Advanced Statistics in Research

Reading, Understanding, and Writing Up Data Analysis Results

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What This Book Will Do

Why Ruin a Good Story with Research?

A news correspondent is interviewing a college professor—an expert on the subject of video games. The correspondent notes that a lot of these games are violent. Does playing them cause people to be violent in real life?

The professor has heard this one a million times. He says:

No. There have been tons of studies, and none of them show that. Playing video games makes people more excited. . . it makes their senses more excited. But it doesn’t have any effect on real aggression.

The expert’s comments were logical and reassuring. They were pretty much what you would have expected.

Unless you had read the research.

Consider an article by Anderson et al. (2010) in the prestigious journal *Psychological Bulletin*. The article describes a *meta-analysis*—a statistical synthesis of over 100 separate studies that investigated the effects of violent video games. The studies employed a variety of different research methods, measured multiple outcome variables, and included over 130,000 participants (in all) from the United States, Japan, and other nations.

The meta-analysis painted a much less reassuring picture. It concluded that playing violent video games was associated with significant increases in aggressive behavior, aggressive thoughts, and aggressive emotions. It showed that gaming was associated with significant *decreases* in empathy for victims as well as decreases in prosocial behavior (i.e., the willingness to help others).

The size of the effects were not large; depending on the dependent variable and research method used, they were generally somewhere between *small* and *medium* effects, according to Cohen’s (1988) widely used criteria. But the findings
were robust across cultures and across research designs—investigators obtained pretty much the same outcomes with cross-sectional studies, longitudinal studies, correlational studies, and true experiments.

An article like this is gold. It summarizes decades of research and provides information that could be of great use to the media, to lawmakers, and to harried parents trying to decide which video games to allow. But it comes with a catch: Somebody has to read it.

**Why This Book is Important**

What would you call a society that awards millions of tax dollars for research on topics related to its health, prosperity, and general welfare, and then pretty much ignores that research when making decisions about how to govern and manage itself?

You would call it our society.

**An Enigma Wrapped Inside a Bonferroni Adjustment**

Most people avoid reading empirical research articles. They avoid journals like *Psychological Science, Health Psychology, The Journal of Counseling Psychology, The Journal of Educational Psychology, The Academy of Management Journal, Nature, Sport, Exercise, and Performance Psychology*, and *The New England Journal of Medicine*. They don’t do this because they are lazy or stupid or apathetic. They do it—in large part—because of the statistics that the articles contain.

Just consider the terms that appear in a typical journal article: *heteroscedasticity, standard error of the estimate, Bonferroni adjustment, semi-interquartile range, failure to reject the null hypothesis, sum of squares*, and *Type II error*. And don’t forget the symbols and abbreviations: $\omega^2$, 95% CI, $\sigma$, $r_{rep}$, $\eta^2$, MSE, $\alpha$, $r_{(1.2)}$, $\chi^2$, and $\Delta R^2$.

**What We Could Learn by Reading Journal Articles**

This collective aversion to statistics is unfortunate, because so much really good research is being done. All of us *should be* reading about this research. And any numerically literate person (college graduate or not) should be able to read about this research at the source—in the peer-reviewed academic journals where most important research first appears. These journals are bursting with articles that address important research questions—issues that affect each of us in one way or another.

Here are just a few examples of real-world questions that most of us would find interesting, along with a specific journal article that tackled this question (complete references are provided in the *References* section at the end of this book):
• Does maternal employment have a negative effect on child development? (Lucas-Thompson, Goldberg, & Prause, 2010)

• Does placing infants on their backs at bedtime decrease the likelihood of sudden infant death syndrome? (Gilbert et al., 2005)

• Does exposure to thin models in magazines contribute to eating disorders among young women? (Grabe, Ward, & Hyde, 2008)

• Are young people more alienated today than they were in 1960? (Twenge, Zhang, & Im, 2004)

• Does talking on a cell phone increase the likelihood of automobile collisions? (Horrey & Wickens, 2006)

• What are the differences between the people who do volunteer work at a homeless shelter versus those who do not? (Harrison, 1995)

• What are the differences between employees who report organizational wrongdoing versus those who see the wrongdoing and do not report it? (Miceli & Near, 1984)

And, yes, even the topic introduced at the beginning of this chapter is compelling:

• Does exposure to violent video games cause people to become more aggressive? (Anderson et al., 2010; Ferguson, 2007)

**Reading the Middle of the Article**

I have been teaching college courses since sometime around 1980. At the end of each semester, my students evaluate me using whatever instructor-course evaluation form is being used at the time. Of the thousands of evaluations I have received, the most memorable one came from a graduate student in an advanced statistics course who said something like this:

> Finally, I can read the middle of the article.

The student was referring to the fact that the middle of the typical research article is where the *Results* section is found—that part of the article that presents the statistical analyses. A lot of college students read the beginning of the article (the *Abstract* and *Introduction* sections), along with the end of the article (the *Discussion* section). From these disconnected parts they then attempt to piece together what was probably presented in the *Results* section. As illogical as this approach might sound, many students find it preferable to slugging their way through the *Results* section itself. The *Results* section is filled with Greek letters, *p* values, post-hoc tests, and dense tables with lots of notes at the bottom. They probably wonder, *what’s the point?*

After taking my advanced statistics course, however, this student (the one with the memorable course evaluation) had cracked the code. The middle of the article was no longer terra incognita.

And if one student can do it, all students can do it. That’s why I wrote this book.
The Purpose of This Book

The market offers many excellent textbooks that show how to use statistical applications (such as SAS® or SPSS® or Minitab®) to perform advanced statistical analyses. This is not one of those texts.

What This Book Will Do

This book has three interrelated goals:

1) To refresh your memory on basic concepts in research and elementary statistics.

2) To improve your ability to read, understand, and evaluate advanced statistical procedures that appear in empirical research articles.

3) To improve your ability to write about advanced statistics by summarizing results in tables, text, and figures according to standard conventions.

Refreshing your memory on the basics. Reading that the $F$ statistic for a multiple regression equation is “statistically significant” will not make much sense if you have forgotten the meaning of “statistical significance.” Therefore, the first few chapters will review these basics.

I suspect that many individuals using this book have never completed an elementary statistics course (or may have completed it so long ago that those memories are no longer retrievable). If you are in this category, you will need an introduction (or a re-introduction) to the basic, foundational concepts in statistics. The first few chapters of this book provide just such an introduction. They cover concepts such as:

- The differences between experimental versus non-experimental research
- Systems for classifying variables
- Measures of central tendency and variability
- $z$ Scores and area under the normal curve
- The meaning of statistical significance
- The interpretation of confidence intervals
- The interpretation of effect size

Improving your ability to read and understand advanced statistics. The majority of this book—the last two-thirds or so—shows how to read and understand the advanced statistical procedures that are commonly reported in empirical research journals in the social and behavioral sciences. It explains these procedures in relatively simple, non-mathematical terms, so that readers with a minimal background will be able to understand and critically evaluate these statistics when they are presented in the Results sections of articles. These procedures include multiple regression, discriminant analysis, exploratory factor analysis, structural
equation modeling, meta-analysis, and others. For most procedures, you will learn:

- The research questions can be investigated with the procedure
- The assumptions must be met for the results to be valid
- The null hypothesis that is typically tested using the procedure
- The index of effect size that is produced
- How the results are typically presented in the text, tables, and figures of an article

**Improving Your Ability to Write About Advanced Statistics.** In addition to teaching how to read and understand advanced statistics, this book also shows how to write about advanced statistics. It illustrates the standard conventions that you should follow when summarizing the results of your own analyses in research articles.

The results presented here are prepared (for the most part) according to the *Publication Manual of the American Psychological Association 6th ed.* (2010): the format required by most journals in the social and behavioral sciences. To keep things concise, these guidelines will be referred to collectively as *APA format*.

Most of the individual chapters in this text are devoted to a specific statistical procedure. Within a given chapter, you will see:

- The symbols (e.g., $t$, $F$, $\eta^2$, $M$, $R^2$) that are widely used to represent the specific statistics produced by that procedure
- The standard conventions that are used when summarizing results from that procedure within the text (body) of the article
- The formats and approaches that are typically used when summarizing complex results in tables
- The formats and approaches that are typically used when illustrating results graphically in bar charts, path diagrams, and other types of figures

Students and instructors tell me that they need lots of examples of how to write up specific statistical procedures such as multiple regression or factor analysis. Most chapters in this book describe some empirical investigation and then provide “excerpts” from fictitious research articles that summarize the results obtained. In most cases, the chapter provides examples of how the results could be summarized in text, in tables, and in figures. Readers can use these excerpts as models to guide them as they write up the results from their own investigation.

*Appendix B* of this book is titled *Basics of APA Format (and How This Book Sometimes Deviates)*. The appendix touches on a few of the more important aspects of APA format: margins, preferred font, how to arrange headings, how to prepare tables, and so forth. It is a short chapter, so it will not even mention many aspects of APA format (e.g., citations within text, preparing references, and about 60,000 other things). But it will refresh the reader’s memory on the basics of APA.
format, so it is a good place to start for those who need to write up research results.

The title includes the words …and How This Book Sometimes Deviates. This is to emphasize the fact that some aspects of the research article excerpts that appear in this book are not consistent with APA format. For example, the tables presented here are typed using a font called Phoenica Std Mono, although APA Format recommends Times New Roman. This appendix summarizes deviations such as this in one location, so that readers will not be misled when using this book’s fictitious article excerpts as models for their own manuscripts.

What This Book Will Not Do

As was noted earlier, this book is not intended to show you how to actually perform statistical analyses. It will not show you how to use statistical applications such as SAS® or SPSS®, and it will not show you how to use matrix algebra to perform the analyses by hand (yes, my readers—there was once a time when researchers had to do this by hand). Remember—this book is about reading and understanding statistics; it is not about computing them.

Intended Audience

Three groups can benefit from this book. They include:

- Undergraduate students in upper-level courses dealing with statistics and research
- Graduate students enrolled in graduate-level courses on the same topics
- Individual students, researchers, or laypeople who want to read and understand the advanced statistical procedures that often appear in scientific articles.

Do You Need To Be Good at Math?

Math plays a fairly minor role in this book. Although you will encounter formulas from time to time, they are included as supplements to your understanding, not as a focus. The concepts in this course are described in relatively simple verbal terms, not as purely mathematical concepts.

Advanced statistics are like a foreign language. If you are like most readers, you will find this book to be more like a language text than a math text.

Book Contents

This section provides a preview of things to come: (a) the topics to be covered in the five sections that constitute the book, along with (b) a general outline of what you will find in most chapters.
Topics Covered

This book is divided into five sections, with two to six chapters per section. Here is what you will find in the five sections:

**SECTION I: BASIC CONCEPTS AND BASIC STATISTICS.** This is the refresher section described above—the foundation chapters designed to get everyone up to speed. The chapters in this section review basic concepts in research and statistics: measures of central tendency, measures of variability, descriptive statistics, z scores, area under the normal curve, and the big-three results reported in most research articles—significance, confidence intervals, and effect size.

**SECTION II: CORRELATION, REGRESSION, AND PARTIAL CORRELATION.** Many of the advanced statistics covered in this book are essentially correlational statistics, so the chapters in this section are provided to refresh your memory regarding bivariate correlation and regression (bivariate means two variables). This section also includes a chapter on partial correlation and statistical control to prepare you for the more advanced procedures to follow.

**SECTION III: ADVANCED STATISTICAL PROCEDURES.** This section constitutes the heart of the book. It covers an array of data-analysis procedures that allow researchers to investigate the relationship between (a) one or more predictor variables and (b) one or more criterion variables. Most of the statistics in this section are the more sophisticated procedures that are seldom covered in introductory statistics courses. The section begins with chapters on basic multiple regression and hierarchical (sequential) multiple regression. From there, it moves to various members of multiple-regression’s extended family: discriminant analysis, logistic regression, MANOVA, ANOVA, and ANCOVA. Each chapter shows how researchers use a specific procedure to (a) determine whether there is a significant relationship between the variables, (b) understand the nature of the relationship (as revealed by regression coefficients and similar statistics), and (c) evaluate the strength of the relationship.

**SECTION IV: FACTOR ANALYSIS AND STRUCTURAL EQUATION MODELING.** This section begins with a dimension-reduction procedure called exploratory factor analysis (EFA). EFA is widely used to discover the factor structure that underlies responses to questionnaire rating items (as well as other sets of variables). From EFA, the section moves to three popular applications of structural equation modeling (SEM). SEM is a family of statistical procedures that includes path analysis with manifest variables, confirmatory factor analysis, and path analysis with latent factors. Path analysis with manifest variables allows researchers to investigate complex causal models by analyzing correlational data. Confirmatory factor analysis (CFA) allows researchers to test hypotheses about the number and nature of the latent factors that underlie a dataset (think of it as EFA on steroids). Finally, path analysis with latent factors allows researchers to investigate complex models that propose causal relationships between latent factors (similar to the factors that are investigated with CFA). These analyses are sometimes called LISREL analyses, because LISREL® was the first widely-available statistical application which made them possible.
Section V: Meta analysis and beyond. The first chapter in this section discusses meta-analysis: the statistical synthesis of results from multiple empirical studies. For many research questions, a large number of studies have already been conducted by teams of researchers working independently across the globe. Meta-analysis allows researchers to combine these results quantitatively in order to see what position is supported by the “bulk of the evidence.” This chapter discusses the various indices of effect size that are reported in a meta-analyses, how researchers test for moderator variables, how they investigate possible publication bias, and the differences between the most popular approaches to meta-analysis. The section ends with suggestions for further reading.

Contents of a Typical Chapter

Different chapters in this book are organized in different ways, depending on the topic being covered. However, once you get to the main part of the book (Sections III through VI), most chapters follow an outline that goes something like this:

This chapter’s *terra incognita*. This section provides a short excerpt from the Results section of a fictitious article. Its purpose is to illustrate the cryptic, obtuse language that researchers sometimes use when reporting results.

What, exactly, is *terra incognita*? It is the unknown territory. Centuries ago, map makers drew the outlines of newly-discovered continents as they were surveyed and described by explorers. The inland (and unknown) parts of the continents were sometimes labeled *terra incognita* and illustrated with fearsome monsters.

At the beginning of most chapters, you may feel that you are lost in terra incognita. But don’t be afraid—by the end of the chapter, all symbols, terms, and conventions shall be revealed, and you will be the master of this statistic, not its victim.

The basics of this procedure. Each chapter begins at the beginning: What types of variables may be analyzed with this statistic? What research questions may we investigate? To make things more concrete, the section typically describes a specific investigation that will be used to illustrate all aspects of the procedure.

Details, details, details. Some statistics require more explaining than others. For the really nasty procedures, this section introduces the basic terms and concepts that will help you make sense of things.

Results from the investigation. This section constitutes the largest part of most chapters. It provides results from the illustrative investigation, and shows how the results might be presented in journal articles. You will see how researchers determine whether there is a statistically significant relationship between the variables, how they investigate trend, and how they evaluate the strength of the relationship. A major emphasis is placed on reporting practices recommended by the *Publication Manual of the American Psychological Association* 6th ed. (2010). For example, you will learn about the importance of reporting confidence intervals and effect size. Where possible, the chapter describes best practices for data analysis and write-up as recommended by well-regarded sources such as
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ADDITIONAL ISSUES RELATED TO THIS PROCEDURE. This is another Details, Details, Details section. It reviews the assumptions underlying the procedure, alternative data-analysis procedures, and related topics.

Is Dr. O’Day Fictitious? Is Her Research Fictitious?

Most of this book’s statistical procedures are illustrated by a researcher named Dr. O’Day. In a typical chapter, you will see how Dr. O’Day refines a research question, gathers data, and uses the statistical procedure of interest to answer her question. You will see the problems that she encounters along the way, and how she solves those problems.

Dr. O’Day is a work of fiction. Her arch-enemy, Dr. Grey, is also a work of fiction. They are intended to add an element of drama to the book (assuming we define “drama” very, very loosely).

Most chapters in this text report an empirical investigation that produces data that must be analyzed. In some cases these investigations are completely fictitious, and others they are only semi-fictitious.

First, the investigations reported in Chapter 5 and Chapter 19 are entirely fictitious. For those chapters, I created fictitious data sets from scratch in order to obtain specific results that would allow me illustrate specific concepts. In those chapters, I clearly indicate that the data were contrived.

However, most of the results reported in the remaining chapters are only semi-fictitious. The results presented in those sections are based on the analysis of real-world data sets. This applies to most of the findings related to the so-called Questionnaire on Eating and Exercising, which appears in Appendix A. For what it is worth:

- The Questionnaire on Eating and Exercising is a real questionnaire.
- It was, in fact, administered to about 260 college students.
- Most of the results reported in this book are the actual statistical results that I obtained when I analyzed the resulting data.

Despite this, you must not treat these results as if they were legitimate research findings appearing in a research journal. All of these analyses were performed merely to illustrate specific statistical procedures such as multiple regression or factor analysis. In most cases, I selected specific variables for a given analysis because those variables allowed me to illustrate some specific concept (such as “a negative multiple regression coefficient”). In most cases, my analyses were not performed as part of an actual program of scientific research. Although the investigation was approved by my university’s Internal Review Board, none of the results reported here have been published in any peer-reviewed journal.
After all, I had a more important audience in mind: you.

**Chapter Conclusion**

Enough with the previews—it’s time to get started.

The next chapter begins at the beginning, with elementary concepts in research and statistics. Think of it as a crash course for absolute beginners. Or think of it as the refresher course for seasoned learners. Either way, this chapter lays down the foundation: the key terms and core concepts that will allow you to make sense of the advanced and multivariate procedures to follow. So take a deep breath, gather all your courage, and turn the page.

The *terra incognita* awaits.