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Consciousness science at a crossroads: lessons from disorders of consciousness

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An Editorial on the Frontiers in Science Lead Article

Consciousness science: where are we, where are we going, and what if we get there?

Key points

- Detecting covert awareness challenges long-standing assumptions about a patient's level on mental responsiveness, requiring new legal, ethical, and clinical frameworks to avoid misjudging patients' capacity and lived experience.
- Progress in consciousness science requires large-scale, well-powered, multicenter collaborations using standardized protocols, with greater emphasis on phenomenological, naturalistic assessments that encompass the richness of lived experience.
- Disorders of consciousness research shows that consciousness science cannot remain an intellectual exercise—progress demands theories that generate testable predictions, reproducible clinical markers, and ethically actionable insights.

The lead article by Cleeremans and colleagues, “Consciousness science: where are we, where are we going, and what if we get there?” (1), argues that the field of consciousness science stands at a turning point. The authors call for theory-driven research, adversarial collaborations, large-scale, multi-laboratory studies, and a renewed focus on phenomenology. Their agenda is forward-looking, emphasizing not only the scientific but also the clinical, ethical, and societal consequences of progress in this field.

One area where these issues converge most obviously is in the study of disorders of consciousness (DoC). For patients emerging from a coma into vegetative or minimally conscious states, the question of whether consciousness is present is not just theoretical but also has profound implications for diagnosis, prognosis, and care (2). DoC therefore provides a critical test of the proposals outlined by Cleeremans and colleagues.

Theories of consciousness in the clinical context

The field of consciousness science is characterized by multiple competing theories, including the global workspace theory (GWT), integrated information theory (IIT), higher-order thought theories (HOTTs), and predictive or recurrent processing accounts (3). Some of these frameworks are not just theoretical with respect to clinical neuroscience but have made concrete contributions that sometimes map onto existing approaches to DoC. For example, IIT's emphasis on integration and complexity has inspired measures such as the perturbational complexity index (PCI), which uses transcranial magnetic stimulation combined with electroencephalography (TMS–EEG) to estimate the capacity for consciousness in unresponsive patients (4). GWT, although not the source of inspiration for them, does align with functional magnetic resonance imaging (fMRI) mental imagery paradigms, where volitional tasks elicit widespread network activation.

Neuroimaging as a window into covert awareness

In the context of Cleeremans and colleagues' call for theory-driven and ecologically grounded science, advances in DoC research have yielded reproducible, clinically meaningful tests of consciousness. Nowhere is this more apparent than in the discovery of covert awareness. In 2006, it was shown for the first time that a patient who appeared to be in a vegetative state was, in fact, unequivocally aware, despite showing no behavioral evidence of awareness (5). Using fMRI, the patient was able to modulate her brain activity in response to external commands by engaging in two mental imagery tasks: imagining playing tennis and imagining walking through her home. This finding, published in *Science*, marked a pivotal moment in consciousness research. It demonstrated that patients diagnosed as vegetative could nonetheless retain the capacity for willful, volitional thought, and that neuroimaging could reveal hidden awareness where bedside examination had failed. Subsequent studies with fMRI and EEG have shown that approximately one quarter of DoC patients demonstrate covert awareness when assessed with advanced neuroimaging or electrophysiological methods (6). Yet both also face limitations: fMRI is resource-intensive and logistically impractical, while EEG suffers from poor spatial resolution and susceptibility to artifact.

Functional near-infrared spectroscopy (fNIRS) offers an alternative solution. Proof-of-principle studies have shown that motor imagery can be detected using optical signals (7). More recently, this approach has been applied to comatose patients, demonstrating that fNIRS can detect covert awareness in up to 25% of patients in the acute phase of severe brain injury (8). This development moves the field closer to a practical and measurable bedside test for consciousness, one capable of directly addressing the clinical needs of patients and families.

Methodological challenges and the problem of false negatives

Despite these advances, significant challenges remain. A persistent limitation of neuroimaging paradigms is the small but noteworthy rate of false negatives. Even some healthy individuals fail to generate detectable responses in standard imagery tasks, and for patients with a severe brain injury the obstacles are even greater—sedation, structural injury, fluctuations in arousal, and sensory or motor impairments can all mask residual capacity. As a result, absence of evidence cannot be equated with evidence of absence (9).

This problem highlights the importance of the agenda set by Cleeremans and colleagues. Greater emphasis on phenomenology is needed, moving beyond paradigms that simply reduce consciousness to the detection of specific task content. Despite their proven clinical effectiveness (6), imagery-based tasks and command-following approaches may still miss patients who retain awareness but lack the capacity to engage in structured instructions. A patient may be conscious without the motor control, attention, or cognitive endurance required to complete such paradigms, leaving crucial aspects of their phenomenological experience inaccessible to current measures. Naturalistic paradigms, such as passive movie viewing, provide a promising alternative. These approaches engage broad, multimodal networks, better approximate real-life experience, and may reveal covert awareness in patients unable to comply with traditional task demands (10). By aligning assessments more closely with the richness of lived experience, naturalistic methods move the field closer to tests of consciousness that capture both the presence *and* the quality of awareness.

Reliability and replicability are also pressing concerns. Many DoC studies involve small samples and single sites, limiting confidence in generalizability. Progress requires large-scale, multi-center collaborations designed with sufficient statistical power and standardized protocols, aligning directly with the collaborative spirit advocated by Cleeremans and colleagues (1).

Clinical implications of progress

If consciousness science moves toward the kind of rigor envisioned in the lead article, the implications for medicine are substantial. In DoC, reliable detection of covert awareness could alter diagnostic categories, guide rehabilitation, and inform decisions about life-sustaining treatment. Families often ask whether a patient is “still there” and, for the most part, current behavioral assessments provide only limited answers. Imaging-derived markers can shed light both on whether the patient is “still there” and on what being “still there” means for a given individual. Indeed, these methods have even allowed some chronic DoC patients to communicate with the outside world, reporting on their memories, emotions, and clinical symptoms (e.g., whether they are in pain) (11). Early demonstrations of volitional signal

modulation suggest that such approaches could eventually be adapted for the intensive care unit (ICU), raising the possibility that patients might one day contribute directly to decisions about their own care. While this remains aspirational, the technical capacity already exists, and continued progress makes such an outcome increasingly plausible. Developing robust, validated tests for consciousness, as the lead article suggests, would therefore be transformative in this context.

Moreover, the implications extend beyond DoC. Disorders such as depression, schizophrenia, and advanced Alzheimer's disease involve profound disruptions of subjective experience. Yet therapeutic development has often proceeded by focusing on behavioral or animal models without explicit reference to phenomenology. A stronger scientific understanding of consciousness could enable new approaches to directly target subjective states, creating opportunities for diagnosis and treatment across psychiatry and neurology.

Ethical and legal dimensions

DoC highlights the ethical stakes of consciousness science with exceptional clarity. The detection of covert awareness compels a fundamental reconsideration of long-held assumptions about prognosis and end-of-life decision-making. If even a small minority of patients retain consciousness despite appearing behaviorally unresponsive, then policies that rely exclusively on bedside examination risk serious error—either by withdrawing life-sustaining treatment from patients who are in fact aware or by continuing aggressive interventions in those without any prospect of recovery (2). Both scenarios carry profound consequences not only for patients but also for families and clinicians.

The legal system faces parallel challenges. Questions about whether life support should be withdrawn, treatment should continue, or patients retain decision-making capacity have all, in different cases, involved the unresolved issue of consciousness. At the heart of these disputes is the uncertainty over whether a patient possesses any phenomenological experience—any awareness at all—and whether there is realistic potential for recovery. In such contexts, advances in neuroimaging and bedside techniques capable of detecting covert awareness could provide evidence that directly informs judicial decisions.

These are not abstract dilemmas. Courts have already had to adjudicate cases where the central issue was whether a patient retained a level of consciousness sufficient to justify continued care. Until recently, such judgments rested almost entirely on clinical impressions and behavioral observations. The prospect of reproducible, scientifically validated tests for consciousness introduces the possibility of more objective evidence in these deliberations. While no single measure can eliminate uncertainty, the integration of these approaches into legal and ethical frameworks has the potential to reshape how society understands and governs decisions at the boundary of life and death.

Why disorders of consciousness matter for the field

Cleeremans and colleagues caution that consciousness science risks an “uneasy stasis” if it continues to proliferate theories without decisive tests (1). Nowhere is this more apparent than in DoC. For the most part, the substantial clinical progress of the last two decades has not been driven by theories of consciousness at all. Instead, it has come from the urgent, practical need to assess patients and prognosticate about them. Indeed, one could argue that it is the theories that have been informed by clinical discoveries rather than the reverse.

This imbalance cannot persist. If theories of consciousness are to be more than intellectual exercises, they must now make practical, measurable contributions to patient care. DoC research provides exactly the arena in which such contributions can be made. It demands that theories make precise, testable predictions and forces direct engagement with phenomenology in a way that few other domains of science can.

DoC situates consciousness science within urgent clinical, ethical, and societal contexts. The stakes are not measured in publications, citations, or debates but in the ability to recognize patients who are otherwise invisible and to guide families navigating the profound uncertainty of severe brain injury. Now is the time for theories of consciousness to step up. In doing so, they need to not only advance our scientific understanding but also prove that theories can change lives, not just reputations and careers.

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Author contributions

KK: Conceptualization, Writing – original draft, Writing – review & editing.

AO: Conceptualization, Funding acquisition, Writing – original draft, Writing – review & editing.

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The author AO declared a past collaboration with the lead article authors as well as a shared affiliation within the Brain, Mind, & Consciousness program of the Canadian Institute for Advanced Research (CIFAR).

The remaining author declared that this work was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Generative AI statement

The authors declared that no generative AI was used in the creation of this manuscript.

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