

RUSSELL T. HURLBURT
SIXTH EDITION

Comprehending
BEHAVIORAL STATISTICS

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About the Author

Russell T. Hurlburt, Ph.D., is professor of Psychology at the University of Nevada, Las Vegas. He received his Ph.D. in clinical psychology from the University of South Dakota after a BS in aeronautical engineering from Princeton and an MS in mechanical engineering from the University of New Mexico. His clinical psychology and engineering back grounds make him ideally situated to write about introductory statistics with accuracy and sensitivity.

Dr. Hurlburt has been writing computer demonstrations of statistical concepts for students since 1979 (for historical reference, the first Macintosh was built in 1984). He developed the “eyeball estimation” techniques for comprehending the concepts of statistics that are incorporated in this textbook and *Personal Trainer* beginning in the early 1980s. All those materials have been revised and refined in constant collaboration with students in well over 100 statistics classes.

Dr. Hurlburt is also one of the pioneers of “thought sampling,” the use of beepers to trigger the random sampling of thoughts and feelings in participants’ own natural environments. He is the originator of the “descriptive experience sampling method,” which provides qualitative, idiographic descriptions of inner experience.



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Preface

Dear Student (faculty members may eavesdrop)

Statistical reasoning is a fundamental skill of educated people: scientific, economic, political, and everyday decisions almost always rest on some sort of formal or informal statistical analysis. There is no choice about this: we are all statisticians (skilled or not) in our everyday lives. You shop at store *X* instead of store *Y* because of an informal statistical analysis of price and selection. You drive on Avenue *A* instead of Avenue *B* because of an informal statistical analysis of transit times. Some statistical analyses have life and death consequences. The surgeon prefers procedure *M* rather than procedure *N* because of a formal statistical analysis of outcomes.

And yet statistics courses often have a reputation for being dry, boring, incomprehensible, and irrelevant. So at the outset, let me try to balance that reputation with a few comments from your peers, students who have used *Comprehending Behavioral Statistics* and its coordinated website *Personal Trainer*:

“This book and *Personal Trainer* made learning statistics so easy and accessible. I have been putting off this course for a while because I was afraid I couldn’t handle the material, but it was so much better than I ever thought.”

“I like all of the materials available in *Personal Trainer*. The lectlets were extremely informative. ESTAT is a great tool to help visually understand concepts. I learned a lot more than I was planning to.”



Personal Trainer is the website that creates the *Comprehending Behavioral Statistics* multiple-learning-methods approach. There are seven parts of *Personal Trainer*: Lectlets, ESTAT, DataGen, Labs, Algebra, ReviewMaster, and Resources.



Lectlets and ESTAT are described below.



Personal Trainer is free with this textbook. Access it wherever you have an Internet connection.



Comprehending Behavioral Statistics/Personal Trainer does not simplify statistics. It makes learning statistics approachable, which for most students is very satisfying.

“If a student takes the necessary time to listen to the lectlets, use ESTAT, do the labs, quizzes and homework, anyone should be able to learn this material.”

“I loved the materials and was proud to learn that I was not as mathematically or statistically challenged as I’d previously thought.”

I have great faith in students. I’m convinced that most students have a deep, intrinsic motivation to comprehend important subjects, including statistical reasoning. I have created *Comprehending Behavioral Statistics/Personal Trainer* to help you unlock that motivation and discover the inherent logic that makes the study of statistics important not only for the understanding of behavioral science research but also for a deepening appreciation of the human condition.

I’ve been teaching statistics for over 35 years, and from that experience I think I understand why some students fear statistics courses. I wish to open you to the possibility that you, like those who preceded you, might find the *Comprehending Behavioral Statistics/Personal Trainer* package quite different from anything you have encountered in your prior studies. So if you think of yourself as math challenged, I hope you will keep an open mind. Many students discover (to their relief and delight) that they aren’t math challenged at all—they simply had never met a course that presented mathematical concepts in sync with their strengths. I love it when a student writes, “Before this class, I HATED math! I had to drop about half of the courses or retake them because I just was not getting it. To my surprise, I actually found this class fun because the problems made sense and were interesting. Unlike the boring story problems from other math courses, these were experiments and studies that were realistic, so it made it easier to grasp.”

If math is your strength, so much the better. The *Comprehending Behavioral Statistics/Personal Trainer* materials are thorough and careful; there is nothing “dumbed down” or oversimplified. You will find that the complementary presentations in the *Comprehending Behavioral Statistics/Personal Trainer* materials weave themselves together to produce for you a deeper comprehension of statistical reasoning.

Multiple Learning Approaches

Comprehending Behavioral Statistics/Personal Trainer presents opportunities for comprehension that let you approach statistics from whatever direction makes the most sense for you:

- If you **prefer reading**, the *Comprehending Behavioral Statistics* textbook is a clearly written explanation of statistical concepts.
- If you **prefer listening**, *Personal Trainer* includes a complete set of what I call “lectlets”—miniature interactive audio/visual lectures delivered on your computer.
- If you **prefer visualizing**, *Personal Trainer* includes ESTAT, software that teaches you to “see” (I call it “eyeball-estimate”) and interact with the concepts that statistics are measuring.
- If you **prefer doing**, *Personal Trainer* includes a complete set of interactive computer-presented labs that give you guided practice in statistical concepts,

along with automated quizzes that can report your progress back to you and your instructor.

- If you **prefer exploring computations**, *Personal Trainer* includes DataGen, statistical software that I wrote specifically to help in the acquisition of statistical skills. DataGen makes it easy to explore the relationships between data and statistics.

Thus *Comprehending Behavioral Statistics/Personal Trainer* exploits 21st century capabilities to provide you with multiple ways of approaching this important topic. I love it when the student writes, “If I didn’t understand the audio lectlet, the chapter reading usually cleared it up. Or if I couldn’t understand what the chapter was trying to explain, the audio lectlet usually made sense to me.”



“Statistics has a pretty scary reputation. Right away, and as the course progressed, I was consistently pleased and relieved. The material was presented in such an understandable fashion. It’s awesome when a professor finds just the right way to connect the student with the material.”

Philosophy

There are three features that set *Comprehending Behavioral Statistics/Personal Trainer* apart. First is the multiple-learning book/web approach that I have been describing. The other two are eyeball-estimation and progressive cumulative review.

Eyeball-estimation

eyeball-estimation

Predicting the approximate magnitude of a statistic



Eyeball-estimation of the standard deviation is described on pages 95–100

Eyeball-estimation techniques will enable you to predict, without the use of a calculator or statistical tables, the approximate magnitude of statistics. Sections of the text that present eyeball-estimation skills are flagged with the eyeglass symbol shown here. Eyeball-estimation is not a substitute for accurate computation; *Comprehending Behavioral Statistics* is thorough in its treatment of computation skills. You will benefit from eyeball-estimation, however, for these reasons:

- Students who eyeball-estimate are actively involved. You will inspect the data and decide for yourself the approximate magnitude of a reasonable answer.
- Eyeball-estimation cultivates genuine understanding of statistical concepts. When you can look at a data set and say, “The standard deviation is about 12.5,” you’ll know you comprehend the standard deviation.
- Eyeball-estimation is quick. You can eyeball-estimate a standard deviation in about 15 seconds. Computation would take you about 15 minutes.
- Following eyeball-estimation, computation has an element of excitement because it provides immediate feedback on the accuracy of your own eyeball.
- Eyeball-estimation will engage you regardless of your level of mathematical sophistication. Inexperienced students can practice fundamentals at the same time as mathematically sophisticated students refine their skills.
- Eyeball-estimation is a valuable skill. It will enable you to spot mistakes immediately. Students trained in eyeball-estimation techniques estimate with much greater accuracy than do students taught by traditional methods (Hurlburt, 1993).

progressive cumulative review Gradual, incremental, comparative recap of previously learned concepts



A typical cumulative review is on page 324.



“The structure of this course is a great template for classes involving math or science, because it allows the student to learn fundamentals at a reasonable pace. The material then builds upon itself until eventually the big picture becomes clear. The progression is right on.”



Register for *Personal Trainer* for free. See inside front cover.

lectlet A short, interactive audiovisual lecture

Progressive Cumulative Review

Students of statistics who do well on quizzes and midterm exams may nonetheless perform poorly on a cumulative final. Why? Because traditional statistics textbooks fail to incorporate practice in one of the most important skills, the ability to discriminate between procedures. The student who uses a typical text knows that all the problems in the t test chapter require t , all the problems in the ANOVA chapter require ANOVA, and so on. The student therefore gets no practice in deciding which test to use.

Comprehending Behavioral Statistics remedies this omission by including progressive cumulative review exercises. In each chapter, cumulative review exercises present, in random order, problems of the types found in that and previous chapters. Rather than compute, you’ll be asked to state which null hypothesis is appropriate and to describe the characteristics of the appropriate statistical test.

Cumulative review exercises are progressive in that the complexity of required discriminations increases gradually with each successive chapter. In Chapter 10, for example, you’ll discriminate among three easy options: finding the area under a normal distribution, creating a confidence interval, or testing a hypothesis. The task becomes slightly more complex in Chapter 11, where you must also discriminate between testing a hypothesis about the mean of one group or the means of two groups. This step-by-step pattern of slightly increasing complexity continues throughout the text. By the end of the course, you’ll have become proficient in making complex discriminations.

I began developing cumulative review exercises for my graduate students. The exercises were so effective that I started using them with sophomores more than 20 years ago. My sophomores’ performance on cumulative exams now surpasses that of the graduate students I taught prior to using cumulative review exercises.

Personal Trainer

Personal Trainer is the website that creates the *Comprehending Behavioral Statistics* multiple-learning approach. There are seven parts of *Personal Trainer*: Lectlets, ESTAT, DataGen, Labs, Algebra, ReviewMaster, and Resources. *Personal Trainer* is accessible from wherever you have an Internet connection, and can be used by any Windows or Macintosh computer.

The original purchaser of this textbook receives a semester of free access to *Personal Trainer*: simply locate the textbook access code number inside the front cover of the book, log in, personalize your access code, and you’re on your way. If you purchased a used copy of this book, you may also obtain access to *Personal Trainer* (see inside the front cover). E-book purchasers will be e-mailed an access code.

Personal Trainer exploits the power of computers to advance your comprehending of statistics. I personally wrote everything in *Personal Trainer* just for you. Each part of *Personal Trainer* is expressly designed to use its own unique capabilities to amplify your grasp of the *Comprehending Behavioral Statistics* concepts.

Lectlets

A “lectlet” is a short, interactive, computer-based audiovisual lecture/discussion, my answer to the question, “How can I harness the power of computers to help you master



lectlet (LEKT-let)



Now that the culture has simplified “applet” to “app,” some prefer to simplify “lectlet” to “lec.”

statistical comprehension in ways that might be superior to a textbook alone?” The term “lectlet” is my invention (Hurlburt, 2001), created by analogy to “applet,” a short computer application. In a lectlet, I talk to you through your computer speakers; you respond using your keyboard.

You’ll hear me introduce and explain the concepts in the textbook and see (synchronized to the audio) graphs, figures, equations, and so on displayed on the computer screen. Each lectlet begins with a series of interactive review questions; you’ll type brief answers and then click a button for immediate feedback.

Hurlburt (2001) discussed why lectlets are effective learning tools:

- Some students learn better by hearing than they do by reading.
- Because the media are different, the lectlets’ approach to the subject matter is somewhat different from the textbook’s which in turn is somewhat different from the instructor’s classroom. The convergence promotes genuine learning.
- Lectlets solve problems for students. Students use the lectlets in a variety of ways, some before coming to class as a way of preparing for understanding in the classroom, some after class as a way of consolidating what they learned or clearing up what was fuzzy, some when they miss a class for illness or extra-curricular activity, some for review before exams.
- Lectlets solve problems for students with special needs. Students with learning disabilities, hearing difficulties, or for whom English is a second language benefit from the multiple-media approach. The lectlets can easily be rewound and replayed, as often as desired, and the volume personally controlled. The lectlets have a word-for-word transcript available at the click of a button, so you can both hear and see the same message (the transcript has been found very useful by many native English speakers).
- Lectlets ease important lecture issues. For distance learning classes, they are substantially more effective than are talking-head lectures. In live classrooms, the class pace does not need to be slowed down for students who need additional repetition. Now the instructor can say, “Listen to Dr. Hurlburt’s explanation of this concept in Lectlet 5B. Replay it as often as you need. Then if you still don’t understand it, come back and talk to me.”

ESTAT Computer Simulations



ESTAT (EST-stat)

ESTAT is a series of exercises that teach the skills of eyeball-estimation. ESTAT is my answer to the question, “How can I harness the visual display capabilities of computers to make statistical concepts come concretely alive for you?” (Hurlburt, 1993).

ESTAT provides practice in eyeball-estimation by generating and displaying data, inviting you to eyeball-estimate a statistic, and then providing immediate feedback on the accuracy of your estimate. For example, in one of the standard deviation exercises, “sdest,” you will learn to inspect a histogram and say something like, “I think the standard deviation is about 4.5.” (That will seem as natural to you as inspecting a restaurant check and saying something like, “I think everyone owes about \$25.”) Then when you click a button, the actual standard deviation appears in both graphic and numeric form. Another click and ESTAT produces a new histogram from a randomly generated infinite series of data sets. A step-by-step tutorial is available.

ESTAT Computer created eyeball-estimation exercises



ESTAT is a contraction of ESTimating STATistics.



“ESTAT and the lectlets were very well prepared and helped me out a lot! Thanks for making a difficult subject something that was realistic to learn.”

DataGen Computational computer software designed to help you learn statistics



DataGen (DAY-tuh-jenn)



Computation is important. Computation with comprehension is even more important.



SPSS



Excel

I think you will find the ESTAT exercises fun, and (even better) satisfying as you watch your skills and comprehension improve. There's lots of evidence that immediate feedback is important, and ESTAT's feedback is always just a click away.

The ESTAT programs are completely reworked for this edition, now available for Windows and Macintosh users in a web-based format.

DataGen Statistical Computation

DataGen is statistics pedagogical software, my answer to the question, “How can I harness the computational power of computers to help you understand statistics and their computation (not merely to get answers)?” There are plenty of excellent statistics computation packages available (this textbook supports two: SPSS and Excel), but other than DataGen, none are designed to be comprehension builders. DataGen has three features: (1) no complex interface to learn; (2) immediate and automatic display of results; and (3) the display of subcomputations that might be used in a hand calculation.

For example, say you enter two groups of data (in two columns, as is natural). DataGen will automatically (you don't have to know how to ask) and immediately give you the t statistic and all the subcomputations necessary to compute it: for each group, the means (and the sum that is its numerator), the standard deviation, and the variance (and the sum of squared deviations that is the numerator), and the pooled variance. This will help build your comprehension because you can use your calculator to follow along with the DataGen calculations as much or as little as you wish.

If the groups you entered happen to be equal sized, then DataGen will also automatically and immediately give you the dependent-samples t statistic, the correlation coefficient, and the regression line constants (as well as all the subcomputations for each).

Because statistics are displayed automatically, DataGen elicits a decision process that is the reverse of the process required by other programs. Typical programs require you to decide which statistic to *request* from among *many* that might be available. With DataGen, you decide which statistics to *use* from among *a few* that are automatically displayed.

As a result, DataGen dispels anxiety for the beginning student whose grasp of statistical concepts is not yet secure. You can immediately interact successfully with DataGen.

Comprehending Behavioral Statistics also supports SPSS and Microsoft Excel, providing step-by-step instructions in each chapter. Look for the SPSS and Excel logos.

Labs

Personal Trainer provides a lab for each textbook chapter, giving you practice and feedback in the skills necessary for comprehending statistics. I wrote these labs with my colleague Dr. Kimberly A. Barchard in answer to the question, “How can we unleash the power of computers to help students practice statistical skills?” Each lab ends with a quiz with items randomly selected from that chapter's 100-item quiz bank so that you may take the quiz up to three times (depending upon your instructor); each time you'll get new (randomly selected) questions that cover the same topics.

The results of the quizzes are automatically reported back to your instructor. Your instructor can assign as many or as few labs as is desired, and you may take the labs



“The labs were interesting and even fun with ESTAT.”

and their quizzes for practice and mastering of the material even if your instructor does not assign them.

Algebra

Personal Trainer provides an interactive review of the basic concepts in algebra necessary for comprehending statistics. The student who needs a refresher can spend an hour with this tool and refocus the required algebra skills, including summation notation.

ReviewMaster

Each chapter also has a ReviewMaster, an interactive electronic review of the concepts covered in that chapter as well as a multiple-choice quiz on the chapter. Like ESTAT and the lectlets, ReviewMaster asks questions and provides immediate feedback in an almost game-like atmosphere.

Resources

A Resource is a portable document (actually, a .pdf file) designed to be displayed on a computer screen (or printed if desired).

Resources look and feel exactly like pages from the textbook, and are included on the *Personal Trainer* site so the textbook itself can be shorter and more focused (and less expensive!). Resources allow your instructor to tailor material just for you. If deeper or extended coverage of a topic are desired, there is a Resource that seamlessly extends the textbook to provide that coverage.

A Bit of History

In the early 1980s, early in my statistics-teaching career, one of your peers asked me, “What does a validity coefficient of .3 really mean?” I said, “One variable explains about 10% of the variance of the other.” She said, “Yes, but what does explaining about 10% of the variance really mean?” Both were good questions, for which I had no answer adequate to the depth of her satisfaction, so I said I would write a computer simulation for her on my new Atari 800XL computer. That validity coefficient program (which I called ‘corest’) turned out to be a markedly successful way of informing her (and me!) about the nature of a correlation coefficient of .3.

During the decade of the 1980s, other students asked other questions, each of which I answered with a computer simulation. I began regularly using these simulations in my statistics classes. Students liked these simulations and encouraged me to write a manual which described how to use them. Students liked the manual, too, and encouraged me to expand it. Eventually that expanded manual became *Comprehending Behavioral Statistics* and the computer simulations became ESTAT. Both were published in 1993.

In the intervening years, I have rewritten ESTAT eight times, each time driven by the ever-improving computer capabilities. Each new version has provided me the opportunity to watch students like you interact with this software, to ask them what they liked and didn’t like about it, and then to rethink what is essential. Thus in an important sense, ESTAT was written in collaboration with your peers.

I’ve rewritten *Comprehending Behavioral Statistics* five times. Each time, I gave students like you a pad of paper (well, this time I gave them access to a web site) and

asked them to keep it with them as they read the text. They were to jot down the page and line number any time they stumbled, any time they became distracted, any time they had to go back and read a passage again. If several students stumble on the same passage, then it's likely that something about the passage is problematic, and my job is to diagnose the problem and fix it. Thus in that important sense, *Comprehending Behavioral Statistics* was written in collaboration with your peers. Unless I've unwittingly introduced some complication in the sixth edition, you can be confident that your peers have filtered out distractions and unnecessary difficulties.

Textbook Features

I've organized *Comprehending Behavioral Statistics* to capitalize on every opportunity to enhance your comprehension. For example, *Comprehending Behavioral Statistics* has:

- A running glossary: The definitions of statistical terms are provided in the margin when they first appear (and then these terms are provided again in the Glossary at the back of the book).
- Info notes: These comments in the margins allow me to communicate with you outside the flow of the main material. Some info notes look backwards, encouraging you to review. Some look forwards, providing a glimpse of what's upcoming. Some give computational tips. Some identify frequently made mistakes. And so on.
- SILI (Say It Learn It) notes: Learning statistics is like learning a foreign language—you have to say it, repeatedly, until the sounds of the terms and concepts feel natural to you. The SILI notes recommend that you say the listed items aloud, at least three times or until the terms roll off your tongue. Then when you encounter the term in the chapter, you will be prepared to comprehend it, not impeded by any pronunciation stumbles. So...start your practice: the note at left is recommending that you say "SILI note" three times. Do it! (It may seem silly, but pronunciation starts the cognitive structuring.)
- Many figures: I've provided annotated figures wherever possible. There are more than 400 figures in this textbook, perhaps two or three times more than in other texts.
- Efficiency features: Comprehending statistics requires work and practice, and I'd like that to be as efficient as possible. I don't want to waste your time! So I've colored the edges of the statistical tables in Appendix A so that you can find the tables easily. I've gathered all the formulas used in this text into one place (Appendix C), and reprinted the frequently used formulas on the pages at the back of the textbook. I've provided one worked problem in each homework assignment. I've provided complete answers, including intermediate steps, to half the exercises.


This is an info note, the textbook analog of the TV "news crawl" or ESPN "sports ticker."


SILI (SILL-ee) note

Effect Sizes, Power Analysis, and Practical Significance

Comprehending Behavioral Statistics gives a clear, thorough presentation of practical significance, including discussions of power and effect sizes throughout the textbook. In fact, my main motivation for writing this book in the first place (in about 1990) was

to provide a vivid, comprehensible, visualizable presentation of effect sizes. I created the eyeball-estimation techniques that are used throughout this book because they help students get intimately, concretely, and skillfully acquainted with (among other things) effect sizes and statistical power. My reasoning was this: If students gain a clear understanding of effect sizes and power, they will naturally report those measures in any later publications.

Responding to the same issues, the American Psychological Association convened a Task Force to study the use of statistics in the psychology literature. Perhaps the most discussed outcome of this study was the recommendation that journal editors require the reports of effect sizes and power analyses (Wilkinson, 1999). The fifth edition of the *Publication Manual of the American Psychological Association* (2001) adopted most of the Task Force's recommendations. I am in wholehearted agreement with these recommendations, most of which were already incorporated in the first (1994) and/or second (1998) editions of this textbook. Thus, this textbook incorporated the Task Force recommendations not just at the reporting level but also at the comprehension level.

Light-hearted but Not Lightweight

I have several times referred to the materials in *Comprehending Behavioral Statistics* and *Personal Trainer* as being “fun” or “game-like,” and that is how I hope you will find them. However, I wish to emphasize that there is absolutely no sacrifice of comprehension for fun. The light-hearted approach of *Comprehending Behavioral Statistics* does not compromise depth of comprehension. High-quality teaching and learning can be inherently fun, and these materials demonstrate that, but you will not find cartoons or condescension. Learning statistics is important—important enough to enjoy it while you do it.

Help for Old Friends (what's new in the sixth edition)

The *Personal Trainer* interface has been completely rewritten and updated. This is a major change, mostly behind the scenes, designed to make *Personal Trainer* more up-to-date and to facilitate a seamless connection of *Personal Trainer* with *Comprehending Behavioral Statistics*.

The lectlets now have a speed control so that you can speed up or slow down the audio. (This is the result of a suggestion from Casey, a UCLA student who wrote, “my own comprehension is increased when I increase the speed of audio. [When my] brain gets bored, ... the mind drifts. As counterintuitive as this may sound, ... next time your mind wanders during reading try speeding up rather than slowing down and see if comprehension improves.” So I included a feature giving everyone control of audio speed.)

Personal Trainer now presents SPSS, Excel, and text files for all textbook chapter examples.

Comprehending Behavioral Statistics has been refined according to suggestions by student and faculty users. Thanks! There are over a thousand small improvements, all aimed to clarify the text from the standpoint of the student reader.

The textbook now includes 90 SILI (Say It Learn It) notes throughout the text. Cognitive psychologists understand that learning is not merely the acquisition of facts but is also the development of skills in manipulating concepts. Part of that skill is the ability to speak and hear (whether aloud or in your imagination) important concepts. For example,



SILI (SILL-ee) note



σ (SIG-ma)

when you encounter the standard deviation σ symbol, it substantially facilitates your comprehension if you immediately recognize that σ is pronounced SIG-ma; your comprehension is undermined if you pronounce it OH or OH-thingy, or, worse, if you just somewhat blank out when encountering σ . So the SILI notes ask you to say important concepts (like SIG-ma) aloud three times, thus smoothing the learning process.

The sixth edition presents improvements of 50 figures with the aim of clarifying exactly what you should be seeing.

Students have liked the marginal info notes, so the sixth edition adds 70 new ones.

The sixth edition improves the SPSS instructions with the addition of six new SPSS annotated output figures in the early chapters.

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Finally, I thank the talented and dedicated staff at Kendall Hunt for bringing this project to a new level. In particular I thank editors Samantha Smith and Angela Lampe for their faith in these materials and their encouragement and support, Amanda Smith for her efficient oversight of the details of the project, and the whole team at Kendall Hunt and Great River Learning for their skilled contributions.

A Final Word

I am particularly grateful to your peers, the many student users of the fifth and earlier editions who made constructive suggestions and allowed me to watch their way of approaching these materials. I hope you will join them in the mastery of this important subject matter and let me know any comments/suggestions you might have.

Russell T. Hurlburt