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The debate over the source of human consciousness has persisted for thousands of years, dating back to Plato and Aristotle. While we have made huge advancements in neuroscience in recent years, our own subjective experience of the world remains one of the biggest mysteries in the universe. Today's theories don't resemble Plato's or Rene Descartes' conceptions of the mind and soul as entities separate from the physical body, because it has become clear that consciousness depends on the brain. Still, it remains difficult to say what exactly constitutes consciousness, and we are far from understanding the neural mechanisms by which it is produced. One pitfall has been the search, ultimately unsuccessful despite the considerable efforts of many scientists, for a single "consciousness center" in the brain. The failure to find such a locus has led many contemporary scientists to maintain that consciousness is an integrated process involving many, if not all, areas of the brain. One such proposal is called the Integrated Information Theory (IIT), which was advanced by Tononi and Edelman[1] as a "theoretical framework for understanding consciousness." The objective of this framework is to precisely define consciousness, then to characterize it using mathematics and use this information to account for current knowledge of the brain[2].

Tononi argues that consciousness has two basic properties: it is informative, and it is integrated[3]. Barrs[4] attributed the same properties to consciousness. Information is defined as the ability to reduce uncertainty among a number of possible alternatives[5]. For example, when you are in a pitch black room, your brain processes all the available visual information and can determine that the room is dark by eliminating all other possibilities. It is clear that the more possible states a system possesses, the more informative it can be. Second, consciousness is integrated. This means that the informative system with many possible states is unified—that is, it is not divisible into independent components. In other words, a conscious system according to IIT cannot have any self-sufficient elements. Similarly, it is not enough for a system to have either a large number of possible states or a large amount of integration. A highly conscious system will have both[5].

Integrated Information Theory initially became popular because it offered a quantitative value (Φ, or phi) that purportedly represented a system's capacity for consciousness that could theoretically be applied to any sufficiently-known information-processing system. For this reason, IIT is sometimes known as "the mathematical theory of consciousness." While the math behind Φ's calculation is quite dense, the underlying concept of what Φ represents can be broken down. Basically, Φ is the amount of integrated information (information that is indivisible into smaller components) that a system possesses. Φ is measured by splitting the entity being evaluated for consciousness into parts A and B, then perturbing A in all possible ways to see how many states it produces in B, and vice versa. A system that has a high value of Φ is highly conscious according to the theory, but to obtain a large Φ requires that the system be highly interconnected[2]. All elements should be connected to a different subset of elements, and each element should be able to interact with other elements. If a system satisfies these requirements, then congratulations: it has a high Φ value and could be at least minimally conscious! Because IIT is concerned with consciousness as an abstract state of an arbitrary information-processing system, your smartphone, the internet, and even some cars could be at least minimally conscious according to IIT.

Of course, a successful theory must both explain the known facts and make accurate predictions. Thus, the final step in Tononi's theory is to apply the fundamental properties of consciousness—information and integration—to what is known about the brain. One of the questions Tononi confronts is why lesions of certain brain areas affect consciousness while lesions in other areas have no apparent effect. For example, lesions to the thalamocortical system can severely disrupt consciousness, yet lesions in the cerebellum rarely have the same effect. Given that the cerebellum contains more neurons than the cerebral cortex, one might wonder why it would seem not to play a large role in consciousness. Tononi argues that it's because the cerebellum can be easily separated into nearly independent modules, which would drastically lower the Φ value. The thalamocortical system, however, is not easily subdivided and, as such, would have a higher Φ value[5]. In practice, however, no one has yet been able to determine a Φ value for a brain region—only for model systems. Advances in the field of connectomics will hopefully lead to calculation of Φ values for real brain regions.

Another limitation of IIT is that it does not address what David Chalmers calls the "hard problem of consciousness"[6]. IIT is potentially useful for its ability to offer an objective, mathematical model of consciousness in terms of information processing, but it cannot tell us why the activity within our brains "feels" like anything—why we have internal experience at all, and why it is the way it is. The hard problem of consciousness is thought by some to be a fundamentally-insurmountable barrier, and so far no theory of consciousness has satisfied the hard problem while also accounting for known facts and making accurate predictions. Whether IIT, or any other scientific theory, can ever account for the hard problem of consciousness remains to be seen. Perhaps this fundamental part of our own experience will always remain mysterious to us.

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