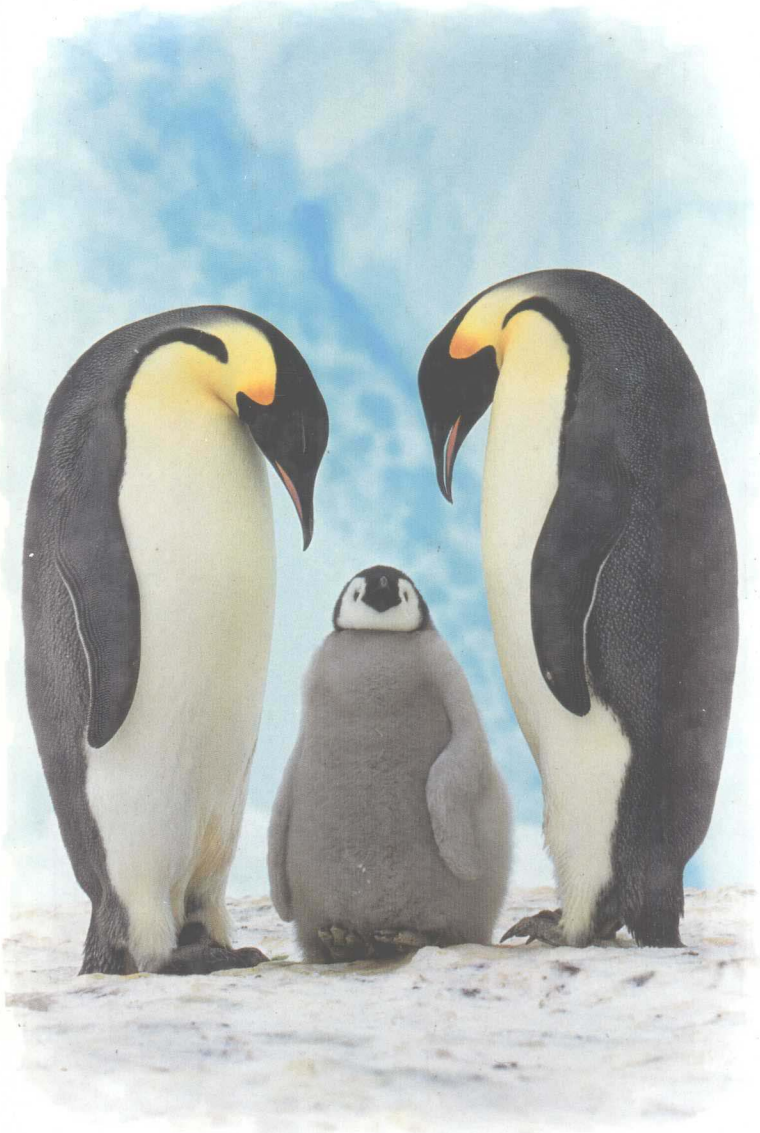
STATISTICS *for* PSYCHOLOGY

Second Edition



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STATISTICS FOR PSYCHOLOGY

Second Edition

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Preface to the Instructor

The heart of the first edition of this book was written over a summer in a small Paris apartment near the Place Saint Ferdinand, having been outlined in nearby cafés and on walks in the Bois de Boulogne. It was based on our 30 years' experience teaching, doing research, and writing. We believe that the book we wrote was as different from the conventional lot of statistics books as Paris is from Calcutta, yet still comfortable and stimulating to the long-suffering community of statistics instructors.

The approach embodied in this text was developed over three decades of successful teaching—successful not only in the sense that students consistently rated the course (a statistics course, remember) as a highlight of their major but also in the sense that students come back to us years later saying, "I was light years ahead of my fellow graduate students because of your course," or "Even though I don't do research now, your course has really helped me read the journals in my field."

The response to the first edition has been overwhelming. We have received scores of thank-you e-mails and letters from instructors (and from students themselves!) from all over the English-speaking world. Of course, we were also delighted by the enthusiastic review in *Contemporary Psychology* (Bourgeois, 1997).

In this second edition we have tried to maintain those things about the book that were especially appreciated, while reworking the text to take into account the feedback we have received, our own experiences, and advances and changes in the field. However, before turning to the second edition, we want to reiterate some comments we made in the first edition about the history of textbooks in the field and what we have done differently.

A BRIEF HISTORY OF THE STATISTICS TEXT GENRE

In the 1950s and 1960s statistics texts were dry, daunting, and mathematical books that quickly left most students behind. In the 1970s, there was a revolution—in swept the intuitive approach, with much less emphasis on derivations, proofs, and mathematical foundations. The approach worked. Students became less scared of statistics courses and found the topic more accessible, if not quite clear.

The intuitive trend continued in the 1980s, adding in the 1990s some truly clear writing. A few texts have now also begun to encourage students to use the computer to do statistical analyses. However, discussions of intuitive understandings are becoming briefer and briefer. The standard is a kind of minimalism in which there is a cursory overview of the key idea and sometimes the associated "definitional" formula for each technique. Then come the procedures and examples for actually doing the computation, using another, "computational" formula.

Even with all this streamlining, or perhaps because of it, at the end of the course, most students cannot give a clear explanation of the logic behind the techniques they have learned. A few months later, they can rarely carry out the procedures either. Most important, the three main purposes of the introductory statistics course are not accomplished: Students are not able to make sense of the results of psychology research articles, they are poorly prepared for further courses in statistics (where instructors must inevitably spend half the semester reteaching the introductory course), and the exposure to deep thinking that is supposed to justify the course's meeting general education requirements in the quantitative area has not occurred.

WHAT WE HAVE DONE DIFFERENTLY

We continue to do what the best of the newer books are already doing well: emphasizing the intuitive, deemphasizing the mathematical, and explaining everything in clear, simple language. But what we have done differs from these other books in 11 key respects.

1. ***The definitional formulas are brought back to center stage*** because they provide a concise symbolic summary of the logic of each particular procedure. All our explanations, examples, practice problems, and test bank items are based on these definitional formulas. (The numbers involved in practice problems and test items are appropriately reduced to keep computations manageable).

Why this approach? To date, statistics books have failed to adjust to technological reality. What is important is not that the students learn to calculate a *t* test with a large set of numbers—computers can do that for them. What is important is that students remain constantly aware of the underlying logic of the procedure. For example, consider the population variance—the average of the squared deviations from the mean. This concept is immediately clear from the definitional formula (once the student is used to the symbols): Variance = $\Sigma(X - M)^2/N$. Repeatedly working problems using this formula ingrains the meaning in the student's mind. In contrast, the usual computational version of this formula serves only to obscure this meaning: Variance =

$[\Sigma X^2 - (\Sigma X)^2/N]/N$. Working problems using this formula does nothing but teach the student the difference between ΣX^2 and $(\Sigma X)^2$!

Teaching computational formulas today is an anachronism. Researchers do their statistics on computers now. At the same time, the use of statistical software makes the understanding of the basic principles, as they are symbolically expressed in the definitional formula, more important than ever.

It is a mystery to us why statistics textbooks have not changed their methods with the advent of statistical software, but we are convinced that the change is overdue. Of course, because computational formulas are both historically interesting and occasionally needed—and because some instructors may feel naked without them—we still provide them (with a worked-out example), in a brief appendix to each chapter in which a computational formula would normally be introduced.

2. *Each procedure is taught both verbally and numerically—and usually visually as well—with the same examples described in each of these ways.* Practice exercises and test bank items, in turn, require the student to calculate results and make graphs or illustrations and also to write a short explanation in layperson's language of what the statistics mean. The chapter material, including at least two examples worked out in these different ways, completely prepares the student for the practice problems and test questions.

It is our experience that these different ways of expressing an idea are very important for permanently establishing a concept in a student's mind. Many students of psychology are more at ease with words than with numbers. In fact, some have a positive fear of all mathematics. Writing the lay-language explanation gives them an opportunity to do what they do best and, if they are having trouble, forces them to see that and to put the procedures in front of them in the verbal form they process best.

3. *We emphasize statistical methods as a living, growing field of research.* We take the time to describe controversies and recent developments in simple terms. The goal is for students to see statistical methods as human efforts to make sense out of masses of data points; to see that statistics are not "given" by nature, not infallible, not perfect descriptions of the events they try to describe but rather constitute a language that is constantly improving through the careful thought of those who use it. We hope that this orientation will help them maintain a questioning, alert attitude while students and keep up with new developments in statistics as professionals.

4. The main goal of any introductory statistics course in psychology is to ***prepare students to read research articles.*** In fact, the way a procedure such as a *t* test or an analysis of variance is described in a research article is often quite different from what the student expects from the standard textbook discussions. Therefore, as this book teaches a statistical method, it also gives examples of how that method is reported in the journals (excerpts from current articles). The practice exercises and test bank items also include excerpts from articles for the student to explain.

5. The book is unusually ***up-to-date.*** For some reason, most introductory statistics textbooks we have seen read as if the authors were writing in the 1950s. The basics are still the basics, but the subtleties of the way statisticians and researchers think about those basics has changed radically. Today, the basics are undergirded by a different appreciation of issues like effect size, power, and accumulation of results through meta-analysis; the central role of

models; the underlying unity of difference and association statistics and the growing prominence of regression and its associated methods; and a whole host of new orientations arising from the prominent role of the computer in analyses. We are very much engaged in the latest developments in statistics theory and application and we believe this book reflects that engagement. For example, we devote an entire chapter to effect size and power, and in discussing how to handle situations in which assumptions are not met, we cover data transformations (this widely used approach is easily accessible to introductory students, but is rarely mentioned in most current introductory texts). Of course, the sections on controversies and recent developments play a central part in keeping the book current with how statistics are actually used in research today.

6. ***Chapter 16*** is unique in that it ***integrates the major techniques that have been taught,*** explaining that the *t* test is a special case of the analysis of variance and that both the *t* test and the analysis of variance are special cases of correlation and regression. (In short, we introduce the general linear model.) In the past, when this point has been made at all, it has usually been only in advanced texts. But many students find it valuable for digesting and retaining what they have learned, as well as for sensing that they have penetrated deeply into the foundations of statistical methods.

7. ***The final chapter looks at advanced procedures*** without actually teaching them in detail. It explains in simple terms how to make sense out of these statistics when they are encountered in research articles. Most psychology research articles today use methods such as analysis of covariance, multivariate analysis of variance, hierarchical multiple regression, factor analysis, and structural equation modeling. Students completing the ordinary introductory statistics course are ill-equipped to comprehend most of the articles they must read to prepare a paper or study for a course. This chapter makes use of the basics that students have just learned (along with extensive excerpts from current research articles) to give a rudimentary understanding of these advanced procedures. It also serves as a reference guide that they can keep and use in the future when reading such articles.

8. The book is written to ***appeal to the motivations that prompt a student to become a psychology major.*** While attempting to represent the diversity of psychology, our examples emphasize topics and populations that students seem to find most interesting. The very first example is from a real study in which 151 students rate how much stress they feel they are under during their first week of an introductory statistics class. Other examples emphasize clinical, organizational, and educational psychology while being sure to include sufficient interesting examples from experimental, social, developmental, and other areas to inspire students with the value of those fields. Also, in our examples, we continually emphasize the usefulness of statistical methods as tools in the research process, never allowing students to feel that what they are learning is theory for the sake of theory. Appendix A provides an overview of research methods, giving the context in which statistics function. And as each technique is taught, its role in the research process is illustrated and underscored.

9. The accompanying ***Student's Study Guide and Computer Workbook*** focuses on mastering concepts and also includes instructions and examples for working problems using a computer. Most study guides concentrate on plugging numbers into formulas and memorizing rules (which is consistent

with the emphasis of the textbooks they accompany). For each chapter, our *Student's Study Guide and Computer Workbook* provides learning objectives, a detailed chapter outline, the chapter's formulas (with all symbols defined), and summaries of steps for conducting each procedure covered in the chapter, plus a set of self tests, including multiple-choice, fill-in, and problem/essay questions. In addition, for each procedure covered in the chapter, the study guide furnishes a thorough outline for writing an essay explaining the procedure to a person who has never had a course in statistics. As a further study aid, it includes cutout flash cards of all the key terms.

Especially important, our *Student's Study Guide and Computer Workbook* provides the needed support for teaching students to conduct statistical analyses on the computer. First, there is a special appendix introducing the language and procedures of SPSS for Windows. Then, corresponding to the text chapters, there is a section detailing how to carry out each chapter's procedures on the computer. (This section includes step-by-step instructions, examples, and illustrations of how each step of input and output appears on the computer screen.) There are also special activities for using the computer to deepen understanding. As far as we know, no other statistics textbook package provides this kind of flexibility or this much depth of explanation.

10. We have written an ***Instructor's Manual that really helps teach the course.*** The *Manual* begins with a chapter summarizing what we have gleaned from our own teaching experience and the research literature on effectiveness in college teaching. The next chapter discusses alternative organizations of the course, including tables of possible schedules and a sample syllabus. Then each chapter, corresponding to the text chapters, provides full lecture outlines and ***worked-out examples not found in the text*** (in a form suitable for copying onto transparencies or for student handouts). These are particularly useful in that creating worked-out examples is one of the most difficult parts of preparing statistics lectures.

11. Our ***Test Bank and Answers to Set II Practice Problems makes preparing good exams easy.*** We supply approximately 40 multiple-choice, 25 fill-in, and 10–12 problem/essay questions for each chapter. Considering that the emphasis of the course is so conceptual, the multiple-choice questions will be particularly useful for those of you who do not have the resources to grade essays. This supplement also includes answers to each textbook chapter's Set II practice problems, which are not given in the text. (The textbook provides answers to all Set I practice problems, including at least one example essay for each chapter.)

INFLUENCES ON THE SECOND EDITION

We did the revision for the second edition in Manhattan. We hope that this has not resulted in a loss of whatever romance the first edition gained from being written in Paris. On the other hand, this edition has been leavened by a lot of theater and ballet.

More important, this revision is enriched by our experience teaching with the first edition and by the experience and encouragement of scores of instructors who have written to us about their experiences in using the book. This revision is also informed by our own use of statistical methods—the last five years have been a very productive time for the two of us in our own

research programs in personality and social psychology. (For overviews of our main research programs, see A. Aron & E. Aron, 1997; E. Aron & A. Aron, 1997.) Perhaps particularly useful has been that one of us (AA) has served as associate editor for the *Journal of Personality and Social Psychology* during the last three years. This has kept us in touch with how the best researchers are using statistics (as well as how reviewers rate their colleagues' use of statistics).

This revision is also much affected by developments in statistics and their use in psychology during these last five years. Foremost in this regard has been the controversy over the value of significance tests and the associated proposals for replacing them with effect size point estimates and confidence intervals. The issues being raised will undoubtedly shape the way psychologists use statistics in decades to come. In the short run, the influence has been surprisingly meager. In his three years as *JPSP* editor, AA has handled about 150 manuscripts, yet only one has evidenced the current controversy. Editors of other journals tell us their experience is similar. Thus, we think that in the near future students will continue to need to be well versed in traditional significance testing in order to read new articles, as well as to read older ones.

Nevertheless, in this revision we have tried to take account of what may be winds of change. In particular, we have enhanced our treatment of confidence intervals and extensively covered the issues involved in the current debate about hypothesis testing (see the controversy sections of Chapters 5, 7, and 8). Perhaps most important are subtle wording changes throughout the text based on our cognizance of current issues. Our goal is to prepare students who use this book for whatever change comes, but at the same time ensure they know the basics as they exist today. So, while everyone agrees that significance tests have been all too commonly misused, we emphasize just those points that make sure that students won't repeat common misuses.

SPECIFIC CHANGES IN THE SECOND EDITION

The revisions we have done are of four main kinds:

1. ***Writing.*** We have thoroughly reviewed every sentence, simplifying constructions and terminology wherever possible. It is hard enough to learn statistics without having to read complicated sentences.

2. ***Updating examples.*** We have replaced over 100 examples from the first edition with new ones published in the last year or two. This is particularly important for the sections on how to understand and evaluate research articles. The whole point of these sections is for students to see how statistics actually look when reported in current research. In reviewing the old examples and finding new ones, we were struck by quite a few subtle changes in the way statistical results are being reported. For example, five years ago interaction effects in analysis of variance were generally reported with line graphs—today they usually use bar graphs (see Chapter 13).

3. ***Updating content and controversies.*** We have updated the content taking into account new developments in the field relevant to the basic statistics course. This includes the material noted earlier about the controversy over significance testing as well as a number of other changes, such as the influence of DeCarlo's (1997) paper on kurtosis or Frick's (1995) paper on proving the null hypothesis. The content revisions also recognize such basic

language changes as using "participants" instead of "subjects" in keeping with current American Psychological Association style.

4. *Adjustments to enhance pedagogy and better meet the needs of instructors using the book.* We have added new sections on probability and on repeated measures analysis of variance (see appendixes to Chapters 5 and 13), a section in Chapter 1 on levels of measurement, and a substantial section on confidence intervals. We have spelled out most of the subscripts. We have also made even more of an effort than in the first edition to use multicultural examples whenever possible.

Some changes we have not made. The 11 points noted earlier in this introduction remain as the central, unique features of this book. Wherever possible, we also avoided changing examples involving large tables of computations to minimize the chance of errors creeping in.

KEEP IN TOUCH

Our goal is to do whatever we can to help you make your course a success. If you have any questions or suggestions, please write or e-mail (**ARON@PSYCH1.PSY.SUNYSB.EDU** will do for both of us). If—heaven forbid—you should find an error somewhere, we promise that we will (a) fix it in the very next printing, (b) send out the details to everyone on the network, and (c) include your name with our thanks in the Preface to the next edition.

ACKNOWLEDGMENTS

First and foremost, we are grateful to our students through the years, who have shaped our approach to teaching by rewarding us with their appreciation for what we have done well, as well as their various means of extinguishing what we have done not so well.

For getting us started on this project, we are grateful to our friend Bryan Strong, who encouraged us to undertake it in the first place, and to Brete Harrison, who guided the project through its initial development. We also appreciate the input and support from our friend John Touhey, who read several of the early draft chapters. The reviewers of the book at various stages have been extremely helpful in identifying weak points of logic and pedagogy, and their generosity of praise provided momentum when we occasionally became lost in the immensity of the project. We want to thank Paul C. Amrhein, University of New Mexico; James V. Couch, James Madison University; Livia M. D'Andrea, University of Nevada, Reno; Susan E. Dutch, Westfield State College; Peter C. Hill, Grove City College; J. Robert Newman, California State University, Long Beach; Michael L. Frank, Stockton State College; Martin A. Johnson, Missouri Western State College; Carol Pandey, L. A. Pierce College; Roger Bakeman, Georgia State University; Jeffrey S. Berman, Memphis State University; and Michael J. Scozzaro, SUNY College at Buffalo

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Introduction to the Student

The goal of this book is to help you *understand* statistics. We emphasize meaning and concepts, not just symbols and numbers.

This emphasis plays to your strength. Most psychology majors are not lovers of calculus but are keenly attuned to ideas. And we want to underscore the following, based on our experience of 30 years of teaching: *We have never had a student who could do well in other college courses who could not also do well in this course.* (However, we will admit that doing well in this course may require more work than doing well in others.)

In this introduction, we discuss why you are taking this course and how you can gain the most from it.

WHY LEARN STATISTICS? (BESIDES FULFILLING A REQUIREMENT)

1. *Understanding statistics is crucial to being able to read psychology research articles.* Nearly every course you will take as a psychology major emphasizes the results of research studies, and these are usually expressed in statistics. If you do not understand the basic logic of statistics—if you cannot make sense of the jargon, the tables, and the graphs that are at the heart of any research report—your reading of research will be very superficial.

2. *Understanding statistics is crucial to doing research yourself.* Many psychology majors eventually decide to go on to graduate school. Graduate study in psychology—even in clinical and counseling psychology and other applied areas—almost always involves *doing* research. Often learning to do research on your own is the entire focus of graduate school, and doing

research almost always involves statistics. This course gives you a solid foundation in the statistics you need for doing research. Further, by mastering the basic logic and ways of thinking about statistics, you will be unusually well prepared for advanced courses that focus on the nitty-gritty of analyzing research results.

Many psychology programs also offer opportunities for undergraduates to do research. The main focus of this book is understanding statistics, not using statistics. Still, you will learn the skills needed to do the most basic data analyses used in the kinds of research you are likely to do.

3. *Understanding statistics develops your analytic and critical thinking.* Psychology majors are often most interested in people and in improving things in the practical world. This does not mean that psychology majors avoid abstractions. In fact, the students we know are exhilarated by the almost philosophical levels of abstraction where the secrets of human experience so often seem to hide. But even this kind of abstraction is often grasped only superficially at first, as slogans instead of useful knowledge. Of all the courses you are likely to take in psychology, this course will probably do the most to help you learn to think precisely, to evaluate information, and to apply logical analysis at a very high level.

HOW TO GAIN THE MOST FROM THIS COURSE

There are five things we can advise:

1. *Keep your attention on the concepts.* Treat this course less like a math course and more like a course in logic. When you read a section of a chapter, focus your attention on grasping the principles. When working the exercises, think about why you are doing each step. If you simply try to memorize how to come up with the right numbers, you will have learned very little of use in your future studies—nor will you do very well on the tests in this course.

2. *Be sure you know each concept before you go on to the next.* Statistics is cumulative. Each new concept is built on the last one. Even within a chapter, if you have read a section and you don't understand it—*stop.* Reread it, rethink it, ask for help. Do whatever you need to do to grasp it. (If you think that you understand a section but are not sure, try working a relevant practice problem from the end of the chapter.)

Having to read the material in this book over and over does not mean that you are stupid. Most students have to read each chapter several times. And each reading is much slower than reading an ordinary textbook. Statistics reading has to be pored over with clear, calm attention in order for it to sink in. Allow plenty of time for this kind of reading and rereading.

3. *Keep up.* Because statistics is cumulative, if you fall behind in your reading or miss lectures, the lectures you then attend will be almost meaningless. And it will get harder and harder to catch up.

4. *Study especially intensely during the first half of the course.* It is especially important to master the material thoroughly at the start of the course. This is because everything else in statistics is built on what you learn at the start. Yet the beginning of the semester is often when students study least seriously.

If you have mastered the first half of the course—not just learned the general idea, but really know it—the second half will be easier. If you have not mastered the first half, the second half will be close to impossible.

5. *Help each other.* There is no better way to solidify and deepen your understanding of statistics than to try to explain it to someone who is having a harder time. (Of course, this has to be done with patience and respect.) For those of you who are having a harder time, there is no better way to work through the difficult parts than by learning from another student who has just mastered the material.

Thus, we strongly suggest that you form study teams with one to three other students. It is best if your team includes some members who expect this material to come easily and some who don't. Those who learn statistics easily will get the most from helping others who have to struggle with it—the latter will challenge the former's supposed understanding enormously. For those who fear trouble ahead, you need to work with those who don't—the blind leading the blind is no way to learn. Also pick teammates who live near you so that it is easy for you to get together. And meet often—between each class, if possible.

A FINAL NOTE

Believe it or not, we love teaching statistics. Time and again, we have had the wonderful experience of having beaming students approach us to say, "Professor Aron, I got a 90% on this exam. I can't believe it! Me, a 90 on a statistics exam!" Or the student who tells us, "This is actually fun. Don't tell anyone, but I'm actually enjoying statistics, of all things!" We hope you will have these kinds of experiences in this course.

Arthur Aron
Elaine N. Aron

Contents