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# Analysis of Neural Data

Springer

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*To our families*

# Preface

This book serves as a guide and reference for anyone who wishes to understand analysis of neural data generated from studies that range from molecules, to circuits, to systems, to behavior.

Its origins may be traced to the decision by two of us (E.N.B. and R.E.K.), in 1998, to write a review article on statistical analysis of spike train data. Shortly after commencing we realized that some of the methods we thought we ought to be reviewing had, in fact, not yet been developed. After we and others rectified this situation, we published a pair of reviews (Brown et al. 2004; Kass et al. 2005). During this time we also broadened our interests to other experimental modalities, such as neuroimaging, and we began teaching workshops and semester-long courses on statistical methods for neuroscience. In addition, we met the third author of this book (U.E.), who came to share our interests in research and pedagogy (and who pursued his Ph.D. thesis under the guidance of E.N.B.).

It became clear that a book on this subject was desperately needed, and we agreed to write one. While this turned into a longer project than we anticipated, numerous research collaborations, conversations with colleagues at meetings, and extensive comments from students gave us many insights into the content and presentation of the principles and techniques that evolved to form this volume. We feel we are much wiser than when we started, and we hope we have succeeded in imparting a good deal of what we have learned in the process.

Some readers may expect a book organized by type of neural data. We decided, instead, to organize by analysis, with each chapter devoted to broadly categorized statistical concepts described succinctly in section headings that are available in the extended version of the table of contents. Each chapter, however, also contains multiple examples of the way these analytical ideas have been used in the brain sciences: there are more than 100 such examples throughout the book, and they are indexed. A reader wishing to see how we have discussed fMRI data, for instance, should start with the example index. More specific organizational guidelines are given in Chapter 1.

The book is intended as either a reference, or a text. R.E.K. has used preliminary versions of the manuscript in classes populated by graduate students of varying backgrounds, ranging from biologists with minimal mathematical knowledge, who were looking for conceptual understanding, to engineers, who needed to see derivations. We opted to try to satisfy both kinds of audiences.

An appendix is provided as a reminder of key mathematical ideas, and derivations are often marked as optional by indenting them. To those who wish to use the book as a text, R.E.K. would suggest the following ordering of topics:

Part I (Elementary Statistics): Chapters 1–7, 10, 12.1–12.4, 13.1.

Part II (Basic Statistical Theory): Chapters 8, 9, 11, 12.5, 13.2–13.4.

Part III (Advanced Topics): Selections from Chapters 14–19.

In his experience, Parts I and II take approximately 12 and 7 classes, respectively.

Many readers will want to see computer code for the methods we have described. We ourselves used both Matlab and R to produce figures. Although we decided not to inject Matlab or R code into the body of the book, we have put code up on our the website http://www.stat.cmu.edu/~kass/KEB.

In addition to the many colleagues and students who made suggestions along the way, including those who are acknowledged within the text, we are indebted to Spencer Koerner, who helped clean up and create much code and many figures, Patrick Foley, who created the website, Heidi Sestrich, who fixed numerous defects in our LATEX, and Matthew Marler, who read the whole manuscript carefully and provided extremely helpful comments. We are also grateful to Elan Cohen and Ryan Sieberg, who each created several figures.

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