Statistics for the Social Sciences

A General Linear Model Approach

Second Edition

The second edition of *Statistics for Social Sciences* prepares students from a wide range of disciplines to interpret and learn the statistical methods critical to their field of study. By using the General Linear Model (GLM), the author builds a foundation that enables students to see how statistical methods are interrelated, enabling them to build on the basic skills. The author makes statistics relevant to students' varying majors by using fascinating real-life examples from the social sciences. Students who use this edition will benefit from clear explanations, warnings against common erroneous beliefs about statistics, and the latest developments in the philosophy, reporting, and practice of statistics in the social sciences. The textbook is packed with helpful pedagogical features including learning goals, guided practice, and reflection questions.

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For Katie.

The likelihood of finding a woman as wonderful as her is $p = .000001$.

Contents

Preface

If you had told me when I was 18 years old that I would write a statistics textbook, I would have laughed. Sitting in that first statistics course a decade and a half ago as an undergraduate psychology major, I struggled with the concepts that my professor was teaching. I didn't understand why statistical methods were relevant to my major or my career goals. The terminology was difficult, and the explanations that I received were confusing. I tried my hardest, and I passed the course – but not with an impressive grade. My goal in writing this textbook is to help students in the social sciences avoid the unpleasant experience I had in my first statistics course. I've had years to think about what went wrong in the course, and I have designed this textbook to help students have the best possible introduction to statistics.

Decades of research in educational and cognitive psychology have shown that students learn more material when they have a way to organize what they are expected to learn. I have therefore given students and instructors a way to think about statistical methods called the general linear model (GLM). The GLM underlies most of the statistical analyses that are used in social science research, and having this general framework of understanding statistics will avoid the tendency of students to see statistics as a disconnected set of procedures. My hope is that the GLM can help students understand statistical methods so that their commonalities and differences make sense.

Another common finding in the research on learning is that students retain more knowledge when the material is relevant to them. Whenever possible, I have used examples of real data from across the social sciences to illustrate statistical concepts. Empirical research suggests that using real data to teach statistical concepts increases student learning (e.g., Allen & Baughman, 2016). I also believe that using real data shows students how the equations and theory of statistics have been used to create real knowledge in their fields. Additionally, examples from the actual work in the social sciences are far more likely to be interesting and relevant to students than the made-up examples that my professor gave me when I was an undergraduate.

My final goal with this textbook is to reduce anxiety for students. When I took my first statistics course (and the second and the third), I was overwhelmed. Statistics was intimidating, and my anxiety made it more difficult to learn what I was supposed to. To avoid this, I have made several efforts to make statistics accessible and manageable for students. First, I have made explanations simple and straightforward. Technical terminology is defined clearly, and a glossary in the back of the book provides an easy reference for students. Second, because formulas can be intimidating for some students, every formula is labeled, and the various symbols are explained. There is also a reference guide for important formulas at the end of the book. In this text I have tried to show why the formulas are set up in the way that they are and how they are linked with their interpretation. Finally, I have included detailed examples of statistical problems that are worked out step-by-step. By following these examples, students will better understand the steps and interpretation of statistical analyses and be able to solve problems and complete homework assignments more efficiently.

What Makes this Textbook Different

A foundation in the research on student learning. Although I consider myself a quantitative psychologist, my doctoral program was housed in a college of education, and my PhD is in

educational psychology. That means that I am familiar with the research on how people learn, and I have applied this research to the structure and writing of every chapter. Although I rarely make my debt to cognitive and educational psychology explicit, readers can be assured that every decision behind this book was made from an evidence-based perspective.

Teaching statistical concepts the way that experts think about them. Statistical novices see statistics as an unrelated hodgepodge of analysis methods. On the other hand, statistical experts see statistics as being united by general concepts, such as their correlational nature or the universality of effect sizes. Yet, no other author of a textbook for social science undergraduates teaches about these general concepts – most of which are united in the GLM. I think that students will master and retain more material by learning about the GLM in their first statistics course. Moreover, learning the GLM makes future statistical procedures (e.g., nonparametric statistics, multivariate statistics) easier to learn because they are also members of the GLM – albeit more complex members.

Practical application. The use of examples from real studies was made with an eye on showing students how statistics can lead to practical knowledge in the social sciences. Browsing through the book will show that I have included examples from psychology, sociology, family studies, anthropology, education, social work, and more. This is the result of my effort to make statistics relevant to students from a broad cross-section of majors.

Discussion of controversies. For the sake of simplicity, most authors of undergraduate textbooks try to avoid controversies in statistics. I can sympathize with this viewpoint, but I think that it is not beneficial to students. Social science statistics is a field that has been punctuated by periodic controversies for the last 120 years. I believe that avoiding these controversies encourages simplistic thinking and a naive view of statistics. Instead, I feel that undergraduate students can be more nuanced thinkers and more professional in their interpretations if they are aware of some of the disagreements and arguments among professionals. Therefore, I have included discussions of the shortcomings of null hypothesis testing, the interpretation of effect sizes, questionable research practices, and more. I believe that this enlivens the textbook and prepares students for joining the social science community.

For Students

If you are a student using this textbook, there are a few things you can do to improve your performance in your statistics course.

First, make this course a priority. Devote the time and attention necessary to do well in your statistics course. Although I have tried to make this textbook accessible, some concepts are simply counterintuitive or strange, and very few people can grasp the logic and mathematics of statistics without effort. Read the text carefully and with full attention. Cognitive psychologists have shown that human beings can effectively focus attention on only one thing at a time, and it is going to be difficult to learn statistics with any distractions, including the TV, your phone, or social media. Make sure you can devote all your attention to what you are reading.

Second, study carefully. As you read, highlight important sentences. Take notes in the margins, and jot down questions that come to your mind as you read. Coming to class prepared with questions and notes will make you more able to excel in the course. I also recommend that you practice the concepts you read about by working out the questions at the end of each chapter – even if they are not assigned as homework. My students have found these questions to be particularly useful in cementing their understanding of statistical concepts. Test yourself with the questions.

Every chapter has questions that are interspersed throughout the text and a set of questions at the end of the chapter to help you test yourself. Self-testing is a more effective strategy than re-reading (Adesope et al., 2017), and I have given you ample material to help you quiz yourself about what you know about statistics.

Third, participate in class. Ask questions that you have prepared in advance. My experience in teaching statistics is that when a student asks a question, there are almost always classmates who have the same question. Also, don't hesitate to ask your instructor to repeat a concept or to restate it in other words. You won't look stupid – it's just part of learning statistics. When I learn a new statistical concept, I have to hear it stated a few different ways before it "clicks" and makes sense to me. Most of my students are the same.

Fourth, pay close attention to the Guided Examples throughout this textbook and make sure you clearly understand every step of a procedure. Get out a piece of scratch paper and have a go at the Guided Examples to ensure you know how to find the correct answer and aren't just reading passively. This will make homework and tests go more smoothly.

Fifth, even if your instructor does not require you to do so, take advantage of the software guides so that you can learn how to perform statistical procedures with a computer. Learning about the mathematics of statistics is valuable. But the reality of the twenty-first century is that almost all statistical work is done by computer. Using the Software Guides to learn how to perform and interpret statistical procedures will give you a valuable skill. More employers and graduate schools are seeking people who can analyze data, and mastering a software program can give you an advantage when you apply for jobs or graduate school.

Finally, if it has been a long time since you have had to do mathematics or if you have forgotten your algebra, then a basic review may be helpful. I wrote this book expecting that students would have already mastered decimals, fractions, percentages, graphs, linear equations, and basic algebra. If you do not remember these concepts or you need a review, I recommend getting an algebra refresher from Khan Academy (www.khanacademy.org/math/algebra) or from Udacity (www.udacity.com/course/intro-algebra-review–ma004). Your university's tutoring center or your instructor may also be useful resources.

For Instructors

When using this textbook, instructors should be aware of a few things. First, it may be difficult to teach every concept in this textbook during a single semester. So, most instructors will have to select the concepts they teach. A route I recommend is to skip Chapter 9 (paired samples *t*-tests) and Chapter 15 (which serves as a reference guide for students who wish to encounter more complex statistical methods as they read published articles or hope to execute their first research project). Some instructors may also find that their students are sufficiently prepared that they can skip – or cover very quickly – Chapter 3 (central tendency and variability) and Chapter 4 (visual models). Additionally, parts of some chapters can be skipped, such as the trimmed mean (in Chapter 3), the arbitrary nature of axes (at the end of Chapter 5), the null hypothesis testing of correlation coefficients (in Chapter 12), or the last half of Chapter 11, which covers the logic and assumptions of ANOVA and *post hoc* tests. It is not essential for students to master the minutia of every chapter to have a useful understanding of statistical thinking and methods.

Second, even though the chapters are generally arranged in ascending order of complexity of the statistical procedures, some chapters can be taught out of order. Sometimes I prefer to teach Chapters 12 and 13 (correlation and regression) before Chapter 7 (null hypothesis testing and *z*-tests) because one of the basic themes of the GLM is that all statistical procedures examine the relationship between variables. This is easiest to see in a correlation, so I sometimes teach about correlations first in order to show how other procedures are themselves correlational. Other instructors may prefer to teach Chapter 14 (chi-squared tests) before Chapter 11 (ANOVA) and save the complex hand calculations of ANOVA for the end of the semester. I also sometimes teach unpaired-samples *t*-tests (Chapter 10) before paired-samples *t*-tests (Chapter 9) because it makes the concept of paired data easier for students to understand. The point is to be flexible and teach concepts in the order that works best for you and your students.

I have placed boxed texts throughout the book. These contain ideas that are relevant, but that may not be essential to understanding a concept. They range from handy tips (like mnemonic devices and restatements of important material) to discussions of controversies and statistical practices related to the main ideas of the chapter or the book. Instructors may find these boxes useful in generating classroom discussions. Be creative in using these features to increase students' understanding.

Finally, this textbook includes step-by-step guides for conducting statistical analyses using the Statistical Package for the Social Sciences (SPSS) and Microsoft Excel. Although some instructors will prefer to use other programs, I chose these because (1) Microsoft Excel – or very similar spreadsheet programs – will often be available to students after they graduate, and (2) in the social sciences SPSS is one of the most frequent statistical analysis packages that students use in graduate school. I hope that these software guides will make the textbook a useful reference guide for students after they finish their statistics course. Some instructors believe that using statistical software is an important component of an introductory class; this textbook is designed to handle that need, and instructors who wish to emphasize software use will likely concentrate on the software guides and skip the step-by-step calculation found in many chapters. On the other hand, some people believe that it is important to understand the mathematics and theory of statistics in order to interpret computer program output properly. Instructors with this viewpoint will see value in hand calculation while recognizing that computers dominate modern statistical procedures. Additionally, some instructors are forced to emphasize hand calculation for various reasons, such as a lack of computer resources at their institution or an assessment requirement that emphasizes calculation. In my opinion, there are valid reasons to spend time both on hand calculation and on software use. This book is designed to handle both methods of learning statistics.

Changes to the Second Edition

The feedback from students, instructors, and my colleagues about the first edition of this book has been overwhelmingly positive. However, many people gave me suggestions that I have incorporated to make the book stronger. The most noticeable changes in the second edition are:

- Changes to mathematical notation to increase consistency across chapters.
- Improving the discussion and explanation of statistical weights.
- Revisions to Chapter 14 to improve interpretations of effect size and emphasize the importance of nominal dependent variables.

- Incorporating the latest Journal Article Reporting Standards (JARS) from the American Psychological Association.
- Better data in the main example for ANOVA in Chapter 11 and the restriction of range discussion in Chapter 13.
- In Chapter 15, discussing Type I error inflation in examining main effects and interactions in multiple regression and ANOVA.
- A clearer explanation for calculating the interquartile range.
- Switching the order of Chapters 3 and 4.
- Corrections and revisions to some figures.

All these changes have improved the book, and I am thankful for everyone who gave me feedback. It was not possible to incorporate every suggestion that readers made to me, but I hope that the changes I have implemented have made a good book into a better book.

Last Words

This textbook is the textbook that I wish I had had as an undergraduate student. I remember what it was like for statistics to be non-intuitive and confusing. The struggle was not fun, but in an odd way I'm grateful for my negative experience in my first statistics class because it has made me a better teacher today. Hopefully, this book will help students leave the course with a positive view of statistics. If there is anything I can do to improve the book, please contact me at rwarne@uvu.edu or via my website, www.russellwarne.com. I also invite readers and instructors to follow and interact with me on social media. My Twitter handle is @Russwarne, and on Facebook my professional page URL is www.facebook.com/russwarnephd. I would love to hear from my readers.

Have a great semester!

Acknowledgements

Left to my own devices, I could never have produced a textbook of this quality without the input and help of many people. At Cambridge University Press, the acquisitions editor David Repetto convinced me to write this textbook and had faith in a young, untried psychologist. His confidence never wavered, and his belief in my competence was a great source of encouragement when problems arose or when the writing became a challenge. His associates, Claudia Bona-Cohen, Elisa Adams, and Claire Eudall, all provided help and input in drafts of the chapters. Their responses to my drafts and their efficient coordination of the peer reviews of my chapters were immensely helpful in removing inaccuracies. Indeed, I hold a special appreciation for the anonymous peer reviewers – all of whom (even the ones who passionately hated the drafts they read) made suggestions that improved the book greatly. These reviewers saved me from several foolish errors, and my thanks for them know no bounds.

As with any piece of writing, this book is a product of the time in which it was written. The months when I drafted the first edition (March 2014–September 2016) were a particularly fierce time in the "replication crisis" in psychology, a time in which many long-respected findings were brought into question after these studies could not be replicated. Many readers will notice the concern for replicable findings and stable results, which is a result of the debate about replication and the reforms that psychology and the other social sciences are implementing. I appreciate the social and biomedical scientists who have worked tirelessly to make their fields aware of the seriousness of these replication problems. I have tried to incorporate their suggestions into the textbook so that the next generation of students can avoid the mistakes of the past (including some that I have made in my career).

I am also indebted to several colleagues whose ideas have shaped my thinking about statistical issues. Ross Larsen gave me insight into important issues related to the central limit theorem and has been a valued friend and coauthor since my graduate school days. The statistical thinking of my former professors and mentors, including Bruce Thompson and Oi-mon Kwok, is also apparent in most chapters. Several instructors and readers gave me feedback that I found helpful as I made revisions for the second edition, including Carissa Zimmerman, Sam Hardy, Ståle Pallesen, and David C. S. Richard. The discussion on multicollinearity in Chapter 15 was illuminated by correspondence with John Komlos.

One unanticipated influence on the content of the book was Twitter. Ulrich Schimmack, Victoria Savalei, Daniël Lakens, Jelte Wicherts, Uri Simonsohn, Rickard Carlsson, Dorothy Bishop, Jonatan Pallesen, and others provided inspiration and clarification for chapters – often without knowing that they were doing so. I have said it many times, and now I want to say it in print: "Science Twitter is the best Twitter."

The hundreds of students I have taught statistics to over the years were another source of help and inspiration for this book. I am very grateful for the students enrolled in my classes as I wrote this book. These students were my "guinea pigs" as I tried out different ways of explaining statistical concepts. Many students helped me see which examples were effective (or not) and worked out the problems in my explanations and datasets. Student feedback was especially helpful in identifying portions of the first edition of the textbook that could be improved.

A few students were particularly helpful as I worked on this book. Kimberlee Waite graciously allowed me to use her data from her study on sibling relationships among people with and without autism. Zachary Rawlings assembled the key for the end-of-chapter problems, many of

which were tested as homework assignments for the students in my classes. David Loveland gave me a student perspective on the book that I found helpful in making revisions. However, three students were "all-stars" and deserve unending praise for their help: Kathy L. Youngkin, Becky Bytheway, and Liliana López Lemus. These three students read the drafts of every chapter and met with me to give feedback. They ensured that every chapter of the book was student-centered, comprehensible, and used as little jargon as possible. These three students were phenomenal in ferreting out the weaknesses in my writing and teaching. If this book is accessible to students, it is largely because of their efforts.

On a more personal note, it is essential to acknowledge the help and support of my amazing wife, Katie. She was the one who talked me into committing myself to write this book. Every time I had a "writing day," she let me work undisturbed, even though it was difficult for her sometimes. It was often very challenging to meet every single deadline (especially with seven family trips to the hospital during the 18 months I was writing the first edition), but with my wife's unwavering support, it happened. I do not deserve a woman as wonderful as she is.

I used to think it was a cliché for authors to state that the credit for the strengths of their book belongs to many people, but that the faults belong to the author alone. Now that I have finished my first book, I understand why so many authors say this. Every person listed in these acknowledgements made the book better; their influence was always positive. As a result, I must frankly admit that the book's shortcomings are solely my responsibility. This isn't magnanimity. Rather, it is reality.

Examples

Chapter(s)	Example	Field
1	Baby naming	Sociology
1	Birth dates and hockey teams	Sports
1	Freud's theories were not scientific	Psychology/philosophy of science
1	Working memory theory is falsifiable	Psychology
1	Personality and job performance	Psychology/business
1, 3, 4, 9	Sibling relationships and autism	Psychology/family studies
1	Parental spending on children	Psychology/sociology/family studies
1	Why do people commit crimes?	Sociology/criminology
1	Changing schools and dropout rates	Education
1	Mate selection (matching hypothesis)	Psychology/sociology/family science
1	Darwin's theory of evolution	Biology
1	Newton's laws of motion	Physics
2	Affection	Psychology/family science
2	Perception of stimuli and actual stimuli intensity	Psychology
2	Levels of data examples (temperature, weight, gender, etc.)	Social sciences
2	Educational and psychological test scores and rating scales	Education/psychology
3	Outliers in math ability	Education/psychology
3	Resilient children in poverty	Psychology/sociology
3	65% of households have below-average income	Economics/sociology
4	Murder rate in Canadian provinces	Sociology/criminology
4	Deceptive truck ad	Business/marketing
4	Deceptive political poll	Political science/journalism
4	Baby Name Voyager (interactive chart link)	Sociology
4	Location of individuals making cultural advances (animated map link)	Sociology, history

Chapter(s)	Example	Field
5	Quetelet's data	Biology
5	Normally distributed variables	Biology/psychology/education
5	Non-normally distributed variables	Economics/sociology/psychology
5	Skewed data	Education
5	Bimodal distribution example	Psychology
5	Social workers' clients' unemployment time	Social work
6	Dice rolls	Probability/mathematics
6	Incorrect beliefs in gambling	Psychology
6	Probability of a baby's sex	Probability/mathematics/biology
6	Drawing cards from a playing pack	Probability/mathematics
6	Mood states of people with bipolar disorder	Psychology
7, 8	Impact of anti-seizure medicine exposure *in utero*	Medicine/psychology
7	Invisible dog	Philosophy of science
7	Importance of effect sizes	Psychology/education
7	Reporting impossible *p*-values	Educational psychology
7	Social workers' job satisfaction	Social work
8	Are people taller today?	Human biology/economics
8	First graders' IQ scores	Psychology
9	Quality of life improvement after therapy	Psychology
9	Husbands and wives producing paired scores	Family science
9	Matching on gender and handedness	Neuroscience
9	Medical test errors	Medicine
9	Selecting students for educational programs	Education
9	Effectiveness of play therapy	Psychology
10	Acceptable behavior online for young adults in relationships	Sociology/psychology/family science/communications
10	Schizophrenia in children	Psychology
10	Frequently occurring unlikely events	Sports/probability
10	Are males or females smarter?	Psychology
11	Cross-cultural comparisons of indecisiveness	Anthropology/psychology

Chapter(s)	Example	Field
11	Stroop Test	Psychology/neuroscience
11	Comparing life stressor for unmarried, married, and recently divorced subjects	Family science
12	Company earnings over time	Economics
12	Video games and intelligence	Psychology
12	National corruption and legislature functioning	Sociology
12	Talking speed and schizophrenia	Psychology
12	Test anxiety	Psychology
12	Depression and job satisfaction	Psychology
12	ADHD and creativity	Psychology
12	Sugar consumption and behavioral changes	Psychology/medicine
12	Husbands' and wives' personality traits	Psychology/family science
12	High-school grades and first-year college grades	Education/psychology
12	Height at birth and in adulthood	Medicine/physical anthropology
12	Height and weight	Medicine/physical anthropology
12	Lifelong stability of intelligence	Psychology
12	Stability of extraversion	Psychology
12	Effects of spanking on children	Psychology/Family science
12	Husband and wives' religiousness	Family science/psychology
12, 13	Job testing	Psychology/sociology
13	Air temperature	Earth science
13	Intergenerational height increases	Biology/physical anthropology
13	Test score increases and decreases in children	Psychology/education
13	Regression to the mean in patients with high blood pressure	Medicine
13	Movie sequels are not very good	Entertainment
13	The *Sports Illustrated* curse	Sports
13	High-school size and math achievement scores	Education
13	Basketball players and restriction of range	Sports
13	Test validity for different groups	Psychology
14	The *Titanic*	History/sociology

Chapter(s)	Example	Field
14	Therapy outcomes	Psychology
15	Impulsivity, future orientation, and delay of gratification	Psychology
15	Personality–sex interaction in school grades	Education/psychology
15	Simpson's paradox in gifted education	Education/psychology
15	Antisocial personality disorder symptoms	Psychology