Preface

In the past two decades, a plethora of magnetic resonance (MR) techniques have rapidly evolved to become indispensable in studies of the human brain in health and disease by providing otherwise unavailable measurement capabilities. This avalanche of methodological developments was, to a large extent, initiated with the introduction of functional magnetic resonance imaging (fMRI), using endogenous deoxygenated hemoglobin contrast in 1992. fMRI provides the ability to indirectly map neuronal activity noninvasively in animal and human brains. Early results depicting images of increased neuronal activity in the human brain came from work conducted at the University of Minnesota, Massachusetts General Hospital and University of Wisconsin, Milwaukee. Subsequent to its introduction, fMRI evolved at a rapid pace, propelled by initiatives undertaken in many research centers and laboratories to understand the basic mechanisms underlying the MR-detected functional mapping signals, improve instrumentation, image acquisition, and image reconstruction methods, enhance detection sensitivity and accuracy, develop evermore complex analysis approaches to exploit the data maximally, and design increasingly sophisticated experiments to probe the unique capabilities of the human brain. In this book, we have asked some of the leaders in each of these areas that define the contemporary state of fMRI, including the individuals whose early work introduced fMRI, to review, explain, and discuss the state of their respective areas and peer into the future. The book also contains selected applications of the methodology that probe the brain at several different spatial scales dictated by its complex architecture and organization.

After the first section recalling the history of the invention of fMRI (Chaps. 1–3), the physiological and anatomical underpinnings of fMRI are reviewed (Chaps. 4–6). As fMRI is not a direct measure of neuronal activity, these chapters provide the background knowledge on the underlying brain processes (namely neurovascular coupling and electrophysiology) and anatomical correlates of fMRI activity. In the next section (Chaps. 7–14), the fMRI acquisition and modeling methods are introduced. Besides the standard gradient- and spin-echo fMRI acquisitions, there are many fMRI methods measuring alternative contrasts, such as cerebral blood flow and volume, modeling schemes to quantify tissue parameters, such as cerebral metabolic rate of oxygen, and deducing brain connectivity. The last chapter of this section on

resting-state fMRI provides the bridge to fMRI applications (Chaps. 15–22). The success of fMRI was largely due to the possibility to noninvasively study cognitive systems, which was previously a domain of cognitive psychology, by delivering the neuronal correlates of visual and auditory perception, of sensation and motor execution and of high-cognitive processes such as decision-making. In addition, fMRI has entered the fields of clinical and animal research. Note that it is not possible within a volume of an fMRI book to cover all fields of fMRI applications. The interested reader is referred to specialized books on these topics. The last section of this book (Chaps. 23–30) reviews emerging fMRI approaches and applications, such as genetics and fMRI, multimodal imaging, multivariate decoding, high-field fMRI, spectroscopy, and smart contrast agents, beyond the mainstream of current research and ends with a speculative outlook on the future of fMRI.

This book is a witness to the large progress made in the past two decades in probing brain activity at various spatial scales and specificity. For example, neuronal clusters with similar and highly specialized and elementary response properties have been traditionally investigated in animal models using numerous different invasive approaches (e.g., electrophysiology, optical imaging, etc.); however, continued developments of the noninvasive functional and morphological imaging capabilities with MR make this work increasingly possible directly in humans. At the second, larger spatial scale, the focus is on identifying interacting ensembles of such functionally distinct computational clusters and the neural circuits that connect them to account for mental activities and behavior. The methodological developments in fMRI in its approximately two decades of lifetime have provided critical and often pioneering contributions to research at this scale.

Putting this volume together owes its origins not only to the prominent and unparalleled space occupied by fMRI in studying the human brain but also to a get together of the three editors in Germany. One of the editors (L. Berliner) at the time was on a sabbatical in Berlin. Uğurbil, after having given a lecture on fMRI at a workshop in Berlin was happily trapped there due to the volcanic eruptions in Iceland that led to the cancellation of all flights over northern Europe. Uludağ, who is a true Berliner (of Istanbul origin), was visiting his family. The plan for the book was hatched at a breakfast meeting at a coffee shop in Berlin Mitte.

Kâmil Uludağ
The Netherlands

http://www.springer.com/978-1-4899-7590-4

fMRI: From Nuclear Spins to Brain Functions
Uludağ, K.; Uğurbil, K.; Berliner, L. (Eds.)
2015, XVIII, 929 p. 235 illus., 179 illus. in color.,
Hardcover
ISBN: 978-1-4899-7590-4