

Statistics in Criminal Justice

Statistics in Criminal Justice

Fourth Edition

David Weisburd

*Hebrew University of Jerusalem, Jerusalem, Israel
and George Mason University, Fairfax, VA, USA*

and

Chester Britt

Northeastern University, Boston, MA, USA

 Springer

David Weisburd
Faculty of Law
Institute of Criminology
Hebrew University of Jerusalem
Jerusalem, Israel

and
Department of Criminology, Law and Society
George Mason University
Fairfax, VA, USA

Chester Britt
School of Criminology and Criminal Justice
Northeastern University
Boston, MA, USA

Additional material to this book can be downloaded from <http://extras.springer.com>

ISBN 978-1-4614-9169-9 ISBN 978-1-4614-9170-5 (eBook)
DOI 10.1007/978-1-4614-9170-5
Springer New York Heidelberg Dordrecht London

Library of Congress Control Number: 2013952914

© Springer Science+Business Media New York 2014

This work is subject to copyright. All rights are reserved by the Publisher, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, reuse of illustrations, recitation, broadcasting, reproduction on microfilms or in any other physical way, and transmission or information storage and retrieval, electronic adaptation, computer software, or by similar or dissimilar methodology now known or hereafter developed. Exempted from this legal reservation are brief excerpts in connection with reviews or scholarly analysis or material supplied specifically for the purpose of being entered and executed on a computer system, for exclusive use by the purchaser of the work. Duplication of this publication or parts thereof is permitted only under the provisions of the Copyright Law of the Publisher's location, in its current version, and permission for use must always be obtained from Springer. Permissions for use may be obtained through RightsLink at the Copyright Clearance Center. Violations are liable to prosecution under the respective Copyright Law.

The use of general descriptive names, registered names, trademarks, service marks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant protective laws and regulations and therefore free for general use.

While the advice and information in this book are believed to be true and accurate at the date of publication, neither the authors nor the editors nor the publisher can accept any legal responsibility for any errors or omissions that may be made. The publisher makes no warranty, express or implied, with respect to the material contained herein.

Printed on acid-free paper

Springer is part of Springer Science+Business Media (www.springer.com)

For Bryan, who made the desert bloom, used
sun to brighten the night, and brought such joy
to family and friends

D. W.

For my parents, Chester and Lila, who have been
a constant source of support

C. B.

Contents

Preface **xiii**

Chapter one

- Introduction: Statistics as a Research Tool 1
 - The Purpose of Statistics Is to Clarify 3
 - Statistics Are Used to Solve Problems 4
 - Basic Principles Apply Across Statistical Techniques 5
 - The Uses of Statistics 7

Chapter two

- Measurement: The Basic Building Block of Research 13
 - Science and Measurement: Classification as a First Step in Research 14
 - Levels of Measurement 15
 - Relating Interval, Ordinal, and Nominal Scales: The Importance of Collecting Data at the Highest Level Possible 22
 - What Is a Good Measure? 23

Chapter three

- Representing and Displaying Data 36
 - What Are Frequency Distributions and Histograms? 37
 - Extending Histograms to Multiple Groups: Using Bar Charts 43
 - Using Bar Charts with Nominal or Ordinal Data 50
 - Pie Charts 51
 - Time Series Data 52

Chapter four

- Describing the Typical Case: Measures of Central Tendency 65
 - The Mode: Central Tendency in Nominal Scales 66
 - The Median: Taking into Account Position 68
 - The Mean: Adding Value to Position 74
 - Statistics in Practice: Comparing the Median and the Mean 82

Chapter five

- How Typical Is the Typical Case?: Measuring Dispersion 94
 - Measures of Dispersion for Nominal- and Ordinal-Level Data 95
 - Measuring Dispersion in Interval Scales: The Range, Variance, and Standard Deviation 102

Chapter six

The Logic of Statistical Inference: Making Statements
About Populations from Sample Statistics 125

- The Dilemma: Making Statements About Populations from Sample Statistics 126
- The Research Hypothesis 129
- The Null Hypothesis 131
- Risks of Error in Hypothesis Testing 133
- Risks of Error and Statistical Levels of Significance 135
- Departing from Conventional Significance Criteria 137

Chapter seven

Defining the Observed Significance Level of a Test:
A Simple Example Using the Binomial Distribution 145

- The Fair Coin Toss 147
- Different Ways of Getting Similar Results 151
- Solving More Complex Problems 154
- The Binomial Distribution 155
- Using the Binomial Distribution to Estimate the Observed Significance Level of a Test 159

Chapter eight

Steps in a Statistical Test: Using the Binomial Distribution
to Make Decisions About Hypotheses 171

- The Problem: The Impact of Problem-Oriented Policing on Disorderly Activity at Violent-Crime Hot Spots 172
- Assumptions: Laying the Foundations for Statistical Inference 174
- Selecting a Sampling Distribution 180
- Significance Level and Rejection Region 182
- The Test Statistic 187
- Making a Decision 187

Chapter nine

Chi-Square: A Test Commonly Used for Nominal-Level Measures 197

- Testing Hypotheses Concerning the Roll of a Die 198
- Relating Two Nominal-Scale Measures in a Chi-Square Test 206
- Extending the Chi-Square Test to Multicategory Variables: The Example of Cell Allocations in Prison 212
- Extending the Chi-Square Test to a Relationship Between Two Ordinal Variables: Identification with Fathers and Delinquent Acts 217
- The Use of Chi-Square When Samples Are Small: A Final Note 222

Chapter ten

The Normal Distribution and Its Application to Tests
of Statistical Significance 234

- The Normal Frequency Distribution, or Normal Curve 235
- Applying Normal Sampling Distributions to Nonnormal Populations 247
- Comparing a Sample to an Unknown Population: The Single-Sample z -Test for Proportions 252
- Comparing a Sample to an Unknown Population: The Single-Sample t -Test for Means 257

Chapter eleven

Comparing Means and Proportions in Two Samples 269

Comparing Sample Means 270

Comparing Sample Proportions: The Two-Sample t -Test for Differences of Proportions 282

The t -Test for Dependent Samples 288

A Note on Using the t -Test for Ordinal Scales 293

Chapter twelve

Comparing Means Among More Than Two Samples: Analysis of Variance 306

Analysis of Variance 307

Defining the Strength of the Relationship Observed 328

Making Pairwise Comparisons Between the Groups Studied 331

A Nonparametric Alternative: The Kruskal-Wallis Test 334

Chapter thirteen

Measures of Association for Nominal and Ordinal Variables 351

Distinguishing Statistical Significance and Strength of Relationship:

The Example of the Chi-Square Statistic 352

Measures of Association for Nominal Variables 355

Measures of Association for Ordinal-Level Variables 367

Choosing the Best Measure of Association for Nominal- and Ordinal-Level Variables 385

Chapter fourteen

Measuring Association for Interval-Level Data:

Pearson's Correlation Coefficient 398

Measuring Association Between Two Interval-Level Variables 399

Pearson's Correlation Coefficient 401

Spearman's Correlation Coefficient 419

Testing the Statistical Significance of Pearson's r 421

Testing the Statistical Significance of Spearman's r 428

Chapter fifteen

An Introduction to Bivariate Regression 439

Estimating the Influence of One Variable on Another: The Regression Coefficient 440

Prediction in Regression: Building the Regression Line 445

Evaluating the Regression Model 453

The F -Test for the Overall Regression 467

Chapter sixteen

Multivariate Regression 481

The Importance of Correct Model Specifications 482

Correctly Specifying the Regression Model 494

Chapter seventeen

Multivariate Regression: Additional Topics 514

- Non-linear Relationships 516
- Interaction Effects 522
- An Example: Race and Punishment Severity 525
- An Example: Punishment Severity 533
- The Problem of Multicollinearity 534

Chapter eighteen

Logistic Regression 548

- Why Is It Inappropriate to Use OLS Regression for a Dichotomous Dependent Variable? 550
- Logistic Regression 555
- Interpreting Logistic Regression Coefficients 567
- Comparing Logistic Regression Coefficients 577
- Evaluating the Logistic Regression Model 583
- Statistical Significance in Logistic Regression 587

Chapter nineteen

Multivariate Regression with Multiple Category Nominal or Ordinal Measures:
Extending the Basic Logistic Regression Model 601

- Multinomial Logistic Regression 603
- Ordinal Logistic Regression 615
- Substantive Example: Severity of Punishment Decisions 619

Chapter twenty

Multilevel Regression Models 637

- Variance Components Model 640
- Random Intercept Model 646
- Random Coefficient Model 655
- Adding Cluster (Level 2) Characteristics 660

Chapter twenty one

Special Topics: Randomized Experiments 674

- The Structure of a Randomized Experiment 676
- The Main Advantage of Experiments: Isolating Causal Effects 677
- Internal Validity 682
- Sample Size, Equivalence, and Statistical Power 683
- Statistical Power and Block Randomization 691
- Using Covariates to Increase Statistical Power in Experimental Studies 693
- Examining Interaction Terms in Experimental Research 695

Chapter twenty two

Special Topics: Confidence Intervals 702

- Confidence Intervals 704
- Constructing Confidence Intervals 708

Chapter twenty three

Special Topics: Statistical Power 726

Statistical Power 728

Components of Statistical Power 731

Estimating Statistical Power and Sample Size for a Statistically Powerful Study 738

Summing Up: Avoiding Studies Designed for Failure 747

Appendix 1 Factorials 759

Appendix 2 Critical Values of χ^2 Distribution 760

Appendix 3 Areas of the Standard Normal Distribution 761

Appendix 4 Critical Values of Student's t Distribution 762

Appendix 5 Critical Values of the F -Statistic 763

Appendix 6 Critical Value for P (P_{crit}), Tukey's HSD Test 766

Appendix 7 Critical Values for Spearman's Rank-Order Correlation Coefficient 767

Appendix 8 Fisher r -to- Z^* Transformation 768

Glossary 770

Index 778

Preface

Oliver Wendell Holmes, the distinguished associate justice of the Supreme Court, was noted for his forgetfulness. On a train leaving Washington, D.C., he is said to have been approached by a conductor who requested his ticket. Holmes, searching through his case and his pockets, could not locate his pass. After a few awkward moments, the conductor recognized the distinctive-looking and well-known jurist and suggested that he just send the rail company the ticket when he found it. Justice Holmes, however, is said to have looked sternly at the conductor and responded, “Young man, the problem is not where is my ticket; the problem is where am I going.”

For the student of statistics, a textbook is like a train ticket. Not only does it provide a pass the student can use for entering a new and useful area of study; it also defines the route that will be taken and the goals that are important to achieve. Different textbooks take different approaches and emphasize different types of material. *Statistics in Criminal Justice* emphasizes the uses of statistics in research in crime and justice. This text is meant for students and professionals who want to gain a basic understanding of statistics in this field. In the first chapter, the main themes of the text are outlined and discussed. This preface describes how the text is organized.

The text takes a building-block approach. This means that each chapter helps prepare you for the chapters that follow. It also means that the level of sophistication of the text increases as the text progresses. Basic concepts discussed in early chapters provide a foundation for the introduction of more complex statistical issues later. One advantage to this approach is that it is easy to see, as time goes on, how much you have learned about statistics. Concepts that would have seemed impossible to understand, had they been introduced at the outset, are surprisingly simple when you encounter them later on. If you turn to the final chapters of the book now, you will see equations that are quite forbidding. However, when you come to these equations after covering the material in earlier chapters, you will be surprised at how easy they are to understand.

Throughout the text, there is an emphasis on *comprehension* and not *computation*. This approach is meant to provide readers with an accessible but sophisticated understanding of statistics that can be used to examine real-life criminal justice problems. In the opening chapters of the

book, basic themes and materials are presented. Chapter 1 provides an introduction to how we use statistics in criminal justice and the problems we face in applying statistics to real-life research problems. Chapters 2 through 5 introduce basic concepts of measurement and basic methods for graphically representing data and using statistics to describe data. Many of the statistics provided here will be familiar to you; however, remember that the more advanced statistics presented in later chapters build on the themes covered in these early chapters.

One of the fundamental problems researchers face is that they seek to make statements about large populations (such as all U.S. citizens) but are generally able to collect information or data on only a sample, or smaller group, drawn from such populations. In Chapters 6 through 12, the focus is on how researchers use statistics to overcome this problem. What is the logic that underlies the statistics we use for making statements about populations based on samples? What are the different types of statistical procedures or tests that can be used? What special problems are encountered in criminal justice research, and how should the researcher approach them? Some texts skip over the basics, moving students from test to test before they understand the logic behind the tests. The approach here is to focus in greater detail on relatively simple statistical decisions before moving on to more complex ones.

Having examined how we can make statements about populations from information gained from samples, we turn to how we describe the strength of association between variables. In the social sciences, it is often essential not only to determine whether factors are related but also to define the strength and character of those relationships. Accordingly, in Chapters 13 and 14, we look at measures of association, and in Chapters 15 through 20, we examine bivariate and different types of multivariate regression. These are likely to be new topics for you, though they are statistics commonly used in criminal justice.

In the concluding chapters, we look at three special topics. Chapter 21 focuses on the design of randomized experiments. Randomized experiments allow criminal justice researchers to be confident about the causal relationships between variables, and are often used in the evaluation of criminal justice interventions. Chapter 22 describes confidence intervals, a method for assessing how much trust you can place in the specific estimates that you obtain from a sample. Because our emphasis is on research in criminal justice, we conclude the text with a chapter that examines methods for evaluating and improving the design of a research project. The statistical concept that is central to Chapter 23—statistical power—follows directly from the concepts developed in prior chapters. Statistical power is often ignored in introductory statistics texts. However, it has become a central concern in criminal justice research and accordingly is given emphasis in this text.

While it is always difficult in statistics to decide where an introductory text should stop, with an understanding of these techniques you

will have the basic tools to comprehend and conduct criminal justice research. Of course, these tools constitute a building block for more advanced methods. The goal of the text is not only to bring you to this point in learning statistics, but also to leave you with the confidence and tools to tackle more complex problems on your own. Each chapter starts with a statement of the basic concepts and problems addressed and ends with a full chapter summary. There is also a list of equations, when relevant, at the end of the chapter. These materials should help you to review what you have learned and to identify the basic knowledge you need to move on to subsequent chapters.

All of the chapters contain a list of key terms with short definitions. The key terms appear in boldface the first time they are mentioned in the chapter. Sometimes a term may have been briefly explained in an earlier chapter, but is designated as a key term in the chapter where the concept is more central. A general glossary of key terms appears at the end of the book. Chapters 2 through 23 each have a set of questions at the end. The questions are designed to make you think about the subjects covered in the chapter. Sometimes they are straightforward, following directly from the text. Sometimes they ask you to develop ideas in slightly different ways than in the text. In constructing the questions, we sought to make working on statistical issues as much fun as possible. In statistics, it is crucial to go over material more than once. The questions are meant to reinforce the knowledge you have gained.

A working knowledge of computers is not required to understand the statistical concepts or procedures presented in the text. However, computers have become a very important part of research in statistics, and thus we provide computer exercises for relevant chapters and a web site where you can access the data needed for those exercises (see the Computer Exercises at the end of Chapter 2 for details). You are encouraged to use the web site. It will help you to see the connection between the topics discussed in the chapters and statistical computing.

Statistics in Criminal Justice will allow you to approach statistics in a familiar context. It emphasizes the statistics and the problems that are commonly encountered in criminal justice research. It focuses on understanding rather than computation. However, it takes a serious approach to statistics, which is relevant to the real world of research in crime and justice. The text is meant not only as an introduction for students but also as a reference for researchers. The approach taken will help both students who want an introduction to statistics and professionals who seek a straightforward explanation for statistics that have become a routine tool in contemporary criminal justice systems.

Acknowledgments

In the development of any academic enterprise, many students and colleagues provide support and advice. We are particularly indebted to Professor Joseph Naus of the Department of Statistics of Rutgers University, who played a crucial advisory role in the preparation of the original edition of this book, and to Daniel Salem, a graduate of the Institute of Criminology of the Hebrew University, who played a major role in the production of the first edition. Robert Brame of the University of South Carolina was particularly helpful in helping us to refine some of the new material for the third edition. A number of current and former graduate students helped us in revising and editing the manuscript across the four editions, including SueMing Yang and Kristen Miggans at the University of Maryland, and Shomron Moyal, Rochelle Schnurr, Tal Yonaton and Gali Weissman of the Hebrew University, and Arian Ferrer Emmanuelle Klossou, and Michael Rocque of Northeastern University. We also want to thank the many scholars who have read and used our work and provided comments over the previous editions, particularly the comments and suggestions made by Todd Armstrong of Sam Houston State University, Pamela Lattimore of the Research Triangle Institute, Stephen Schnebly of the University of Illinois at Springfield, and Marc Swatt of Justice & Security Strategies, Inc. The final product reflects their keen insights and thoughtful suggestions.

About the Authors

David Weisburd is a Distinguished Professor of Criminology, Law and Society at George Mason University (and Director of the Center for Evidence Based Crime Policy) and Walter E. Meyer Professor of Law and Criminal Justice at the Hebrew University. He also serves as a Senior Fellow at the Police Foundation in Washington DC and is Chair of its Research Advisory Committee. Professor Weisburd is an elected Fellow of the American Society of Criminology and of the Academy of Experimental Criminology. He is a member of the Science Advisory Board of the Office of Justice Programs, the Steering Committee of the Campbell Crime and Justice Group, the National Institute of Justice/Harvard Executive Session in Policing, the Scientific Commission of the International Society of Criminology, and the Committee on Law and Justice of the National Research Council of the National Academy of Sciences (USA). Professor Weisburd is one of the leading international researchers in crime and justice. He is author or editor of more than twenty books and more than 100 scientific articles that cover a wide range of criminal justice research topics, including crime at place, white collar crime, policing, illicit markets, terrorism, criminal justice statistics and social deviance. Professor Weisburd is the recipient of the 2010 Stockholm Prize in Criminology and the 2011 Klachky Family Prize for the Advancement of the Frontiers of Science. Professor Weisburd is also the founding editor of the *Journal of Experimental Criminology*.

Chester L. Britt is a researcher and scholar in criminology and criminal justice. He is Dean of the School of Criminology and Criminal Justice at Northeastern University in Boston. After receiving his Ph.D. in sociology from the University of Arizona, Professor Britt taught at the University of Illinois, Penn State University, and Arizona State University. He served as the Editor of *Justice Quarterly* from 2005 through 2007. He has also co-edited a volume on criminological theory entitled *Control Theories of Crime and Delinquency*. His research articles have appeared in such journals as *Law and Society Review*, *Justice Quarterly*, *Journal of Quantitative Criminology*, and *Journal of Research in Crime and Delinquency*.