# Preface

The study of brain function is one of the most fascinating pursuits of modern science. Functional neuroimaging is an important component of much of the current research in cognitive, clinical, and social psychology. The excitement of studying the brain is recognized in both the popular press and the scientific community. In the pages of mainstream publications, including *The New York Times* and *Wired*, readers can learn about cutting-edge research into topics such as understanding how customers react to products and advertisements ("If your brain has a 'buy button,' what pushes it?", *The New York Times*, October 19, 2004), how viewers respond to campaign ads ("Using M.R.I.'s to see politics on the brain," *The New York Times*, April 20, 2004; "This is your brain on Hillary: Political neuroscience hits new low," *Wired*, November 12, 2007), how men and women react to sexual stimulation ("Brain scans arouse researchers," *Wired*, April 19, 2004), distinguishing lies from the truth ("Duped," *The New Yorker*, July 2, 2007; "Woman convicted of child abuse hopes fMRI can prove her innocence," *Wired*, November 5, 2007), and even what separates "cool" people from "nerds" ("If you secretly like Michael Bolton, we'll know," *Wired*, October 2004). Reports on pathologies such as autism, in which neuroimaging plays a large role, are also common (for instance, a *Time* magazine cover story from May 6, 2002, entitled "Inside the world of autism"). The 1990s were designated "The Decade of the Brain" by the National Institute of Mental Health and the Library of Congress; the 2003 Nobel Prize in Medicine was awarded for research that lies at the foundation of functional magnetic resonance imaging (fMRI), one of the most prevalent and popular tools used for studying brain function.

Statisticians have a key role to play in this research, since the data that are obtained from these studies are remarkably complex (correlated in time and in space in ways that are still not fully understood) and massive (a typical number might be hundreds of thousands of time series for a single subject, one for each "voxel," or volume element, of the brain). The number of subjects on the other hand is generally small, a situation that creates challenges for statistical inference. Statisticians have already made many important contributions

to the field, and as more universities set up imaging centers of their own, the presence of on-site statistical experts becomes more important. Obtaining the necessary background in neuroimaging and neuroscience, however, can take many years of intense study. My goal in writing this book was to provide an introduction to functional magnetic resonance imaging, aimed at statisticians, that would highlight the important scientific issues and survey the common (and some not so common) analysis pathways.

The primary intended audience is statisticians who are interested in this growing field and who wish to gain an understanding of the major problems and current solutions. A secondary audience is cognitive psychologists and other neuroscientists who use fMRI as a research tool. This book can also serve them as a summary of the major statistical questions in the analysis of functional neuroimaging data and of the commonly used methods. Readers need only be familiar with basic graduate level statistics – linear models, general and generalized linear models, nonparametric statistics, Bayesian theory, and the like.

The first three chapters of this book give the scientific background: a brief introduction of how fMRI data are acquired appears in Chapter 1, followed by chapters on experimental design and data preprocessing. Chapter 4 is a "bridge" chapter, summarizing the major statistical issues and setting the stage for the core of the book, chapters 5 through 10. These chapters describe the various statistical approaches that have been taken for analyzing fMRI data, from the popular general linear model (Chapter 5), through spatiotemporal models (Chapter 6), multivariate approaches (Chapter 7), analyses using basis functions (Chapter 8), and Bayesian analysis (Chapter 9). Chapter 10 covers the important problem of multiple testing in fMRI. Chapter 11 is the other end of the "bridge" connecting to Chapter 4 – a look back at additional statistical questions in light of the knowledge acquired in the previous chapters. Finally, Chapter 12 presents analysis of a real data set as a simple case study.

It is worth emphasizing that no book of this nature can ever be completely comprehensive, nor can it be totally current. The pace of statistical research and innovation is such that, almost by definition, such a book would be out of date before it could be published. I have aimed instead to give readers an overview, with some detail, of the most commonly used methods, sprinkled with an accounting of some of the more idiosyncratic approaches. In this way I hope to show the richness and creativity of existing statistical analyses and make new researchers aware of what has already been attempted.

I have been fortunate in my more than ten years of working in this field to have learned from and interacted with many talented statisticians and psychologists. My thanks go to Jeongyoun Ahn, Jim Becker, Yoav Benjamini, Dulal Bhaumik, DuBois Bowman, Pat Carpenter, Bill Eddy, Chris Genovese, Robert Gibbons, Marcel Just, Ming-Hung (Jason) Kao, Tim Keller, Christine Krisky, Yehua Li, Beatriz Luna, Jennifer McDowell, Rebecca McNamee, Abhyuday Mandal, Stephen Miller, Ana Moura, Tom Nichols, Todd Ogden,

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