A Conceptual and Computational Approach with **SPSS** and **SAS**

ANALYSIS OF VARIANCE DESIGNS

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Analysis of Variance Designs

A Conceptual and Computational Approach with SPSS and SAS

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Preface

TO THE INSTRUCTOR

The present text is an exploration of univariate methodology where the effects of one or more independent variables are assessed on a single dependent variable. Such univariate designs are ubiquitous in the social, behavioral, and biological science literature. We have chosen, in this book, to focus our efforts on analysis of variance (ANOVA). Issues concerning multivariate methodology, including multiple regression analysis, are not covered in the present text as a result of space limitations, but they are addressed in a companion text (see Meyers, Gamst, & Guarino, 2006).

This book owes both a conceptual and computational debt to early ANOVA pioneers, beginning with the seminal work of Fisher (1925, 1935), who focused on solving agricultural problems with experimental methods. Fisher's early work was adapted to other fields, including the social and behavioral sciences, and in doing so moved from childhood to early adolescence with the work of Baxter (1940, 1941), Crutchfield (1938), Garrett and Zubin (1943), Lindquist (1940), Snedecor (1934), and Yates (1937). By the 1950s, ANOVA procedures were well established within most social and behavioral sciences (e.g., Cochran & Cox, 1957; Lindquist, 1953; Scheffé, 1959).

Beginning in the early 1960s, ANOVA procedures were further delineated and popularized by Winer (1962, 1971) and Winer, Brown, and Michels (1991). These works, while sometimes challenging to read, were considered the "gold standard" by many ANOVA practitioners. In the 1970s, and up until the present, Geoffrey Keppel and his associates (Keppel, 1973, 1982, 1991; Keppel & Saufley, 1980; Keppel, Saufley, & Tokunaga, 1992; Keppel & Wickens, 2004) have helped to formalize the teaching of ANOVA through their innovative mnemonic notation system.

Pedagogically, there are at least three ways that an instructor can approach ANOVA; the present text attempts to address each of these course schemas. One approach is to emphasize the drill and practice of computational formulas and procedures for creating sums of squares, mean squares, and so on. Texts that have catered to such courses have run the gamut from purely step-by-step computational procedures (e.g., Bruning & Kintz, 1968; Collyer & Enns, 1987) to conceptual and computational medleys (e.g., Keppel et al., 1992). Instructors of these courses believe that students are best served by teaching them the computational mechanics behind the ANOVA results.

A second approach has been motivated by the proliferation of microcomputer technology and its attendant statistical software (e.g., SPSS and SAS). Statistical software-oriented instructors believe student interest and motivation for conducting statistical analyses may be better enhanced and maintained with a focus on statistical conceptualization accentuated with computer application. Hence, these instructors focus on the interpretation of computer-statistical output and are less inclined to have students "plug away" with a calculator to solve a statistical problem. A number of texts that vary in ANOVA topic coverage have emerged that attempt to address this instructional niche (e.g., Kinnear & Gray, 2006; Page, Braver, & MacKinnon, 2003).

Of course, a third pedagogical approach is to combine the first two approaches. Instructors who operate from this third orientation see the benefit, to the student, of requiring computational drill and practice with a calculator *and* computer application.

First, the present text attempts to bridge the gap between the two primary pedagogical orientations mentioned previously. This is accomplished by providing a thorough, readable, and well-documented conceptual foundation for each of the ANOVA topics covered in the text. Second, computational examples are provided for most of the topics covered. Third, SPSS and SAS screen images and computer output are illustrated for all ANOVA problems covered in the text.

This text consists of seventeen chapters that are segmented into six topical sections.

Section 1, "Research Foundations," consists of two chapters. Chapter 1, "ANOVA and Research Design," explores various types of research strategies, including nonexperimental, quasiexperimental, and experimental research designs. Key concepts of independent and dependent variables, scales of measurement, and between-subjects and within-subjects designs are also introduced. In Chapter 2, "Measurement, Central Tendency, and Variability," the central tendency concepts of the mean, median, and mode, along with the variability concepts of range, variance, and standard deviation, are explained. Numerical examples are also provided.

Section 2, "Foundations of Analysis of Variance," consists of three chapters. In Chapter 3, "Elements of ANOVA," the partitioning of the total variance into between-groups and within-groups variability is explained with a concrete study example. Chapter 4, "The Statistical Significance of *F* and Effect Strength," includes topics of the *F* ratio, the sampling distribution of *F*, statistical significance, and magnitude of treatment effects. In Chapter 5, "ANOVA Assumptions," the three fundamental assumptions underlying ANOVA are covered: independence of errors, normality of errors, and homogeneity of variance. Ways of assessing these violation assumptions with SPSS and SAS are offered.

Section 3, "Between-Subjects Designs," consists of four chapters. Chapters 6, 8, and 9 provide conceptual and computational foundations for one-, two-, and three-way between-subjects designs, respectively. Chapter 7 provides an overview of multiple comparisons procedures.

Section 4, "Within-Subjects Designs," consists of three chapters. Chapters 10, 11, and 12 cover the conceptual and computational details associated with one-, two-, and three-way within-subjects designs.

Section 5, "Mixed Designs," also consists of three chapters. Chapters 13, 14, and 15 cover simple mixed designs, complex mixed designs with two between-subjects factors and one within-subjects factor, and complex mixed designs with one between-subjects factor and two within-subjects factors, respectively.

Section 6, "Advanced Topics," concludes with Chapter 16 on analysis of covariance and Chapter 17 on advanced topics, which provides a brief introduction to a number of advanced ANOVA topics.

We believe that Chapters 1–8, 10, and 13 provide sufficient depth for an advanced undergraduate course that emphasizes ANOVA procedures. Beginning graduate students would benefit from these chapters also, in addition to the chapters dealing with the three-way and mixed designs, as well as the advanced topics chapters.

TO THE STUDENT

This text assumes that you, the student, have had at least one undergraduate course in statistics. Typically, these introductory courses do not cover ANOVA in much depth, if at all. This book will show you when to use these procedures and also how to perform these computations with a calculator and with SPSS and SAS statistical software. In preparing this book, we used SPSS version 16.0 and *SAS Enterprise Guide* 4.0. At the time you are reading this, it is quite likely that newer versions will have become available; however, we anticipate that virtually all of what you find here will be able to be applied to the newer software.

We accomplish these goals by providing you with what we believe to be a readable conceptual overview of all ANOVA topics covered. For many of these topics, we delineate step-by-step computational procedures for calculating various statistics by hand. We follow the hand computations with step-by-step screen images of how to perform these same procedures with SPSS and SAS. We also provide an example results section write-up for each procedure that we cover. Based on the specific task demands of your particular course and instructor, you may want to allocate more or fewer resources to certain parts of each chapter.

We hope you enjoy using this text. We also hope that it helps you in reading the journal articles that make use of ANOVA techniques in their data analysis sections, and that it encourages you to explore the use of ANOVA designs in your own research applications.

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Glenn Gamst
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SECTION 1

Research Foundations

CHAPTER ONE

ANOVA and Research Design

1.1 WHAT IS ANALYSIS OF VARIANCE?

Analysis of variance (ANOVA) is a statistical technique used to evaluate the size of the difference between sets of scores. For example, a group of researchers might wish to learn if the room color in which college students are asked to respond to questions assessing their mood can affect their reported mood. Students are randomly assigned to complete a mood inventory in one of two rooms. Random assignment, one of the hallmarks of experimental design, is used in an attempt to assure that there is no bias in who is placed into which group by making it equally likely that any one person could have been assigned to either group. One of the rooms is painted a soft shade of blue that was expected to exert a calming effect on the students; the other room is painted a bright red that was presumed to be more agitating than calming. Higher numerical scores on the mood inventory indicate a more relaxed mood. At the end of the study, we score the mood inventory for all participants.

The research question in this example is whether mood as indexed by the score on the mood inventory was affected by room color. To answer this question, we would want to compare the mood scores of the two groups. If the mood scores obtained in the blue room were higher overall than those obtained in the red room, we might be inclined to believe that room color influenced mood.

One way to start the comparison process is to take an average (a mean) for each group of the responses to the mood questions and visually inspect these two values. But comparing the scores between the groups in order to draw a conclusion about the effect of the color of the room on mood is not always going to be a simple matter. Among the related questions that we face in doing the comparison are:

- How much of a difference is there between the means?
- How much overlap is there in the scores of the members of each group?
- Based on the difference in the means and the overlap in scores, is the mean difference sufficiently large for us to say that room color made a difference?