Source: Albert Shakirov/Alamy Stock Photo

1

WHAT IS PERCEPTION?

Do not copy, post, or distribute

Copyright ©2024 by SAGE Publications, Inc.
This work may not be reproduced or distributed in any form or by any means without express written permission of the publisher.

LEARNING OBJECTIVES

1.1	Discuss why understanding sensation and perception is important.
1.2	Describe how transduction transforms a physical signal into a neural signal.
1.3	Illustrate the history of the study of sensation and perception.
1.4	Understand the impact of neuroscience on our understanding of sensation and perception.

INTRODUCTION

Try to imagine the last concert you attended. It does not matter what kind of music you like—rap, country, even the opera. Most likely, your experience at the concert was thrilling—an experience initiated by the pleasure that auditory perception can bring. The sounds of the singer's voice and the guitarist's riffs stir your emotions. The music pulses into your ears. Despite your distance from the stage, and the assortment of voices and instruments, you correctly sort out the lead singer's voice from the guitar, the bass, the keyboard, and the drums. Moreover, even though there is a disconnect between the source of the sound (the loudspeakers) and the location of the musicians (the stage), you correctly attribute the sound to the stage. But in almost all cases, in all varieties of music, a concert is more than just sound. The flashy clothes and the elaborate video screens fill your eyes with color and movement. This mixture of sight and sound is not unique to pop concerts. The same is true for opera (Figure 1.1). Because opera incorporates drama as well as music, costumes and visual appearance are as much a part of the art form as is the music itself. Our enjoyment of a live concert comes from this coordinated combination of sensory stimulation.

FIGURE 1.1 ■ Chinese Opera

In Chinese opera, elaborate and colorful costumes make the performance as much a visual experience as it is a musical one.

Source: iStock.com/xiao-ming

We tend to take our amazing sensory abilities for granted, even when we are specifically engaging in activities such as concerts or visits to art museums, in which we deliberately challenge our sensory systems. In general, we seldom think about the manner in which we see, hear, touch, taste, and smell

Do not copy, post, or distribute

Copyright ©2024 by SAGE Publications, Inc.
This work may not be reproduced or distributed in any form or by any means without express written permission of the publisher.

the world. Perceptual abilities work fast, and they provide us, during every waking moment, with an ongoing update of the state of the world around us. We may attend to only certain aspects of the world at any given moment, but a wealth of potential information exists around us.

Consider the simple act of reading this paragraph. Unless you are blind and using either touch or audition to read these words, you are looking at a pattern of black squiggles on a white background. Your attentional focus is on decoding these squiggles from an intricate pattern of visual stimulation into meaningful concepts. However, even if you are in a quiet room, you are surrounded by myriad other sources of sensory stimulation. Just a slight break of concentration, and you may become aware of the slight hum of the heating system, voices from upstairs chatting about campus events, the pulse of the refrigerator, the Escalade with the deafening bass line driving by outside, and maybe the plaintive cooing of a mourning dove in a tree outside the window. Look up from your text and you can see the flowers your mother sent you, the leftover dinner that needs to be cleaned up, or your relaxed cat sleeping by your feet. An inadvertent sniff, smelling the cookies baking in the kitchen, breaks your concentration (Figure 1.2). Feel free to put "Schwartz and Krantz" down for a moment and have one of those cookies before you continue reading. And don't worry about the vase.

FIGURE 1.2 ■ Chocolate Chip Cookies

Just seeing chocolate chip cookies may make you hungry. However, most people cannot make a taste image. Try to imagine what chocolate chip cookies taste like (not look like) with nothing actual to taste. Most people cannot do it. However, when we smell the cookies, we get a sensation very distinct from what they look like.

Source: iStock.com/Scoutts

The fact of the matter is that each of these sensory processes, from reading words in a book to smelling cookies baking in an oven, is incredibly complicated; each one is completed by exquisitely fine-tuned processes in our brains. By and large, however, we become conscious only of the finished product—the words on the screen, the music of Ariana Grande gradually getting louder, then softer, as the car with the loud stereo passes by outside, the brush of your cat's soft fur against your skin, and the taste of the warm chocolate mixing with the sugary cookie dough. The incredible computing power of the human brain is focused on processing each of these sensory inputs and allowing your conscious mind to pick and choose among them. Indeed, sensory systems have evolved to accomplish these processes quickly and efficiently.

Do not copy, post, or distribute

Copyright ©2024 by SAGE Publications, Inc.
This work may not be reproduced or distributed in any form or by any means without express written permission of the publisher.

This textbook is an introduction to the science of sensory processes. We will address the issue of sensation and perception from the perspectives of both psychology and neuroscience. We will discuss both the neural underpinnings of sensation and perception and the psychological processes based on those neural processes. This textbook is written to help you understand the complex processes that go into sensory perception. We hold that the study of sensation and perception is a fascinating area that sheds light on the basic nature of what it is to be human. We hope you find this journey interesting.

However, at the outset, we find it necessary to inform the reader: Understanding sensory processes is not easy. No matter how clear our description is of each topic in this book or how well your professor explains the material, understanding this material takes hard work and patience. The human mind and brain are complex; therefore, to understand how they work and create our ability to sense and perceive is also a complex task. Thus, read your text slowly and repeatedly, consult the online resources, experience the illusions and demonstrations provided on ISLE, answer the review questions, test yourself repeatedly, and give yourself the time to learn about sensation and perception. Moreover, the terminology is often complex and certainly requires ample memorizing. Make sure to learn the key terms, because they are important in understanding the concepts (and presumably doing well in your class). Do not get frustrated—it is likely that other students need just as much time to learn the terms and help understanding sensation and perception as you do. We think it is worth the time. We hope you will find the incredible designs and abilities nature has evolved in our sensory systems to be inspiring, interesting, and important.

INTRODUCTION TO SENSATION AND PERCEPTION

You may wonder why sensation and perception are part of the psychology curriculum and not, say, the biology curriculum. This is a fair question given that much of what you will read in this book concerns anatomy and physiology, albeit with a bit of cognitive science thrown in. The answer is simple: The goal is to understand perceptual experience, that is, how our brains process the sensory world around us and how that processing is interpreted. Understanding how our minds, through our brains, interpret the world around us is an inherently psychological goal. We will see, as well, that psychological processes, such as attention, intention, emotion, and biases, influence the ways in which we perceive the world. Consider the sensory experience of pain. Every marathon runner, whether an amateur or an Olympic medalist, crosses the finish line in intense bodily discomfort (Figure 1.3). Body temperature is at fever levels, muscles are filled with lactic acid, sunburn covers the skin, dehydration is present, and sores are opening on the feet. But despite the pain and discomfort, the marathon runner is likely ecstatic for having met an incredibly challenging goal. The pain is interpreted in the context of completing a long-sought objective—to demonstrate that the marathon can be run. If the same physical conditions were duplicated in a prison setting, it could be interpreted as torture.

Consider, too, how our personal biases can influence perception. Think about two friends from Los Angeles watching a basketball game between the Los Angeles Clippers and the Los Angeles Lakers. Each person is watching the same game from the same vantage point in the stands. That is, both friends are receiving the same perceptual input. However, each person perceives different things. The Clippers fan sees Lakers star Anthony Davis "charging," that is, committing an offensive foul. The Lakers fan sees the same play as a blocking foul on Clippers star Kawhi Leonard, maybe even a flagrant foul. The same sensory input results in two different perceptual outputs. Research has shown that even when participants are instructed to be totally objective, they cannot overcome the kinds of biases that are created by being a fan of one team or another (e.g., Hastorf & Cantril, 1954). That is, even when trying to be totally objective, Lakers fans cannot see the game from a Clippers perspective, and Clippers fans cannot see the game from a Lakers perspective. For this reason, referees who grew up as Lakers fans are seldom assigned the job of refereeing games involving Los Angeles teams. The hope is that a referee from Seattle can see a game in an unbiased way (or at least a less biased way) compared with a referee from Los Angeles. However, because of the biases of the Clippers fans and the Lakers fans, they will never see what the referee sees. Thus, the fairest of referees may often be scolded by fans of both teams as being biased toward one or the other team—in the very same game.

Do not copy, post, or distribute

Copyright ©2024 by SAGE Publications, Inc.
This work may not be reproduced or distributed in any form or by any means without express written permission of the publisher.

FIGURE 1.3 ■ Runner Overcoming Pain

Marathon runners must overcome intense pain by the end of the race. Our bodies have a number of ways of easing the pain. The marathon runner may value the sense of accomplishment of finishing the race. But pain is still an intense sensory experience.

Source: iStock.com/bytepark

Knowledge can influence perception in more subtle ways than occur among biased sports fans. Consider seeing a small dot on the horizon of the ocean. Because you know that it is a cruise ship out there, you tend to see it as such. That the object could be an alien spaceship is considered far less likely, so you do not see it as such. Indeed, we use our knowledge of objects to help us perceive them even in relatively simple and static scenes.

Most of us were taught in elementary school about the five senses—vision, hearing, touch, smell, and taste. This standard taxonomy is not a simplified classification system, though it goes all the way back to Aristotle. It is wrong! The truth is that we have more than five senses. For example, in addition to these sensory systems, we have a vestibular system to help keep our balance and a proprioception system to allow us to monitor the position of our bodies. Our sense of touch is composed of multiple physiological systems designed to sense different features of the environment. Heat, cold, pain, itchiness, and soft touch are all implemented by separable systems. Indeed, the receptors for the "itch" experience are a unique kind of receptor different from those that sense touch and those that sense pain. Thus, depending on how the different touch systems are counted, it is more realistic to say that human beings have anywhere from 7 to 12 different sensory systems (Table 1.1). Indeed, some have even argued that hunger and thirst should be counted as senses. We leave them out, as they deal strictly with internal states that are not directly linked to perception of the external world.

The standard five-sense approach also fails if you think of the sensory systems as hierarchically organized. For example, our perception of the flavors of foods is a complex interaction of smell and taste, and it is something we feel is quite different from smell itself. Flavor may also take into account other sensory modalities, such as vision. For example, if you have ever tried to eat green eggs and ham, you know what we are saying. However, because smell and taste are so bound together, it makes sense to group these two senses in the same way that soft touch, pain, and temperature are grouped together as the sense of touch or as a somatosensory system. Nonetheless, old habits are hard to break, and this book is roughly organized according to the traditional five-sense taxonomy. This is merely a bow to convention, not an endorsement of any scientific truth behind it. In Chapter 14 we cover the skin senses (touch, pain, and temperature). You will see that the various senses that make up this group are

Do not copy, post, or distribute

Copyright ©2024 by SAGE Publications, Inc.
This work may not be reproduced or distributed in any form or by any means without express written permission of the publisher.

TABLE 1.1 ■ Senses of the Human Body

Function	Organ	External or Internal Stimuli
Vision	Eyes	External
Hearing	Ears	External
Smell	Nose	External
Taste	Tongue	External
Light touch	Skin	External
Pressure	Skin	External
Cold	Skin	External
Heat	Skin	External
Pain	Skin/viscera	External/internal
Itch	Skin	External
Vestibular	Inner ear	External
Proprioception	Muscles	Internal

This table shows that there are more sensory systems than the traditional five.

different both perceptually and anatomically. Indeed, even the sensation of "hotness" and the sensation of "coldness" are brought about by different receptor systems, not a differential response from a "temperature" receptor. The classic "burn" sensation of feeling super-cold liquid nitrogen on one's skin is an example of this. (Removing of warts and moles with freezing liquid nitrogen is a common dermatological procedure.)

It makes scientific sense to discuss the visual system and the auditory system as discrete sensory systems. And given the centrality of these two systems to human sensory processing, much of this book is devoted to them. Indeed, all but the last two chapters are about vision and audition. Increasingly, however, how sensory systems interact is becoming an important topic of study known as multisensory processing, studies of which address how one sense can affect perception in another (Alvarado et al., 2007).

Test Your Knowledge

1. Why are sensation and perception studied by psychologists?
2. How do personal biases influence perception? Do such biases influence what we see and hear, or do they bias what decisions we make about what we see and hear?
3. What is meant by the myth of five senses?
4. What is the difference between internal and external senses? Can you give an example of each?

THE BASICS OF PERCEPTION

Sensation refers to the registering of a physical **stimulus** on our sensory receptors. That is, sensation is the earliest stage of a process that starts off in the eyes, ears, or skin and ends in the higher centers of the brain. Sensation changes physical stimuli, such as light, sound waves, and mechanical vibrations, into information in our nervous systems. **Perception**, by contrast, refers to the later aspects of the perceptual process. To be specific, perception involves turning the sensory input into meaningful

Do not copy, post, or distribute

Copyright ©2024 by SAGE Publications, Inc.
This work may not be reproduced or distributed in any form or by any means without express written permission of the publisher.

conscious experience. In this sense, perception means the translation of that neural signal into usable information.

Sensation and perception are usually thought of as distinct processes, one referring to the basic process of converting external information into a neural signal and the other concerned with interpreting what that signal means. Other researchers think that the dichotomy between sensation and perception is a false one (e.g., J. J. Gibson, 1979). We will begin with the standard model, in which sensation occurs in the sensory organs. For audition, sensation occurs in the ear, in particular, the hair cells of the cochlea. For our sense of touch, sensation occurs along the surface of the skin. Perception occurs after cognitive processing begins, typically in the cerebral cortex of the brain. Sensation is about stimuli; perception is about interpretation. To perceive the world, we need both. We cannot perceive the Russian doll on the coffee table as a Russian doll on the coffee table without both ends of the process (Figure 1.4). The image of the doll must fall on the retina in order for us to perceive, but equally important is the parsing of the perceptual environment, that is, knowing where the doll ends and the table begins.

FIGURE 1.4 ■ Seeing: A Complex Process

To understand this photograph, you must sense the colors and images, but cognitive processes aid in understanding what it is you are looking at. Without some cultural knowledge, the sensation makes little sense. However, to our conscious selves, the process of perceiving the Russian doll is seamless.

Source: iStock.com/SylvieBouchard

Let's take a look at the perceptual process, that is, the sequence of mental operations that bring us from the initial sensory input to our understanding of our conscious experience (ISLE 1.1).

Stimuli reflect light, produce sounds and vibrations, have surface texture, and produce volatile chemicals (which we can smell). The job of our perceptual processes is to determine what is out there in

Do not copy, post, or distribute

Copyright ©2024 by SAGE Publications, Inc.
This work may not be reproduced or distributed in any form or by any means without express written permission of the publisher.

the world around us. We want our perceptual processes to produce a veridical (truthful) representation of what surrounds us and allow us to focus on those stimuli that are most important to us. Veridicality is important because we want our sensory systems to be guiding us in adaptive ways. For example, if we perceive an object as being farther away than it actually is, we may bump into it and injure ourselves.

Because there are many potential stimuli in our world, we must be able to focus on potential stimuli that are important or interesting. Such stimuli are called the attended stimuli. When most of us listen to a song, our attention is drawn to the voice of the singer or the melody of an instrumental tune. We can pick out different parts of the music, say, the drums or the bass, by switching the attended stimulus from the lead singer to the bass line, but usually our attention is focused on the melody. With vision, we may be looking at a beautiful beach, but our attended stimulus may be the beer bottle a previous careless beachgoer left behind.

Through our senses, we are presented with an incredibly rich and varied experience of the world, including the aroma of roasting coffee, the texture of fine silk, the taste of dark chocolate, the sound of our favorite musician, and the sight of a glorious sunset. Not all sensory experiences are pleasant and lovely, of course. We have all smelled rotting garbage, felt a painful pinprick, placed our fingers on a hot stovetop, tasted foods we detest, heard fingernails screeching on the blackboard, and seen images in movies that have made us close our eyes. The senses unflinchingly bring to us an immense range of experiences from the world around us, positive and negative alike.

How do stimuli in the outside world become perceptual experiences? How do our sensory systems, such as our eyes, ears, and skin, translate light, sound, and surface textures into perceptions? For example, how does our nose turn the volatile chemicals of coffee into the tantalizing aroma of coffee (Figure 1.5)? We need to explore how physical stimuli are converted into a sensory representation. For this reason, we introduce the concepts of **transduction** and neural responses.

FIGURE 1.5 ■ The Smell of Coffee

The smell of coffee comes from molecules in the air that rise from the coffee. Special cells in our noses must convert the presence of those molecules into neural signals, which we interpret as the wonderful aroma of coffee.

Source: Shutterstock.com/Rachata Teyparsit

For each of our sensory systems, we have specialized neural cells called **receptors**, which transduce (transform) a physical stimulus into an electrochemical signal, called a **neural response**, which then

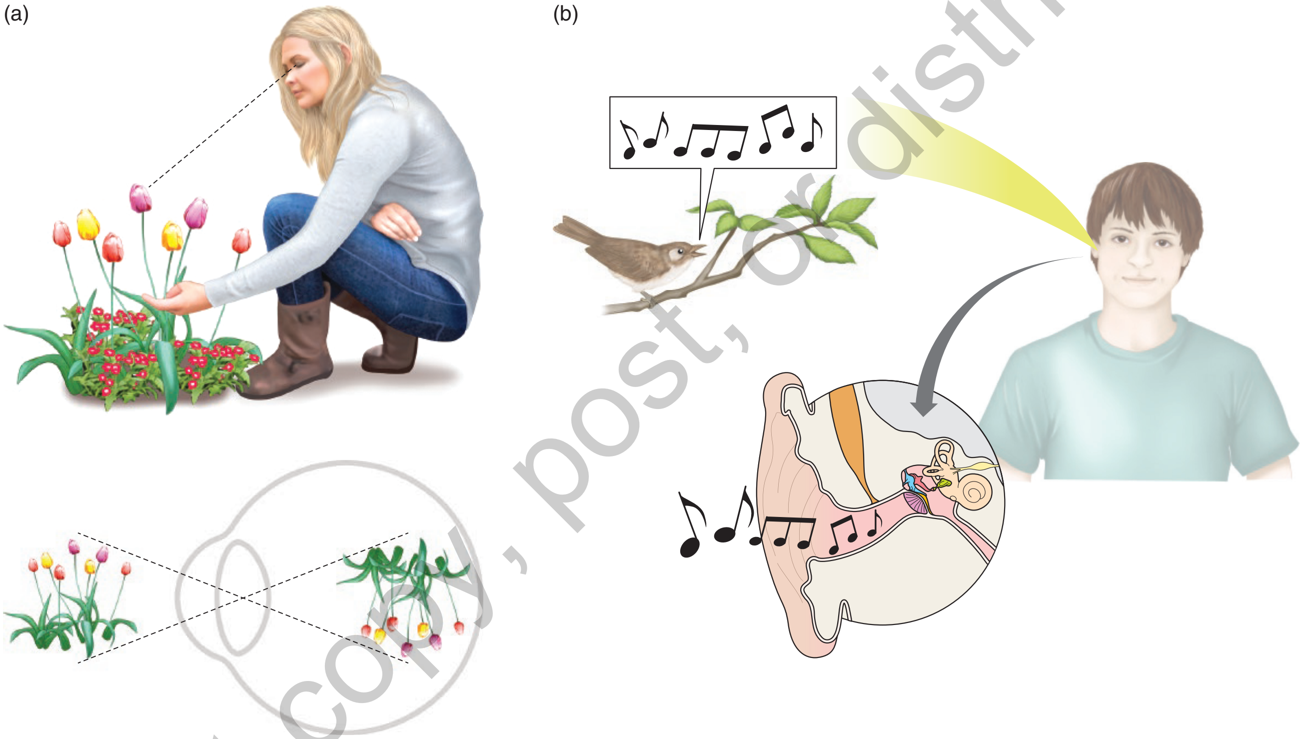
Do not copy, post, or distribute

Copyright ©2024 by SAGE Publications, Inc.
This work may not be reproduced or distributed in any form or by any means without express written permission of the publisher.

can be sent to the brain. For vision, these specialized cells are called rods and cones, and they are located on the retina of the eye. For hearing, these specialized cells are called the hair cells, and they are found in the cochlea in the inner ear. For our sense of taste, we have cells in our taste buds, which create neural signals when they come into contact with certain chemicals in our food. Rods and cones transduce the physical energy of light into an electrochemical signal, which is then transmitted to the brain via the optic nerve. Hair cells convert the vibrating of the cochlear membrane (which vibrates in response to physical sound) into a neural response, which is then transmitted to the brain via the auditory (or cochlear) nerve. Taste bud cells convert the presence of a particular chemical (such as sugars) into a neural response transmitted to the brain by gustatory nerves (Figure 1.6).

FIGURE 1.6 ■ Converting Energy Into a Neural Signal

Perception is the process of converting physical stimuli, such as light and sound energy, into neural signals within our sensory organs. (a) Light is reflected off the petals of the flowers and into the eyes. The eyes then transduce this light into a neural signal to be sent to the brain. (b) Sound is produced by the bird and reaches our ears. Special hair cells in the cochlea of the ear transduce the sound into a neural signal to be sent to the brain.



Once a neural signal is transduced by the receptors, it is transmitted to the brain for processing. Though the neural signal contains much information, it is necessary for the brain to process that information in order to extract relevant information, such as color for vision and pitch for sound. It is for this reason that we find it useful to distinguish between sensation and perception. *Sensation* refers to the process of transduction, in which receptors convert physical signals into neural responses, and *perception* refers to the process of taking that signal and processing it into a usable image or experience. For example, when we hear orchestral music, the hair cells in our cochleae convert the sound waves into neural signals, but it is our brains that convert that neural signal into the experience of the music we hear, the rich sound of the violins contrasting with the sharp tones of the trumpets, and the underlying low tones of the basses and bassoons. Sensation enables us to take in the sounds, but perception allows us to appreciate the music.

Action

The goal of sensation and perception is to guide us through our environment. We use visual information to avoid obstacles while walking around campus or driving on the highway. When it is completely

Do not copy, post, or distribute

Copyright ©2024 by SAGE Publications, Inc.
This work may not be reproduced or distributed in any form or by any means without express written permission of the publisher.

dark, we avoid obstacles by touch. We feel our way by touching the obstacles in front of us. In this way, most of us can negotiate our own homes at night with the lights off just using touch. We use auditory information to determine what people are saying and whether the phone is ringing. We use olfactory (smell) information to determine if we want to eat something or avoid any contact with it. We use information about temperature on our skin to determine if we want to wear a sweater or a T-shirt. Thus, perceiving what is around us guides us to action. We can define **action** as any motor activity. Thus, action includes moving one's eyes along the page of a book as well as a baseball player's swinging his bat at an incoming curveball (Figure 1.7). It includes turning your head when you hear the voice of a friend or a concert pianist's fingers darting across a piano keyboard. Thus, any movement we make can qualify as action. If that movement is directed by something we perceive in the environment, then we can see that it is perception-guided action. In sum, one of the chief goals, if not the goal itself, is to guide functional action. There are some interesting illustrations of this on ISLE 1.2.

FIGURE 1.7 ■ Perception and Action

The baseball player's swing is guided by the perception of the approaching baseball. Opposing pitchers may throw curveballs, which change direction at the last moment, to confuse batters' perceptions.

Source: iStock.com/RBFried

The Nature of Experience and Phenomenology

Think about the experience of listening to very beautiful music. For example, think of a violin virtuoso playing Bach's Violin Partita No. 2 in D minor. If you are not familiar with this piece of music, you can listen to an excerpt of it (ISLE 1.3). If you do not like this style of music, imagine a piece of music that you think is very sad but also very beautiful. In the Bach partita, our ears are responding to differences in frequency, tempo, rhythm, and loudness as we hear the sound of the lone violin. Our toes may move in time to the music, and our eyes may cloud with tears at the poignancy of the music. These movements may be considered action. But why does the piece affect us emotionally? Why do we find music beautiful in the first place? How is it that we feel Bach's grief at losing his wife through this music nearly 300 years after the piece was written? If you are a music theorist, this speaks to the power of Bach's music. But for our purposes, it introduces us to the issue of phenomenology. Phenomenology is our subjective experience of perception. **Phenomenology** refers to our internal experience of the world around us. Phenomenology

Do not copy, post, or distribute

Copyright ©2024 by SAGE Publications, Inc.
This work may not be reproduced or distributed in any form or by any means without express written permission of the publisher.

is the beauty of the lone violin, the aromaticity of your coffee in the morning, and the wonder of seeing the colors of the sunset in the west of an evening sky (Figure 1.8). By the same token, *phenomenology* can refer to the annoying cacophony of the neighbor's lawnmower, the stink of an airplane bathroom, and an up-close look at a stranger's nose hairs. Regardless of the effects they induce in us, perception induces these internal mental experiences in each of us.

FIGURE 1.8 ■ Phenomenology

When we see a beautiful sunset, we notice the colors and the landscape. The experience of all this is considered its phenomenology. Issues of phenomenology interest psychologists and philosophers alike.

Source: iStock.com/tomofbluesprings

Phenomenology distinguishes us from computer-driven robots. Robots have microphones to capture sound and internal computer processing units to decode the messages into something that can drive the robots to follow certain courses of action. But computer devices do not have internal experiences (as best we know). Phenomenology appears to be a unique creation of the living brain. Philosophers have argued about what purpose it serves, whether people share common phenomenology, how widespread it is among nonhuman animals, and if it is possible in nonliving systems. The discussion of these questions is largely outside the scope of this book, but there is a lively debate in philosophy concerning how we would know if animals or artificially intelligent devices experience phenomenology when they process the external world.

An interesting issue in phenomenology is that it is a private experience. Each of us has sensory experiences, and we agree on common terminology for them, but because phenomenology is private, philosophers often wonder if we share phenomenology. For example, scientists know what frequencies of light elicit an experience of blue, and people all across the world agree on what constitutes blue (regardless of language and culture). We may also share common cultural referents to blue, which we all agree on (blue jeans, blue moods, blue states, etc.). However, is our internal experience of blue the same? Do you and I have the same phenomenology of blue? This conundrum is often referred to as the inverted-rainbow question. We all agree on the relation of frequency to color name when we see a rainbow, but what if our internal experiences were different? By and large, this question takes us out of the domain of scientific psychology, as it cannot be answered empirically. But philosophers take these questions quite seriously. At sagepub.com, you can find some approachable readings on the philosophy of phenomenology.

Do not copy, post, or distribute

Copyright ©2024 by SAGE Publications, Inc.
This work may not be reproduced or distributed in any form or by any means without express written permission of the publisher.

Test Your Knowledge

1. What is transduction? How might it differ from one sensory system to the next?
2. What is phenomenology? Why do you think it is so difficult to study by experimental psychologists?

THE HISTORY OF SENSATION AND PERCEPTION

To understand any field of study, it is helpful to understand its history. Often the questions asked in the past and the way they were posed influence modern research. Therefore, knowing the history can often help us understand why issues are framed the way they are and why our knowledge has both the strengths and the weaknesses that it does. It can also help us understand our own assumptions about the nature of the world by seeing ideas from different epochs, when ideas and technology were different. Sometimes a field does not even make sense until its history is considered. In this section, a short history of the field of the study of sensation and perception is covered to give some context to the material in this chapter and throughout the book.

The Beginnings

Thinking about our senses probably predates any written record. We would like to think that even in prehistoric times, people marveled at the beauty of a rainbow or a sunset. The formal study of sensation and perception goes nearly as far back as written records exist. The Ramesseum medical papyri date back to approximately 1800 BCE. That's nearly 4,000 years ago! The unknown authors describe disruptions in visual perception and their connection to diseases of the eye (Weitzmann, 1970). Interestingly, the papyri recommend hemp as a treatment for eye disorders, much as doctors now prescribe medical marijuana for glaucoma. In ancient Greece (some 1,500 years after the Ramesseum medical papyri), Greek architects were aware of how perception could be distorted by visual illusions (Coren & Girgus, 1978). Indeed, the Parthenon was built to appear as if it had straight columns, though in order to do so, the architects had to design columns that were not perfectly vertical. Elsewhere, Greek architects built perfectly straight columns, but these appear bent (ISLE 1.4).

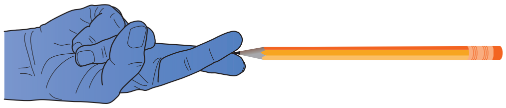
Aristotle (384–322 BCE) conducted conceptual work and observations in the field of sensation and perception. He clearly distinguished between sensory and motor functions; he described the sensory organs and their functions; he even gave us our prototypical list of five senses: sight, hearing, smell, taste, and touch (Murphy & Kovach, 1972). In addition to these basic ideas, Aristotle was a keen observer and is the first to have recorded two very interesting sensory phenomena, which we describe here, as they are relevant to topics we discuss in later chapters.

The first is an illusion of touch that still bears his name, the Aristotle illusion (Benedetti, 1985). In this illusion, a single touch between the tips of two crossed fingers, say with a pen, will be experienced as if there were two touches, as if there were two pens and not a single one (ISLE 1.5). You can experience the illusion very simply by crossing your index and middle finger (Figure 1.9). Then pick up a pencil and touch the place just where the two fingers meet. You probably experience two touches (as there is one touch to each finger) that feel like two pencils. The Aristotle illusion is relevant to material discussed in Chapter 14.

Do not copy, post, or distribute

FIGURE 1.9 ■ **The Aristotle Illusion**

In the illustration, we see two crossed fingers and a pencil touching in the middle. In this illusion, we feel as if we have been touched by two pencils rather than one.



Copyright ©2024 by SAGE Publications, Inc.
This work may not be reproduced or distributed in any form or by any means without express written permission of the publisher.

The second illusion discussed by Aristotle is known as the motion aftereffect, also known as the waterfall illusion (Verstraten, 1996; Wade, 1996). A motion **aftereffect** is a sensory experience that occurs after prolonged experience of visual motion in one particular direction (ISLE 1.6). If we think of a waterfall, the water is all moving in the same direction: down. After staring at a waterfall for some time, if you move your eyes to a solid stationary object, you may get the sense that the stationary object is moving upward, that is, in the direction opposite the one in which the waterfall was moving. Another way to observe this illusion at home is to watch the credits at the end of a movie without taking your eyes off the television screen. After watching the credits for 2 minutes, have a friend or family member hit the pause button. You will see an illusion of the movie credits' moving up the screen, even though you know the video is now stopped. Aristotle observed this by looking at nonmoving surfaces after watching the downward motion of waterfalls (Figure 1.10).

FIGURE 1.10 ■ Waterfall Illusion

After watching the constant downward motion of a waterfall, the motion detectors in our brains adapt or tire in response to the downward motion. When we look away from the waterfall, upward motion detectors become active, and we experience the illusion that whatever stationary object we are looking at is moving upward.

Source: iStock.com/Maxlevoyou

Western philosophers were not the only early thinkers writing theories of perception. Whether perception is veridical and how perception affects our thinking is a major theme in classical Indian philosophy in both Hindu and Buddhist traditions (Chadha, 2014). Foremost of these concerns was the observation of illusion. Many classical Indian scholars puzzled over how we could know reality when our perception was faulty (Chadha, 2014).

Many Western philosophers and scientists prior to the 19th century developed ideas about perception, some of which still influence our thinking today. For example, the astronomer Robert Hooke

Do not copy, post, or distribute

Copyright ©2024 by SAGE Publications, Inc.
This work may not be reproduced or distributed in any form or by any means without express written permission of the publisher.

(1635–1703) developed the first acuity test for vision (Grüsser, 1993). However, it is with the 19th century that we see the beginnings of a real science of sensation and perception. The contributions came from people in many different disciplines. Physicist Thomas Young (1773–1829) argued that light is a wave and that color is detected by three kinds of nerve fibers, an idea elaborated on later by Hermann von Helmholtz. Biologist Johannes Mueller (1801–1858) developed the doctrine of the specific nerve energies. The **doctrine of specific nerve energies** argues that it is the specific neurons activated that determine the particular type of experience. That is, activation of the optic nerve leads to visual experiences, whereas activation of the auditory nerve leads to auditory experiences. This seemingly obvious conception was controversial at the time because one of the confusing findings of that time period was how similar the electrical activity was in all of the neurons, regardless of the sensory modality. This led Mueller and others to wonder how the brain could distinguish between seeing an apple and hearing a song, for example. Those neurons involved in seeing will cause the impression of seeing regardless of how they are stimulated. Thus, if a sound stimulates the neurons involved in vision, you will still have a visual experience. Some early evidence for this view is the visual experience we have when we manually stimulate the retina. Try pushing at the side of your eye, and you will see that pushing on the eye can cause shifts of color and shading.

Helmholtz Versus Hering

One of Mueller's students was Hermann von Helmholtz (1821–1894) (Figure 1.11). Helmholtz was born in Potsdam in what was then the Kingdom of Prussia (now part of Germany). He was a professor for many years at the University of Berlin. Helmholtz was trained in medicine and physiology but became famous for his work in both sensory perception and physics. His work in physics includes the formulation of the law of the conservation of energy, an important landmark in physics. He was also a pioneer in thermodynamics and electrodynamics. In biology, Helmholtz was the first person to determine the speed of the neural impulse (or action potential). He also contributed greatly to the beginnings of sensory physiology and the scientific study of perception. Indeed, Helmholtz wrote a three-volume study of physiological optics and also wrote a book on music perception. In particular, he elaborated on the work of Thomas Young and developed the concept of the trichromatic theory of color vision. For this reason, the trichromatic theory of color vision is often called the Young–Helmholtz theory of color perception. Helmholtz thought of our color vision as being based on the perception of three primary colors, red, green, and blue, even though he was not certain that there were three cone types in the retina. (This was not known for certain until much later.) By and large, his color theory is still relevant today.

Helmholtz developed a general theory of how our senses work, which is mostly still held today by most researchers within the field of sensation and perception. In his **constructivist approach**, Helmholtz argued that the information from the sensory signal itself is inadequate to explain the richness of our experiences. That is, the sensory signal needs to be interpreted by active cognitive processes. For example, recognizing the face or voice of a loved one is more than basic sensations. Your auditory system must integrate the sound of the voice with your knowledge of your sister and the knowledge of what she usually talks to you about in order to fully perceive the speech directed at you. Thus, we must incorporate information from our existing knowledge to completely perceive the world around us. According to Helmholtz, because our senses do not produce sufficient information about the world, we must use a form of reason, unconsciously, to make an educated guess about what we actually perceive. Helmholtz called this an **unconscious inference** (Turner, 1977). This type of theory is useful for explaining the occurrences of auditory and visual illusions, such as the waterfall illusion. In this way, Helmholtz's work foreshadowed the cognitive approaches known as information processing and the computational approach.

Helmholtz's colleague and rival was Ewald Hering (1834–1918) (Figure 1.12). Hering was born in Saxony, in what is now Germany, but he was a professor in Prague in what is now the Czech Republic and Leipzig in Germany. Hering disagreed with Helmholtz both on the specifics of color vision and on a general model of how sensory processes worked. With respect to color vision, Hering did not see color vision as being based on three primary colors but as being based on color opponency (Turner,

Do not copy, post, or distribute

Copyright ©2024 by SAGE Publications, Inc.
This work may not be reproduced or distributed in any form or by any means without express written permission of the publisher.

FIGURE 1.11 ■ Hermann von Helmholtz

Hermann Ludwig Ferdinand von Helmholtz (1821–1894) was a German physician, physicist, and sensory physiologist. He is credited with developing a theory of color vision and promoting the constructivist view of sensory perception.

Source: GL Archive/Alamy Stock Photo

FIGURE 1.12 ■ Ewald Hering

Karl Ewald Kostantin Hering (1834–1918) was a German physiologist who introduced the opponent theory of color vision. He was also interested in binocular vision. He disagreed with Helmholtz on constructivism. Hering argued that stimuli themselves had sufficient information to allow for direct perception.

Source: U.S. National Library of Medicine, History of Medicine Division

Do not copy, post, or distribute

Copyright ©2024 by SAGE Publications, Inc.
This work may not be reproduced or distributed in any form or by any means without express written permission of the publisher.

1993). He saw two major pairs of color opponents, green–red and blue–yellow. Any receptor excited by green turns off red, and any receptor excited by red turns off green. Modern research suggests that both Helmholtz and Hering were correct to some extent. Trichromacy seems to best explain the workings of the retina, whereas opponency can account for how areas of the visual brain (occipital cortex) treat color. That they were both right would have displeased both of these proud scientists, who deeply respected each other but were also fiercely competitive with one another. This controversy is discussed at length in the chapter on color perception (Chapter 6). Look ahead to the demonstration on this issue in that chapter.

Hering also disagreed with Helmholtz's theory of unconscious inference. Hering viewed environmental inputs and our sensory apparatus as sufficient for us to grasp the structure of the perceived world, without the need for internal unconscious inferences. That is, stimuli contain adequate information for viewers to perceive the world. In Hering's view, the perceptual processes in the brain do not need to make sense of the perceptual world; the brain simply needs to register it. Whereas Helmholtz's view is more popular with most experimental psychologists as well as physiologists, Hering's view influenced the development of gestalt psychology and, later, direct perception theory (also known as the Gibsonian view).

Weber, Fechner, and the Birth of Psychophysics

Both Helmholtz and Hering approached sensation and perception from the perspective of physiology. Around the same time as Helmholtz and Hering were looking at the relation of physiology and perception, other German scientists were doing work with a more psychological perspective. Ernst Heinrich Weber (1795–1878) discovered Weber's law (though it was Gustav Fechner, another German scientist, who named the law after Weber). Weber's law states that a just-noticeable difference (JND) between two stimuli is related to the magnitude or strength of the stimuli. What does this mean? Well, it concerns two stimuli that are very similar. Can we detect the difference between two very close red colors, or can we detect the difference between 1.44 mg of sugar dissolved in a cup of water and 1.48 mg of sugar dissolved in a cup of water? Thus, **Weber's law** concerns the perception of difference between two stimuli. For more examples, do we hear the difference between a 1,000-Hz tone and one of 1,005 Hz? Another example is whether we see the difference in length between a line 466 mm long and one that is 467 mm long. Weber's law suggests that we might not be able to detect a 1-mm difference when we are looking at lines 466 and 467 mm in length, but we may be able to detect a 1-mm difference when we are comparing a line 2 mm long with one 3 mm long. Another example of this principle is that we can detect 1 candle when it is lit in an otherwise dark room. But when 1 candle is lit in a room in which 100 candles are already burning, we may not notice the light from this candle. Therefore, the JND varies as a function of the strength of the signals. For example, the JND is greater for very loud noises than it is for much more quiet sounds. When a sound is very weak, we can tell that another sound is louder, even if it is barely louder. When a sound is very loud, to tell that another sound is even louder, it has to be much louder. Thus, Weber's law means that it is harder to distinguish between two samples when those samples are larger or stronger levels of the stimuli. To repeat, Weber's law states that a "just-noticeable difference" (JND) between two stimuli is related to the magnitude or strength of the stimuli.

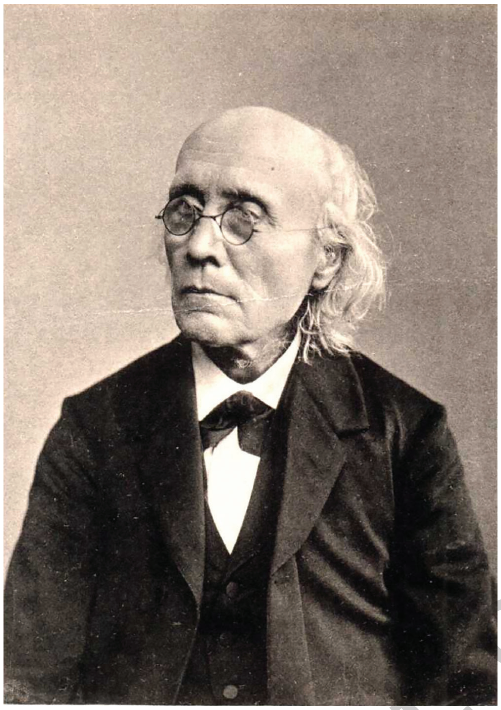
Gustav Fechner (1801–1887) is generally considered the founder of **psychophysics**, the study of the relation between physical stimuli and perception (Figure 1.13). Fechner's (1860/1966) book *Elements of Psychophysics* is often considered the beginning of the psychological study of sensation and perception. Fechner discovered the illusion known as the Fechner color effect, whereby moving black-and-white figures create an illusion of color (ISLE 1.7). This illusion is also known as Benham's top (Figure 1.14). Fechner also developed Fechner's law, which states that sensation is a logarithmic function of physical intensity. This means that our sensory experience changes at a lower rate than does the physical intensity. That is, our perception of the intensity of a stimulus increases at a lower rate than does the actual intensity of the stimulus. For example, his law is captured in the decibel scale that we use to measure loudness, on which 20 dB is 100 times louder than 10 dB in terms of the physical stimulus. But in psychological studies, we hear 20 dB as only twice as loud as 10 dB, not 100 times. In vision, the psychological concept of brightness is a function of the intensity of a light. But to perceive a doubling of

Do not copy, post, or distribute

Copyright ©2024 by SAGE Publications, Inc.
This work may not be reproduced or distributed in any form or by any means without express written permission of the publisher.

FIGURE 1.13 ■ Gustav Fechner

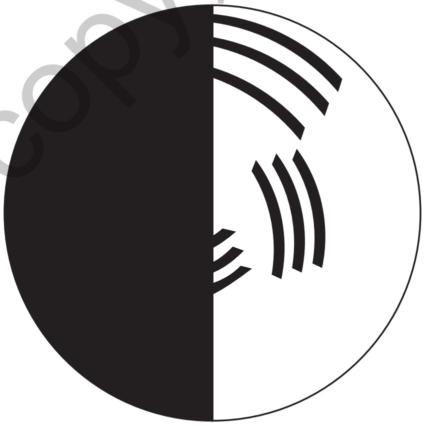
Gustav Fechner (1801–1887) is considered the "father of psychophysics." His landmark work on the relation between physical stimuli and perception established sensory psychology as a unique discipline separate from physiology. His work inspired the beginning of scientific psychology.



Source: Digital Library - Smithsonian Institution Libraries

FIGURE 1.14 ■ Benham's Top

This illusion was discovered by Fechner. Copy the image shown here. Or look up Benham's tops on the Internet and print out a copy of the above image. Put a pin or needle through the very center of the image. Then spin the image as fast as you can. While the image is moving, you may see colors. Stop the movement and look at the image again. The colors will be gone.



brightness, the intensity of the light must increase 10-fold. Fechner's book and his view on the relation between physical stimuli and psychological perception influenced many early psychological scientists, including Wilhelm Wundt, Hermann Ebbinghaus, and William James.

The 20th Century and the Study of Perception: Cognitive Psychology Approaches

The 20th century brought a burst of interest and research in the study of sensation and perception. First, sensation and perception research spread from Germany to many other countries across the

Do not copy, post, or distribute

Copyright ©2024 by SAGE Publications, Inc.
This work may not be reproduced or distributed in any form or by any means without express written permission of the publisher.

world, and a number of perspectives emerged, including gestalt psychology, direct perception (or the Gibsonian approach), the information-processing approach, and the computational approach. These latter two, information processing and the computational approach, can be considered cognitive psychology approaches. We briefly describe each approach here.

Gestalt Psychology

Gestalt psychology is based on the view that we perceive the world in terms of general patterns and well-organized structures rather than separable individual elements (Schultz & Schultz, 1992). Consider Figure 1.15. In this figure, we see the A only when we order the smaller elements together. In another example, gestalt psychologists were interested in apparent motion, which can be explained only by reference to the interaction between parts, not the individual parts themselves. Gestalt psychologists were also interested in how edges are perceived, an interest that has continued in both computational and neuroscience approaches to sensation and perception. Gestalt psychologists considered the visual perception of edges as critical to determining what objects were. They also identified several situations in which we see illusory edges on the basis of gestalt principles. One of these is the famous Kanizsa triangle, depicted in Figure 1.16 (ISLE 1.8). In the Kanizsa triangle, we see illusory contours, which are suggested by the overall pattern of the figure but are not physically there. The gestalt psychologists established a number of laws, which they argued were constants in visual perception. These laws were devised to explain how patterns are seen from individual elements (Figure 1.17).

FIGURE 1.15 ■ Gestalt Psychology

To see the A, one must order the individual elements into a pattern. By examining only the individual elements, we would never see the A. Gestalt psychologists considered patterns such as these the rule rather than the exception.

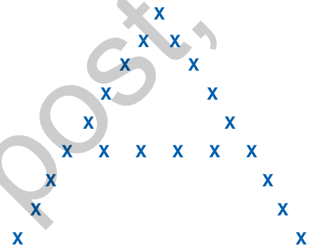
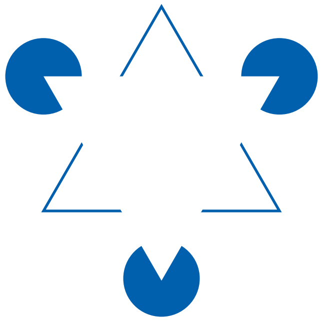


FIGURE 1.16 ■ Kanizsa Triangle

When most people look at this figure, they see a bright white triangle lying on top of a background consisting of a less bright triangle and some odd-shaped "Pac-Man" figures. The bright white triangle is illusory. The triangle is suggested by the pattern of figures, and our perceptual systems enhance the perceived brightness of the figure, but close inspection of the figure will convince you that there is no actual change in brightness.

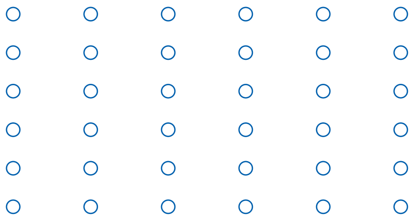


Gestalt psychology flourished in Europe in the early 20th century. However, during the same time period, American psychology was under the influence of behaviorism, which had a very different perspective than did gestalt psychology. Behaviorists were firm believers in the importance of "nurture" when it came to developmental issues in psychology, whereas gestalt psychologists were firmly in the "nature" camp; that is, they believed that these perceptual laws and other principles of human behavior were genetically wired. Thus, gestalt psychology did not take hold in the United States. However, when the Nazis

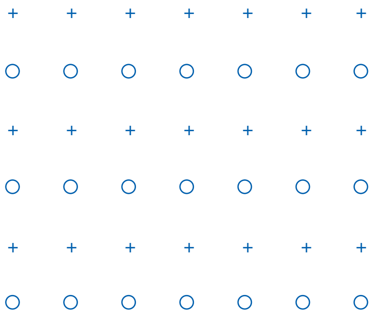
Do not copy, post, or distribute

Copyright ©2024 by SAGE Publications, Inc.
This work may not be reproduced or distributed in any form or by any means without express written permission of the publisher.

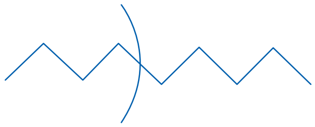
FIGURE 1.17 ■ The Laws of Gestalt Psychology



a. **The law of proximity.** You will see this arrangement as a set of columns–not a set of rows. Items that are near each other are grouped together. Now notice the typing in this book. You see rows of letters rather than columns because a letter is closer to the letters to the right and left than it is to the letters above and below.

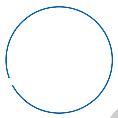


b. **The law of similarity.** You will see this arrangement as a set of rows rather than columns. Items that are similar to each other are grouped together. Now look at the two words at the end of this sentence that are in **boldface type.** Notice how these two words in heavier print cling together in a group, whereas the words in regular, lighter print form their own separate groups.

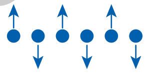


c. **The law of good continuation.** You will see a zigzag line with a curved line running through it, so that each line continues in the same direction it was going prior to intersection. Notice that you do not see the figures as being composed of the two elements below.

Look out the window at the branches of a tree, and focus on two branches that form a cross. You clearly perceive two straight lines, rather than two right angles touching each other.



d. **The law of closure.** You will see a circle here, even though it is not perfectly closed. A complete figure is simply more tempting than a curved line! Now close this book and put your finger across one edge, focusing on the shape of the outline of your book. You should still see your book as complete, but with a finger in front of it.



e. **The law of common fate.** If dots 1, 3, and 5 suddenly move up and dots 2, 4, and 6—at the same time—suddenly move down, the dots moving in the same direction will be perceived as belonging together.The next time you look at automobile traffic on a moderately busy street, notice how clearly the cars moving in one direction form one group and the cars moving in the opposite direction form another group.

came to power in Germany, many gestalt psychologists came to the United States and Canada, where they influenced the development of the direct perception view of perception, which we discuss shortly.

One prominent gestalt psychologist was Wolfgang Köhler (1887–1967). Köhler was a patriotic and aristocratic German, who vehemently opposed the Nazis (Figure 1.18). In 1933, he was the last person in Germany to publish an article critical of the Nazis during their regime. Soon afterward, he escaped to the United States. Once there, he became a successful professor first at Swarthmore College in Pennsylvania and then at Dartmouth College in New Hampshire. While at Dartmouth, he was also president of the American Psychological Association. Early in his career, Köhler applied gestalt psychology to auditory perception but then expanded gestalt psychology into other domains of psychology, including his famous study of problem solving in chimpanzees.

Direct Perception (The Gibsonian Approach)

The direct perception view was developed by the American husband-and-wife team J. J. and Eleanor Gibson, who were professors at Smith College in Northampton, Massachusetts, and later at Cornell

Do not copy, post, or distribute

Copyright ©2024 by SAGE Publications, Inc.
This work may not be reproduced or distributed in any form or by any means without express written permission of the publisher.

FIGURE 1.18 ■ Wolfgang Köhler

Wolfgang Köhler (1887–1967) was a major theorist in the gestalt psychology movement. Köhler immigrated to the United States prior to World War II. He expanded the use of gestalt psychology beyond its traditional domain of sensation and perception to other areas of psychology, such as problem solving.

Source: INTERFOTO/Alamy Stock Photo

University in Ithaca, New York (E. Gibson, 2001). The Gibsons emphasized that the information in the sensory world is complex and abundant, and therefore the perceptual systems need only directly perceive such complexity. In this view, the senses do not send to the brain incomplete and inaccurate information about the world that needs to be reasoned about to generate a perception. Perception is not about interpreting sensation, but reflecting it. Thus, the direct perception view is diametrically opposed to Helmholtz's concept of unconscious inference. Rather, in the **direct perception** view (**Gibsonian approach**), the world generates rich sources of information that the senses merely need to pick up directly. The direct perception view also emphasized ecological realism in experiments. This means that rather than showing simple displays to participants in experiments, direct perception theorists advocated using more naturalistic stimuli. Indeed, J. J. Gibson (1979) criticized much work in perception because the stimuli used by researchers were just points of light, tones, or stimuli that otherwise would not normally be encountered in everyday life. He emphasized that researchers should study real-world stimuli. For this reason, the direct perception view is often called the **ecological approach to perception**. For a demonstration of optic flow, one of the key contributions of this approach, see ISLE 1.9.

Information-Processing Approach

The **information-processing approach** postulates that perceptual and cognitive systems can be viewed as the flow of information from one process to another. Information is collected by sensory processes and then flows to a variety of modules that decode the information, interpret it, and then allow the organism to act on it. Consider the processing of visual information. Information flows from the eyes to various units in the brain that extract color, motion, figure–ground, and object information and then pass that information to cognitive systems that extract meaning and then pass it to other cognitive

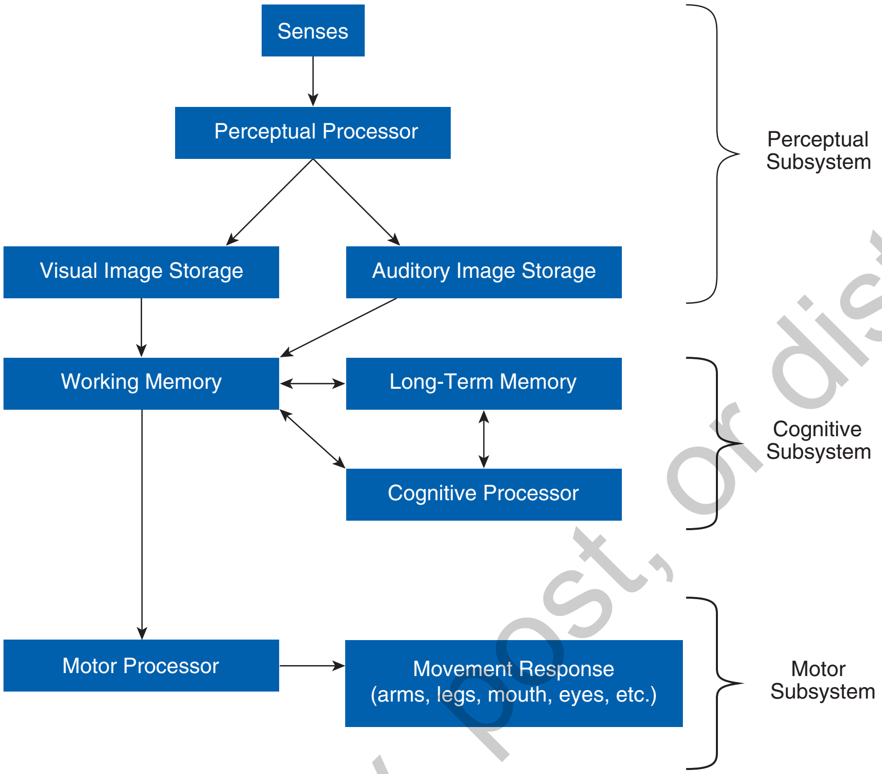
Do not copy, post, or distribute

Copyright ©2024 by SAGE Publications, Inc.
This work may not be reproduced or distributed in any form or by any means without express written permission of the publisher.

systems that determine actions that should be implemented on the basis of the visual information. The information-processing view stipulates that each of these stages or processes takes a finite amount of time, even if they are very fast, and therefore these processes can be observed or measured by recording reaction times as observers do various tasks (Figure 1.19).

FIGURE 1.19 ■ An Information-Processing Model

Information processing means that information flows from one process or stage to another during perception. Thus, in the diagram, we see an early sensory stage in which transduction takes place. Information then flows to a series of perceptual modules, eventually leading to final percept, which drives action.



The information-processing view greatly influenced cognitive psychology. During the 1960s and 1970s, information-processing models were used in both perception research and memory research. The approach continues to influence both of these fields, though contemporary researchers realize that the brain is massively "parallel" and many processes can be occurring simultaneously.

The information-processing view is different from Gibson's direct perception view because, like Helmholtz's view, the information-processing view requires internal cognitive processes to interpret the perceptual image, whereas the direct perception view asserts that the sensory input is sufficient in and of itself. The information-processing view is similar to the gestalt view in the specification of internal processes that extract information. However, the gestalt view emphasizes patterns and organization, whereas the information-processing view emphasizes the analysis of information and its flow from one system to another.

Computational Approach

The **computational approach** studies perception by trying to specify the necessary computations the brain needs to carry out to perceive the world. Originally developed by David Marr (1982), it was heavily influenced by the growth of computer science and, in particular, early theory in artificial intelligence. Marr attempted to specify perception in terms of what computations the brain needs to perform the task of perception. He conceived of the brain as an incredibly complicated computer and sought a mathematical explanation for perceptual processes, especially vision. The computational approach built on the information-processing approach but acknowledged from the beginning that many

Do not copy, post, or distribute

Copyright ©2024 by SAGE Publications, Inc.
This work may not be reproduced or distributed in any form or by any means without express written permission of the publisher.

perceptual processes may occur in parallel in the brain. Using the approach's modern form, researchers attempt to develop mathematical models that predict perceptual phenomena. Many of these mathematical models are based on neural networks, computer simulations of how nervous systems work (Venrooij et al., 2013).

Many who value the computational approach try to train computers to "see" in ways that make sense given our knowledge of the brain. In this way, the computational approach is often more theoretical, focusing on modeling perception in computer simulations, whereas the information-processing approach is more directly linked to observations in behavioral experiments. In computational models, if the computer can "see," theoretically so should the brain, and it is quite possible that the brain will also use many of the same computations as the computer. Studies using this approach often attempt to simulate perception on computers. A researcher will give a computer some visual task. The task may be to see a real object, and the computer has some form of electronic "eye," such as a video camera, attached. It might also involve simply a computer-generated world. In either case, the computer may be given the task of identifying an object, perhaps partially hidden by another object (e.g., Doerschner et al., 2009). If the computer can do the task and also tends to make the same types of mistakes humans do, then those doing research according to the computational approach have some confidence that they have made progress in their goal.

Test Your Knowledge

1. What was at the center of the difference in viewpoints of Helmholtz and Hering? Does this difference in view still have resonance for today's science?
2. What is the difference between the views of gestalt psychology, direct perception, information processing, and the computational approach?

NEUROSCIENCE IN SENSATION AND PERCEPTION

The goal of **neuroscience** is to understand sensation and perception in terms of the structures and processes in the nervous system that produce it. Thus, the neuroscience approach starts with examining the physiological processes whereby a physical signal is transduced into a neural signal. Neuroscience then continues to investigate sensation and perception by looking at connections from the sensory organs to the brain and then at regions in the brain itself that are involved in perceptual processes. Neuroscience research can span the gamut from work on single cells within the brain to examining connections among differing regions in the brain.

Neuroscience is interested in the cellular level, necessary to understand how individual neurons convert physical stimuli into electrochemical signals (Figure 1.20). At the cellular level, neuroscientists can look at the actions of individual cells and how they respond to particular signals. Neuroscience is also interested in what processes occur in the brain to process and interpret sensory information. Here, neuroscientists can look at larger units in the brain and attempt to correlate those regions with particular perceptual functions. For example, studies show activity in an area of the brain, known as MT (middle temporal) or V5, in the occipital lobe, when people are watching moving stimuli.

One of the most important developments in neuroscience was the development of the microelectrode in the 1940s and 1950s. A **microelectrode** is a device so small that it can penetrate a single neuron in the mammalian central nervous system without destroying the cell. Once in the cell, it can record the electrical activity there or even stimulate the cell by carrying electrical current to the cell from an electrical source at the command of the scientist. Thus, this method allows the recording of the behavior of single neurons in the mammalian brain. It was first used in the sensory systems by Kuffler (1953) (ISLE 1.10). In this way, it can be used to determine what kind of stimuli a particular cell responds to. Thus, for example, a cell in area V1 (also known as the primary visual cortex) of the brain may respond to presented lines of different orientations. Another cell might respond only to stimuli in the left visual

Do not copy, post, or distribute

Copyright ©2024 by SAGE Publications, Inc.
This work may not be reproduced or distributed in any form or by any means without express written permission of the publisher.

FIGURE 1.20 ■ A Sensory Neuron

Bipolar cells, such as the one depicted in this image, connect the receptor cells to the tracts that lead information from the sensory organ to the brain. Bipolar cells in vision, for example, connect rods and cones to the cells that lead information out of the eye and through the optic nerve.

Source: Science Picture Co/Alamy Stock Photo

field. This technique led to some profound breakthroughs in our understanding of how the brain processes sensory information.

Hubel and Wiesel (1959, 1962, 1965) are probably the names most associated with this technique. Their Nobel Prize–winning work not only helped us understand the behavior of individual cells but uncovered unexpected levels of organization in the brain (Hubel & Wiesel, 1965) and information on how the brain develops (e.g., Hubel & Wiesel, 1962). For example, they found cells in the brains of cats and monkeys that were selective to one eye or the other and other cells that responded only when both eyes were able to see the same objects in the visual world. Single-cell recording made major contributions to neuroscience with animal models, but it is used less often nowadays because it is difficult to do with humans and we have increased concerns about animal welfare.

The neuroscience approach also includes the field of neuropsychology. **Neuropsychology** is the study of the relation of brain damage to changes in behavior. In neuropsychological research, scientists know what part of a person's brain is damaged and then look for behavioral changes in that individual. Behavioral changes may include problems with language, memory, or perception. They may also include difficulties in decision making, action, or emotion. Brain damage may arise from a variety of tragedies and accidents, including strokes, tumors, aneurysms, loss of blood during surgery, auto accidents, blows to the head, bullet wounds, concussions, and near drowning. Certainly, it is possible to trace the history of neuropsychology to the history of medicine in warfare. The study of neuropsychology began in earnest in the 1870s in Europe, as antiseptic procedures allowed soldiers in the Franco-Prussian War to survive gunshot wounds that would previously have been fatal. Neuropsychologists continue to learn from and help individuals returning from war (Vasterling et al., 2006).

Consider a particular case in which brain damage resulted from lifesaving surgery. A patient called D.B. had part of his occipital lobe removed as treatment for a malignant tumor. The tumor was causing seizures and could have threatened his life if it had spread to other regions of his brain and body. Thus, surgeons removed it as carefully as possible but also had to excise a great deal of tissue within the V1 area of his occipital lobe. Medically, the operation was a tremendous success. The tumor removal

Do not copy, post, or distribute

Copyright ©2024 by SAGE Publications, Inc.
This work may not be reproduced or distributed in any form or by any means without express written permission of the publisher.

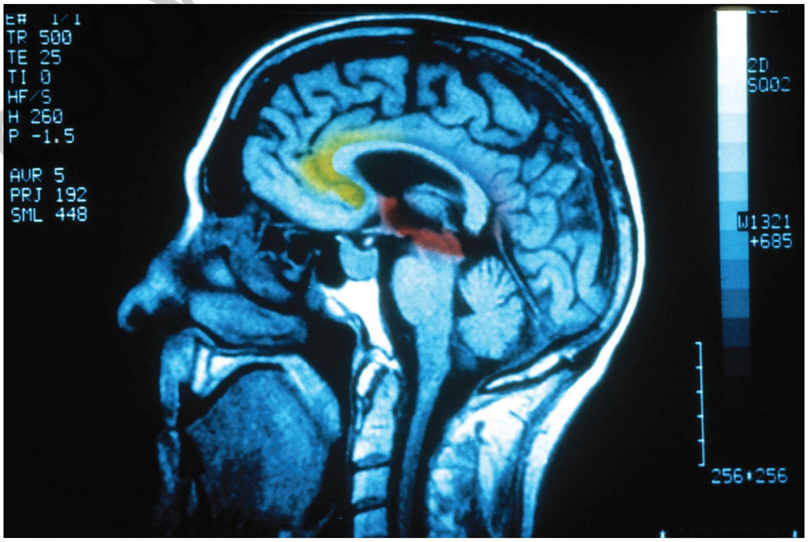
allowed D.B. to return to his job as a computer programmer and lead a normal life, with few or no side effects. However, as a result of the loss of area V1 tissue, D.B. developed partial blindness in one area of his visual field (Weiskrantz, 1996). This sounds more serious than it actually was. D.B. had no difficulties moving his eyes, so his eye movements quickly compensated for this patch of blindness. However, it allowed D.B. to be an interesting research participant. The researchers could correlate the brain damage (known to be in a particular area of the occipital lobe) and the behavioral deficits (partial blindness). As such, it was possible to correlate the area of the occipital lobe that was removed with being responsible for seeing in a certain part of the visual field. D.B. was also an important patient in the study of the phenomenon of blindsight, a topic that is covered in depth in Chapter 4.

One form of brain damage affecting perception is known as agnosia. **Agnosia** is a deficit in some aspect of perception as a result of brain damage. For example, there is a form of agnosia caused by damage to an area of the temporal lobe known as the fusiform face area (**prosopagnosia**, or face agnosia). Damage to this area results in a deficit in recognizing faces. Damage to certain areas of the right temporal lobe can result in a person's loss of appreciation of music. This condition, known as **amusia**, a form of agnosia, is covered in Chapter 13. Thus, neuropsychological methods are effective at relating areas of the brain to particular perceptual functions.

Neuroscience research also includes the neuroimaging techniques. **Neuroimaging** involves technologies that allow us to map living intact brains as they engage in ongoing tasks. Neuroimaging allows us to observe an intact living brain as it perceives, learns, and thinks. This is the newest technology used in neuroscience, with the first magnetic resonance imaging (MRI) research not beginning until the 1990s. Since then, however, neuroimaging research has become a major force in understanding both the brain and cognition and perception. One method is **functional magnetic resonance imaging (fMRI)**. This technique can image the blood levels in different areas of the brain, which correlate with activity levels in those regions, allowing activity in the human brain to be correlated with our actual sensory abilities (Tremblay et al., 2011). Figure 1.21 shows what an fMRI scan looks like.

FIGURE 1.21 ■ fMRI

This functional magnetic resonance image shows the areas of the brain that are active when an odor is presented to an individual. The areas depicted in color include areas of the brain critical in odor perception, such as the piriform cortex in the temporal lobe. In this image, the piriform cortex (colored yellow) can be seen just above the corpus callosum, which can be located right in the center of this image. The corpus callosum looks like a blank spot or hole in this image. In terms of surface anatomy, the temporal lobes can be found behind the ears.



Source: BSIP SA/Alamy Stock Photo

The fMRI technique is thought of as a hemodynamic technique because it measures the blood flow to the brain. The technique starts with the reasonable assumption that because the brain is a biological organ, it requires oxygen. Moreover, the areas of the brain that are active require more oxygen and

Do not copy, post, or distribute

Copyright ©2024 by SAGE Publications, Inc.
This work may not be reproduced or distributed in any form or by any means without express written permission of the publisher.

therefore more blood than other areas of the brain. Thus, a person talking will need oxygen delivered to the parts of the brain that are responsible for speech production. A person listening to music will require a greater oxygen supply to areas that are responsible for music perception. Thus, if you can trace the flow of blood in the brain, you will know what areas of the brain are currently in use. For example, Kau et al. (2013) recorded the neural activity in the brains of participants tracking moving dots across a screen. When the participants were attending to the motion, there was activity in an area of the brain known as V3, located in the occipital lobe. Other studies have associated area V3 with movement perception.

Neuroimaging may be the fastest growing area in scientific psychology. It offers us the opportunity to watch the human brain as it does its work, certainly a fascinating proposition. In this way, it can tell us a great deal about the structure and function of the human brain and the nature of sensation and perception. But neuroimaging can also be misleading. For example, small differences in methodology between studies can sometimes lead to big differences in the neural patterns. Moreover, because fMRI researchers may do many statistical tests per scan, there is a risk that neural activity in some regions may exceed a criterion level simply by chance (Bennett et al., 2009). It is also true that, at present, researchers using neuroimaging are still looking at vast groupings of cells. Neuroimaging technology still cannot bridge the gap from gross anatomy to the fine-tuned results of single-cell studies. Thus, it is still worthwhile to cast a critical eye at data that come from fMRI studies, as they are not immune to such methodological problems. Nonetheless, neuroimaging is a useful tool and one that has definitely broadened the scope of the neuroscience of perception.

Test Your Knowledge

1. What is neuropsychology and why does it rely on accidents?
2. What are the assumptions upon which neuroimaging is based?

EXPLORATION: *COGNITIVE PENETRATION*

Basketball players will sometimes say that the basketball rim looks wider when they are doing well and looks narrower when they are not making their shots. Golfers report similar experiences with their putting. Tired hikers may say the mountain looks steeper when they are tired than when they are fresh. Many of us will report colors being brighter when we are in good moods than when we are depressed. Most of us agree that food tastes better when we are hungry. Is this really true? Do factors such as our success, our physical state, and our emotional state really affect how we perceive? Does our state of hunger really affect what our taste buds are reporting?

The view that cognitive and emotional factors influence the phenomenology of perception is known as cognitive penetration (Marchi & Newen, 2015). Cognitive penetration means that non-perceptual factors affect the experience of what we see, hear, taste, and feel. The opposing view is that perception is not affected by cognitive factors and that only our reporting of perception is. This view is called cognitive impenetrability (Firestone & Scholl, 2016). Impenetrability implies that our perception remains the same, regardless of our cognitive and emotional state. What changes instead is attention, expectation, or our mood state, which is different than our perceptual state. The dominant view in the field is that perception is cognitive impenetrable (Cecchi, 2019). However, there is research that supports some instances in which cognitive or emotional factors influence the phenomenology of the perceived world.

Delk and Fillenbaum (1965) asked participants to match the color of figures with the color of their background. Some of the figures depicted objects associated with a particular color. These included typically red objects such as an apple, lips, and a symbolic heart. Other objects were presented that are not typically associated with red, such as a mushroom or a bell. However, all the figures were made out of the same red–orange cardboard. Participants then had to match the figure to a background varying from dark to light red. They had to make the background color the same as the color of the figures. Delk and Fillenbaum found that red-associated objects (e.g., the apple) required more red in the background to be judged a match than did the objects that were

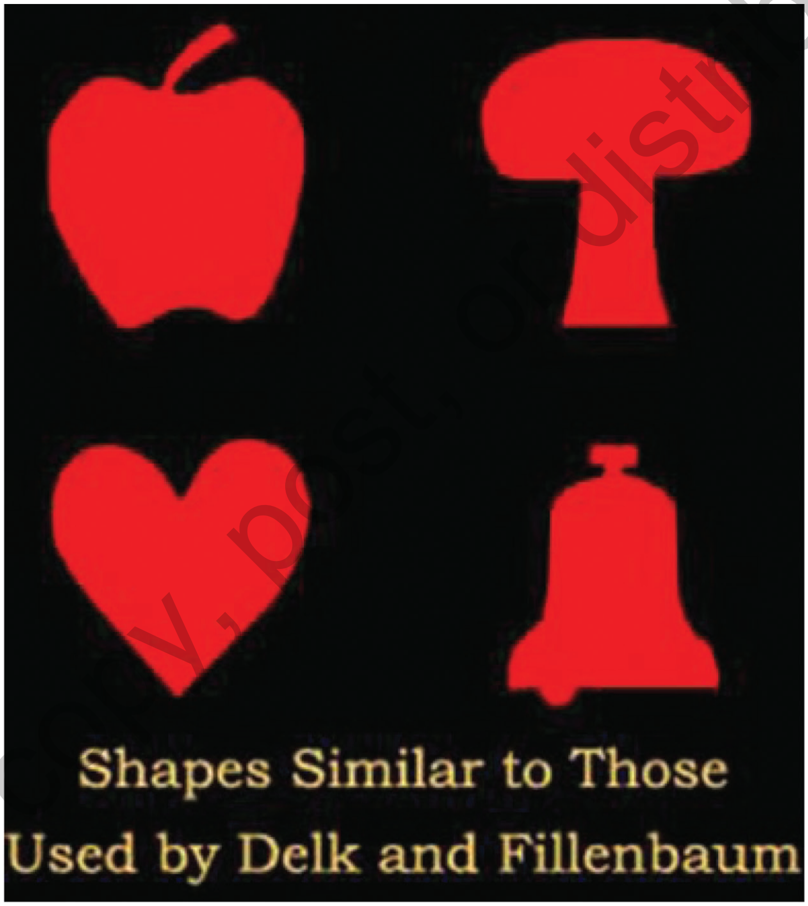
Do not copy, post, or distribute

Copyright ©2024 by SAGE Publications, Inc.
This work may not be reproduced or distributed in any form or by any means without express written permission of the publisher.

not associated with the color red. This suggests that the knowledge of the objects was influencing people to perceive them as being more red than other objects (Figure 1.22). Hansen et al. (2006) replicated this basic finding. They presented participants with photographs of fruit such as bananas and simple patches of colors. Participants were asked to adjust the color of the object (banana or patch) to the uniform gray background. Hansen et al. found that participants adjusted the fruits differently than the patches of equivalent color. For example, participants added more blue to the banana in order to cancel out the more perceived yellowness of it. (We will discuss color cancellation more in Chapter 6.) Hansen and colleagues suggest that this implies that the cognitive association of objects to color influences how we perceive that color.

FIGURE 1.22 ■ Cognitive Penetration Experiment (Delk & Fillenbaum, 1965)

Red-associated objects (e.g., the apple) required more red in the background to be judged a match than did the objects that were not associated with the color red.



Source: iStock.com/AlexBrylov

There may be cognitive penetration in other sensory domains as well. For example, in research on pain, there have been many studies documenting the placebo effect, which is the finding that when people expect reduced pain from a medicine, they experience less pain, even if the medicine is essentially inert (Miller & Miller, 2015). Freeman and colleagues (2015) gave three identical creams to three different groups of participants before presenting a somewhat painful stimulus. In the first condition, they told participants that the cream was "lidocaine" and would reduce pain (i.e., an analgesic). In the second condition, they told participants that the cream was "capsaicin" and might increase the pain (i.e., hyperalgesia). In the third condition, participants were told the cream was "neutral"; that is, it would not affect their pain levels at all. The belief that the cream was an analgesic led to less pain experienced relative to the control condition. The belief that the cream was hyperalgesic (leading to greater pain) led to more reported pain relative to the control. These results suggest that our expectations actually influence the pain we experience (but see Gligorov, 2017; Shevlin & Friesen, 2020).

Do not copy, post, or distribute

Copyright ©2024 by SAGE Publications, Inc.
This work may not be reproduced or distributed in any form or by any means without express written permission of the publisher.

Despite the evidence, cognitive penetration is a tricky issue. There are lots of alternate explanations for why the results might be the way they are instead of the view that perceptual phenomenology actually changes (Firestone & Scholl, 2016). For example, in one study, participants judged a hill to be steeper when they were wearing heavy backpacks (Bhalla & Proffitt, 1999). Firestone and Scholl point out that many factors other than perception may go into such judgments, such as the expectation that a mountain must be climbed. When participants had to match the hill that they saw with a test incline, they did not show different choices based on the heaviness of the backpack. Thus, Firestone and Scholl think that nonperceptual factors influenced their decisions, not their perceptions. Indeed, the idea of cognitive penetration is now one generating much interest and controversy in the field of perception.

APPLICATION: *AVOIDING COLLISIONS*

There is probably no field of psychology in which there have been greater applications of psychological work than the area of sensation and perception. It is also likely that applications of this research area will continue to grow in the future. We use our perceptions of the world around us in nearly everything we do in our lives, with the possible exception of daydreaming. Every practical aspect of life involves looking, listening, touching, and tasting. Thus, if you are considering a career in applied psychology or human factors, you should pay very close attention to the topics in this book and to your course in sensation and perception. Understanding the basics of sensation and perception is critical for any human factors psychologist working in industry or government. Understanding the basics of sensation and perception is important for civil engineers who are designing safer roads (Lodinger & DeLucia, 2019).

Just consider a few of our technological horizons. Think of designing the face of a modern smartphone. The size of text and icons must be large enough for the human eye to distinguish, and buttons must be positioned so that human fingers can distinguish between the button for the phone and the button for the music player. Companies such as Apple and Samsung hire many human factors psychologists to help them design these products in ways that are consistent with human perception. Moreover, consider the console of a modern jet plane. Warning lights and controls must be positioned so that they quickly demand the attention of the pilot if there is a problem with a particular system in the airplane.

Sensory systems are also important in developing new technologies. A major technological innovation that many car companies are working toward is functional self-driving cars. What goes into engineering such a system? Cameras and computers have to be wired like eyes and brains (only without blinking, falling asleep, or experiencing road rage). Understanding the cues that the human eye attends to while driving is critical in designing safe self-driving cars (Brett, 2016). Consider also computerized voice recognition systems. The engineers who design these systems must first understand the processes by which humans recognize one another's voices and interpret meaning. Thus, several of our major technological fronts involve a role for understanding human perception.

Returning to cars, it may be many years before self-driving cars are widespread, but road safety is a major issue both in the United States and throughout the world. According to U.S. government statistics, there are more than 32,000 fatalities per year in car accidents in the United States alone. This translates into more than 2,600 deaths per month on American roads. That means that approximately the same number of Americans die in car accidents every month as did in the tragic attacks of September 11, 2001. It is estimated that there were over 6 million automobile accidents in the United States in 2022 (U.S. Department of Transportation, 2022). Thus, there is still much that can be done to improve road safety outcomes. Sensation and perception research has much to offer here.

Many sensation and perception researchers study the visually guided action associated with driving cars or flying planes. Some of this research concerns the effects of distraction on driving, a topic we discuss in depth later (Chapter 5). Other research considers the effect of fatigue on perception and driving ability. In this *Application* section, we consider the perceptual processes that drivers use to avoid automobile accidents.

Think about driving (assuming that you are a driver). It is a visual task: We look in front of us to see where we are going, and we check our rearview mirrors often for potential dangers coming from behind us. We use this visual information for simple tasks, such as noticing when our exit is coming and moving to the right or seeing a swerving car and quickly applying the brakes. In this way, avoiding impending collisions involves perceptually guided action. When people see approaching

Do not copy, post, or distribute

Copyright ©2024 by SAGE Publications, Inc.
This work may not be reproduced or distributed in any form or by any means without express written permission of the publisher.

objects, their visual systems rely on their perception of depth, that is, how far away the oncoming objects are, and judgments of time to collision. These judgments need to be very accurate in order to make good driving decisions.

However, research shows that people have systematic biases in making these decisions. People estimate that a large but farther away approaching object will collide with them sooner than a smaller but closer approaching object (DeLucia, 2013; DeLucia et al., 2016). That is, people estimate accurately the likelihood that a truck will strike them but underestimate the likelihood that a smaller object such as a motorcycle will enter their path. Motorcyclists often complain about how cars "cut them off." This may not always be the result of recklessness or rudeness but rather a poor estimate on the part of the car's driver of how close the motorcycle actually is (Figure 1.23). We consider the research of Dr. Patricia DeLucia of Rice University, who has devoted her career to understanding the factors that affect our perceptual decisions in collision situations (DeLucia, 2013; DeLucia et al., 2016).

FIGURE 1.23 ■ Avoiding Collisions

The automobile driver must estimate the time to collision with the bicyclist. If the driver determines that a collision is imminent, the driver must apply the brakes immediately, in this case, to spare the bicyclist major injury.

Source: iStock.com/palinchakjr

DeLucia's research shows that the human visual system uses two cues to make judgments about impending collisions. The first is called time to collision. This means that, in theory, your visual system estimates the time it will take for an object to collide with you by dividing the object's optical size at a given point in time by the object's rate of expansion within the visual field. That is, time to collision is determined by the object's optical size per unit time. In simpler language, approaching objects increase in size, and more rapidly approaching objects increase in size more as they approach you. Think of a baseball player judging when to swing his bat. A fastball increases in optical size as it approaches him more so than does a changeup (a pitch thrown deliberately slow). Or think of a pilot guiding a plane to touchdown on a runway. As the plane approaches the ground, the runway increases in optical size for the pilot. There is ample evidence that people attend to this aspect of looming objects in a variety of situations (Hecht & Savelsbergh, 2004).

However, people also use another cue to determine time to collision. The second cue is the size of the object. Larger objects are judged to be closer than smaller objects. This is known as the size–arrival effect (DeLucia, 2013). Numerous studies have shown that perception of collision is affected by the relative sizes of objects (Brendel et al., 2012; DeLucia, 2013; Hahnel & Hecht, 2012). You can see an illustration of this effect in ISLE 1.11.

The size–arrival effect results in the illusion that smaller objects are less likely to collide with the viewer. This has a number of unfortunate consequences for driving and transportation safety. For example, drivers may underestimate the likelihood of collision when turning when a smaller oncoming vehicle is approaching because it is perceived as being farther away. Indeed, data from both actual accidents and experimental simulations show that a crash between a motorcycle and a car can occur when the car intrudes on the motorcycle's path, with the car's driver thinking the motorcycle is farther away (Brendel et al., 2012; DeLucia, 2013; DeLucia et al., 2016). In one simulated study, participants were asked to press a button when they thought an approaching vehicle would arrive at a particular location (Horswill et al., 2005). The experimenters varied the sizes of

Do not copy, post, or distribute

Copyright ©2024 by SAGE Publications, Inc.
This work may not be reproduced or distributed in any form or by any means without express written permission of the publisher.

the vehicles (motorcycle, car, or van) and their speeds (30 or 40 mph). Time-to-collision estimates were greater for motorcycles than for cars and vans, consistent with the size–arrival effect. Thus, DeLucia and others have recommended that roads and motorcycle design should consider this factor in order to make transportation safer. It is also possible that education can be directed at drivers to help them realize that they often underestimate the likelihood of collision with smaller objects. Motorcycles designed to look bigger may also be safer for motorcyclists to ride. Thus, this first *Application* section introduces the concept of applications of sensation and perception research and describes a particular area, research on time to collision and its implications.

CHAPTER SUMMARY

1.1 Discuss why understanding sensation and perception is important.

The study of sensation and perception sheds light on the basic nature of what it is to be human. Sensation is the registration of physical stimuli on sensory receptors, and perception is the process of creating conscious perceptual experience from sensory input. In this textbook, we discuss the science and applications of research on sensation and perception. In this chapter, we have discussed the nature of physical stimuli, whether they be light for vision on the retina or sound waves for the auditory system. In addition to vision, hearing, touch, smell, and taste, we have a vestibular system to help keep our balance and a proprioception system to allow us to monitor the position of our bodies. Our sense of touch is composed of multiple systems designed to sense different features of the environment. Heat, coldness, pain, itchiness, and soft touch are all implemented by separable sensory systems.

1.2 Describe how transduction transforms a physical signal into a neural signal.

Sensory systems transduce physical signals into neural responses, which are sent to the brain for processing. The brain processes the signals, determines their meaning, and decides on appropriate actions. Perception also produces a characteristic phenomenology, which is the purely subjective experience we get when perceiving the world.

1.3 Illustrate the history of the study of sensation and perception.

Writings on disorders of sensation and perception go back all the way to the ancient Egyptians. Aristotle theorized extensively about perception and its causes. Later, in the 19th century, German physiologists began experimenting on the neural processes that underlie sensation, and others started the field of psychophysics, which studies the relation of physical stimuli to the psychological experience. Later influences in the development of sensation and perception research include gestalt psychology, Gibsonian direct perception, information processing, and the computational approach.

1.4 Understand the impact of neuroscience on our understanding of sensation and perception.

Neuroscience also addresses issues of sensation and perception. Neuroscience research includes single-cell recording, neuropsychology, and neuroimaging. Neuroscience allows us to understand the brain mechanisms involved in sensory processes.

REVIEW QUESTIONS

1. What is the myth of five senses? Can you list eight different human sensory systems?
2. What do the terms *sensation* and *perception* mean? What is the difference between the two?
3. What is the process of transduction? Why is it important to perception?
4. What is phenomenology? Why is it so difficult to address in science?

Do not copy, post, or distribute

Copyright ©2024 by SAGE Publications, Inc.
This work may not be reproduced or distributed in any form or by any means without express written permission of the publisher.

5. Who was Hermann von Helmholtz? What was his view of color vision? How did it differ from that of Ewald Hering?
6. What is an unconscious inference in perception? Why is it important to the constructivist approach?
7. What is a JND? Can you give a real-world example of a JND?
8. What is the direct perception view? How does it differ from the information-processing view?
9. What is cognitive impenetrability? How does it differ from cognitive penetration?
10. What is meant by the term *time to collision*? How is it that the size–arrival effect changes our judgments of collision times? What practical suggestions could you make to improve transportation safety on the basis of these findings?

PONDER FURTHER

1. Our perceptual abilities are shaped by natural evolution. Weber's law states that a just-noticeable difference between two stimuli is related to the magnitude or strength of the stimuli. Why might it be adaptive to have a system that has this kind of varied sensitivity as a function of the magnitude of the stimuli? That is, why can we tell the difference in weight between a 1-gram weight and 2-gram weight, but not between a 2,000-gram weight and a 2,001-gram weight?
2. Most likely, you have a piece of art on your wall. Maybe it is something original, perhaps a poster of a famous work of art. Look at it now. Can you see if the artist applied any gestalt principles in constructing the visual image? Does knowing about the gestalt principles change the way you appreciate the art?

KEY TERMS

Action
Aftereffect
Agnosia
Amusia
Computational approach
Constructivist approach
Direct perception (Gibsonian approach)
Doctrine of specific nerve energies
Ecological approach to perception
Functional magnetic resonance imaging (fMRI)
Gestalt psychology
Information-processing approach
Microelectrode
Neural response
Neuroimaging
Neuropsychology
Neuroscience
Perception
Phenomenology
Prosopagnosia
Psychophysics
Receptors
Sensation
Stimulus
Transduction
Unconscious inference
Weber's law

Do not copy, post, or distribute

Copyright ©2024 by SAGE Publications, Inc.
This work may not be reproduced or distributed in any form or by any means without express written permission of the publisher.