Handbook of Functional MRI Data Analysis

Functional magnetic resonance imaging (fMRI) has become the most popular method for imaging brain function. *Handbook of Functional MRI Data Analysis* provides a comprehensive and practical introduction to the methods used for fMRI data analysis. Using minimal jargon, this book explains the concepts behind processing fMRI data, focusing on the techniques that are most commonly used in the field. This book provides background about the methods employed by common data analysis packages including FSL, SPM, and AFNI. Some of the newest cutting-edge techniques, including pattern classification analysis, connectivity modeling, and resting state network analysis, are also discussed.

Readers of this book, whether newcomers to the field or experienced researchers, will obtain a deep and effective knowledge of how to employ fMRI analysis to ask scientific questions and become more sophisticated users of fMRI analysis software.

Dr. Russell A. Poldrack is the director of the Imaging Research Center and professor of Psychology and Neurobiology at the University of Texas at Austin. He has published more than 100 articles in the field of cognitive neuroscience, in journals including *Science, Nature, Neuron, Nature Neuroscience*, and *PNAS*. He is well known for his writings on how neuroimaging can be used to make inferences about psychological function, as well as for his research using fMRI and other imaging techniques to understand the brain systems that support learning and memory, decision making, and executive function.

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Preface

Functional magnetic resonance imaging (fMRI) has, in less than two decades, become the most commonly used method for the study of human brain function. FMRI is a technique that uses magnetic resonance imaging to measure brain activity by measuring changes in the local oxygenation of blood, which in turn reflects the amount of local brain activity. The analysis of fMRI data is exceedingly complex, requiring the use of sophisticated techniques from signal and image processing and statistics in order to go from the raw data to the finished product, which is generally a statistical map showing which brain regions responded to some particular manipulation of mental or perceptual functions. There are now several software packages available for the processing and analysis of fMRI data, several of which are freely available.

The purpose of this book is to provide researchers with a sophisticated understanding of all of the techniques necessary for processing and analysis of fMRI data. The content is organized roughly in line with the standard flow of data processing operations, or processing stream, used in fMRI data analysis. After starting with a general introduction to fMRI, the chapters walk through all the steps that one takes in analyzing an fMRI dataset. We begin with an overview of basic image processing methods, providing an introduction to the kinds of data that are used in fMRI and how they can be transformed and filtered. We then discuss the many steps that are used for preprocessing fMRI data, including quality control, correction for various kinds of artifacts, and spatial smoothing, followed by a description of methods for spatial normalization, which is the warping of data into a common anatomical space. The next three chapters then discuss the heart of fMRI data analysis, which is statistical modeling and inference. We separately discuss modeling data from fMRI timeseries within an individual and modeling group data across individuals, followed by an outline of methods for statistical inference that focuses on the severe multiple test problem that is inherent in fMRI data. Two additional chapters focus on methods for analyzing data that go beyond a single voxel, involving either the modeling of connectivity between regions or the use of machine learning techniques to model multivariate patterns in the data. The final chapter discusses approaches for the visualization of the complex data that come out of fMRI analysis. The appendices provide background about the general linear model, a practical guide to the organization of fMRI data, and an introduction to imaging data file formats.

The intended audience for this book is individuals who want to understand fMRI analysis at a deep conceptual level, rather than simply knowing which buttons to push on the software package. This may include graduate students and advanced undergraduate students, medical school students, and researchers in a broad range of fields including psychology, neuroscience, radiology, neurology, statistics, and bioinformatics. The book could be used in a number of types of courses, including graduate and advanced undergraduate courses on neuroimaging as well as more focused courses on fMRI data analysis.

We have attempted to explain the concepts in this book with a minimal amount of mathematical notation. Some of the chapters include mathematical detail about particular techniques, but this can generally be skipped without harm, though interested readers will find that understanding the mathematics can provide additional insight. The reader is assumed to have a basic knowledge of statistics and linear algebra, but we also provide background for the reader in these topics, particularly with regard to the general linear model.

We believe that the only way to really learn about fMRI analysis is to do it. To that end, we have provided the example datasets used in the book along with example analysis scripts on the book's Web site: http://www.fmri-data-analysis.org/.

Although our examples focus primarily on the FSL and SPM software packages, we welcome developers and users of other packages to submit example scripts that demonstrate how to analyze the data using those other packages. Another great way to learn about fMRI analysis is to simulate data and test out different techniques. To assist the reader in this exercise, we also provide on the Web site examples of code that was used to create a number of the figures in the book. These examples include MATLAB, R, and Python code, highlighting the many different ways in which one can work with fMRI data.

The following people provided helpful comments on various chapters in the book, for which we are very grateful: Akram Bakkour, Michael Chee, Joe Devlin, Marta Garrido, Clark Glymour, Yaroslav Halchenko, Mark Jenkinson, Agatha Lenartowicz, Randy McIntosh, Rajeev Raizada, Antonio Rangel, David Schnyer, and Klaas Enno Stephan. We would also like to thank Lauren Cowles at Cambridge University Press for her guidance and patience throughout the process of creating this book.