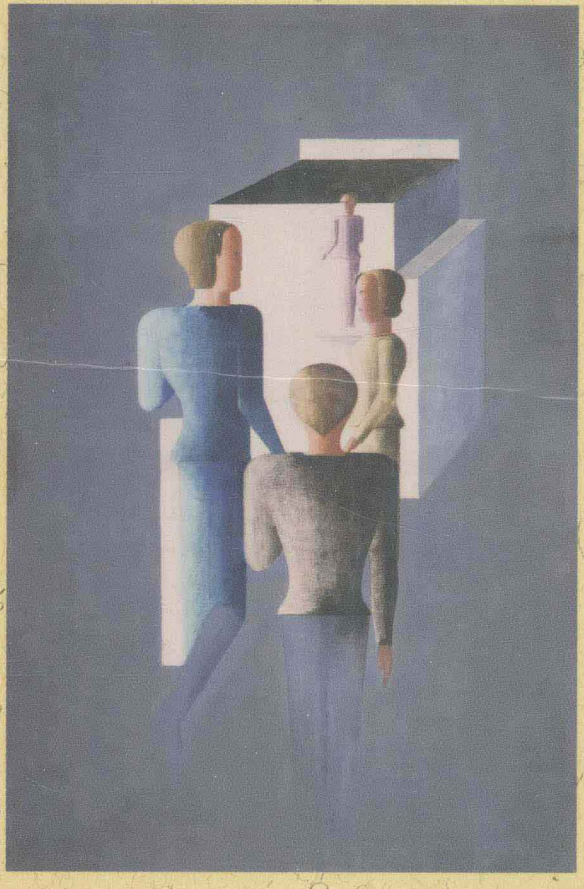
STATISTICS
AN INTRODUCTION

Third Edition



ROGER E. KIRK

STATISTICS

AN INTRODUCTION

Third Edition

Roger E. Kirk

Baylor University

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PREFACE

Statistics: An Introduction was written for students in the behavioral sciences, health sciences, and education who are taking their first course in statistics. Its goals are twofold: to provide a sound introduction to descriptive and inferential statistics and to acquaint students with computer software packages.

Computers have taken the drudgery out of statistics. Computers also have broadened the students' statistical horizons—now students can compute the most complex statistics in a matter of seconds. With the increasing accessibility of computers, it's time to rethink the way we teach statistics. The time honored approach of learning statistics by mechanically following cookbook formulas is no longer appropriate. Students need to understand the logic of statistical procedures, they need guidelines to help them decide when various procedures are appropriate, and they need to understand the assumptions and limitations of the various statistics. In addition, students need to become familiar with computer software and printouts. *Statistics* was written to meet these needs.

Changes in the third edition of *Statistics* include a greater coverage of *p*-values, multiple comparison procedures, and the logic of designing experiments. The coverage of analysis of variance has been simplified and expanded to two chapters. The computer supplements also have been changed. These optional supplements now contain annotated programs and printouts for the most popular statistical software packages, including BMDP, Minitab, SAS, and SPSS^X. Some of the printouts contain terms and statistics that are not normally covered in introductory statistics books. In order to make this material accessible to students, I have provided simplified discussions of selected advanced topics such as multiple regression, detecting outliers, and the use of unpooled variances in the two-sample *t* test for means. Also, I have included a few statistics such as the coefficient of variation that are not widely used in the behavioral sciences and education but, nevertheless, routinely appear in printouts.

For the immediate future, students at many universities will not have access to computers. I believe that these students can profit from reading the computer supplements even though they cannot run the programs. However, the computer

supplements are optional, and instructors may prefer not to cover them in order to emphasize other topics.

Students will find this edition easier to read than previous editions. Every section has been rewritten in an effort to smooth out the hard places. I remain convinced that clarity and readability can be achieved without sacrificing accuracy and depth of coverage. In this edition, I have relied more heavily on verbal rather than mathematical explanations. To be sure, the student will encounter some formulas and a few proofs, but the level of mathematics is very elementary. A familiarity with high school algebra is sufficient for understanding the text. For those whose mathematical skills are rusty, Appendix A provides a review of elementary mathematics. The diagnostic mathematics skills test in Appendix A can be used for testing one's knowledge or for identifying concepts that should be reviewed.

Statistics contains a number of special features that should make learning statistics easier. These features include a chapter outline at the beginning of each chapter, the use of color and boldface type to emphasize new terms and definitions, an extensive glossary of statistical terms (Appendix B), chapter summaries, an unusually complete index, and 553 review exercises. These exercises (1) indicate which concepts and procedures are most important, (2) present interesting real-life examples from recent journal articles of the way statistics are used, and (3) provide practice in applying what has been learned. Answers are given in Appendix C for 245 of the exercises. The student database in Appendix E provides an additional source of exercises. This database enables students to gain experience drawing random samples and computing statistics using real data. Students will find that selecting an appropriate statistic is easier with the help of the Selection Guide for descriptive and inferential statistics on the back endpaper. The laminated insert provides a quick reference for important formulas.

It is a pleasure to express my appreciation to the following reviewers for reading the manuscript and for their thoughtful comments: Richard V. Alumbaugh, Central Washington University; Timothy N. Ansley, University of Iowa; Wendy J. Beller, Quincy College; Clarke A. Burnham, University of Texas at Austin; James Chumbley, University of Massachusetts at Amherst; Lizanne DeStefano, University of Illinois; William A. Frederickson, Central State University; John Hensley, Midwestern State University; Lawrence Jones, University of Illinois, Urbana-Champaign; Richard H. Lindley, California State University, Fullerton; Matthew McGuinness, Western Kentucky University; David Morse, Mississippi State University; Gwen Nugent, University of Nebraska; Robert O'Bannon, Jackson State University, Mississippi; Gaylon L. Oswalt, University of Nebraska at Omaha; Louis H. Porter, West Chester University; Daniel L. Roenker, Western Kentucky University; Julia Wallace, University of Northern Iowa; Steven Wise, University of Nebraska-Lincoln. Also, it is a pleasure to express my appreciation to Jack Baty, Tom Chenier, and Sharon O'Connor for contributing exercises; to Frank Wyman who wrote many of the

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computer programs; and to Leah Coate for verifying the answers to all of the review exercises. Marc Sherman, Herman Makler, Angelo Puleo, Tad Gaither, Judy Allan, Guy Jacobs, and Charlie Dierker of Holt also deserve recognition for their efforts in making this book a reality.

I am grateful to the Literary Executor of the late Sir Ronald A. Fisher, F. R. S., to Frank Yates, F. R. S., and to Longman Group Ltd., London, for permission to reprint Tables D.1, D.2, D.3, D.4, D.6, and D.8 from their book *Statistical Tables for Biological, Agricultural and Medical Research* (6th edition, 1974).

I am also grateful to E. S. Pearson and H. O. Hartley, editors of *Biometrika Tables for Statisticians,* Vol. 1, and to the *Biometrika* trustees for permission to reprint Tables D.5 and D.10; and to the editor of the *Journal of The American Statistical Association* for permission to reprint Tables D.7 and D.11.

Portions of this book were written while on sabbatical from Baylor University. I am grateful to the administration of Baylor University and in particular to Herbert H. Reynolds, John S. Belew, and William G. Cooper for providing an environment that encourages creative and scholarly activity.

And finally I want to express my appreciation to my statistics classes for what I trust has been a mutually rewarding learning experience.

R.E.K.

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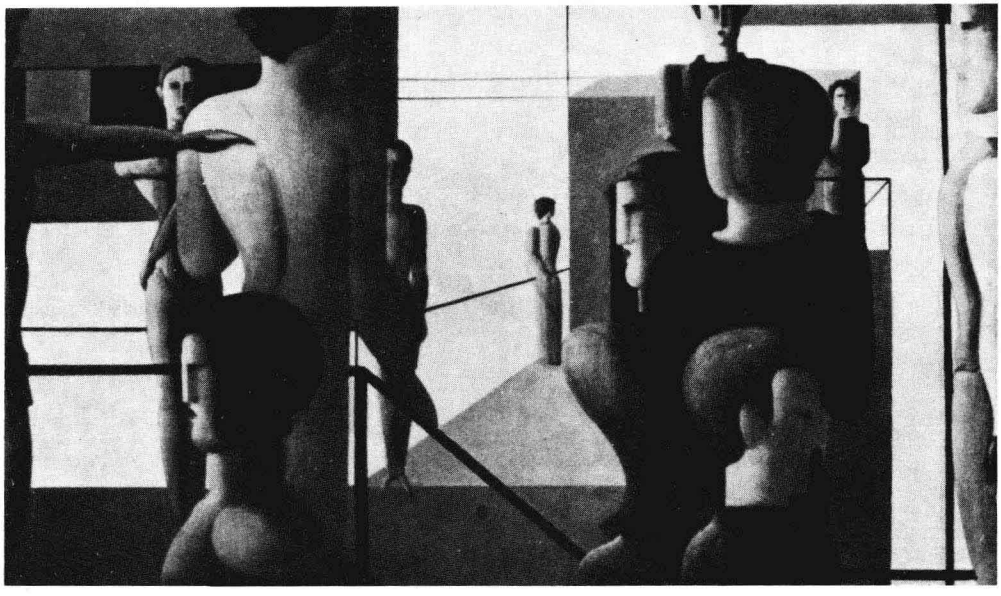

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1.1 INTRODUCTION

Some Misconceptions

It is widely believed that statistics can be used to prove anything—which implies, of course, that it can prove nothing. Furthermore, the word *statistics* conjures up visions of numbers piled upon numbers, uninterpretable charts, and computers cranking out gloomy predictions. To the ordinary person, besieged from all sides by advertising claims, statistics is hocus-pocus with numbers. It was Benjamin Disraeli who said "there are three kinds of lies—lies, damned lies, and statistics!"[1] In primitive cultures, exaggeration was common. One writer, with tongue in cheek, reasoned that, since primitive people did not have a science of statistics, they were forced to rely on exaggeration, which is a less effective form of deception. Another writer remarked that "if all the statisticians in the world were laid end to end—it would be a good thing." Whatever its public image, statistics endures as a required course, and my students continue to refer to it, affectionately no doubt, as Sadistics 2402.

What Is Statistics?

In spite of frequent misuse, statistics can be an elegant and powerful tool for making decisions in the face of uncertainty. The word *statistics* comes from the Latin *status*, which is also the root for our modern term *state* or political unit. Statistics was a necessary tool of the state, since to levy a tax or to wage war a ruler had to know the number of subjects in the state and the amount of their wealth. Gradually the meaning of the term expanded to include any type of data.

Today the word **statistics** has four distinct meanings. Depending on the context, it can mean: (1) data; (2) functions of data, such as the mean and range; (3) techniques for the collection, analysis, and interpretation of data for subsequent decision making; and (4) the science of creating and applying such techniques.

Why Study Statistics?

A knowledge of statistics yields more than the obvious benefits. For example, it generates new ways of thinking about questions and provides effective tools for answering them. It takes only a cursory examination of the professional literature in your own field to see the inroads made by statistical techniques and ways of thinking. Statistics is an indispensable tool for researchers in the behavioral sci-

[1]Two recent books indicate that Disraeli's view of statistics is still with us. The books are *How to Tell the Liars from the Statisticians* by Hooke and Liles and *Misused Statistics: Straight Talk for Twisted Numbers* by Jaffe and Spirer.

ences, health sciences, and education, but its usefulness is not limited to research. In many fields, it is virtually impossible to keep up with new developments without an understanding of elementary statistics. Also, statistics is an interesting subject—some people even find it fascinating.

In all likelihood you are reading this book because it was assigned in your required statistics course. You have been told that the study of statistics is necessary, and there is a strong implication that it will be good for you. At this point you may be skeptical. Just what can you expect to learn by studying statistics? A quick scanning of this book will give you an idea. You will acquire a new vocabulary, since in many ways learning statistics is like learning a foreign language, and you will learn to manipulate numbers according to symbolic instructions. But more important, you will learn when and how to apply statistics to research problems in the behavioral sciences, health sciences, and education. Your study of statistics should enable you to read the literature in your field with greater understanding, and it will prepare you to learn more complex procedures in the design and analysis of experiments. You will probably become more critical of statistical presentations in your field and in the mass media. And you should gain a greater appreciation of the probabilistic nature of scientific knowledge. Statistics involves a special way of thinking that can be used not only in research but also in one's daily life. I hope that you will add this way of thinking to your conceptual arsenal.

Kinds of Statisticians

Users of statistics fall into four categories: (1) those who must be able to understand statistical presentations of findings in their fields; (2) those who select, apply, and interpret statistical procedures in their work; (3) applied statisticians; and (4) mathematical statisticians.

This book is addressed to those in the first two categories, including psychologists, educators, sociologists, speech therapists, biologists, nurses, medical researchers, political scientists, and physical therapists, to mention only a few. In each case the person's primary interest is in his or her own field, be it sociology or city planning; he or she is interested in statistics because it is a useful tool for answering questions in that field. Such persons are both consumers and users of statistics. Their knowledge of statistics may range from meager to expert.

The applied statistician helps professionals in substantive areas to use statistics effectively.[2] He or she may work for industry or a government agency, engage in a private consulting practice, or teach in a university. Unlike individuals in the first two categories, an applied statistician usually has advanced degrees in mathematics and/or statistics.

[2]Two pamphlets, "Careers in Statistics" and "Statistics as a Career: Women at Work," describe career opportunities for statisticians. These pamphlets are available from the American Statistical Association, 806 15th St. N.W., Washington, D.C. 20005.

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