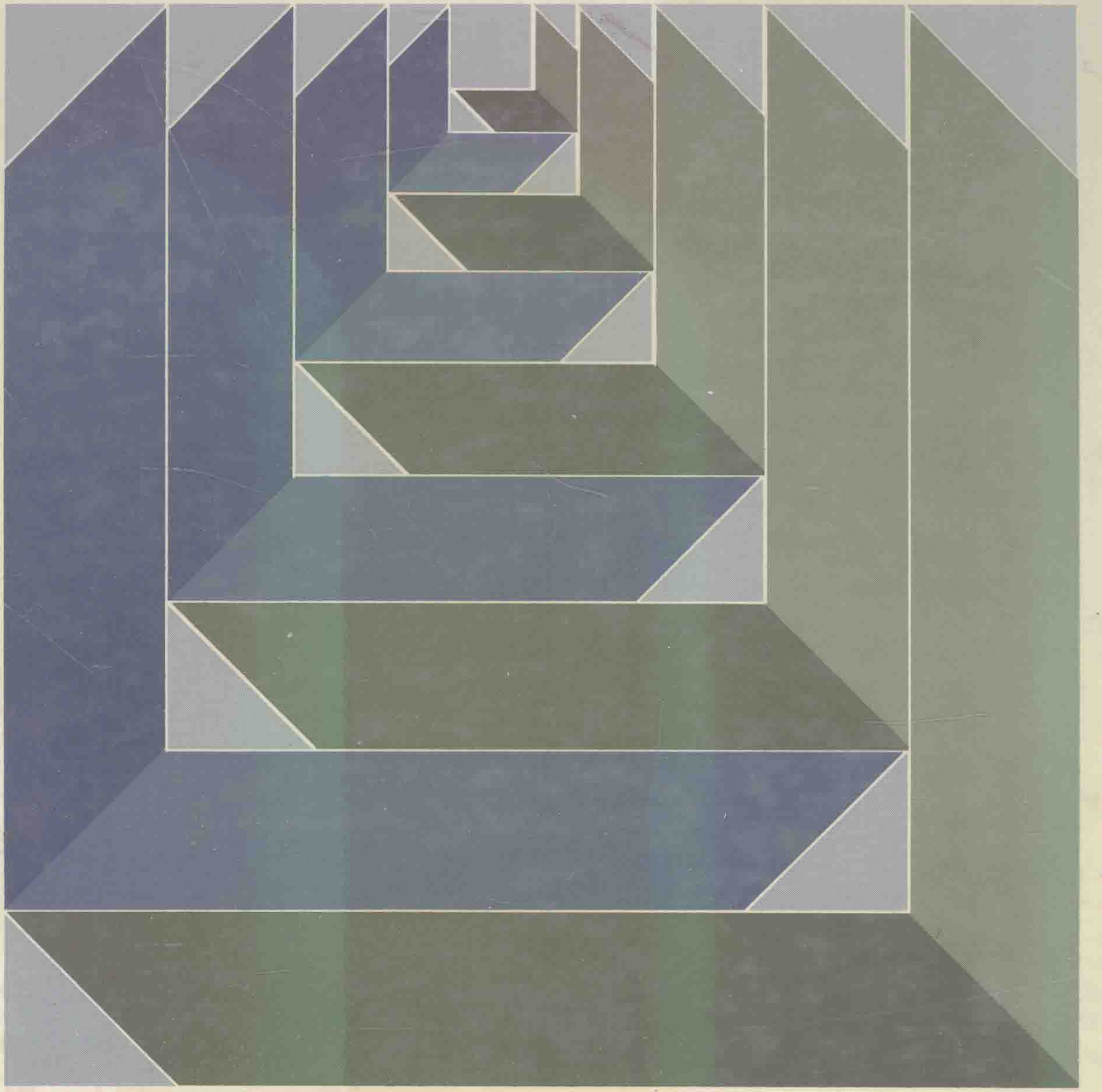
GENE V GLASS / KENNETH D. HOPKINS

STATISTICAL METHODS IN EDUCATION AND PSYCHOLOGY



SECOND EDITION

STATISTICAL METHODS IN EDUCATION AND PSYCHOLOGY

second edition

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University of Colorado-Boulder, who teach and apply statistics
all over the world, for their contributions to our thinking about statistical methods.*

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PREFACE

This textbook is designed for a one- or two-semester course in applied statistics. The methods are applicable to empirical research in many disciplines. We have drawn applications from several disciplines, although most come from education and psychology. In most instances, the data are not hypothetical but are from actual studies.

Our selection of topics has been guided by three considerations: (1) What are the most useful statistical methods? (2) Which statistical techniques are the most widely used in scholarly journals in the behavioral and social sciences? (3) Which statistical concepts and methods are fundamental to further study?

This text attempts to produce a more thorough coverage of analysis of variance techniques than usually appears in basic statistics texts for social scientists. Edgington (1974) found that more than 70 percent of all articles published in journals of the American Psychological Association employed this extremely versatile and powerful technique. According to the survey of Wick and Dirkes (1973), more than 95 percent of the doctoral dissertations in education use the statistical techniques that are treated in this text.

This edition of *Statistical Methods in Education and Psychology* (*SMEP*) differs from the first edition in both substance and style. The substantive changes include (1) an expanded and integrated treatment of multiple comparisons, including trend analysis, (2) a new chapter on multiple regression, (3) a new chapter on inferential methods with proportions, and (4) expanded treatment of more complex applications of the analysis of variance and covariance.

The pedagogical improvements include (1) diagnostic mastery tests following each chapter, (2) reorganization of content involving separate chapters on inferences regarding means, variances, proportions, and correlation coefficients, and (3) an attempt to provide more options in course content and emphasis. *SMEP* has endeavored to continue to be "extraordinary in its collection of examples, exercises, and statistical tables" (Schmidt, 1972, p. 169).

The approach of this text is conceptual, not mathematical or "cookbookish." Deriving a formula is no proof of real understanding, nor is the ability to plug numbers into formulas and "turn the crank." Indeed, the number of formulas used is kept small; the verbal-to-mathematical ratio of text material would rank high among statistics texts. We have stressed concepts rather than derivation and proof.

We have pruned away much deadwood present in some other statistics texts. Although every text claims to reflect the latest influences of electronic computers and hand calculators, obsolete techniques of calculating the mean, variance, and correlation coefficient from "grouped" data continue to be taught. These "shortcut" methods lead to roundabout formulas that, in addition to being less accurate, impede conceptualizing the meaning of the statistic being calculated.

We have tried to be sensitive to changes in statistical pedagogy occasioned by the rapid spread of hand calculators. We strongly advise students to purchase a hand calculator having at least one memory and the square root ($\sqrt{x}$) and reciprocal ($1/X$) features; better yet would be one with preprogrammed functions for mean, standard deviation, and correlation.

In this edition, we have tried to maintain the high professional standards of the first edition of *SMEP.* Michael (1970, pp. 1015 and 1018) found that the first edition of *SMEP* "probably affords the most nearly current and best balanced treatment of statistical methodology to be found in any well-known introductory text. . . . This volume should set the standard for many years to come."

In *Twenty-Five Years of Recommended Readings in Psychology*, Solso (1979) found that *SMEP* was among the 25 most recommended books by graduate departments of psychology, a distinction recorded by only one other statistics book (and it was less popular than *SMEP*). In their survey of statistics professors in graduate departments of education, Gay, Campbell, and Gallagher (1978) found that *SMEP*, in comparison to the other common statistics texts studied, had the highest ratings of (1) technical accuracy, (2) breadth of coverage, and (3) depth of topic coverage. *SMEP* was judged (1) to have no statistics prerequisites for comprehension, (2) to have a good sequence of topics, and (3) to be appropriate for undergraduate and graduate work, and (4) to have an orientation that is appropriate for both research consumers and producers. Stein and Kuenne (1979) found *SMEP* to have the lowest (easiest) readability of the seven statistics and research textbooks they studied. In a recent survey of the 100 top research-producing universities in education, *SMEP* was the most-used text (Brinzer & Sinatra, 1982). During the two years this text was being revised, our colleagues and students contributed in innumerable ways to our efforts. We cannot name them all here, but the following colleagues deserve special thanks for contributing recently to our education in statistical methods: Julian Stanley deserves credit for his influence as mentor and his contributions to the first edition. His modesty and heavy research commitments led to his decision not to remain a co-author for the second edition. Roberta Flexer, Stuart Kahl, Jason Millman, and Lorrie Shepard made several suggestions based on extensive classroom experience with *SMEP* that improved it as a text. Others made technical or pedagogical contributions: Maurice Tatsuoka, Edward Cureton, William Michael, Lorrie Shepard, James Collins, Roberta Flexer, Stuart Kahl, Victor Willson, Todd Rogers, Arlen Gullickson, Percy Peckham, Bob Hopkins, Mary Lee Smith, James Sanders, Stephen Jurs, Gregory Camilli, George Kretke, James Morrow, Frank B. Baker, and Carol Vojir.

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Gene V Glass
Kenneth D. Hopkins

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1
INTRODUCTION

1.1 THE "IMAGE" OF STATISTICS

Popular attitudes toward statistics contain a mixture of awe, cynicism, suspicion, and contempt. Freudian slips have transformed statistics into "sadistics," and "Don't become a statistic" is taken to mean "Don't let something evil befall you."

Statisticians have been scornfully placed in the company of liars and accused of "statisticulation"—the art of lying with statistics while maintaining an appearance of objectivity and rationality. Someone once remarked: "If all the statisticians in the world were laid end to end—it would be a good thing." A statistician has been depicted as a person who drowns while wading in a river having an average depth of 3 ft., or who sits with his head in a refrigerator and his feet in an oven and reports, "On the average, I feel fine."

W. H. Auden wrote, "Thou shalt not sit among statisticians, nor commit a social science." But nonsense can be expressed as readily verbally as it can be quantitatively. Knowledge of logic is a good safeguard against uncritical acceptance of verbal nonsense, and knowledge of statistics is the best defense against quantitative nonsense. The study of statistical concepts and methods will certainly reduce numerical credulity and help one be a wise consumer of quantitative information. The first step toward replacing popular images of statistics with more realistic ones is to study the structure of the discipline of "statistical methods" and its historical antecedents.

Some persons avoid statistics because of philosophical bias, apprehension about its rigors, or misconceptions about the discipline. Some prefer to operate on the basis of tradition, intuition, authoritative judgment, or "common sense." But it is increasingly recognized that there is a place for systematic, objective, and empirical research for which statistics is a tool.

Knowledge of statistical methods is becoming necessary for scholarship in most empirical disciplines. In the past twenty years, most graduate schools have acknowledged its importance as a research tool by accepting course work in statistics as a substitute for one of the two foreign languages traditionally required for a Ph.D. degree. The substitution is apt: statistics is an increasingly important means of communicating knowledge.

There were two widely divergent influences on the early development of statistical methods. Statistics had a mother who was dedicated to keeping orderly records of governmental units (*state* and *statistics* come from the same Latin root, *status*) and a gambling father who relied on mathematics to increase his skill at playing the odds in games of chance. From the mother sprang counting, measuring, describing, tabulating, ordering, and the taking of censuses—all of which led to modern *descriptive statistics.* From the father eventually came modern *inferential statistics*, which is based squarely on theories of probability. This text offers an introduction to the descriptive and inferential statistics that are most widely used in educational and behavioral research (Edgington, 1974; Wick and Dirkes, 1973; Willson, 1980). Descriptive statistics are emphasized in Chapters 2 through 8. Beginning with "Probability" in Chapter 9 and extending through Chapter 15, topics from inferential statistics are covered. Chapters 16 through 20 present the considerations and inferential techniques especially important in the design and analysis of experiments.

1.2 DESCRIPTIVE STATISTICS

Descriptive statistics involves tabulating, depicting, and describing collections of data. These data may be either *quantitative*, such as measures of height or intelligence—variables that are characterized by an underlying continuum—or the data may represent *qualitative* variables, such as sex, college major, or personality type. Large masses of data generally must undergo a process of summarization or reduction before they are comprehensible.

The human mind cannot extract the full import of a mass of data (How do they vary? About how large are they? Is one set useless in reducing uncertainty about the other?) without the aid of special techniques. Thus descriptive statistics serves as a tool to describe or summarize or reduce to manageable form the properties of an otherwise unwieldy mass of data.

1.3 INFERENTIAL STATISTICS

Inferential statistics is a formalized body of methods for solving another class of problems. This general class of problems involves attempts to infer the properties of a large collection of data from inspection of a sample of observations. For example, a school superintendent wishes to determine the proportion of children in a large school system who come in without breakfast (have used drugs, have been vaccinated for Asian flu, or whatever). Having a little knowledge of statistics, the superintendent would know that it is unnecessary and inefficient to question each child; the proportion for the entire district could be estimated fairly accurately from a sample of as few as 100 children.

Thus the purpose of inferential statistics is to predict or estimate characteristics of a population from a knowledge of the characteristics of only a sample of the population. The descriptive characteristics of a sample can be generalized to the entire population, with a known margin of error, using the techniques of inferential statistics.

The design and analysis of experiments is an important branch of inferential statistical methods. These methods were developed for testing causal relationships among variables. Experimental design is so important for the study of causal relationships that in some philosophical systems an experiment constitutes an operational definition of a causal relationship. Adults make causal inferences during all their waking moments. The frequent use of the word "because" reveals this: "The school bond failed to pass because it was not well publicized" or "He scored poorly on the intelligence test because he was overly anxious about the consequences of the score." Statistical methods assist researchers in describing data, in drawing inferences to larger bodies of data, and in studying causal relationships.

1.4
STATISTICS AND MATHEMATICS

The discipline of statistics is a branch of applied mathematics. Mastering statistical methods requires some mathematical proficiency, but less than commonly assumed. Do not think statistics is accessible only to the specially trained. In this book, much use is made of intuition, logical reasoning, and simple arithmetic. Much of the rationale of applied statistics and many of its techniques can be learned without advanced mathematical skills.

If you have not studied mathematics, logic, or any other rigorous and deductive discipline recently, you may find studying statistics uncomfortable for a while. In many disciplines characterized by vague verbal discourse and personalistic use of language, a student can sustain sloppy and erroneous thinking for long periods without being aware of it. A speaker might receive an enthusiastic audience reaction to the statement, "Viable individualized, democratic, and creative alternatives are necessary to meet the needs of the whole child." If the statement is scrutinized, however, its meaning is so ambiguous and imprecise that it is essentially meaningless. The student of statistics is likely to be confronted abruptly and uncomfortably with the results of careless thinking. If you are inclined toward critical and precise thought, this restrictive and confining mantle will soon begin to feel comfortable. The satisfying reassurance of knowing that you are mastering a logical and unambiguous language will outweigh the work involved in learning it. Being wrong on occasion is the price we must pay for knowing when we are correct. Not knowing if we are speaking nonsense is too expensive a luxury to entertain in an age in which sense is scarce.

A word to the wise: "Be ye doers of the word, and not hearers only, deceiving your own selves" (James 1:22). By far the greatest demand that the study of statistics exacts from the student is thorough, detailed, and careful attention to the subject. A quick reading of this book will not produce a mastery of statistics. A statistics text is not