Fundamentals of Behavioral Statistics

心理统计

第九版

［美］ Richard P. Runyon
理查德·鲁尼恩 等著

人民邮电出版社
POSTS & TELECOM PRESS

心 理 统 计

第 九 版

理查德·鲁尼恩

[美] 凯 · 科尔曼　　著

戴维 · 皮滕杰

总　序

中国心理学有一个很早的开端,却有不长的历史。从 1900 年京师大学堂开设"心理学概论"课程,1917 年北京大学成立中国第一个科学心理学实验室,到随后清华大学、杭州大学等一批学校成立心理学系,说起来有一个多世纪了。但由于 20 世纪战争与和平的较量以及文化意识形态领域里的跌宕起伏,相当多的时间被耽误了,学科发展被拖了后腿,算起来,真正用心做学问的时间大约不过半个世纪。

中国心理学有一个不错的开端,却有坎坷的历程。早在 1908 ~ 1910、1912 ~ 1913 年,蔡元培先生两度在德国游学,两度选修了冯特的"实验心理学"课程,这对他后来极力推动北京大学心理学的发展起了很大的影响。更有 20 世纪二三十年代,唐钺、孙国华、陈立、潘菽、曹日昌、朱智贤、周先庚等一批学者在美国哈佛、斯坦福、康奈尔、芝加哥大学等名校留学归来,投入国内心理学建设,形成了北方、南方诸多学校心理学齐发展的格局。但由于经费困难,后来的战乱,五六十年代对心理学的不公正对待和后来的文化大革命,中国心理学"几起几落"。

改革开放以来,中国心理学迎来了大发展的春天,教学和研究迅速普及,师资队伍和学生规模始终呈加速度扩张。在 1980 年,国内只有北京大学、北京师范大学、华东师范大学和杭州大学 4 个学校设有心理学系,到 90 年代初中期增加到了约 20 余所学校,再到 21 世纪初这几年增加到了 100 多所学校,几乎是每 10 年翻两三番! 发展速度可谓惊人。

然而,高速发展也产生发展中的瓶颈。一方面,众多学校建设心理学系,开展心理学教学和研究,同时国内社会经济与文化的发展对心理学的需求越来越旺盛;另一方面,国内心理学的总体水平相对西方发达国家还比较落后,教学研究队伍并不壮大,教学研究水平仍急待提高。这种需求与供给、速度与质量的矛盾,不断激化,要保证国内心理学的健康发展,必须寻求一些有效的方法和途径。

"西学东渐"、"洋为中用"是可以推荐的诸多方法之一。教育部高教司近年来大力提倡引进外版教材和开展双语教学,这无疑对内地心理学教学的发展产生巨大的推动作用。心理学诞生在西方。据统计,美国每年授予博士学位人数最多的学科是心理学,可见心理学在美国的重要和普及程度。心理学的高等教育在西方积累了较丰富的经验,教材在内容、形式上都比较成熟,而且快速有效地跟进国际心理学科学发展的前沿趋势,对于保持高等教育的水平有举足轻重的作用。相比来看,我国内地一些地区心理学师资匮乏,一些自编教材低水平重复,对教、学质量均有很大负面影响,情况堪忧。

教育部高等学校心理学教学指导委员会是国家教育部设立的心理学高等教育指导、咨询机构,负责制定国家心理学高等人才培养的宏观战略和指导规范。根据教育部发展高等教育的有关精神,我们与国内外多家出版机构合作,作为一个长期的工程,有计划、分期分批地引进外版教材,以期推动我国心理学教学的快速高效发展。

麦格劳－希尔出版公司在出版心理学教材方面富有经验,此次引进的教材均是麦格劳－希尔多年再版,被实践证明为适合高等学校教学的优秀教材。特别是,这些教材均经过国内著名专家学者鉴定并大力推荐,这对引进教材的质量起到了重要的把关作用。在此谨对这些专家学者表示特别的感谢和敬意!

希望这套教材对高校的心理学教学有所帮助,并祝愿我国的心理学高等教育事业蓬勃发展!

王　垒
北京大学心理学教授
教育部高等学校心理学教学指导委员会主任

序

张厚粲

　　行为统计学作为统计学的一个应用性极强的分支学科，教人们在社会和行为科学研究中，以探索数据内在的数量规律性为依据，获得对客观事物的科学认识。就当今的社会与行为科学来说，其繁荣发展在很大程度上得益于统计方法的引入。无论实验研究还是社会调研，对所得数据的统计分析都是重要环节。

　　然而多年的教学经验表明，统计学常常给学生带来困惑。他们为学习统计学感到焦虑，虽然花费很多的时间和精力却收效甚微，在面临实际问题时还是手足无措。究其原因在很大程度上是缺乏一本合适的教材。纵观国内相关专业著作，大多数都没有能在原理推导和实际问题解决方面平衡得很好：有的数学背景较强，太多的统计原理和推导，较少实际意义的说明，有的则只重介绍统计技术的应用，缺乏对原理概念的必要说明。在当今，诸如 SPSS、SAS 之类的软件已经将我们从繁重的数学计算中解脱出来，记忆大多数运算公式及其推导过程，已无多大意义。对统计学的学习来说，最主要的是掌握统计思想，理解相关的统计原理，能够根据实际情境提出解决问题的一个或几个合适方案，并懂得选择其中的最优。

　　因此适合非统计专业学生的统计学理想教材，应该是能兼顾专业特点、深入浅出阐述统计学基本原理和方法，同时在轻快风趣的讲述中激发读者的学习兴趣，培养统计思维，并辅之例题分析，对使用中容易发生的错误加以提醒，切实提高学生应用统计方法分析解决实际问题的能力。

　　《心理统计》(第9版)正是这样一本非常出色的教材，它在美国被很多大学的相关院系定为教学用书。从第1版开始，作者就努力尝试在理论阐释和实际应用两种取向之间寻找一个适恰的平衡点，注重在教学中培养统计推理和批判性思维的能力，到第9版更臻于完善。在中国出版影印本，使学生在学习中自然地掌握英语专业词汇，还有利于查阅资料。在目前鼓励使用原文教材的情况下，更有着特殊意义。

　　概括起来，这本书至少有如下三个特点：

　　(1) 以浅显易懂的语言很好地解释了复杂的统计思想，清晰阐明隐藏在繁杂统计程序背后的统计方法和原理。在书中看到的既不是以往那些冗长

的公式推导过程，也不是一些数学公式的简单罗列，而是在通过多种途径对一个统计学概念作分析说明。对于必要提供的公式，不仅用语言解释其中的原理，还将抽象概念转化成视觉图表，有利于读者的理解和记忆。

(2) 在清晰阐述统计原理的同时，配以具体的样例，很好地做到了理论和实际应用的结合，从而有助于读者更好地掌握各种统计方法与技能。这些研究样例展示了统计方法在各实际领域中的应用，不仅贴近社会生活而且生动有趣。它们有机结合在书中各处，似是作者信手拈来，却又恰到好处，反映出作者深厚的学术功底和丰富的教学经验。最后，在样例中还展示了如何规范化地呈现研究结果，教学生以清楚撰写研究报告的技能也具有重要意义。

(3) 在组织结构和写作手法上也颇具特色。所有章节之间有着内在联系，但每一章都相对独立，使教学过程中教师可以根据需要调整授课顺序；作者将重要概念在页边单独列出，有助于引起读者注意和学习把握；每章后面的小结和练习题更是作者的精心安排，它可使读者更清晰地把握每章的主要内容和要点，巩固理解，并深入思考一些使用中应该注意的问题。

此外，书后几个作用不同的附录，包括统计符号，公式的总合，和各种统计表及其使用的编排，充分体现了作者丰富的教学经验和方便读者的良苦用心，尤其是附录 C，正像一本简明的统计学手册，对实际应用提供了极大便利。

我认为，本书是心理和教育统计学方面一本优秀的基础教材，同时对于在社会科学领域中的广大研究人员，是一本不可多得的重要参考书。全书的写作风格轻松活泼，英语流畅易懂，数学深入浅出，读者在学习和阅读时是不会感到枯燥乏味的。在目前中文教科书中统计符号印刷错误很难避免的情况下，使用它作为教材或学生的主要参考，应该是一项有益的尝试，我愿予以推荐。
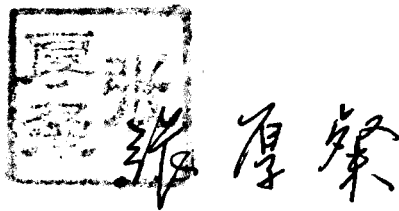
中华人民共和国国务院参事
中国心理学会常务理事
北京师范大学心理系教授、博导

2004 年 9 月

About the Authors

Richard P. Runyon lived a full and rewarding life. He received his B.A. from Drew University and his Ph.D. from Yale University, and was a fellow in the Sheffield Scientific School. At the peak of his career, he served as chair of the Department of Psychology and as Dean of the Science Faculty at C.W. Post College in Brookville, New York. He published a number of articles in psychology journals and authored or coauthored many books in statistics and psychology, including this text; *Fundamentals of Behavioral Statistics:· The Core; Fundamentals of Psychology; General Statistics; Fundamentals of Statistics in Biological, Medical, and Health Sciences; Business Statistics; Psychology of Adjustment; Winning with Statistics;* and *How Numbers Lie.*

Kay A. Coleman is an Associate Professor of Psychology in the College of Liberal Arts at Boston University. She received her Ph.D. from Boston College and a Master's of Public Health from Harvard University. At Boston University she is Director of Undergraduate Studies for the Psychology Department, where she teaches courses in experimental design, statistics, and memory at the graduate and undergraduate levels. Her research focuses on studies of remote autobiographical memory, particularly the accuracy of memories from childhood and health-related memories. In addition to co-authoring this textbook, she is also co-author with Richard Runyon of another textbook, *Behavioral Statistics: The Core.* She is a past President of the New England Educational Research Organization and was elected to membership in the Society for Multivariate Experimental Psychology. She is an honorary member of the Golden Key National Honor Society, a member of Psi Chi and the American Psychological Society, and a Fellow in the American Psychological Association.

David J. Pittenger is an Associate Professor and the chair of the Department of Psychology at Marietta College in Marietta, Ohio. He received his B.A. in psychology from the College of Wooster, his Master's of Science from Texas A & M University, and his Ph.D. from the University of Georgia. In addition to teaching courses in statistics and research design, David teaches courses in physiological psychology, psychometrics, learning and behavior, and cognitive psychology. David has many interests in psychology and has written articles on the partial reinforcement extinction effect, the ethical responsibilities of psychologists, the validity of personality inventories, and the teaching of psychology. In 1987 he received the Early Career Award for teaching from Division 2 of the American Psychological Association. In 1997, David received the McCoy Teaching Fellowship from Marietta College, the college's award for excellence in teaching. He is a Fellow of the American Psychological Association, and a member of the American Psychological Society, and the American Statistical Association.

Preface

"Chance favors the prepared mind."

—Louis Pasteur

Statistical reasoning is an essential component of our everyday lives. We think in terms of probability and constantly make inferences about future events. Whether we acknowledge the role of this type of reasoning on a conscious level is not important. The fact remains that we constantly predict the future and constantly use statistical reasoning to accomplish this. Given the crucial nature of this type of reasoning, it follows that these skills would be an essential component of any person's education. Thus, the underlying philosophy of this text, *Fundamentals of Behavioral Statistics*, is that statistical reasoning is a crucial element in education. In this same spirit, this ninth edition extends the book's long tradition of presenting statistical reasoning skills in a clear and meaningful way so that readers may understand and learn to appreciate the ubiquitous nature of quantitative thinking.

Today, as we usher in a new millennium, the perceived value of statistical analysis in our lives is more acute than when the first edition of this text was written. Newspapers, national news magazines, and trade journals chronicle the impact of statistics. The federal judicial system now requires judges to be conversant in basic statistical principles; these skills are needed to determine the merit of testimony offered by expert witnesses. Lawmakers use the results of statistical analysis to create policy initiatives that may have a lasting impact on the lives of their constituents. Market researchers test the reactions of the public to political events and retail products using focus groups, surveys, and statistical analysis. In brief, statistics are everywhere.

THE NEW WORLD OF STATISTICS

As the role of statistics has become increasingly important in our lives so too has the nature of these analyses evolved. Typical undergraduate courses now cover many more types of statistical tests than they did a generation ago. The nature of the material itself has become more sophisticated. A greater emphasis is now placed on exploration of the data prior to conducting statistical tests. We now have computers that easily explore the data and perform analyses that would otherwise take hours to accomplish manually. Greater thought is now given to the importance of issues such as effect size and power analysis prior to conducting an experiment. Undergraduates now read journal articles that

discuss the power of the experiment and use tests that were unknown 30 years ago. Much has changed, yet much remains the same. The change is clear. Statistical analyses have become increasingly sophisticated. What has remained constant is that we still optimistically expect our students to develop their critical thinking skills and use these skills in their coursework and later in their professional lives.

OUR PHILOSOPHY IN WRITING

Our comprehensive review of statistical procedures strives for simplicity. While we use crucial examples from psychology to guide the reader, this text is not cluttered with distractions or superfluous information. We have maintained the book's signature of simplicity even as we have updated the pages with the most significant recent trends and advances in statistical reasoning.

Balanced Reasoning

We believe that our book strikes a balance between teaching the conceptual foundations of statistics while providing the computational foundations of statistics. When Richard Runyon and Audrey Haber wrote the first edition of this book more than 30 years ago, they carefully balanced two extremes in teaching statistics: at one extreme, the "cookbook" approach presents formulas and leads students through them step-by-step; at the other extreme, statistics is treated as a branch of applied mathematics. It is our belief that neither extreme is useful for undergraduates in the behavioral sciences, so we continue the critical compromise created in the first edition by carefully integrating the two approaches within this latest revision.

Critical Thinking Skills

Much has been written about the value of critical thinking skills, how to foster their development, and how to ensure that students apply the principles in their lives. From research on this topic it is clear—critical thinking does not develop in a vacuum. Memorized formulas and definitions are of little value. Blind applications of formulas and hours of mind-numbing calculations do nothing to develop critical thinking. Instead, students must expose themselves repeatedly to situations in which they practice the application of critical thinking skills. We have endeavored to structure the presentation of the material in a manner that allows students to develop their skills based on quantitative data and well-rehearsed applications of heuristics. For each test and descriptive statistic we provide the rules and procedures, illustrate their application to relevant examples, and then discuss the generalizations that can legitimately be drawn from the analysis.

Useful Pedagogy

Students who read our textbook will learn about the theory and rationale of the various statistical tests used by behavioral scientists. When a statistical concept is introduced in the text, we may illustrate it in a number of ways. We provide both conceptual formulas and computational formulas. At the same time, we use words to explain the rationale of the statistic. Finally, we use visual illustration to help convert abstract concepts into images to help the reader understand important principles.

We recognize that once you have learned the material you will obviously need to review the material either for an exam or for an assignment in another course. Whether you use the book as a reference or for review we provide the following:

- **Basic Math Review**: *Appendix A* gives you a quick refresher on basic math.
- **Statistical Symbols Glossary**: *Appendix B* references all the major symbols you need in a clear and straight-forward manner.
- **Statistical Formula Guide**: *Appendix C* provides a step-by-step synopsis of formulas with useful examples worked out.
- **Statistical Tables**: *Appendix D* provides important tables for statistical tests.
- **Summary of Equations**: These are found on the front and back inside covers of the book and can be used as a quick reference for studying.
- **Running Glossary**: Important terms are defined as they are discussed in the text.

A NOTE TO THE STUDENT

We understand you probably did not sign up voluntarily to study statistics. Many of you are taking this course because it is required as part of your major or minor concentration. Others of you are taking it because your parents and career counselors have suggested a course in statistics to give you a competitive edge in a difficult job market. Many of you expect to go to graduate school and are aware of the central importance of analysis of empirical data in that milieu. Just as the reasons for taking this course will vary, so too your backgrounds and prior mathematical experience will vary.

We know this because we have taught statistics to hundreds of students over many, many years. And we have learned some valuable and surprising things from our students during that time. For example, we have learned that some students grasp the most complex statistical concepts immediately while others have to struggle to master each and every one. And we have been struck by the variety of techniques students find useful and important to them in mastering the material. Their reports vary tremendously. One person will swear by a technique and five others will find it useless.

Our conclusion has been that no one teaching technique is successful for all students. Some students have the ability to read an equation and immediately understand its workings. Others have better success when they see an illustration of the concept. Some students need verbal descriptions and others find the worked-out problems, marginal definitions, and end-of-chapter exercises to be the most useful. It is remarkable, the very same formula or illustration that provides instant insight for one individual can be of little or no value to others.

What have these observations meant, in practical terms, for us as authors? We have concluded that it is not enough to provide one explanation, one study technique. We have worked hard to provide you with a range of instructional devices that students have told us over the years have worked for them. We have included techniques useful for learning the material, for reviewing it at exam time and for mastering the calculations required by the exercises. For example, we have included marginal definitions to highlight important concepts as they are presented and listings of important terms at the end of each chapter. These may be used to guide your learning and to highlight important concepts when

you review for exams. The end-of-chapter exercises provide practice in how to perform the calculations as well as some questions that will force you to think about how a statistical test works, why it works that way, and some of the precautions to take when using the test.

By the way, the answers to the odd numbered exercises are presented at the back of the book. These answers won't tell you exactly how to do the calculations but they will serve as a warning if the answer you come up with differs from the one in the text.

The understanding you develop from your reading and the exercises is reinforced in summary tables in the body of the text. We have introduced these summary tables as a way for you to make your study time more efficient. In one table you can view an outline of the major concepts, their characteristics, when they are used, and cautions in their use. We have provided frequently used formulas and notation in the end pages. We have included, as well, a statistical formula guide to give you clear and easy access to review commonly used statistical procedures. This section will be of particular value to you when you study for exams and when you finish this course and are called upon in subsequent courses to review a particular statistical technique.

A NOTE TO THE INSTRUCTOR

We don't need to tell you that quantitative analysis is an integral part of psychology. Aside from the introductory psychology course, behavioral statistics is one of the few common courses for all psychology majors. You undoubtedly studied statistics as an undergraduate and certainly were required to take some statistics courses in graduate school. In fact you may have used the Runyon and Haber text in some of your courses. If you did, then you already know of the long tradition of this text. We have attempted to maintain that tradition and at the same time we have attempted to present new material, reflective of important evolution of thought within the field and have deleted material that has outgrown its usefulness.

Two monumental developments within the world of statistics have been evolving. The first of these has been the increased recognition of the importance of power in the design and conduct of experiments. The second important development has been the questioning of the value of statistical hypothesis testing. In terms of the latter, we recognize that hypothesis testing has its limitations, yet we believe that it still can serve a useful function. Rather than discard hypothesis testing, we show students how to analyze the data from a number of perspectives in addition to using traditional hypothesis testing. In terms of power we present the concepts of power and effect size and factors such as sample size and alpha that affect the power of a test. Indeed, each chapter related to inferential statistics has a section that reviews issues related to the power of the statistic.

Another addition to the text is the inclusion of clear examples of how to present the results of research in a research paper. Several of the chapters now include short examples illustrating the editorial style of the American Psychological Association. Learning to write clearly about empirical matters is an important skill that will serve your students well. With respect to maintaining the currency of the text, we have removed some material from previous editions and added new material. We decided to finally retire the material on grouped frequency distributions. Grouped data was once a necessary computational approach. The advent of computers and other technological advances has eliminated the

need for its inclusion. Instead, we focus more on how students can use exploratory data analysis and graphing techniques to augment their analysis of data.

Tradition, our own biases in the teaching of statistics, and reviewers' comments have all influenced the sequence of chapters in the text. We recognize that some may not agree with our arrangement. Thus, we intentionally wrote the chapters to be relatively free standing. In some cases, this is an impossible task. Testing hypotheses in the chapter on analysis of variance cannot be understood without a solid foundation on hypothesis testing in general. We tried to write a text that lends itself to differing orders of presentation. We hope that you find this as well as other aspects of the text accommodating.

ACKNOWLEDGEMENTS

We would be remiss if we did not publicly acclaim the valued contributions of the many, many individuals who collaborated in the development and production of this text. At each step, from the initial proposal stages to the final production details we were blessed with input from individuals who generously provided their time and their talents.

We must especially mention our Expert Reviewers, **Dennis Cogan** of Texas Tech University and **Michael Masson** of the University of Victoria, Canada.

We would also like to extend our thanks to the following reviewers:

Ken Hobby, Harding University;
Chuck Brainard, University of Arizona;
Fran Conner, University of Alabama;
Lisa Isenberg, University of Wisconsin;
Stuart Bernstein, Wayne State University;
Thomas Billimeck, San Antonio College;
Hilda Williams, Drake Williams College;
James Green, University of Connecticut;
Danuta Bukatko, College of Holy Cross;
Philip Tolin, Central Washington University;
Rick Jenison, University of Wisconsin-Madison;
Elizabeth Kudadjie-Gyamfi, Long Island University-Brooklyn;
Stephen Chew, Samford University;
Pamela Hunt, College of William and Mary;
Siamak Movahedi, University of Massachusetts-Boston;
Elizabeth Krupinski, University of Arizona.

We gratefully acknowledge our exceptionally hard working and talented collaborators at McGraw-Hill. Executive Editor Joe Terry skillfully nurtured and coordinated the planning of this revision, along with Susan Kunchandy, the Developmental Editor, and Lai Moy, the Editorial Coordinator. Finally, Fred Speers, our Editorial Assistant, must be acknowledged for providing just the right proportion of demanding deadlines mixed with words of encouragement that kept our project on schedule.

We admire and appreciate the efforts of all those named above.

CONCLUSION

Where do you go from here? We have outlined for you the multifaceted approach we have taken to provide the techniques and the tools to master this material. What does this approach mean, in practical

terms, for you? It means that this text is designed to allow *you* to decide how you should master this material. We have described the various instructional devices and learning aids. Try using these aids. Find the ones you feel are helpful. Use them, and keep in mind: the successful students invariably try **many** approaches and study strategies before deciding on the most useful ones. These students actively interact with the study materials and use them as tools to develop their own understanding. Trying to memorize someone else's understanding is of little value. You must be the active learner and critically examine this book and its contents. We give you all you need to become a dynamic student in this course. With some exploration and a bit of effort you have all that you need to acquire a solid, successful education in the fundamentals of behavioral statistics.

Kay A. Coleman
Boston University

David J. Pittenger
Marietta College

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