

This Book's Organization

Read Me First!

CONTENTS

1.1	Real People Can Read This Book	1
1.2	Prerequisites.....	2
1.3	The Organization of This Book	3
1.3.1	<i>What Are the Essential Chapters?</i>	4
1.3.2	<i>Where's the Equivalent of Traditional Test X in This Book?</i>	4
1.4	Gimme Feedback (Be Polite)	6
1.5	Acknowledgments.....	6

Oh honey I'm searching for love that is true,
 But driving through fog is so dang hard to do.
 Please paint me a line on the road to your heart,
 I'll rev up my pick up and get a clean start.

1.1 REAL PEOPLE CAN READ THIS BOOK

This book explains how to actually *do* Bayesian data analysis, by real people (like you), for realistic data (like yours). The book starts at the basics, with notions of probability and programming, then progresses to advanced hierarchical models that are used in realistic data analysis. In other words, you do not need to already know statistics and programming. This book is speaking to a first-year graduate student or advanced undergraduate in the social or biological sciences: someone who grew up in Lake Wobegon,¹ but who is not the

¹A popular weekly radio show on National Public Radio, called *A Prairie Home Companion*, features fictional anecdotes about a small town named Lake Wobegon. The stories, written and orated by Garrison Keillor, always end with the phrase, "And that's the news from Lake Wobegon, where all the women are strong, all the men are good looking, and all the children are above average." So, if you grew up there, . . .

mythical being who has the previous training of a nuclear physicist and then decided to learn about Bayesian statistics.

This book provides broad coverage and ease of access. Section 1.3 describes the contents in a bit more detail, but here are some highlights. This book covers Bayesian analogues of all the traditional statistical tests that are presented in introductory statistics textbooks, including *t*-tests, analysis of variance (ANOVA), regression, chi-square tests, and so on. This book also covers crucial issues for *designing* research, such as statistical power and methods for determining the sample size needed to achieve a desired research goal. And you don't need to already know statistics to read this book, which starts at the beginning, including introductory chapters about concepts of probability and an entire chapter devoted to Bayes' rule. The important concept of hierarchical modeling is introduced with unique simple examples, and the crucial methods of Markov chain Monte Carlo sampling are explained at length, starting with simple examples that, again, are unique to this book. Computer programs are thoroughly explained throughout the book and are listed in their entirety, so you can use and adapt them to your own needs.

But wait, there's more. As you may have noticed from the beginning of this chapter, the chapters commence with a stanza of elegant and insightful verse composed by a famous poet. The quatrains² are formed of dactylic³ tetrameter⁴ or, colloquially speaking, "country waltz" meter. The poems regard conceptual themes of the chapter via allusion from immortal human motifs often expressed by country western song lyrics, all in waltz timing.

If you do not find them to be all that funny,
if they leave you wanting back all of your money,
well honey some waltzing's a small price to pay,
for all the good learning you'll get if you stay.

1.2 PREREQUISITES

There is no avoiding mathematics when doing statistics. On the other hand, this book is definitely not a mathematical statistics textbook in that it does not emphasize theorem proving, and any mathematical statistician would be totally bummed at the informality, dude. But I do expect that you are coming to this book with a dim knowledge of basic calculus. For example, if you

²*quatrain* [noun]: Four lines of verse. (Unless it's written "*qua* train," in which case it's a philosopher comparing something to a locomotive.)

³*dactylic* [adj.]: A metrical foot in poetry comprising one stressed and two unstressed syllables. (Not to be confused with a pterodactyl, which was a flying dinosaur and which probably sounded nothing like a dactyl unless it fell from the sky and bounced twice: THUMP-bump-bump.)

⁴*tetrameter* [noun]: A line of verse containing four metrical feet. (Not to be confused with a quadraped, which has four feet but is averse to lines.)

understand expressions like $\int dx x = \frac{1}{2}x^2$, you're probably good to go. Notice the previous sentence said "understand" the statement of the integral, not "generate" the statement on your own! When mathematical derivations are helpful for understanding, they will usually be presented with a thorough succession of intermediate steps, so you can actually come away feeling secure and familiar with the trip and destination rather than just feeling car sick after being thrown blindfolded into the trunk and driven around curves at high speed.

The beginnings of your journey will go more smoothly if you have had some basic experience programming a computer, but previous programming experience is not crucial. A computer program is just a list of commands that the computer can execute. For example, if you've ever typed an "=" in an Excel spreadsheet cell, you've written a programming command. If you've ever written a list of commands in Basic or Pascal or Java or any other language, then you're set. We will be using a language called *R*, which is *free*. More on R later.

1.3 THE ORGANIZATION OF THIS BOOK

This book has three major parts. The first part covers foundations: the basic ideas of probabilities, models, Bayesian reasoning, and programming in R.

The second main part covers all the crucial ideas of modern Bayesian data analysis while using the simplest possible type of data, namely, dichotomous data such as agree/disagree, remember/forget, male/female, and the like. Because the data are so simplistic, the focus can be on the Bayesian techniques. In particular, the modern techniques of "Markov chain Monte Carlo" (MCMC) are explained thoroughly and intuitively. And the ideas of hierarchical models are thoroughly explored. Because the models are kept simple in this part of the book, intuitions about the meaning of hierarchical dependencies can be developed in glorious graphic detail. This second part of the book also explores methods for planning how much data will need to be collected to achieve a desired degree of precision in the conclusions. This is called *sample size planning* or *power analysis*.

The third main part of the book applies the Bayesian methods to realistic data. The applications are organized around the type of data being analyzed, and the type of measurements that are used to explain or predict the data. For example, suppose you are trying to predict college grade point average (GPA) from high school Scholastic Aptitude Test (SAT) score. In this case the data to be predicted, the GPAs, are values on a *metric* scale, and the predictor, the SAT scores, are also values on a *metric* scale. Suppose, on the other hand, that you are trying to predict college GPA from gender. In this case the predictor is a *dichotomous* value, namely, male versus female. Different types of measurement scales require different types of mathematical models, but otherwise the

AQ:1

underlying concepts are always the same. Table 14.1 (p. ~~xxx~~) shows various combinations of measurement scales and their corresponding models that are explored in detail in the third part of this book.

1.3.1 What Are the Essential Chapters?

The foundations established in the first part of the book, and the Bayesian ideas of the second part, are important to understand. The applications to particular types of data, in the third part, can be more selectively perused as needed. Within those parts, however, some chapters are essential:

- Chapter 4 explains Bayes' rule.
- Chapter 7 explains Markov chain Monte Carlo methods.
- Chapter 9 explains hierarchical models.
- Chapter 14 overviews the generalized linear model and various types of data analyses that can be conducted.

As an emphasis of the book is *doing* Bayesian data analysis, it is also essential to learn the programming languages R and BUGS:

- Section 2.3 introduces R.
- Section 7.4 introduces BUGS.

Finally, the ultimate purpose of data analysis is to convince other people that their beliefs should be altered by the data. The results need to be communicated to a skeptical audience, and therefore additional essential reading is as follows:

- Section 23.1 summarizes how to report a Bayesian data analysis.

Another important topic is the planning of research, as opposed to the analysis of data after they have been collected. Bayesian techniques are especially nicely suited for estimating the probability that specified research goals can be achieved as a function of the sample size for the research. Therefore, although it might not be essential on a first reading, it is essential eventually to read the following:

- Chapter 13 regarding power analysis.

Figure 1.1 puts these recommendations in a convenient reference box, rearranged to match the order presented in the book.

1.3.2 Where's the Equivalent of Traditional Test X in This Book?

Because many readers will be coming to this book after having already been exposed to traditional 20th-century statistics that emphasize null hypothesis significance testing (NHST), this book provides Bayesian approaches to the

- Section 2.3 introduces R.
- Chapter 4 explains Bayes' rule.
- Chapter 7 explains Markov chain Monte Carlo methods.
- Section 7.4 introduces BUGS.
- Chapter 9 explains hierarchical models.
- Chapter 13 explains varieties of power analysis.
- Chapter 14 overviews the generalized linear model and various types of data analyses that can be conducted.
- Section 23.1 summarizes how to report a Bayesian data analysis.

FIGURE 1.1

Essential sections of the book.

Table 1.1 Bayesian Analogues of 20th-Century Null Hypothesis Significance Tests

Traditional Analysis Name	Bayesian Analogue
<i>t</i> -test for a single mean	Chapter 15
<i>t</i> -test for two independent groups	Chapter 18 (Section 18.3)
Simple linear regression	Chapter 16
Multiple linear regression	Chapter 17
Oneway ANOVA	Chapter 18
Multifactor ANOVA	Chapter 19
Logistic regression	Chapter 20
Ordinal regression	Chapter 21
Binomial test	Chapters 5 to 9, 20
Chi-square test (contingency table)	Chapter 22
Power analysis (sample size planning)	Chapter 13

usual topics in NHST textbooks. Table 1.1 lists various tests covered by standard introductory statistics textbooks, along with their Bayesian analogues. If you have been previously contaminated by NHST but want to know how to do an analogous Bayesian analysis, Table 1.1 may be useful.

A superficial conclusion from Table 1.1 might be, “Gee, the table shows that traditional statistical tests do something analogous to Bayesian analysis in every case: therefore, it’s pointless to bother with Bayesian analysis.” Such a conclusion would be wrong. First, traditional NHST has deep problems, some of which are discussed in Chapter 11. Second, Bayesian analysis yields richer and more informative inferences than NHST, as will be shown in numerous examples throughout the book.

1.4 GIMME FEEDBACK (BE POLITE)

I have worked thousands of hours on this book, and I want to make it better. If you have suggestions regarding any aspect of this book, please do e-mail me: JohnKruschke@gmail.com. Let me know if you've spotted egregious errors or innocuous infelicities, typos, or thoughtos. Let me know if you have a suggestion for how to clarify something. Especially let me know if you have a good example that would make things more interesting or relevant. I'm also interested in complete raw data from research that is interesting to a broad audience and that can be used with acknowledgment but without fee. Let me know also if you have more elegant programming code than what I've cobbled together. The outside margins of these pages are intentionally made wide so that you have room to scribble your ridicule and epithets before rephrasing them into kindly stated suggestions in your e-mail to me. Rhyming couplets are especially appreciated. If I don't respond to your e-mail in a timely manner, it is only because I can't keep up with the deluge of fan mail, not because I don't appreciate your input. Thank you in advance!

1.5 ACKNOWLEDGMENTS

This book has been six years in the making, and many colleagues and students have provided helpful comments. The most extensive comments have come from Drs. Luiz Pessoa, Mike Kalish, Jerry Busemeyer, and Adam Krawitz; thank you all! Particular sections were insightfully improved by helpful comments from Drs. Michael Erickson, Robert Nosofsky, Geoff Iverson and James L. (Jay) McClelland. Various parts of the book benefited indirectly from communications with Drs. Woojae Kim, Charles Liu, Eric-Jan Wagenmakers, and Jeffrey Rouder. Leads to data sets were offered by Drs. Teresa Treat and Michael Trosset, among others. Very welcome supportive feedback was provided by Dr. Michael Lee, and also by Dr. Adele Diederich. Many colleagues provided a Bayesian-supportive working environment, including Drs. Richard Shiffrin, Jerome Busemeyer, Peter Todd, James Townsend, Robert Nosofsky, and Luiz Pessoa. Other department colleagues have been supportive of integrating Bayesian statistics into the curriculum, including Drs. Linda Smith and Amy Holtzworth-Munroe. Various teaching assistants have provided helpful comments; in particular I especially thank Drs. Noah Silbert and Thomas Wisdom for their excellent assistance. As this book has evolved over the years, suggestions have been contributed by numerous students, including Aaron Albin, Thomas Smith, Sean Matthews, Thomas Parr, Kenji Yoshida, Bryan Bergert, and perhaps dozens of others who have contributed insightful questions or comments that helped me tune the presentation in the book. To all the people who have made suggestions but whom I have inadvertently forgotten to mention by name, I extend my apologies and appreciation.

Author Query:

AQ:1 Please confirm the page number.