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FOUNDATIONS OF **SENSATION AND PERCEPTION**

Second edition

George Mather

"Mather has included some excellent pedagogical features that put this book in a class by itself. ... Moreover, Mather's conversational and interactive style of writing results in a book that is enjoyable as well as informative ... Would I use it for my S&P course? The answer is a resounding 'yes!'"

- Praise for the first edition from
Stephen F. Davis in *PsycCRITIQUES*, July 2006

"This second edition adds tremendous value to an already excellent text. It presents a solid foundation in physiology and psychology of the senses in a very accessible and engaging manner. It is an excellent choice for introductory as well as advanced courses and has the breadth and depth to serve as a basic reference text for all."

- Patrick Cavanagh, Université Paris Descartes
and Harvard University

Foundations of Sensation and Perception

Second Edition

By **George Mather**

Professor of Experimental Psychology at the
University of Sussex, UK

The first edition of this comprehensive introduction to Sensation and Perception has been highly praised for its unique approach, which begins with the minor senses and progresses to vision.

The book begins with an introductory chapter on general physiological, perceptual, and theoretical principles which gives the reader the conceptual tools to build a clear understanding of how we perceive the world. The next two chapters then flesh out basic topics such as transduction, receptive fields, and sensory adaptation via coverage of the minor senses (touch, balance, smell, and taste). Later chapters on hearing and vision build on these foundations. This approach allows students to thoroughly grasp the fundamental principles in relation to the relatively simple sensory systems before moving on to the more complex topics.

Unlike other perception textbooks, *Foundations of Sensation and Perception* has a whole chapter on Individual Differences, which considers potential sources of difference such as age, sex, expertise, and culture.

This full-color second edition has been revised and updated to include:

- Revised and expanded coverage of taste processing and perception, touch perception, pitch perception, and receptive field modeling
- New sections on word perception, the size after-effect, crowding, scene perception, and optic flow
- A completely new chapter devoted to multi-sensory processing and synesthesia, with a new tutorial on attentional effects in perception
- A new 'Tutorial' on visual dysfunction in artists.

The book includes a number of helpful textbook features, such as key terms, chapter summaries, and student and instructor supplementary resources. There are also 'Tutorial' sections in each chapter, which provide an opportunity for students to advance their studies by exploring supplementary information on recent or controversial developments. Further, over 700 references to original source material lead the interested reader into the specialist literature.

Foundations of Sensation and Perception provides students with a thorough analysis of our perceptual experience, how it relates to the physical properties of the world and how it is linked to the biological properties of the brain. It will be an invaluable resource for those studying psychology and neuroscience, enabling the reader to achieve a firm grasp of current knowledge concerning the complex processes that underlie our perception of the world.

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FIGURE 3.1
Direct physical contact
mediates some of our
most powerful sensory
experiences. © Shutter
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environment he makes is belittled, much like a mountaineer surveying a difficult climb, to judge the degree of slope in the ground surface, to measure the size of any gaps through which he must fit, and to estimate the strength of any wind. FW has made use of his acquired skill in assessing environments, and is now used as an adviser by holiday care services, reporting on the suitability of possible holiday locations for disabled visitors.

The case of FW is a vivid example of the importance of somatosensation.

PHYSIOLOGY OF SOMATOSENSATION

The somatosensory system includes eight different kinds of receptor, and two separate pathways linking receptors to the primary receiving area in the cerebral cortex.

Somatosensory receptors

Table 3.1 below lists the eight types of receptor, their location, and their primary sensory function.

Touch receptors

Figure 3.2 illustrates the location of the five different touch receptors of the skin. As indicated in Table 3.1, some lie near the surface of the skin, whereas others lie deeper below the surface. Free nerve endings are specialized for transducing stimuli, and it is not their preferred stimulus on the basis of morphology. The mechanism is not well understood (DeLooze, 1996), but they are known to

TABLE 3.1 Characteristics of somatosensory receptors

Receptor type	Location	Sense
Touch		
Free nerve endings	All skin, superficial	Pain
Mechanoreceptors	Distal skin, superficial	Light
Merkel's discs	All skin, superficial	Touch
Pacinian corpuscles	All skin, deep	Pressure
Muscle spindles	Muscles	Motor
Joint receptors	Joints	Motor

KEY TERM

Touch receptors
Mechanoreceptors and free nerve endings detect the force of the touch, including sensation of pain, temperature, pressure, vibration, and pressure.

The physics of vision—light and the eye

6

INTRODUCTION

Before we can begin to understand visual perception, we must consider the basic properties of the physical stimulus, light. Answers to fundamental questions about vision, such as why we have a light sense and how our sense organs gather information from light, depend on understanding the nature of the physical stimulus.

The physical nature of light has puzzled philosophers and scientists throughout history, and is still not completely understood. The ancient Greeks believed that vision was the result of a "fire" that is emitted by the eyes to strike objects and to reveal their shape. Plato distinguished three kinds of "fire"—daylight from the sun, fire of the same kind emitted by the eyes, and the streaming off objects to interact with the fire emitted from the eyes (see Gregory, 1981). We now know, of course, that the eye does not emit light (except as a reflection) but only receives it. Issues concerning the nature of light itself have tested some of the greatest minds in the history of science, including Isaac Newton, Christiaan Huygens, Max Planck, and Albert Einstein.

WHAT IS LIGHT?

Light is a form of radiant energy that is capable of stimulating receptors in the eye and evoking a visual sensation. The behavior of light can be described in three apparently incompatible ways as rays, as particles, and as waves. One of the major successes of modern theoretical physics has been to resolve the apparent inconsistencies between these descriptions.

LIGHT AS RAYS

One way in which light normally travels in straight lines or rays from a high speed that it can be considered instantaneous. Light rays point on a source in all directions (see Figure 6-1). Obstacles in the path of the rays create well-defined shadows. Light rays are rays, as they pass from one transmitting medium, such as air, into glass or water. This behavior is crucial to our understanding of how light is used by lenses and mirrors.

KEY TERM

Refraction
The change in the direction of a light ray as it passes from one transmitting medium to another, caused by a change in the velocity of propagation.



FIGURE 3.2
Additive mixture of three primary colors. The area of overlap shows the color seen in mixture of the primary colors.

Why might the color of a given color change when it is mixed with an opponent color?

Observers, when asked by Munsell (1905), using lines parallel with various colors and colored very rapidly to create additive color mixtures.

KEY TERMS

Additive color mixture
A color mixture created by adding together different light wavelengths.

Metameric colors
Two colors that appear the same but are not in fact physically different light wavelengths.

theories. Unlike additive mixture, the color seen in one mixture cannot be predicted straightforwardly from the color seen in other mixtures.

ADDITIVE MIXTURES

Additive mixing involves the addition of wavelength components in a stimulus by the superposition of multiple light sources. To give an example, a stimulus patch emitting light at a wavelength of 700 nm appears red in a normal context; see "Color constancy" on page 372. A patch emitting light at 500 nm appears green. What color is seen when the two patches are superimposed to create a stimulus that emits both 500 nm and 700 nm wavelengths? Yellow is seen, as a result of a perceptual effect known as additive color mixing. If a third wavelength is available, in the blue region of the spectrum, then even different colors can be seen in the

various combinations of the three wavelengths, as illustrated in Figure 3.2.

Color mixture is investigated in the laboratory using the apparatus in Figure 12.5. The observer views a circular stimulus patch that is of two halves. One half receives monochromatic light of a given intensity, known as the test light. The other half of the stimulus patch contains a mixture of wavelengths, known as primaries. The color relative intensities of the primaries until the stimulus patch appears.

Once a color match is achieved, the two halves of the stimuli are metameric colors, or metamers, defined as a pair of stimuli that has the physically different spectra. In the example of Figure 12.5, the mixture of 700 nm and 500 nm may appear identical to a monochromatic yellow region of the spectrum, provided that the relative intensities of the two components are appropriate. Additive color mixtures provide simple laws.

LAWS OF ADDITIVE MIXTURE

Linearity

In a linear system, the response containing several components is the sum of the responses produced when the components are presented separately. For example, one patch matches the color of a primary when the primary intensity is appropriate value. A second test patch, some primary at a different pair of test patch, are added together. Intensities are required to match the test patch intensities can be found to together the primary intensities that

1. Observer views stimulus with color matching apparatus as in Chapter 12.



FIGURE 14.8
Illustration of shape constancy in the visual system. The lines of varying lengths are labeled with numbers 1 through 10, indicating their relative lengths.

Observers showed more perceptual segregation than metamers, as is evident from the height of the curves in Figure 14.8 at short onset intervals. In addition, metamers required a longer onset interval to dissipate the bias than metamers. Metamers apparently have a more finely tuned ability to perceive visual stimuli.

Metamers showed more perceptual segregation than metamers, as is evident from the height of the curves in Figure 14.8 at short onset intervals. In addition, metamers required a longer onset interval to dissipate the bias than metamers. Metamers apparently have a more finely tuned ability to perceive visual stimuli.

Visual artists

Thoreau investigated shape and size constancy in a series of classic psychophysical experiments published in the 1950s. Shape constancy is the tendency for perceived shape to remain relatively constant even when variations in viewing conditions produce marked changes in the retinal image. For example, if a flat circular disk is placed on a table top, and an observer views it from an oblique angle, the image of the disk on the retina will be elliptical because of foreshortening, as illustrated in Figure 14.9 (foreshortening was explained in Chapter 10, Figure 10.7). However, the observer tends to perceive the actual projection of the disk as more circular than it really is.

In Thoreau's experiments, observers were asked to match the shape of the disk as seen from their viewpoint with a series of alternative elliptical shapes varying in their degree of eccentricity. An observer showing perfect shape constancy would select the circle as the matching shape, since this is the actual shape of the disk. An observer showing no shape constancy would select the shape that matches the elliptical retinal image of the disk exactly. Most observers show partial shape constancy, selecting a shape intermediate between these two extremes. Thoreau called this effect "phenomenal regression to the real object," and measured it in a large number of subjects. He expressed constancy scores on a scale from 0 (no constancy) to 1.0 (perfect constancy). Thoreau (1951) compared the degree of constancy shown by trained artists and by nonartists, and Figure 14.10 shows his data (taken from Thoreau, 1951, Table 12).

Artists showed much less constancy than nonartists. Shape constancy is probably responsible for the difficulties most people experience when they attempt to create realistic life-drawings of three-dimensional scenes. It distorts attempts to render viewed shapes accurately in a drawing, since it distorts perceived impressions towards real object shapes. Trained artists counteract constancy more successfully than nonartists, but note that some constancy is present even in artists (their scores in Figure 14.10 are above zero). To overcome this residual tendency, artists have traditionally used aids such as Albert Dürer's device, a viewing window divided into squares using a wire grid. The three-dimensional scene is reproduced on paper divided up into a corresponding number of squares. Artists today generally use sighting to overcome constancy. They draw dimensions, such as the perceived width and height of the disk in Figure 14.8, are measured using a thread positioned along a pencil or brush handle held at arm's length.

More recently, Koffka (2001) compared an artists' drawing of a scene with a photograph of the same scene. He found no difference between the groups in mental rotation scores. But art students performed markedly better than nonartists in the other three tasks involving degraded images, by as much as 52%.

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Student Resources: Perception Student Learning Program

The student website includes our Perception Student Learning Program (Perception SLP) which offers a unique and innovative approach to study. The Perception SLP is available free of charge to departments adopting *Foundations of Sensation and Perception, Second Edition*, by George Mather.

Each chapter from *Foundations of Sensation and Perception* is condensed into a concise summary version, providing an effective set of revision notes. These notes also expand on and elucidate the book's content, with references to specific pages in the textbook. 'Must know' information is presented

in a clear, accessible style, along with sections to stretch more advanced students. The notes also provide an integrative framework for a range of interactive multimedia materials and features, including:

- Animations and simulations of key perceptual phenomena
- Fill-in-the-blank questions
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- Key-term definitions
- Research studies
- Short-essay questions
- Links to related websites.

Demo 6.4. Eye Movement



Instructor Resources

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- A comprehensive chapter-by-chapter slideshow lecture course
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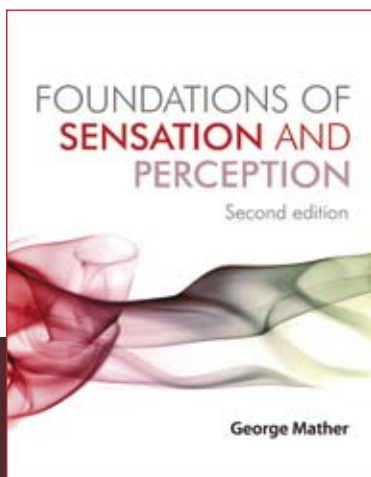
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FOUNDATIONS OF SENSATION AND PERCEPTION

SECOND EDITION

By **George Mather**

"Mather does an excellent job of bringing the topic of Sensation and Perception to life using many examples from the 'real world' as well as giving a comprehensive overview of both recent and classic experimental findings. The book is highly recommended for students who are new to the topic."

- **Dr Jamie Ward,**
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"This is an excellent book with thorough coverage of all five senses grounded in clear descriptions of what is being sensed and why. The book has useful boxes that define key terms and excellent tutorials at the end of each chapter so that students can actively engage with the subject."

- **Professor Iain D. Gilchrist,**
University of Bristol

"George Mather did it again! Students of perception will be even happier with this second edition, especially as it now includes state of the art sections on two highly active research areas: multisensory processing and synesthesia. It will also prove to be an excellent source for anyone who is eager to find out about the fundamental role of our senses in perceiving the real and artificial world."

- **Professor Frans Verstraten,**
Helmholtz Institute, Utrecht University

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