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What makes a theory of consciousness unscientific?

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Theories of consciousness have a long and controversial history. One well-known proposal – integrated information theory – has recently been labeled as 'pseudoscience', which has caused a heated open debate. Here we discuss the case and argue that the theory is indeed unscientific because its core claims are untestable even in principle.

Theorizing about consciousness is challenging because some of the issues lie at the border between empirical science and philosophical inquiry. One recent example of this challenge is the controversial and yet highly publicized view known as the integrated information theory (IIT) of consciousness. IIT seeks to provide an explanation of why certain systems, such as the human brain, generate rich and complex conscious experiences whereas others do not. It does so by linking consciousness with the ability of a system to integrate information. IIT proposes that consciousness arises when a system's components interact in a way that creates a unified whole, quantified by a custom measure of complexity known as 'Phi' (Φ). The higher the Φ value, the more conscious the system is. Central to IIT are the concepts of intrinsic causality, in which a system's current state influences its own future and past states, and cause–effect structure, which determines the specific quality of conscious experiences.

This ambitious theory has been promoted as 'well-established'[1], 'a gigantic step in the final resolution of the ancient mind-body problem', 'the only dominant theory', and 'the most promising scientific theory' of consciousness[2]. However, we argue that the core ideas of IIT lack empirical support and are metaphysical, and not scientific. Because previous expressions of such concerns about the theory[3] have not received sufficient attention, a group of us wrote an open letter that questioned the scientific status of IIT[4].

Whether IIT is pseudoscience is important because of the practical and ethical importance of understanding consciousness. In response to widespread and polarized reactions to the letter, the limited empirical support, and radical claims concerning who and what is conscious, here we expand on the original letter to explain why it was written and to clarify which claims made by IIT proponents are problematic. We distinguish the core claims of IIT, which we argue are unscientific, from work merely inspired by IIT that uses measures of complexity to investigate brain activity associated with different states of wakefulness. This latter work is uncontroversially scientific, but neither supports nor tests the core claims of IIT.

Scientific theories of consciousness should be testable

Scientific theories of consciousness aim to identify specific brain processes and/or psychological functions that are crucial for subjective experiences. These theories generally make claims that are readily testable with the tools of psychology or cognitive neuroscience (Box 1).

By contrast, IIT postulates that 'consciousness is a fundamental feature of the universe', which it seeks to understand starting from a set of claims ('axioms') that are said to be 'irrefutable' and true of every conscious experience[5]. However, some have criticized these axioms[6] and have argued that they lead to circularity[7]. The axioms have also evolved[5,6], which casts doubt on their 'irrefutability'.

Proponents of IIT claim to derive an index of a system's degree of integrated information (Φ) from these controversial axioms, which they argue is an objective measure of the degree of consciousness in any system. However, the axioms do not by themselves specify a particular mathematical model. To develop a precise formula for Φ, further assumptions must be made. This challenge becomes evident in the evolving interpretations and understandings of the theory and in the changes in formulas that define Φ over time[3,8].

More concerning are other problems that prevent the theory from being empirically validated. An obvious test of IIT would be to measure Φ in humans. To calculate Φ one needs to consider how every component of the system at every spatial and temporal scale – say from the quantum scale to brain regions, and from nanoseconds to days – constrains the past and future states of the system[5]. Given the complexity of these calculations, it is impossible in principle to compute Φ, and hence impossible to identify conscious states – a point that proponents of IIT readily admit.

Currently, Φ can only be precisely calculated in idealized systems with a few units[3], such as limited grids of logic gates. Simple artificial systems such as these are conscious according to IIT, even when the relevant nodes are all inactive[8].

Hence, the theory readily ascribes consciousness to static systems that do not perform any function. Stating that such systems have 'consciousness', when their 'consciousness' has no observable consequences is, in this respect, no different than stating that they have 'souls'. Some consider the theory dismissible on the basis of these implications alone[6,7]. However, proponents of IIT embrace this counterintuitive consequence without calling their theoretical assumptions into question[3].

Making theoretical predictions that may not be testable by current methodology does not necessarily render the relevant theories unscientific. However, if the core claims of a theory are not testable even in principle, the scientific status of the theory should be called into question. Nevertheless, some researchers claim to have tested IIT empirically, and have promoted the results as providing partial support for the theory or for its superiority to other theories[1,2]. Yet, as others have argued, the tests are problematic and not meaningful[9] because they do not address the core claims of IIT, and the tested

BOX 1

Common theories of consciousness and their empirical predictions

An influential method for studying consciousness is to compare what happens at the neuronal and psychological levels in conscious versus unconscious experimental conditions. This method, known as 'contrastive analysis', provides the main source of data for current theories, such as global neuronal workspace theory, higher-order theories or the local recurrence theory of consciousness. As such, although some of these views have theoretical origins in computer science or philosophy, the core empirical predictions are usually made at levels of observation that are testable with current methods in cognitive neuroscience. These predictions are often not quantitatively precise, but they are nonetheless constrained by the empirical literature.

For instance, global neuronal workspace theory has long held that a putative frontoparietal network in the mammalian brain should support the broadcast of stimulus-related information during conscious experience. Therefore, if someone reports being conscious of a stimulus without relevant information being represented in this brain network, the theory is put under pressure. One may doubt this particular theoretical proposal, but it is a reasonable theory to test given the importance of frontoparietal areas in functions related to consciousness, such as working memory, attention and cognitive control.

Other theories also make clear predictions. For instance, local recurrence theory predicts that the first feedforward sweep of neuronal processing of visual stimuli occurs unconsciously, and conscious perception only arises when information feeds back from higher visual areas to early visual areas. Several empirical tests have validated this prediction. Importantly, these empirical studies not only tested local recurrence theory but also challenged other theories.

Theories not only make predictions at the neurobiological level, but also at the psychological and cognitive levels. For instance, higher-order theories predict that it should be possible to manipulate subjective experience while holding fixed lower-level sensory responses and perceptual capacities that enable discrimination between similar stimuli.

If proponents of IIT were to give up the core claims (axioms), some weaker version of the theory could perhaps be cast in terms of cognitive neuroscience[11] (see also the section 'IIT-inspired research on brain complexity'). However, to the extent that IIT's metaphysical commitments remain promoted as key features, this stronger version of IIT — which is our target here — is incompatible with standard approaches in cognitive neuroscience for testing ideas empirically[6,7].

BOX 2

Evaluating the scientific status of a theory by applying criteria to IIT

Besides the issue of untestability, the following points also contribute to our doubt about IIT as science.

Overreach

Recent developments have seen the theory expanding into areas that traditionally belong to metaphysics, by asserting bold claims about the nature of reality, causation and the nonexistence of neurons[14]. These assertions are interesting, but they venture beyond the boundaries of empirical science. IIT also ambitiously addresses fundamental existential questions, such as the essence of being and the presence of free will, elevating the theory to an 'all-encompassing explanatory framework'[14]. According to some, this kind of ambition is a common hallmark of pseudoscientific theories[15], which often claim to provide comprehensive explanations for a wide variety of complex phenomena without sufficient empirical support.

Incompatibility with physics

Doubts have been raised regarding IIT's compatibility with current physics[5], a possible concern for any neurobiological theory. The theory's proponents acknowledge these compatibility issues[5], yet IIT continues to be promoted as a promising or well-established scientific theory.

Misrepresentation and promotion

Despite its lack of scientific support, IIT is often presented to the public as a direct competitor to other scientific theories of consciousness[2]. This misrepresentation is amplified by media coverage and public endorsements, which may mislead the general public about the theory's empirical validity. Although misrepresentation itself does not make the theory unscientific, it suggests that the label 'pseudoscience' may be appropriate.

The pseudoscience criterion

Standard dictionary definitions and philosophical discussions[15] describe pseudoscience as featuring unscientific claims (for example, untestable in principle) that are falsely presented as scientific. This criterion applies to IIT as it portrays untestable assertions as empirically grounded science.

predictions do not sufficiently differentiate between IIT and other theories of consciousness.

Although IIT may provoke interesting philosophical discussions, we contend that it falls short of the empirical basis required for scientific inquiry. Untestable metaphysical views can of course be discussed, but it is problematic when they are treated as empirically testable science. In light of the above, we argue that IIT demonstrates characteristics that are hallmarks of pseudoscience (Box 2).

Practical and ethical consequences

Attributing consciousness to systems with minimal complexity has important practical consequences[10]. This is because a theory of consciousness may be used to inform practical decisions regarding morally significant legal and medical issues. By promoting to the general public the untestable idea that 'Φ = consciousness', proponents of IIT may ultimately have an unjustified effect on law and policy, including on decisions that involve measures of quality of life, clinical triage, abortion, the rights of non-responsive patients, and welfare considerations for insects, organoids and artificial intelligences. Given the practical consequences of adopting and promoting any one theory of consciousness over others, we recommend caution and scientific humility – especially for a theory without direct and meaningful empirical support, such as IIT.

IIT-inspired research on brain complexity

It is important to distinguish research that purports to directly test IIT as a theory of consciousness from research that is more loosely inspired by IIT and does not purport to test it[11]. Research inspired by IIT includes studies on the complexity of neural activity induced by magnetic brain stimulation during different states of wakefulness, sleep and general anesthesia. These studies show that in some states (such as non-REM sleep and general anesthesia) neural activity has greater uniformity and therefore lower degrees of complexity when compared to wakefulness[12].

Although this research is assuredly scientific, interesting and potentially of practical importance, it does not lend support to IIT. IIT proposes a general theory that identifies which objects are conscious, from humans to static logic gates: it proposes that the 'degree of consciousness' of any object is assayed by a specific measure of complexity, the integrated information Φ. It is not surprising that human states of conscious awareness show greater neural complexity than states of unconsciousness, and this is likely to be true using almost any sensible measure of complexity. Indeed, many other theories of consciousness also predict lower brain complexity during certain nonawake states, such as slow-wave sleep and general anesthesia[13]. Testing the hypothesis that conscious versus nonconscious states can be distinguished in humans or some other animals by various measures of neural complexity does not distinguish IIT from these other theories, nor does it test the core hypothesis of IIT that Φ is a general measure of the degree of consciousness of any creature or nonliving object. What would be needed to make it a scientific theory is a measure that directly derived from the mathematical apparatus of IIT, akin to how a particular measurement of the motion of a pendulum – such as instantaneous velocity – is directly derived from the harmonic oscillation equation. Yet, the measures used by IIT-inspired studies do not assay Φ specifically, but only some more common notion of complexity[13]. Therefore, these measures are unable to distinguish IIT from other theories.

Furthermore, the comparison of different global states, such as wakefulness and coma, is confounded by many different cognitive and behavioral factors[6,13]. In particular, much of brain activity during wakefulness is not conscious, so a neural correlate of a waking state is not necessarily a neural correlate of consciousness as a mental state. Without other controls, it is impossible to draw strong conclusions about consciousness just by comparing different global states, such as wakefulness and coma.

Conclusion

Our main concerns with IIT are twofold. First, it lacks well-defined empirically testable consequences. Second, it explicitly asserts or entails bold nonempirical claims, such as that 'the entire cosmos is suffused with sentience'[2], that neurons do not truly exist[14] or that consciousness can be attributed to a static array of logic gates. These bold claims threaten to delegitimize the scientific study of consciousness. We need to be careful what we label as scientific, especially given the practical and ethical significance of consciousness. We appreciate that the word 'pseudoscience' should not be used lightly, but there are good reasons to think that it applies in this case. We sincerely hope that discussing these reasons will move the scientific study of consciousness forward.

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