Consciousness

Our most basic state is more complicated than you think!

By Alyssa Dowling

Rude Awakenings

In 1998, Carol Weiher awoke to the sound of disco music—and, if that wasn't bad enough, the next thing she heard was "cut deeper, pull harder." Carol was having her right eye surgically removed and the muscle relaxants she was administered prevented her from alerting anyone that she was still conscious and in pain (1).

"I was doing a combination of praying and pleading and cursing and screaming and trying anything I could do but I knew that nothing was working," said Weiher. Weiher is one of a relatively small group of people who have experienced anesthesia awareness, a phenomenon in which anesthesia does not render the patient properly unconscious. In the worst scenarios, the patient wakes to tremendous pain without any means of communicating; they must simply bear the physical and psychological consequences of this deeply traumatic experience. Still, though one or two people out of every thousand who go under anesthesia experience some degree of awareness during their procedure, only an unlucky few can feel pain (1).

Experiences like Carol's highlight our tenuous understanding of consciousness and the dangers of not researching the subject further. Through the study of comas, anesthesia, and artificial intelligence, scientists and philosophers alike have realized that our ability to understand and scientifically define consciousness is crucial. Even so, a precise scientific definition of consciousness is extremely difficult to establish, in part because we use the word in so many ways. We are conscious, but we can lose consciousness while sleeping, under anesthesia, or from a brain injury. I can also say that I am conscious of something to indicate that I am aware of it, a definition that has little to do with consciousness in reference to the self.

Patient undergoing eye surgery by Sasint on Pixabay.

Consciousness is a problem so nebulous that it is often difficult to know what questions to ask or if science will even be able to provide greater insight. It is a subject that some think is an illusion and others consider the essential question of neuroscience. Some believe it is irreducible, while others want to study it at the molecular level. Still, to productively discuss consciousness, we must have a generally agreed-upon definition. Though the scientifically accepted definition of consciousness will change over time, it is possible to combine several popular definitions to make the concept more accessible. Broadly, consciousness refers to the ability to experience one's existence rather than simply recording and responding to it as a computer program might. Consciousness consists of inner, qualitative, subjective states and processes of sentience or awareness (2). Though a robot may detect the world around it, it is not consciousness because this requires a qualitative feeling along with those inputs in conjunction with communication, thought, and reflection (2). Consciousness can be divided into two functional components: wakefulness and awareness. While wakefulness refers to arousal, awareness refers to how we process the content of our consciousness. Put simply, wakefulness is required to perceive a tree or experience happiness, but demonstrating wakefulness does not guarantee awareness—both are necessary for consciousness (3).

The History of the Study of Consciousness

In the seventeenth century, after the Renaissance, the Greek concept of a "theory" was combined with systematic observation and experimentation (2). However, at this same time, conflict between science and the Church raged, and scientists and philosophers adjusted their teachings to protect themselves and their field of study. To separate science away from the church and thus protect it, Descartes argued that reality has a strict and abiding cleavage between the mental and the

physical, a designation that was long accepted. Given this reasoning, Descartes was able to create a separation between religion and science of sorts, with a degree of success. At the time, this was a decent compromise—the church had uncontested domain over the mind and soul, and scientists were relatively free to study the material world. Although this distinction was useful at the time, it has persisted much longer than its utility. Consequently, for reasons ranging from ease to convention, science has been considered a strictly objective, third-person endeavor. This leaves scientists little agency to provide insight on first-person subjective experiences—especially not one as abstract as consciousness. After all, to study consciousness is to examine our very conception of the human soul (2).

This history meant that it wasn't until the 1990s that neuroscientists began to regard consciousness as a legitimate area of study in the natural sciences. The Merriam-Webster dictionary defines neuroscience as "a branch (such as neurophysiology) of the life sciences that deals with the anatomy, physiology, biochemistry, or molecular biology of nerves and nervous tissue and especially with their relation to behavior and learning." Simply put, it is the study of the brain. It is thus puzzling that we do not study a fundamental function of the brain—consciousness. Studying the brain without studying how the brain causes and sustains conscious states is like studying the lungs without studying how they allow us to breathe. Though consciousness admittedly involves more philosophical, spiritual, and ethical considerations and is certainly more complex than breathing, the logic stands. Further, the study of consciousness should be driven by many of the same medical considerations that would drive the study of any other major physiological process. Even if neuroscience will never be able to fully explain consciousness, and I suspect its study will provide useful insights into comas, anesthesia, and perhaps our very personhood.

The Neuroanatomical Basis of Consciousness

The study of the neuroanatomical basis of consciousness is still in its nascent stages. There are many different theories, but it is important to understand some of them and how they are derived to understand the ways in which neuroscientists are making progress in their study of consciousness. The traditional viewpoint is that consciousness essentially arises from interacting neurons in the midline of the brain, the cerebral cortex (associated with attention, awareness, etc.), and the reticular activation system (regulating alertness and wakefulness) (4). At the same time, contemporary research suggests that consciousness originates in the frontal region of the brain, while others maintain that it comes from the hindbrain. In studying the material basis of consciousness, researchers must address the external sensory network and the internal self-conscious network, making consciousness a uniquely complex function. There may be many theories of consciousness simply because so many parts of the brain are involved.

One way that neuroscientists attempt to simplify the physical study of consciousness is through the study of neural correlates of consciousness (NCC). Because these "signatures of consciousness" are not necessarily causal, they are much easier to study and identify (if slightly less illuminating). Stanislas Dehaene, a neuroscientist at Collège de France, has identified four "signatures of consciousness (5)." Of those, the P3 wave in the dorsolateral cortex (behind the top of your forehead) correlates most reliably with normal conscious states (5). Physicians have successfully used measurements of these "signatures of consciousness" in coma patients to predict which individuals are most likely to regain consciousness. Neuroscience jargon aside, our understanding of neural

Forms of Consciousness

	Brain Function	Motor Capacity	Conscious?
Full Consciousness	yes	yes	
Coma	no	no	
Vegetative State	no	limited	
Locked-in	no	yes	

Forms of Consciousness. Original image by Alyssa Dowling. Created in Biorender.

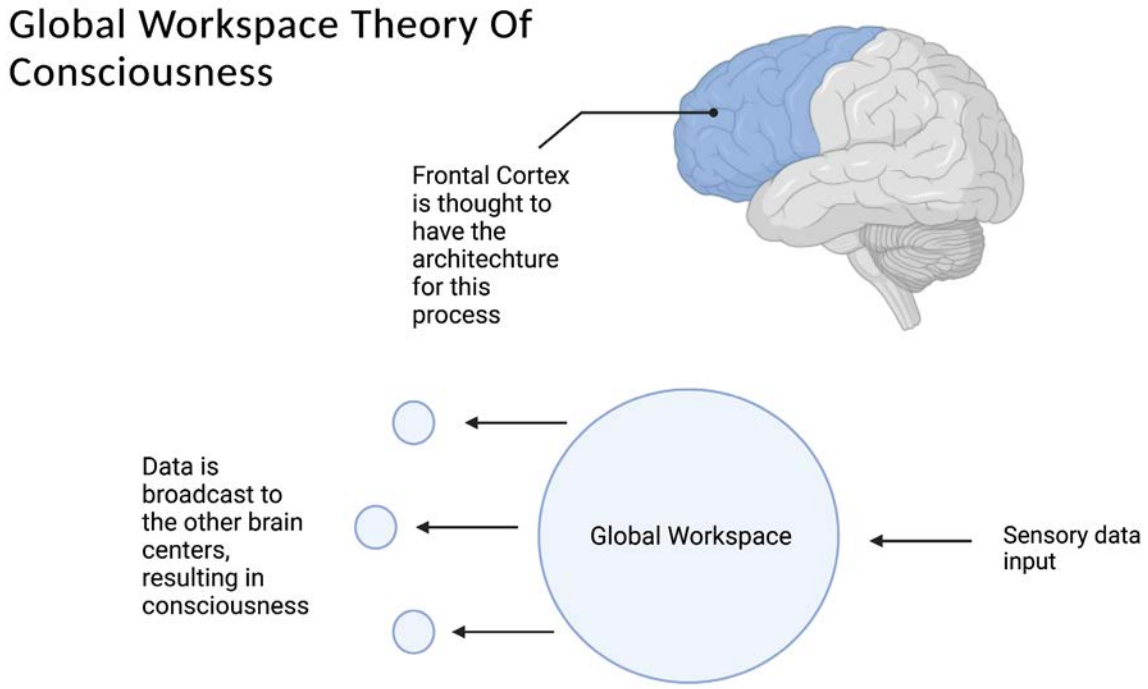
correlates of consciousness is proving to be an essential part of developing more accurate prognoses for individuals in unconscious states.

Curious Case of the Claustrum—A Promising NCC

The claustrum is a thin sheet of neurons attached to the bottom of the neocortex in the middle of the brain (6). Relatively little is known about the function of the claustrum, but we do know it provides functional links between the frontal cortices and the association cortices in the brain. These linkages suggest that the claustrum plays a role in how perceptual information interacts with the arousal (alertness) system, and thus is involved in the generation of consciousness. In 2014, Koubeissi et al., in the pursuit of a cure for epilepsy, implanted electrodes deep in a woman's brain in an attempt to record signals from different brain regions during seizures (7). When an electrode next to the claustrum was stimulated, the woman lost consciousness. When the stimulus stopped, she immediately regained consciousness without recollection of the incident. Other wider-scale studies have found that the degree of claustrum damage affects the duration of consciousness loss, suggesting that the claustrum plays a role in the restoration of consciousness,but not maintenance (3). One study looked at Vietnam veterans with traumatic brain injuries that were limited to one brain region, and impacted the claustrum. Researchers defined traumatic brain injuries as injuries that caused at least 24 hours of loss of consciousness. They found that damage to the claustrum was moderately correlated with the duration of consciousness loss following brain damage. The study of the claustrum as a neural correlate of consciousness demonstrates major issues with the study of NCCs in general. For one, the structure is thin and in close proximity to a variety of other brain structures, making it challenging to study using neuroimaging (3). Additionally, though scientists like Crick and Koch proposed that the claustrum plays a crucial role in consciousness due to its structure and connectivity, more recent research does not support this same hypothesis. Instead, results suggest that several neural networks combine to generate and maintain consciousness, although some, such as the claustrum, may be more involved than others (3).

Theories of Consciousness

While research of the neurobiological basis of consciousness expands this field of study, a more holistic approach is to perhaps examine the experience of consciousness. Instead of trying to reduce consciousness into biological parts, theories of consciousness attempt to give a more systemic explanation. The first, the global workspace theory of consciousness (GW), was proposed in 1998 (14). This idea is essentially that a single brain region is incapable of generating consciousness. Instead, consciousness requires the coordination of many different parts of the cerebrum—an idea that encourages researchers to explore the brain as a whole (8). Interestingly, this theory (along with some related ones) posits that computers will one day gain consciousness. Critics of this theory say that it fails to explore what consciousness is and instead only provides a vague call



Global Workspace Theory of Consciousness (GW). Original image by Alyssa Dowling. Created in BioRender.

to consider the entire brain in the production of consciousness.

The integrated information theory, on the other hand, conjectures that consciousness is simply "the capacity of a system to integrate information," and provides a mathematical framework for evaluating the magnitude and quality of consciousness (9). This theory, while helpful for measuring consciousness on a clinical level, provides conditions that are necessary, but not sufficient on their own to produce consciousness.

More metaphysical theories of consciousness exist, with two being the most prominent. Some think that consciousness is a fundamental building block of the universe in the way that physicists think of space and time and mass (13). According to this theory, there are fundamental laws that govern these building blocks, but they cannot be understood and explained in more basic terms. Others still think that consciousness could be universal and that every system can possess some degree of consciousness. This idea is called panpsychism and suggests that everything, from a human to a photon, has some element of subjective feeling, some primordial precursor to consciousness as a human experience. This idea does not assert that everything is intelligent or thinking, but rather that everything has some aspect of "universal" conception of consciousness. While this idea is somewhat incomprehensible in Western, monotheistic culture, it is seen as a more intuitive explanation in cultures that see the human mind as continuous with the rest of nature.

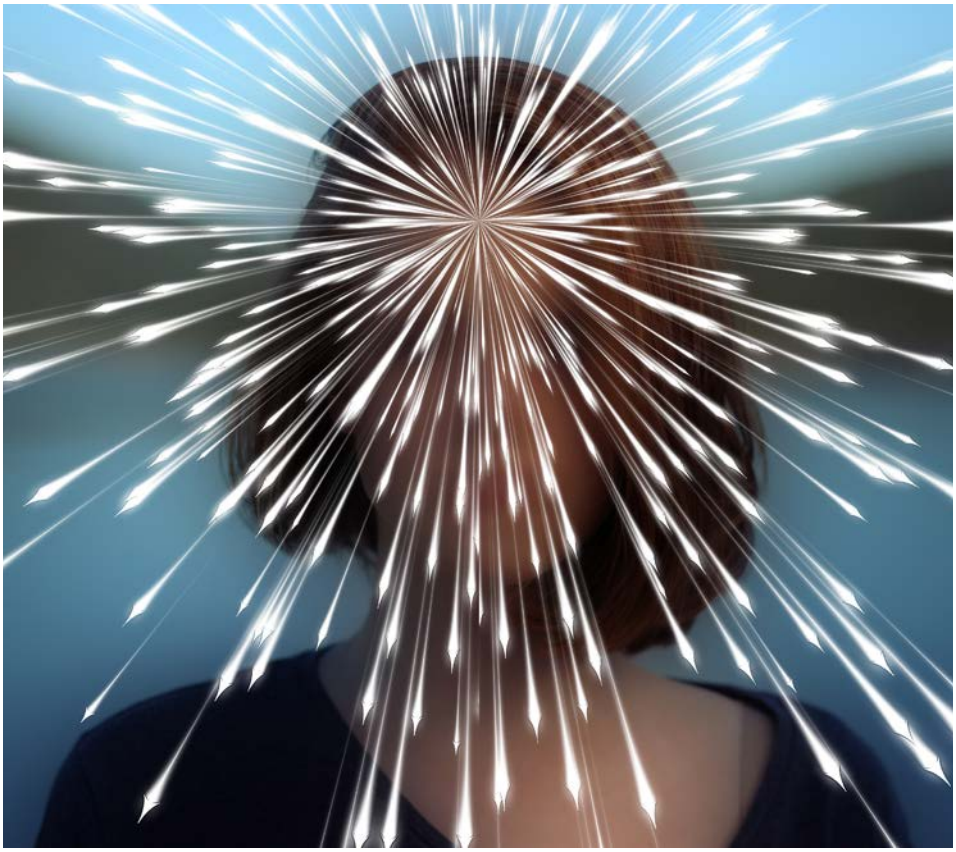
The idea that consciousness is both fundamental and universal has been taken up by a neuroscientist by the name of Giulio Tononi, who has rigorously developed the idea via mathematical theory (13, 9). This mathematical theory is centered around the idea of phi, which is a measure of the amount of information integrated in the system, and thought to be related to consciousness. Therefore, the human brain, with its large degree of information integration, has the highest degree of consciousness. Everything else, down to a microbe, has a non-zero degree of consciousness. In the science of consciousness, this is one of the leading theories, and it has the potential via ethical and social implications to transform how we relate to nature. On the other hand, this theory could apply to non-organic systems like computers, which, according to the pan-psychic view, have the capacity to be completely conscious. This is a view that many neuroscientists, philosophers, and religious leaders would take major issue with. On the topic of computers especially, leading neuroscientists have taken the stance that consciousness has much more to do with our nature as living and breathing organisms than with pure intelligence, and thus would reject Tononi's hypothesis (12). It perhaps follows that the "pan-psychic" view would need to only apply to living things, at least for the time being, to properly mesh with other neuroscientific conceptions of consciousness.

Philosophy of Consciousness and the Limits of Consciousness

There is tension between neurological and philosophical theories and conceptions of consciousness. Although to be human we must have a brain in relative working order, some philosophers believe that there is confusion between the necessary and sufficient conditions for consciousness. Thus, when thinking about neuroscience, it is important to not lose sight of that fundamental mind-brain problem. Most neuroscientists do not think that the mind is the brain, but some neuroscientists seem to get lost in chemical and anatomical explanations of consciousness and risk losing sight of the forest in their study of the trees. There is a legitimate fear that an overly reductionist approach to consciousness will lead to purely chemical explanations of behavior. For instance, there is a quoted instance in which Patricia Churchland, a so-called neuro-philosopher, came home after a difficult day at work as told her husband, "Paul, don't speak to me, my serotonin levels have hit bottom, my brain is awash in glucocorticoids, my blood vessels are full of adrenaline, and if it weren't for my endogenous opiates I'd have driven the car into a tree on the way home. My dopamine levels need lifting. Pour me a Chardonnay, and I'll be down in a minute (10)." It is hard to say how seriously these sorts of sentiments are taken, but at the very least I think it is easy to understand how such statements would alarm those who take a more holistic approach to human consciousness and behavior. Further, such explanations do not yet provide a particularly convincing explanation for consciousness, and cannot be taken entirely seriously.

Covert Consciousness

Severe brain injuries often lead to a loss of consciousness for weeks or even longer. In such unresponsive states, it is difficult to determine to what degree the patient is aware or conscious. Fifty years ago, these patients probably would not have survived their injury, but as life support technology has improved and such patients can be sustained for longer periods, doctors and neuroscientists have identified a newfound demand for more robust techniques for determining the degree of a patient's consciousness. Many patients who are unable to give muscular or behavioral indications of consciousness have been shown, through brain imaging, to have some degree of covert consciousness (11). These findings have many clinical applications and can be used to give more



accurate treatments and diagnoses to unconscious patients. This can also contribute to more accurate prognoses—that is, brain imaging that discovers some degree of covert consciousness can help provide more accurate predictions as to whether or not a patient will regain consciousness. Patients who exhibit some degree of subjective experience as discovered by brain imaging are substantially more likely to recover from their injuries.

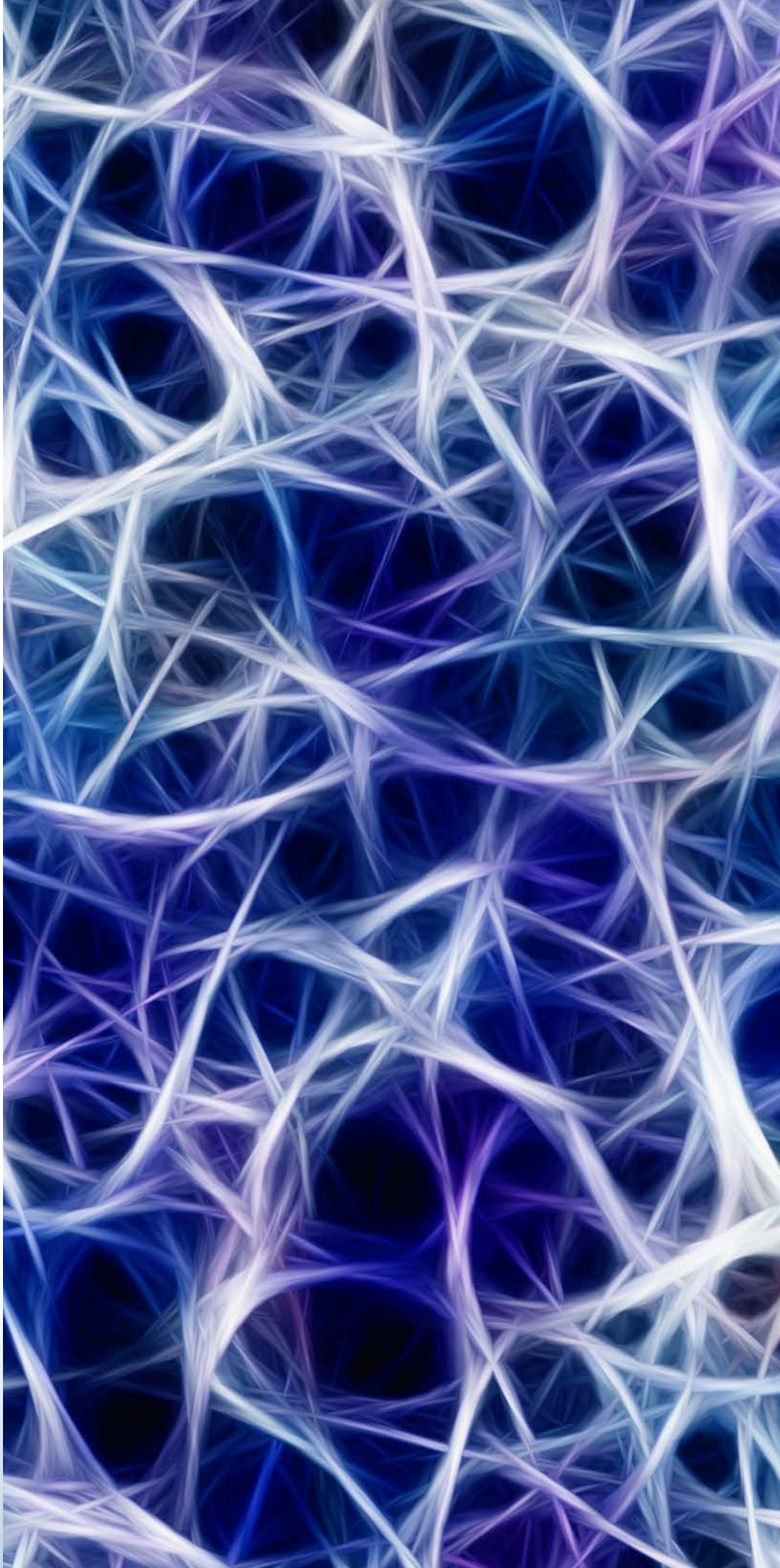
When we discuss impairments of consciousness, it is essential to distinguish between the different states that are possible and the spectrum on which they exist. Although there are ideal types, each unconscious state is different from the next, and a person's level of consciousness exists at different degrees of several different axes. The coma is the most referenced impairment of consciousness and can basically be understood as a very deep sleep that you cannot awake from. In the "ideal type" of coma there is little to no movement, the eyes are closed, and the patient has little to no awareness or processing of their surroundings. The opposite of a coma is understood to be full consciousness in which you have total awareness, normal processing, and physical ability to respond to the environment. Still, there are types of consciousness impairments that fall into other categories, such as the vegetative state, during which a person can open their eyes and there is some level of alertness, but they do not exhibit full consciousness. An individual in a vegetative state is sort of a physical shell of a person in that they lack consciousness, but display some movement and the theoretical ability to use their body (if their brain could utilize that ability) (11). Opposite from a vegetative state is a person who is "locked-in." These patients are fully conscious but have limited to no ability to express their consciousness, often due to an injury to the pons, a part of the brain which plays a large role in transmitting and receiving motor information. This is a condition in which it is particularly vital to discover covert consciousness since it is distinctly inhumane to mistake a fully conscious (though immobile) person for someone in a vegetative state. Consider, for example, instances in which fully conscious patients overheard family members saying that it would be better if they were dead, or adult individuals who were stuck in front of a TV playing Barney for several months (7). Indeed, when locked-in patients recover or find ways to communicate, they generally have suffered trauma from having been treated as an object during the time in which their degree of consciousness was misunderstood. At the very least, discussions of covert consciousness should include the vital importance of what physicians have been taught for decades)—medical professionals and family alike must treat seemingly unconscious individuals as if they can understand and respond to everything that is said and done around them.

Considering that there is no direct test for consciousness, the study of covert consciousness is intimately connected to the technologies which detect it (11). While behavioral and muscular indications of consciousness are undeniably central to our understanding of the concept, brain imaging has demonstrated how limiting and unsatisfactory such markers are. Functional MRI scans have drastically changed the quality of life for seemingly unconscious patients and have helped identify a need for further therapeutic strategies. Still, these scans always require transporting the patients, which can be costly and dangerous. The scan itself is expensive and logistically difficult since there must be physicians,

nurses, and respiratory technologists present to safely perform an MRI on a patient who may be on some degree of life support (11). Additionally, consciousness generally fluctuates during recovery, and so a patient that starts out unconscious may become increasingly conscious without any behavioral change. However, repeated MRI scans may not be logistically or financially possible. Luckily, many new promising technologies are being researched that could be used more consistently. One major study used EEGs and found that around 15% of patients in an "unconscious" state demonstrated some degree of covert consciousness. Other studies have put the number at closer to 30, or even 40 percent (11).

Conclusions

Pinning down a definition of consciousness demonstrates how nebulous the concept can be. At the same time, however, the clinical advantages of better understanding consciousness are evident. Providing more suitable treatment plans and prognoses for unconscious patients, preventing anesthesia awareness, and finding a more connected way of thinking about our place in the world are all reasons the study of consciousness is essential. While there is certainly some validity to complaints of the inscrutable nature of consciousness, it is not an area of neuroscience that we can afford to ignore because it is too complicated or because of the possibility that we might never understand it. All we need to know is that the journey toward a better understanding of consciousness will improve clinical outcomes, our understanding of ourselves, and perhaps even our understanding of our place in the world.



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