

Consciousness science: real progress and lingering misconceptions[☆]

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Nobel Laureate Paul Krugman once remarked that engaging the public about economic theories is hard, partly because everybody feels they are entitled to opine about the economy even if they have no formal training in economics (see: <http://web.mit.edu/krugman/www/virus.html>). Perhaps because we are all conscious, the same sometimes happens in the field of consciousness research. Like Krugman, we think this is a troubling state of affairs that needs to be rectified.

Consciousness used to be a controversial topic of study. Not only during the heyday of behaviorism, but also during the rise of cognitive science in the 1970s and 1980s, only a few senior scientists (such as Gerald Edelman and Francis Crick), who had first achieved success and job security in completely unrelated fields, felt free to attack this final, big question. But how things have changed in the past 20 years! There are now numerous laboratories around the world, led by scientists at various career stages, dedicated exclusively to the study of consciousness. Just as in the most mature areas in psychology and neuroscience, concepts and phenomena are being carefully analyzed, distinguished, explained, and taxonomized.

Readers of Paller and Suzuki's recent article on consciousness in this journal [1] may conclude that the field still faces the question of whether consciousness is a valid topic for scientific inquiry at all. Although Paller and Suzuki go on to argue against this view, there are still those, both in the general public and within the scientific community, who believe this is the case. Consciousness science, however, has long emerged from the dark ages when this was a relevant issue, and moved away from simple intuitions and generalizations. Current debates in

the field – and there are fierce debates – focus on the use of hard empirical evidence to assess the relative merits of theories grounded in established scientific disciplines. Exciting empirical findings have led to a great deal of progress, shedding light on fundamental questions regarding this central aspect of our existence.

We now know, contrary to many people's introspective intuitions, that attention and awareness are dissociable: attention of various types can function in the absence of consciousness [2] and there is some evidence that there may be conscious experience without attention or report [3]. We now have an idea of the kinds of cognitive and perceptual processing that can occur in the absence of awareness, and how these may differ from conscious processing [4]. We are developing an understanding of the neural and cognitive mechanisms of metacognition, or insight into one's own awareness and performance [5]. Recent years have also seen a great leap forward in our understanding of the brain activity associated with different levels of consciousness, including the development of methods to detect its presence in deep sleep as well as anesthetized [6] and neurologically impaired patients [7]; these enable better diagnostic practices in disorders of consciousness and raise the possibility of detecting preserved awareness in vegetative-state patients [8].

These empirical advances are accompanied by the ongoing development and testing of new behavioral methods and quantitative measures for assessing levels and types of awareness, so that we can go beyond simply asking subjects, 'Are you aware of that?' [9]. Whereas in the early days many theories of consciousness took the form of educated personal speculations, theories are now systematically arbitrated on empirical grounds, not just in a post hoc fashion but based on their empirical predictions, as many labs dedicate efforts to directly testing detailed, theory-generated hypotheses [10]. Consciousness is now studied at the levels of behavior, neuroscience, and molecular mechanisms, in patients as well as healthy subjects and animals. This interdisciplinary effort encompasses the fields of psychology, biology, physics, and philosophy.

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There is a lively interchange of ideas concerning empirical results and their philosophical implications, leading to radical changes in the philosophy of mind. Anyone interested should visit the annual meeting of the Association for the Scientific Study of Consciousness (<http://www.theassc.org/>), and witness this spirited exchange. Perhaps most importantly, these efforts lead to real and applicable results, with implications for both theoretical understanding and applied clinical settings.

Have we come to a fundamental understanding of consciousness yet? Of course not. But it is clear that the field is maturing and making significant progress, converging on approaches to understanding this most enigmatic phenomenon. The science of consciousness does not suffer from a lack of public engagement; on the contrary, it is often discussed in the popular press. However, as Paller and Suzuki [1] point out, the public should be made aware of the most recent developments in the field. Such engagement should strive to make clear the distinction between rigorous, testable scientific ideas and outlandish speculations on the nature of consciousness – such as the view that electrons are conscious – that may easily attract media attention but are not grounded in empirical research.

Consciousness science is here to stay. The great empirical strides made in recent years, the continuing development

of rigorous approaches, and the enthusiasm of new generations of researchers lend themselves to a feeling of optimism. We will, eventually, crack this natural phenomenon that is so fundamental to our very being.

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Response to Block *et al.*: first-person perspectives are both necessary and troublesome for consciousness science

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We are grateful to Ned Block and co-authors for their commentary piece, ‘Consciousness science: real progress and lingering misconceptions’ [1], which expands on the arguments we put forward in our earlier *Science and Society* article [2].

Because people are conscious, it is natural for them to have views about the basis of their own conscious experiences and, by extension, about the basis of consciousness generally. Block and colleagues open their piece by pointing out the ‘troubling state of affairs’ that this causes.

People can introspectively reach the conclusion that consciousness is a form of energy or something akin to it that arises in essence from a nonphysical source to generate their unique mental lives. Consequently, consciousness is believed to lie outside the realm of scientific investigation. This introspective conclusion may have an understandable basis in the way consciousness functions as a

vehicle for compartmentalizing the intentions of self and others [3] — but it can be seriously misleading.

Introspection can nevertheless yield helpful foundations for consciousness research. Consider that we routinely switch back and forth between conscious and unconscious modes of information processing. For instance, when you begin to write a paper, you consciously formulate ideas that you want to convey, and if you get lucky, appropriate sentences mysteriously emerge from your unconscious processing. If not, you consciously toy with the ideas in various ways, and if still no good sentences emerge, you may become flustered or decide to procrastinate.

Consciousness reflects a specific mode of information processing wherein information is explicitly available for intentional (goal-directed) control of attention, memory, and thoughts. By contrast, information can remain largely intangible to intentional control mechanisms via the unconscious mode of processing, but still automatically direct attention, evoke memory, and induce thoughts. A major scientific challenge is to understand the neurocomputational mechanisms of both conscious and unconscious processing, as well as their interactions.

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Three lines of research are promising for understanding these mechanisms. First, new methods are being developed for precisely measuring neural correlates of conscious and unconscious processing.

Second, multidisciplinary efforts are being made to integrate analyses of behavior, introspection, physiological constraints, and computational requirements (e.g., efficiency, stability, and adaptability), which will facilitate coherent theoretical frameworks to explicate the operation of and interplay between conscious and unconscious processing.

Third, methods to train expertise in introspection are being investigated in research contexts, some inspired by the long history of meditation practices [4,5]. This development is critical because when it comes to research on conscious experiences, our own perspective is not something to dissolve, but rather something to understand in itself.

We share the optimism that Block and colleagues expressed [1]. It is clear that recent progress has provided

new insights into neural mechanisms relevant for consciousness. However, an even better metric of the fruitfulness of these approaches is the extent to which new horizons have been opened for empirically testing proposals about consciousness and its neural underpinnings. In this sense, the record of research in this field leaves little doubt that consciousness is a valid topic for scientific inquiry.

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