Integrating Consciousness Science with Cognitive Neuroscience: An Introduction to the Special Focus

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Abstract

■ Consciousness science is experiencing a coming-of-age moment. Following three decades of sustained efforts by a relatively small group of consciousness researchers, the field has seen exponential growth over the past 5 years. It is increasingly recognized that although the investigation of subjective experiences is a difficult task, modern neuroscience need not and cannot shy away from the challenge of peeling away the mysteries of conscious experiences. In June 2023, with the joint support of the U.S. National Institutes of Health and the U.S. National Science Foundation, a 3-day workshop was held at the Bethesda, MD, campus of the National Institutes of Health, convening experts whose work focuses primarily on problems of consciousness, or an adjacent field, to discuss the current state of consciousness science and consider the most fruitful avenues for future research. This Special Focus features empirical and theoretical contributions from some of the invited speakers at the workshop. Here, I will cover the scope of the workshop, the content of this Special Focus, and advocate for stronger bridges between consciousness science and other subdisciplines of cognitive neuroscience. ■

A BRIEF HISTORY OF CONSCIOUSNESS SCIENCE

Many a student is drawn to psychology and neuroscience by the curiosity to understand the human mind. "*Why am I the way I am? What are dreams made of? Why do I feel embarrassment or pain? Is my brain a computer and, if so, what kind of computer?*"

Consciousness is at the root of the human experience. Few human beings would be willing to exchange their conscious experiences for superior intellectual abilities or magical powers. Ask a layman on the street, what is cool about neuroscience, they will likely say that it has the keys to unlock the mysteries of the human experience—conscious experiences that make life worth living. Despite this, over the past half century, consciousness science was often marginalized. It was not uncommon to hear accomplished neuroscientists remarking, sometimes humorously, "that's consciousness, and I don't know what means." How did we get there?

In fact, a century ago, around the birth of modern psychology, the investigation of the conscious mind was not a scorned subject. William James, widely thought to be the father of American psychology, devoted two chapters in his book, *The Principle of Psychology* (James, 1890), to the stream of consciousness/thought and self-consciousness. Across the Atlantic, the Gestalt school of psychology in Germany described multiple laws governing perceptual grouping—that is, the grouping principles dictating the result of *conscious* perception—including proximity, similarity, closure, symmetry, common fate, and continuity (Metzger, 1936). And, of course, as controversial and sometimes unscientific as it was, Freud's work emphasized the important distinctions between conscious and unconscious processing (Freud, 1923).

However, the rise of the Behaviorist school around the 1930s changed all this. Under the leadership of prominent behaviorists such as Watson, Skinner, and Thorndike, scientific psychology came to view only observable and measurable behavior as legitimate topics of scientific inquiry. The Behaviorist school of thought diminished the importance of internal mental states, including subjective experiences, thoughts, and feelings, considering them outside the realm of scientific inquiry. It is noteworthy that some of the foundational concepts established by the behaviorists, such as classical conditioning and instrumental learning, were precursors to the framework of reinforcement learning (RL), which has enabled the success of modern deep RL algorithms, such as DeepMind's AlphaGo that beat the human Go champion in 2016 (Silver et al., 2016, 2017). Today, the deep RL field is increasingly recognizing the importance of model-based, as opposed to model-free, RL, emphasizing the importance of considering internal states and internal mental representations.

The cognitive neuroscience revolution, starting in the 1970s, and led by giants such as George Miller and Michael Gazzaniga, re-established the importance of studying the internal mind. The cognitive revolution reversed the behaviorist paradigm and established multiple subdisciplines to study different functional modules of the mind,

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such as perception, attention, learning and memory, language, emotion, and executive control. Against this backdrop, a rebirth of consciousness science happened around the early 1990s, partly ushered in by Nobel laureates Francis Crick (Crick & Koch, 1990) and Gerald Edelman (Tononi & Edelman, 1998). Although neither Crick nor Edelman were awarded their Nobel prize for work in neuroscience, both recognized the importance of explaining consciousness as one of the ultimate goals of modern neuroscience.

THE RELATION BETWEEN CONSCIOUSNESS SCIENCE AND COGNITIVE NEUROSCIENCE

Within cognitive neuroscience, consciousness is often thought of as a distinct subdiscipline as compared with the aforementioned, more established subdisciplines. This is reflected by the devotion of one chapter, often toward the end, to consciousness, in most editions of the edited tome *The Cognitive Neurosciences* (Gazzaniga & Mangun, 2014; Gazzaniga, 1995, 1999, 2004, 2009). The disconnect between consciousness science and other subdisciplines of cognitive neuroscience is also reflected by distinct scientific societies representing these two fields, the Association for the Scientific Study of Consciousness on the one hand and the Cognitive Neuroscience Society on the other hand. These two scientific societies have relatively distinct membership bodies.

However, much can be gained by strengthening the bridge between consciousness science and "mainstream" cognitive neuroscience (He, 2023b). Consciousness researchers have long recognized the tight connection between research on conscious perception and classic vision neuroscience, as reflected by many active Association for the Scientific Study of Consciousness members also attending the annual meetings of the Vision Science Society. This is to a large extent because of the dominance of visual perception as a "model system" in empirical neuroscientific work on consciousness—a paradigm advocated by Crick himself in the early 1990s (Crick & Koch, 1990). Yet, the connection between consciousness science and other subdisciplines of cognitive neuroscience has been unfairly neglected in recent years. Here, I argue that considering the axis of conscious–unconscious processing can bring illuminating insights, or at least raise important questions, for most subdisciplines of cognitive neuroscience.

Take memory as an example. As Daniel Schacter reviews in his contribution to this Special Focus, the distinction between conscious (explicit or declarative) and nonconscious (implicit or nondeclarative) forms of memory lies at the foundation of modern memory research (Squire & Dede, 2015; Tulving, 2002). Although memory researchers have moved away from earlier notions of a dedicated brain system supporting conscious memory, the distinction between conscious and unconscious forms of memory remains a central dimension for conceptualizing memory functions. For instance, a recent study revealed a striking dissociation between declarative episodic memory and one-shot perceptual learning in hippocampal-lesioned patients, placing one-shot perceptual learning under the umbrella of nondeclarative memory (Squire, Frascino, Rivera, Heyworth, & He, 2021). Furthermore, conscious and unconscious reactivations of stored memory traces appear to have distinct consequences on memory consolidation (Tal, Schechtman, Caughran, Paller, & Davachi, 2024). Many intriguing questions remain. For instance, why do conscious experiences have privileged access to long-term storage in the declarative memory system, whereas unconscious experiences can hardly access this system?

Emotion is another prime example. Emotions that matter the most to our human experience are conscious feelings. Yet it is well known that these conscious feelings can be preceded by, or in some cases entirely replaced by, unconscious bodily and neural activity associated with emotional processing (Damasio, 2000). Which neural activity directly underlies consciously experienced emotional feelings remains an open question. For instance, the amygdala, previously thought to be the "fear center" of the brain, is not strictly required for the generation of fearful affect (Feinstein et al., 2013; Anderson & Phelps, 2002). This and other considerations prompted Joseph LeDoux, an invited speaker at the Workshop, to propose that conscious experiences, including emotions, are generated by higher-order prefrontal circuits (LeDoux & Brown, 2017). Definitive answers to these questions await future investigation. For example, subcortical regions might play an important role in generating the interoceptive feelings (e.g., hunger, thirst) that may be foundational to emotional feelings (e.g., sadness, joy), as argued by Antonio and Hanna Damasio in their contribution to this Special Focus.

The relation between attention and consciousness has received much thought and debate over the years. Attention and conscious perception are naturally closely related: Paying attention to something brings it into the focus of consciousness, and top–down attention is under conscious, voluntary control. The close connection between these two domains is also reflected in the fact that the first edition of Cognitive Neuroscience devoted a single chapter to both of them (Gazzaniga, 1995). At one point, an intense debate in the field revolved around the issue of whether attention is necessary for consciousness (Cohen, Cavanagh, Chun, & Nakayama, 2012; Koch & Tsuchiya, 2007). This debate was largely resolved by the realization that the term "attention" can have different definitions, for example, as "top–down attention" in some cases, and as "attentional bandwidth" in other cases.

Finally, some thought-provoking questions can be posed about the relationship between consciousness and other cognitive neuroscience topics too. For instance, how do conscious deliberation and automatic processing interact to shape our reasoning, language, and social cognition (Kahneman, 2013; Evans, 2008)? Are executive control and working memory always conscious (Trübutschek, Marti, Ueberschär, & Dehaene, 2019; Soto, Mäntylä, & Silvanto, 2011)?

CONTENT OF THE WORKSHOP AND THIS SPECIAL FOCUS

The motivation, scope, and key discussion points of the Workshop, titled "Next Frontiers in Consciousness Research," have been previously covered by a Meeting Report (He, 2023a). These points will not be repeated here. The full meeting agenda and speaker list can be found on the Workshop website (https://sites.google.com/view/consciousness2023), and video recordings of all the presentations and most of the discussions from the 3-day workshop are available on the National Institutes of Health video archive and can be viewed freely (Day 1: https://videocast.nih.gov/watch=49160; Day 2: https://videocast.nih.gov/watch=49162; Day 3: https://videocast.nih.gov/watch=49164).

Briefly, the Workshop covered the following areas: History and Theories of Consciousness, Conscious Perception, Conscious and Unconscious Cognition, Action and Volition, Conscious Recall of Long-term Memory, Animal Consciousness, Development of Consciousness, Feelings and Emotions, States of Consciousness, Disorders of Consciousness, and Neuroethics of Consciousness Research and Artificial Intelligence. Thirty-six speakers gave presentations and engaged in the discussions. Among the speakers, 12 contributed to this Special Focus. The 12 contributions include two experimental studies and 10 review/perspective articles.

On the empirical side, Cohen and colleagues (Cohen, Sung, & Alaoui, 2024) present a new experiment using a creative paradigm to alter the visual input in the periphery with intriguing findings that may help to resolve a long-standing debate in the field of conscious perception: whether our subjective phenomenology is rich or sparse. Carrasco and Spering (Carrasco & Spering, 2024) review a series of studies demonstrating a striking dissociation between eye movement patterns and visual awareness, which has both theoretical and practical implications for studies of conscious perception. Schacter and Thakral discuss the relationships between memory recall, imagination and simulation, and conscious experiences (Schacter & Thakral, 2024). Siena and Simons present a new experiment probing the subjective experience of remembering in individuals with aphantasia, showing a striking dissociation between objective memory performance and subjective vividness ratings (Siena & Simons, 2024). Dehaene-Lambertz and Rochat review neuroscientific and psychological findings related to the early development of perceptual awareness and self-awareness, respectively (Dehaene-Lambertz, 2024; Rochat, 2024). Redinbaugh and Saalman present a comprehensive review of the involvement of basal ganglia circuits in perception, attention, and states of consciousness, covering a large neuroscientific literature using functional and anatomical methods (Redinbaugh & Saalmann, 2024). Finally, Mofakham and colleagues review a series of findings from neuroimaging and EEG work aimed at understanding the neural bases of loss of consciousness following severe traumatic brain injury (Mofakham, Robertson, Lubin, Cleri, & Mikell, 2024).

On the theoretical side, Damasio and Damasio present a novel hypothesis regarding the neural genesis of homeostatic feelings and their relations to other components of conscious experiences (Damasio & Damasio, 2024). Godfrey-Smith presents a thoughtful analysis of the capacity for consciousness in phylogenetically distant organisms, especially arthropods and cephalopods, from an evolutionary perspective (Godfrey-Smith, 2024). These thorny questions were recently highlighted by the New York Declaration of Animal Consciousness (https://sites.google.com/nyu.edu/nydeclaration/declaration).

Two contributions deal with neuroethical issues that consciousness research inevitably intersects with. Fins and Shulman provide a detailed review of the history of scientific research and the surrounding ethical discussions related to disorders of consciousness following traumatic brain injury, and the opportunities as well as challenges that nascent AI technologies present to this field (Fins & Shulman, 2024). Johnson considers a broad range of ethical issues raised by our inability to clearly identify consciousness in other individuals and entities, including nonhuman animals, human patients, and machines (Johnson, 2024).

Conclusions

The study of subjectivity is, and might always be, hard. However, as Einstein remarked in his essay "Physics and Reality" (1936),

> *Our psychological experience contains, in colorful succession, sense experiences, memory pictures of them, images and feelings. In contrast to psychology, physics treats directly only of sense experiences and of the "understanding" of their connection; But even the concept of the "real external world" of everyday thinking rests exclusively on sense impressions.*

That is, conscious experience is not only the foundation of our human experience—exhilarating yet sometimes frustrating—but it probably also is the foundation of everything we know about the external world. With all the exciting progress we have seen in empirical neuroscientific studies of different aspects of conscious experiences over the past 10 years, the next decade promises to be an exciting period for this field.

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Diversity in Citation Practices

Retrospective analysis of the citations in every article published in this journal from 2010 to 2021 reveals a persistent pattern of gender imbalance: Although the proportions of authorship teams (categorized by estimated gender identification of first author/last author) publishing in the *Journal of Cognitive Neuroscience* (*JoCN*) during this period were M(an)/M = .407, W(oman)/M = .32, M/W = .115, and W/W = .159, the comparable proportions for the articles that these authorship teams cited were M/M = .549, W/M = .257, M/W = .109, and W/W = .085 (Postle and Fulvio, *JoCN*, 34:1, pp. 1–3). Consequently, *JoCN* encourages all authors to consider gender balance explicitly when selecting which articles to cite and gives them the opportunity to report their article's gender citation balance.

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