
Neuroimaging of Consciousness

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Editors

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 Springer

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Preface

...by night the glass
Of *Galileo* ... observes
Imagined lands and regions in the moon.

John Milton
Paradise Lost, Book 5, lines 261–263

Science and technology are inextricably intertwined and this is particularly true for the field of neuroscience. Thanks to considerable advances in neuroimaging techniques, the past two decades have witnessed an unprecedented increase in the number of studies on the structure and function of the human, which have deepened our understanding of how neural networks subserve our mental life. This scientific endeavor, in turn, is leading to a reappraisal of the very notion of human nature. However, neuroscientists have just begun to unravel the secrets of the brain. In a sense, we are in the same position as sixteenth-century scientist Galileo Galilei when he first pointed his spyglass at the night sky to scrutinize the cosmos and better define the place of man in the wider perspective. Just like Galileo peered into the depths of the sky to see new worlds with the help of his telescope, we can now peer into the brain to see the living patterns of the mind in action with the help of increasingly more ingenious tools. In fact, neuroimaging gives us the privilege to see and analyze pictures of a hidden world – the inner life of the brain – that was until recently paradoxically inaccessible, despite its near and intimate location.

Neuroscientists are the privileged explorers of this vast landscape, and as a result of their investigations, they have realized that the fabric of mind is deeply complex, sometimes bewildering, but also extremely fascinating. During the last 25 years, they have been able to produce images of almost every nook and cranny of the brain, thereby collecting a wealth of data on the whole spectrum of mental functions. Among all cognitive functions, consciousness is arguably the one which has gained the highest interest and attention, because of its implications for the individual's presence of self, as well as human culture and society. What is progressively coming into view from the neuroscientific studies of consciousness is that this essential property of human nature seems to behave like a temporal glue that keeps together information processed by different neural subsystems, in order to construct a unified and coherent flow of sensations, thoughts, and feelings. We can realize how delicate and multifaceted this process is when the conscious glue is disrupted or altered in

specific pathologies of the brain. Particularly in regard to the study of the pathological and altered states of consciousness, brain imaging proves to be an invaluable tool for guiding paradigm shifts in neuroscience research for the new millennium.

The aim of this book is to provide the reader with the state of the art in the field of neuroimaging studies of consciousness. The book is divided into four parts, in order to minimize overlap between highly interlinked topics. Part I is an introductory tour of the historical, theoretical, and methodological aspects of the application of neuroimaging to consciousness studies. Parts II–IV focus on the role of neuroimaging in shedding light on the clinically relevant alterations of consciousness across neuropsychiatric conditions: epilepsy (Part II); coma, sleep, and anesthesia (Part III); and other neuropsychiatric disorders associated with alterations of consciousness (Part IV).

Part I is an overview of brain imaging and pathologies of consciousness. The part opens with a chapter by Nani, Seri, and Cavanna on *Consciousness and Neuroscience*, which outlines the recent historical background of the modern scientific approach to the study of consciousness by using ever more sophisticated neuroimaging techniques. The Chap. 2 (*Consciousness: Theoretical Approaches*), by Bayne and Hohwy, reviews some of the central theoretical challenges confronting the search for the neural correlates of consciousness and develops a conceptual framework for tackling these challenges. Chap. 3 (*Functional Brain Imaging and Consciousness*, by Bagshaw and Khalsa) introduces the reader to a consistent observation in brain imaging studies of altered conscious states: the modification of activity and functional connectivity in distributed cortical and subcortical networks. These findings have led to the description of specific perturbation in resting-state networks (especially the so-called default mode network) across a range of pathologies of consciousness.

Part II discusses brain imaging and alterations of consciousness in epilepsy, beginning with a chapter on neuroimaging and mechanisms of impaired consciousness in focal temporal lobe epilepsy (*Temporal Lobe Seizures* by Furman and Blumenfeld). Next is a chapter on localized components of consciousness which may be selectively impaired and analyzed through functional neuroimaging in absence epilepsy (*Absence Seizures* by Gotman and Kostopoulos). This is followed by a chapter on cortical and subcortical changes in generalized tonic-clonic seizures identified through neuroimaging (*Brain Imaging and Alterations of Consciousness in Epilepsy: Generalized Tonic-Clonic Seizures* by Paige and Cavanna). Part II concludes with a chapter on intracranial electroencephalography and pathological synchrony in partial seizures (*Consciousness, Epilepsy and Intracranial EEG* by McGonigal and Bartolomei).

Part III discusses imaging and alterations of consciousness in coma, sleep, and anesthesia. This part opens with a chapter entitled *Neuroimaging of Consciousness in the Vegetative and Minimally Conscious States*, reviewing studies on residual brain function in very severe pathological alterations of consciousness, by Schnakers, Laureys, and Boly. These studies emphasize the critical role of frontoparietal network connectivity for the emergence of conscious awareness. Next, physiological alterations of consciousness, encompassing sleep and dreaming, are being extensively discussed in terms of neural mechanisms assessed by EEG, PET, fMRI, and TMS-EEG measurements (*Sleep and Consciousness*, by Nir, Massimini, Boly, and

Tononi). Finally, changes in brain function during pharmacological alterations of consciousness as seen in general anesthesia are being presented (*Anesthesia*, by Bonhomme, Boveroux, and Brichant).

Part IV closes the book with three chapters on relatively novel and promising applications of neuroimaging to neuropsychiatric conditions characterized by altered consciousness. Chap. 11 (*Neuroimaging Studies of Interoception and Self-Awareness*, by Garfinkel, Nagai, Seth, and Critchley) explores the insights gained from neuroimaging studies into the brain substrates and mechanisms underlying metacognitive aspects of consciousness which allow the mental representation of the body and self-recognition. In Chap. 12 (*Neuroimaging of Functional Neurological Symptoms*), Carson, Edwards, and Stone illustrate the new era of structural and functional brain imaging studies of conversion disorder, or functional neurological symptoms. The unconscious/subconscious production of symptoms resembling the consequences of organic neurological pathology has been a medical conundrum for centuries, and neuroimaging holds promise in unraveling psychophysiological mechanisms which have proven elusive to previous investigation techniques. The final chapter (*Neuroimaging Studies of the Dwindling Self: Neurodegenerative Dementias*, by Nani and Cavanna) focuses on the link between disrupted anatomical and functional networks and the progressive loss of the sense of self which accompanies different forms of neurodegenerative dementias. These are arguably among the pathologies of consciousness where new developments in the technology of in vivo neuroimaging can more directly translate into clinically relevant applications.

We hope that this book will provide the reader with novel concepts and insightful ideas, in addition to up-to-date information from the leaders in their fields. The present renaissance of consciousness studies is likely to persist and reverberate in the future decades because of their crucial clinical applications and intrinsic fascination. The enterprise inaugurated by Galileo with his telescope is continued by the modern explorers of the mysteries of consciousness, as increasingly more sophisticated brain imaging techniques are getting closer to provide us with the ultimate picture of human nature.

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