1980; Psillos, 1999). Generally these accounts define empirical success by the requirements to fit the experimental data, be instrumentally reliable, and represent a good predictor of new phenomena (Doppelt, 2005).

Yet philosophers have also recognized many issues that underlie the epistemic value of empirical success for the assessment of scientific explanations. Empirical success admits of degrees, and a central challenge facing its explication is the difficulty of justifying the primacy of support from multiple methods or incommensurable models. A well-known problem in the history of science is that many successful theories in fact turned out to be false, resulting in the classic argument of pessimistic meta-induction (Laudan, 1981). Inevitably, this furthers the question of how stable and durable the criterion of empirical success really is for attributions of adequacy to rival scientific explanations. Given the frequency of appeals to empirical success, especially in rational accounts of theory choice (Solomon, 2001), the notion itself thus deserves renewed attention.

This paper focuses on potential challenges to the philosophical understanding of empirical success when we assess the appraisal of current, as in unresolved, research strategies. Almost all of the central ideas in the philosophy of science have been developed and tested against the background of concluded case studies, routinely also involving discussions about their historical accuracy (Schickore, 2011). Fundamentally, the question arises: Should philosophers think differently about the advancement of science when they are looking at continuing research questions instead of past episodes? Our central concern here is that normative accounts appealing to empirical success can indeed produce unreliable conclusions if we think that the appraisal of ongoing science builds on the same understanding as our treatment of historical episodes. A central difficulty we will encounter involves the changeability in

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disciplinary objectives that determine what constitutes empirical success.

What are the considerations that philosophers must take into account before engaging with contemporary issues in a normative fashion? As it has been pointed out, real science is rather messy and its methods do not always coincide with the epistemic ideals of philosophers (Medarwar, 1999; Schickore, 2008). We will discuss the challenges that arise from the inherent dynamics of disciplinary and experimental objectives in ongoing research practice, and we analyze how these dynamics inform the evaluation of empirical success by looking at three standard requirements of empirical success: data accommodation, instrumental reliability, and predictive power. Our argument is exemplified by the analysis of a feigned controversy surrounding the model of a quantum nose in research on olfaction. Notably the public narrative of this controversy rests on a strongly distorted perspective on the practitioners' debate and its measures of empirical success. We conclude that the assessment of empirical success in developing inquiry is set against the background of a model's interactive success and prospective value in an experimental context. Further, we suggest an outline of network criteria by which to identify and qualify the relevance of empirical evidence in ongoing science.

## 2. Problem: Confrontational narratives of model choice

For large parts of the history of science, research on the nose was a playground for eccentrics, and the science of smell did not attract broader scientific or philosophical attention. However, this has changed recently, and research into the molecular and neural basis of smell has increased exponentially over the last thirty years. Today olfaction constitutes an experimental system that promises greater insight into ligand-receptor interactions and the organization of higher-level brain processing (Firestein, 2001; Shepherd, 2004, 2012; Axel, 2005; Barwich, 2015b, 2016). Meanwhile, its current dynamics and susceptibility to the revision of its core premises make olfactory research an excellent example to study the ambiguity of determining what a reliable research strategy is.

The process of smelling is an interpretation of chemical information in the environment through a specialized sensory system. Our nose detects volatile airborne molecules (odorants), and our brain makes sense of their physical information by turning them into perceptual qualities. While research on olfaction has progressed fundamentally over the past years, a number of major questions remain open, in particular, concerning the molecular recognition of smell. In comparison with the visual or auditory systems, the physical stimulus of smell has not been captured in a comprehensive classification. Yet this is not a result of the seemingly subjective nature of smells, but the molecular characteristics of the olfactory stimulus. Instead of being based on a low-dimensional parameter such as wavelength, the chemical basis of smell is multidimensional, encompassing several thousands of parameters (Ohloff, Pickenhagen, and Kraft 2011; Keller & Vosshall, 2016). This complexity of the stimulus challenges experimental approaches detailing the molecular machinery of odor recognition. To date, molecular biologists lack a sufficient understanding of odor coding and how the olfactory receptors interact with their ligands (Barwich, 2015b; Firestein, 2001).

About a decade ago a popular science book shone a spotlight onto olfaction and this open question of how the nose detects scents: *The Emperor of Scent*, a story about a quantum model of the nose that detects infrared vibrations of airborne chemicals and its charismatic inventor Luca Turin (Burr, 2004). The book presented the story of a fierce competition between two rival theories regarding the molecular mechanism of smell recognition. It introduced the "vibration theory of odors" against the orthodox model of the so-called "shape theory." While the shape theory refers to geometric and spatial properties as the causal features of odorants, the vibration theory states that the odor of a molecule is linked to its intra-molecular vibrational frequency. The shape theory is considered inadequate by vibration proponents, as it fails to provide robust regularities, let alone laws, which link the smell of a molecule to its structure. Too many exceptions, the reasoning goes, suggest that there may not be a rule. In contrast, the quantum smell idea sounds neat and clear in its claims: there is one key feature responsible for the odor of a molecule that allows classifying smells according to their molecular basis (Turin, 1996, 2006, 2009). Turin's theory mirrored the dream of fragrance chemists and perfumers throughout the 20th century, that there may be something like a code in the nose that allows you to predict the smell of molecules from their chemical structure. The vibration theory made predictions. It accommodated irregular chemical data. Notwithstanding, it is judged as being wrong.

Although firmly rejected by the majority of olfactory researchers, this story was prefaced as an authentic controversy. Popular science was quick to declare a potential victory for this idea, despite continuous and consistently negative evaluation of the model by the olfactory research community. After Turin's January 2013 publication of a positive but only preliminary and singular study (Gane et al., 2013), several media outlets prophetically declared the following: *'Quantum smell' idea gains ground* (Palmer, 2013, for BBC News); a *Study Bolsters Quantum Vibration Scent Theory* (Anderson, 2013, for Scientific American); and the *Controversial theory of smell is given a boost* (Ball, 2013, for Chemistry World). Some academic channels also proclaimed that the *Secret of scent lies in molecular vibrations* (Ryan, 2013, for UCL News). Even Nature News had been unable to resist the temptation to herald an imminent paradigm change in *Rogue theory of smell gets a boost* (Ball, 2006).

Interest in this apparent controversy in olfaction also entered philosophical analysis. In particular, the eminent social epistemologist Miriam Solomon upheld the quantum model of the nose as a great example to analyze what she calls "norms of dissent" in scientific controversies (2006a, 2006b, 2008). Solomon champions a normative role for the philosophy of science that is not bound to a descriptive adoption of the scientists' perspective on the implications of their work. Throughout her works, involving both past as well as present inquiry, Solomon has emphatically cautioned about the idea of an "invisible hand" in science as a self-governing system of epistemic values. She advises a guide for non-practitioners, such as philosophers or policy makers, to assess the appropriateness of dissent in scientific debates. The primary concern is to establish a normative model that identifies fruitful competition and encourages discussion in situations of scientific dissent. In this context, Solomon lists a measure of empirical, epistemic, and social "decision-vectors" as criteria for the success of a theory:

1. Theories on which there is dissent should each have associated empirical success.
2. Empirical decision vectors should be equitably distributed, i.e., in proportion to empirical success.
3. Non-empirical decision vectors should be equally distributed, i.e., the same number for each theory. (Solomon, 2006a, 2008, 6).

The controversy about the molecular basis of smell offered a great opportunity for putting her model to the test. Notably the central criterion that any scientific model must fulfill before qualifying for a non-relativistic but rational decision-vector analysis is "empirical success" (Solomon, 2001, Ch. 2). According to Solomon, empirical success is not defined by a single criterion, however.

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