



E. Bruce Goldstein

Sensation and Perception

SIXTH EDITION

SENSATION AND PERCEPTION

SIXTH EDITION

E. BRUCE GOLDSTEIN

University of Pittsburgh

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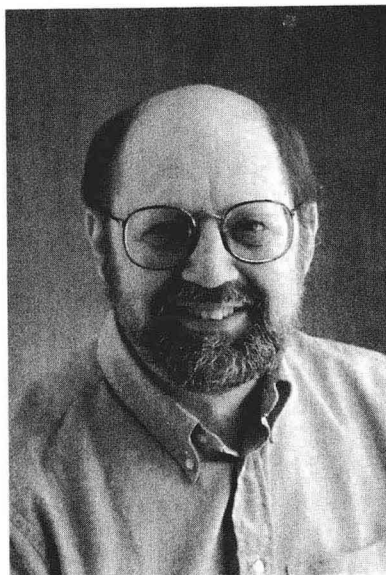
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TO MY STUDENTS
AND
TO MY WIFE BARBARA

ABOUT THE AUTHOR



E. Bruce Goldstein is Associate Professor of Psychology and Director of Undergraduate Programs in Psychology at the University of Pittsburgh. He recently received the Chancellor's Distinguished Teaching Award for his classroom teaching and textbook writing. He received his bachelor's degree in chemical engineering from Tufts University and his Ph.D. in experimental psychology from Brown University, and he was a postdoctoral fellow in the biology department at Harvard University. Bruce has published numerous papers on visual physiology and visual perception and is the editor of the *Blackwell Handbook of Perception* (2001). He teaches sensation and perception, cognitive psychology, introductory psychology, and the psychology of art.

WEBTUTOR ADVANTAGE CONTENTS

WebTutor Advantage, available to students whose instructors ordered it, consists of study material for every chapter in the text and WebTutor Exercises for Chapters 1–14. Go to <http://webtutor.thomsonlearning.com> for sample chapters.

KEY FEATURES

- **Introduction.** Sets the context for what the chapter discusses.
- **Preview.** Lists the core ideas presented in the chapter.
- **Outline.** Reviews the major headings in the chapter.
- **Concept Checks.** Help students to identify the major ideas in the chapter and organizes and keys them according to the Study Questions in the book.
- **Key Terms.** Organized by major headings and give the full definitions for the boldfaced terms in the book; flashcards are provided for each.
- **Multiple-Choice Questions.** Approximately 25 to 30 per chapter provide feedback for every correct and incorrect answer.
- **Annotated Web Pages.** Provide three to five strong Web sites with demonstrations of various phenomena such as point light walkers, motion aftereffects, and the like.
- **WebTutor Exercises.** Interactive modules, demonstrations, experiments, and examples of stimuli used in experiments discussed in the text. These exercises, and their page numbers, are listed below. An asterisk (*) indicates that the phenomenon is not specifically described in the text.

WEBTUTOR EXERCISES

Chapter 1: Introduction to Perception

The Psychophysical Approach:
Linking Stimulation and Perception

- *Method of limits*—Demonstration: Trial-by-trial method of limits (14)
- *Measurement fluctuation and error*—Experiment: How accurately can you match size? (13)
- *Adjustment and PSE*—Experiment: Length matching (13)*
- *DL by method of limits*—Experiment: Judging differences in size (14)*

- *Constant stimuli*—Experiment: Judging length (14)
- *Just noticeable difference*—Experiment: Adjust length so just noticeably different (15)
- *DL vs. weight*—Plot a graph of difference threshold vs. standard stimulus (15)
- *Weber's law and Weber fraction*—Plot a graph demonstrating Weber's law (15)
- *Response compression and expansion*—Review different types of magnitude estimation functions (16)

The Physiological Approach: Linking Stimulation and Neural Firing

- *Structure of neuron*—Identify parts of a neuron (19)
- *Oscilloscopes and intracellular recording*—Demonstrates oscilloscope measuring resting potential (26)
- *Phases of action potential*—Slide a slider and watch sodium and potassium flow (21)
- *Nerve impulse coding and stimulus strength*—Vary pressure and watch firing rate increase (22)
- *Synaptic transmission*—Identify pre- and postsynaptic neurons and watch nerve firing (24)
- *Lock and key neurotransmitter action*—Drag neurotransmitters to correct sites on membrane (24)
- *Excitation and inhibition*—Vary excitation and inhibition and watch effect on firing rate (24)
- *Cortical areas*—Review location of cortical receiving areas (25)

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The Stimulus for Vision and the Structure of the Visual System

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- *The human eye*—Identify components of the eye (40)
- *Cross section of the retina*—Identify types of neurons in the retina (41)

The First Transformations: Light, Receptors, and Electricity

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- *Types of cones*—Review cone absorption spectra (54)

Neural Processing by Convergence

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- *Receptor wiring and acuity*—Demonstrates why cones have better acuity than rods (58)

Neural Processing by Excitation and Inhibition

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- *Receptive fields and stimulus size and shape*—Vary bar width and see how firing rate changes (62)
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- *Intensity and brightness*—Move slider to see difference between intensity and brightness distributions (66)
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- *Complex cells in the cortex*—See how complex cell firing depends on orientation and direction of movement (84)
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- *Enhancing illusory contours*—Shows how changing one part of a display affects perception (148)
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- *Law of similarity*—Vary color of spheres and see how grouping changes (149)
- *Law of good continuation*—Move slider to see how good continuation affects perception (151)*
- *Law of closure*—Click to delete parts of figures and see if perception changes (151)
- *Law of proximity*—Vary spacing of spheres and see how grouping changes (151)
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- *Real-world figure-ground ambiguity*—Move the slider to see two faces turn into a vase (157)

How Objects Are Constructed

- *Factors in textual segregation*—Demonstrates how shape and orientation affect texture boundaries (164)

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- *Cone response profiles and perceived color*—Click on color circle to see cone response profiles for different colors (189)
- *Cone response profiles and hue*—Move slider to see how cone responding changes with wavelength (192)

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- *Mixing complimentary colors*—Move slider to vary mixtures of blue and yellow, red and green (197)*

- *Red–green opponent cells*—Demonstration of opponent cell firing to different amounts of red and green (197)
- *Strength of blue–yellow mechanisms*—Move slider to see strength of B and Y mechanisms at different wavelengths (197)*
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- *Neutral points in dichromats*—Shows how neutral points depend on opponent response (203)*
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- *The horopter and corresponding points*—Explore the horopter and corresponding points (237)
- *Disparity and retinal location*—See how images on the retinas change for differences in depth (238)

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- *Dumbbell Müller-Lyer illusion*—Experiment: Measure the dumbbell version of Müller-Lyer (256)
- *Ponzo illusion*—Experiment: Measure the Ponzo illusion (257)
- *Size perception and depth*—Demonstration of size perception illusion in a corridor (257)*
- *Poggendorf illusion*—Experiment: Measure the Poggendorf illusion (257)*
- *Zollner illusion*—Experiment: Measure the Zollner illusion (257)*
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Four Ways That Movement Perception Can Occur

- *Context and apparent speed*—A bouncing soccer ball appears to speed up near a contour (272)
- *The phi phenomenon, space, and time*—Vary distance and timing of two spheres and observe apparent movement (273)
- *Induced movement*—See how moving clouds make an airplane appear to move (274)
- *The waterfall illusion*—View the moving bars and see what happens when they stop (275)
- *The spiral motion aftereffect*—View the rotating spiral and see what happens when it stops (275)

Corollary Discharge Theory: Taking Eye Movements into Account

- *Corollary discharge model*—See how different movement scenarios affect firing of the corollary discharge circuit (279)

Perceptual Organization and Movement Perception

- *Kinetic depth effect*—See object shapes based on their rotating shadows (287)

- *Motion parallax and object form*—Guess the shape of a mystery object based on views of its shadow (287)
- *Motion capture*—See how dots in the background are captured by apparent movement (288)

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- *Apparent movement and figural selection*—See how speed, separation, and types of figures affect apparent movement (290)*
- *Motion and introduced occlusion*—See how the occlusion heuristic influences apparent movement (291)
- *Field effects and apparent movement*—See the occlusion heuristic make a blinking duck disappear behind a sign (291)
- *Meaning and movement perception*—The stimuli used in Ramachandran’s experiment (292)
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- *Decibel scale*—Listen to how the loudness of tones decrease as decibels decrease (336)
- *Harmonics of a chime*—A way to hear individual harmonics of a chime (337)

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- *Frequency response of the ear*—Experiment: Measure sensitivity to different frequencies (339)
- *Loudness scaling*—Experiment: Magnitude estimation of the loudness of tones (341)
- *Circularity pitch illusion*—Roger Shepard’s auditory staircase illusion (342)*

Auditory System: Structure and Function

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Frequency Analysis in the Cochlea and Auditory Nerve

- *Masking high and low frequencies*—Observe how low and high frequencies mask each other (356)

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- *Effect of repetition on grouping by pitch*—As a string of tones gets longer, perceptual grouping changes (398)
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- *Perceiving a melody obscured by noise*—An example of how knowing the identity of a melody can help separate it from noise (400)

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Stimulus Dimensions of Speech Perception

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- *McGurk effect*—Experience the McGurk effect (419)

Chapter 13: The Cutaneous Senses

The Skin and Its Receptors

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Pain Perception: Neural Firing and Cognitive Influences

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The Taste System

- *Taste system*—Identify structures in the peripheral taste system (488)

PREFACE

This is an exciting time to be doing research in perception or to be reading about it. It is exciting because so many impressive advances in our knowledge have occurred in recent years. Just a few examples of these advances are the development of brain imaging techniques, which make it possible to identify brain areas involved in perception; discovery of the large effects of experience on the structure and functioning of the brain; demonstration of the close links between perception and action; and an increased appreciation of cognitive and inferential processes in perception. One of my goals in this edition of this book has been to describe these exciting new advances. To this end, I have added over 360 new references, most from the last five years; over 110 new key terms; and over 150 new illustrations. Of course, these new results didn't come out of nowhere—they were built upon the foundation created by over 100 years of previous research and theory, and these foundations of perception are the major topic of this book.

In describing both the foundations of perception and recent advances in our knowledge, I have made numerous changes in both content and presentation, while keeping the characteristics that so many people have appreciated in the previous editions. The following summarizes some of the features of the 6th edition of *Sensation and Perception*.

Increased Clarity

In every new edition of this book I strive to increase the clarity of the presentation. I do this by listening to feedback from my students and from instructors who have used previous editions. I have used this feedback

as my guide in revising sections that students found difficult and in reorganizing sections of the book to enhance the logical flow from one topic to the next.

Organization of the Whole Book and Within Chapters

As I began this revision I asked myself how I could organize the book to make sensation and perception easier to teach. I achieved this by changing the order of a few of the chapters (object perception now directly follows higher-order visual processing), moving some material formerly in its own chapter into others (the material on color and size constancy is now in the chapters on color and depth, respectively), and carefully scrutinizing every chapter to be sure one topic followed logically from the other.

Overall Organization

The book begins with five chapters that progress in a logical sequence that takes students step-by-step from the beginning principles of psychophysics and physiology in Chapter 1; to higher order cortical processing, with an emphasis on object perception, in Chapter 4; and then to the psychophysical approach to object perception in Chapter 5. With the basic principles established in these initial chapters, the book then applies the psychophysical and physiological levels of analysis to the perception of color (Chapter 6), depth and size (Chapter 7), movement perception (Chapter 8), and the visual control of action (Chapter 9). This new chapter on perception and action consolidates the classic work of Gibson

with modern research on invariant information for perception and cutting-edge physiological research on the connection between perception and action.

Chapter 10 introduces three chapters on auditory perception, with Chapters 10 and 11 being reorganized to create a clearer progression from the basic physiology and psychophysics of pitch perception in Chapter 10 to the perception of sound quality and auditory scene analysis in Chapter 11. Chapter 12, on speech perception, which was reorganized for the fifth edition, remains the same; and the organization of Chapter 13, on the cutaneous senses, remains essentially the same, but additional sections on plasticity and phantom limbs have been added.

In Chapter 14, the chemical senses, an updated discussion of flavor perception has been moved to the end of the chapter, so students first learn about the basic principles of olfaction and taste and then learn about how these two qualities are combined to create flavor. Chapters 15, perceptual development, and 16, clinical aspects of vision and hearing, have been updated but are largely unchanged. The net result of all of these changes is a book that retains the same basic outline as the fifth edition but explains perception even more clearly.

New Feature: Brain Scan

A new feature called **Brain Scan** has been added to highlight the rapidly developing body of research that has applied neuroimaging techniques to the study the human brain as it is operating. This boxed feature, which appears once in each of Chapters 2 through 14, focuses on functional magnetic resonance imaging (fMRI) experiments. Some examples: face area in the human cortex (Chapter 4); stereopsis in the human brain (Chapter 7); activation of the auditory cortex during silent lipreading (Chapter 12); sniff responses in the human brain (Chapter 14).

New Feature: The Plasticity of Perception

A section titled **The Plasticity of Perception** at the end of each chapter describes how the structure and operation of the brain can be changed by experience. Some examples: selective rearing for orientation

(Chapter 3); how vision can affect hearing (Chapter 11); differences between Japanese and American listeners (Chapter 12); plasticity after amputation of a limb (Chapter 13); learning taste–smell associations (Chapter 14).

More Pedagogy!

Summary Tables that recap the main points in each chapter appear at the middle and end of each chapter. These tables are designed to give students a broad perspective on what they have just read. In addition, the new WebTutor option provides access to Web-based learning that supports and supplements the material in the text. This feature is described in more detail below.

Features from Past Editions


The following features from past editions have been continued in this one:

- **Demonstrations.** The Demonstrations have been a popular feature of previous editions, because they provide perceptual experiences that illustrate principles discussed in the text. The demonstrations are simple enough so that students can easily do them and they are integrated into the flow of the text so that they become part of the ongoing story. The demonstrations are listed on page xix.
- **Across the Senses.** This is a one- to two-page section at the end of each chapter that describes parallels between the topic of the chapter and a similar phenomenon in another sense, sometimes comparing or contrasting the senses and sometimes showing how the senses interact. Some examples: neurons that respond to vision and touch (Chapter 4); visual and auditory space (Chapter 7); Tadoma: “hearing” with touch (Chapter 13); intermodal perception in infants (Chapter 15).
- **Study Questions.** These questions at the end of each chapter, which are keyed to page numbers in the book, are designed to help students master the detailed information in the chapter.

Complete Technology Integration through WebTutor

This edition includes the WebTutor option, available in WebCT and Blackboard formats, which provide the following valuable Web-based study aids:

- Glossary items in a flashcard format.
- Study questions with rejinders.
- Over 100 interactive modules that include animations allowing students to explore perceptual principles in a way not possible in the book alone.
- Animated examples of actual stimuli used in experiments described in the text.
- Two dozen auditory demonstrations that enable students to hear auditory phenomena described in the text.

When the WebTutor icon  occurs immediately following a major heading, this indicates that there are WebTutor interactions related to material in that section. See pages xxi–xxvi, following the regular Table of Contents, for a listing of all of the WebTutor demonstrations and interactions.

A Message to the Student

Although most of this preface has been directed to instructors, I want to close by addressing a few words to the students who will be using this book. As you

read this book you will see that it is a story about experiences that may initially seem simple, such as seeing a face or smelling a rose, but that turn out to be extremely complex. I hope that reading this book helps you appreciate both the complexity and the beauty of the mechanisms responsible for these experiences. I hope that as you gain an appreciation for the impressive advances that researchers have made toward understanding perception, you will also appreciate how much is still left to be discovered. But most important of all, I hope that reading this book will make you more aware of how perception affects you personally. After all, perception is something you experience all the time, and the study of perception can enhance this experience. I've found that studying perception has made me more observant of my environment and more appreciative of the miraculous process that transforms energy falling on receptors into the richness of experience. I hope reading this book has the same effect on you. If you have questions, comments, or other feedback about this book, I invite you to communicate with me via email at bruceg@pitt.edu. In fact, if you alert me to mistakes in the text or to parts of the text that are unclear, and I can use this information to make corrections to this edition or improve future editions, I would be glad to cite your name and university in the acknowledgment section that will appear in the 7th edition or in later printings of this edition.

E. Bruce Goldstein

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Sheena Rogers, James Madison University

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University of California at Riverside

Beverly Roskos-Ewoldsen,
University of Alabama

Maggie Shiffrar, Rutgers University

Michael Silverman,
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Peter Wenderoth, Macquarie University

Jack Yellott, University of California, Irvine

William Yost, Loyola University

Reviewers for the 5th edition

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California State University, Fullerton

William P. Banks, Pomona College

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University of Tennessee, Chattanooga

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University of California, Santa Cruz

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Lebanon Valley College

Leslie Tolbert, University of Arizona

Robert G. Vautin, Wheaton College

William Yost, Loyola University of Chicago

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Robert O'Shea,
University of Otago (New Zealand)

Derek Pontin, University of Calgary

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John Waschin, University of Minnesota