DEVELOPMENTAL SCIENCE
AN ADVANCED TEXTBOOK
SIXTH EDITION

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Developmental science constitutes a unique, comprehensive, and significant domain of intellectual endeavor for three main reasons. First, developmental scientists offer an essential perspective on psychological theory and research. When, for example, psychologists conduct experiments in perception, investigate language, or study personality, they usually concentrate on perception, language, or personality in individuals of a particular age—infants, children, adolescents, adults, or the elderly. In so doing, they gain important knowledge about perception, language, or personality. To study psychological phenomena at only one point in the life cycle, however, is to limit our knowledge of them by failing to consider such factors as their stability and continuity through time that are the province of developmental study. Indeed, it could be argued that, when we undertake a comprehensive analysis of any psychological phenomenon, we necessarily incorporate a developmental perspective. The question is, how well is that perspective addressed? The chapters in this textbook on substantive areas of psychology—neuroscience, perception, cognition, language, emotion, and social interaction—all demonstrate that the developmental perspective transcends and enriches any narrow focus on particular points in the life span. One purpose of this textbook, then, is to furnish inclusive developmental perspectives on all substantive areas in psychology, and the substantive chapters included in this edition underscore the dynamic and exciting status of contemporary developmental science.

Second, developmental science is a major subdiscipline in its own right. It has its own history and systems, its own perspectives, and its own methodologies and approaches to measurement and analysis, as each of the contributions to this textbook illustrates. If studying psychology comprehensively involves attending to development, then there are special traditions, perspectives, and methodologies to which students of psychology must also attend. These traditions, perspectives, and methods are masterfully introduced and reviewed in the chapters that follow.

Third, many aspects of developmental science have obvious and immediate relevance to real-world issues and problems. Each of the chapters in this textbook exemplifies the everyday relevance of developmental science through reviews of the history, theory, and substance of the subdiscipline. Furthermore, one chapter focuses directly and explicitly on the application of developmental research to policy and practice.

In summary, developmental science provides a perspective that illuminates substantive phenomena in psychology, applies across the life span, has intrinsic value, and manifest relevance to daily life. It is for these reasons that we undertook the study of developmental science and subsequently prepared this advanced introduction to the field.

This volume can be used at the advanced undergraduate and introductory graduate levels. It is hardly possible today for any single individual to convey, with proper sensitivity and depth, the breadth of contemporary developmental science at this level. For that reason, we invited experts to prepare original, comprehensive, and topical treatments of the major areas of developmental science. We then organized and edited their contributions, with the cooperation and good will of our contributors, into a single coherent volume. The success of several...
previous editions encouraged us to prepare, update, revise, and reorganize this sixth edition. For this edition, all chapters have been extensively revised to ensure that they represent faithfully the current status of scholarly efforts in all aspects of developmental science. In some cases, dramatic progress or change in orientation over the last decade also led us to include completely original chapters. The sixth edition is now supported by resources developed by Trey Buchanan of Wheaton College. The password protected website at http://www.psypress.com/textbook-resources/ features material for students and material that is accessible only to instructors. Students will find chapter outlines, topics to think about before reading the chapters, a glossary, and suggested readings with active reference links. Instructors will have access to this material as well as electronic access to all of the text figures and tables, suggestions for classroom assignments and/or discussion, and a test bank with multiple-choice, short-answer, and essay questions for each chapter. Developmental Science: An Advanced Textbook provides the only comprehensive and up-to-date introduction to the field for advanced students.

Developmental Science has many purposes. We hope that readers of this textbook will obtain a new perspective on psychology, a greater appreciation of the varied phenomena that constitute psychology, and a fundamental grounding in developmental science itself.

We also wish to thank many reviewers for thoughtful ideas about this new edition: Trey Buchanan (Wheaton College), Annie M. Cardell (Mountain State University), Lisa K. Hill (Hampton University), and Rebecca Wood (Central Connecticut State University). In addition, we are grateful to Mandy Collison, Erin Flaherty, and Debra Riegert at Psychology Press for their excellent production support.

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PERCEPTUAL DEVELOPMENT

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All that a mammal does is fundamentally dependent on perception, past or present.
(D. O. Hebb, 1953, p. 44)

INTRODUCTION

Perception begins our experience and interpretation of the world, and so is crucial to the growth of thought, to the regulation of emotions, to interaction in social relationships, and indeed to most aspects of our development. The input, translation, and encoding of sensory information in perception are essential to thought and action. Even very young children recognize the fundamental position of perception in life (Pillow, 1989); Three-year-olds will attribute knowledge about an object only to people who have viewed the object, and not to people who have not viewed the object (Gopnik, Slaughter, & Meltzoff, 1994). For all these reasons, philosophers, physicists, physiologists, and psychologists have been strongly motivated to study perception and especially its development.

Our everyday experiences raise many challenging questions about perception. How faithful are our perceptions of properties, objects, people, and events in the world? How is a stable world perceived in the midst of continuous environmental variation and biological fluctuation? How are perceptual aspects of the world invested with meaning? How and why do perceptual qualities differ across modalities? How do we apprehend individual features of things and simultaneously know their synthesized whole?

Philosophy provided major initial impetus to study perceptual development: Epistemology asks questions about the origins and nature of human knowledge. Extreme views on epistemology were proposed by empiricists, who asserted that all perceptual knowledge derives from the senses and grows by way of experience, and by nativists, who reasoned that some kinds of knowledge cannot possibly rely on experience and thus that human beings enter the world with a sensory apparatus equipped (at the very least) to order and organize their percepts. Philosophical speculation also focused attention on the early ontogenesis of perception, a period during which epistemologically meaningful issues related to the origins of knowledge are most directly addressed. Thus, the study of perceptual development initially
captured the philosopher’s imagination as it promised to speak to questions about inborn knowledge versus knowledge acquired through experience.

Developmental research in perception has since provided many and varied kinds of information including, for example, normative data concerning the quality, limits, and capacities of perceptual systems across the life span. For example, the sensory systems are brain matter, and they do not lie dormant until suddenly “switched on” at birth; rather, they begin to function before birth. Determining how and approximately when the senses begin to function normally is important for several reasons. One reason is that knowing about development of the sensory systems enlarges our understanding of the general relation between structure and function. A second reason is that it is theoretically and practically important to learn how early brain development is influenced by stimulation. Preterm babies, born before their expected due date, are exposed to environmental stimulation from which they would normally be shielded. If the sensory systems are not functional prenatally, preterms would be protected; if the sensory systems function, however, then preterm babies might be adversely affected by the stimulating environment of the Neonatal Intensive Care Unit. Third, the human infant is recognized today as “perceptually competent”; determining just how perception functions in infancy helps to specify the effective perceptual world of babies. If a substance tastes sweet to adults, they may readily suppose that it tastes that way to infants, and even that infants will like it; in fact, however, taste receptors for sweetness may not even be present in infants or, if present, may not function or signal the same perception or quality to infants as to adults. Defining normative perceptual capacity in early life also permits developmental comparisons of mature versus immature perceptual functions, and studies of perception in childhood provide baseline data against which the normal course of maturation as well as the effects of experience into adulthood can be assessed.

All these reasons motivate studies of perceptual development, and given their nature and prominence it is not surprising that studies of perceptual development have focused most intensively on infancy.1 However, perception is a lifelong developmental process, and this chapter discusses perception and its development in infancy, childhood, adulthood, and old age. We begin the chapter with a discussion of prominent theories of perception and then turn to some central issues in perceptual development, namely, status and origins, and stability and continuity in perceiving. In the next section we describe methodologies commonly employed to study perception across the life span. The third section surveys representatively our current knowledge of perceptual abilities—at the beginning and end of life and at points in between. In the fourth section, we consider the roles of experience in perceptual development.

**PERSPECTIVES ON PERCEPTUAL DEVELOPMENT**

Perception has historically been tied intimately to nature–nurture questions. What do we know before we have any experience in the world? What knowledge requires such experience? The two main outlooks (as just described) were empiricist and nativist: Empiricists asserted that there is no endowed knowledge at birth, that all knowledge comes through the senses, and that perceptual development proceeds through experience and associations. Empiricists

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1 The story of the ontogeny of perception begs the question of the evolution of perception. Organisms and their environments “co-construct” perceptual structure and function. In the terms of Levins and Lewontin (1985), in and through their interactions with the environment organisms determine which aspects of the ambient physical environment constitute the effective environment, they alter the world external to them as they interact with it, and they transduce the physical signals that reach them (and so the significance of those signals depends on the structure of the organism), just as environments select sensory-motor capacities in animals and thereby constrain perceptual development and activity.
argue that stimuli in the world naturally provoke bodily sensations that, occurring close together in space or in time, give rise to more global “ideas” and thereby invest the perceptual world with meaning. It is through association, empiricism further explains, that separate raw sensations aggregate into meaningful perceptions. The empiricist’s view of the nature of the mind early in life was fostered by two separate, though conceptually related, schools of thought. One derived from John Locke (1632–1704), who in An Essay Concerning Human Understanding (1959, Book II, Chapter 1.2) described the mind at birth as a “white paper”: Mental life begins “without any ideas,” and understanding the world depends wholly on the accumulation of experiences. A slightly different empiricist view can be attributed to William James (1842–1910), who in Some Problems of Philosophy (1924, p. 50) described the “immediate sensible life” as a big “blooming buzzing confusion” out of which experience organizes and creates knowledge and order. According to empiricist beliefs, the naive child does not share the same perceptual world of the experienced adult. Empiricism is inherently developmental because, by whatever mechanism is postulated, human beings grow from perceptually immature to perceptually mature.

The belief that human beings begin life “empty headed” has been conceived by many to be both philosophically intolerable and logically indefensible. Extreme nativists postulate that human beings are not “created” mindless and that the knowledge that humans possess cannot be achieved by learning alone in so short a span of time as childhood. As a consequence, philosophers such as René Descartes (1596–1650) and Immanuel Kant (1724–1804) conceived of humans as endowed from birth with “ideas” or “categories” of knowledge that undergird perceptual functions. They postulated innate perceptual ideas for size, form, position, and motion, as well as more abstract conceptions for space and time. The nativist argument, contra the empiricist, holds that the human mind naturally and from the beginning of life imposes order on sensory input, thereby transforming raw sensations into meaningful perceptions. According to the nativist account, the child and adult may share many perceptual capacities, and the two perceive the world in much the same way. For those abilities that are congenital, nativism is not a developmental view; for those abilities that mature, however, nativism is developmental in outlook.

Today we see vestiges of this debate in contemporary theories of perception and perceptual development. Some argue that meaningful perceptual structure exists in the environment independently of the way we perceive the world: “The world is real and this reality includes such things as structure. But the organism also interacts with reality to seek and select structure. Rarely, however, does the organism create structure. There is no need. Structure is everywhere to be found and the information processing organism need only look, find, and select” (Garner, 1974, p. 186). The developmental corollary of this view is that perceptual growth consists of the perceiver’s increasing sophistication to “pick up” relevant available information (E. J. Gibson, 1982; J. J. Gibson, 1979). So-called direct perception theories maintain that meanings of events in the world are automatically perceived (“afforded”) in relations among higher-order variables to which the sensory systems have specifically evolved; they are not constructed from individual sensations. Thus, we directly perceive a support surface when looking at the floor below, and directly use it as such to control our walking.

Alternative views explain our interpretations of the physical world based on information in the world in conjunction with the evolutionary and developmental history of the organism and whatever the contemporary neural, sensory, and cognitive constraints of the organism may be. In this account, structure and information in the external environment are to a certain extent created through ongoing interactions between the organism and the environment (Hebb, 1949; Piaget, 1969). So-called constructivist theories may admit that a few rudimentary perceptual abilities—such as the capacity to distinguish figure from ground—are inborn, but beyond these the bulk of perceptual development is founded in the interplay of
action and experience in the world. In seeing a form, we develop an internal representation of the form that is related to the movements of our eyes as well as to the activity of our brains. Interactive experiences thus promote perceptual organization and help to construct our understanding of the world, space, time, and so forth.

**Status and Origins of Development**

Perhaps the first question the perceptual developmentalist poses is, what the current *status* of the perceptual structure or function of interest is in the organism. This is a proper and logical starting point. For many, the answer to this question is also the end point. Not so for the developmentalist, who will pose (at least) two additional questions: What are the *origins* of the perceptual structure or function? How does the *development* of the perceptual structure or function unfold? In essence, nativism and empiricism constitute two (major) opinions about origins and assign differential weights to the roles that biology and experience play in development. Traditionally, theory and research in perceptual development are designed to characterize when a structure or function emerges, the course of its development (i.e., whether and how it changes over time), and what factors influence its developmental trajectory.

**Development**

Perception begins with the reception and transduction of physical information arriving at the sensory surface. Perceptual representations reflect the quality of this sensory transduction and information transmission. Developmental study broadly, and perceptual development specifically, are interested not only in manifestations and quality of ability and performance but also in the expression of two metrics of development, individual *stability* and group *continuity* of ability and performance (Bornstein & Bornstein, 2008). If a perception showed continuity in development, children as a group would perceive at the same average level at one point in time and at a second point later in time. A discontinuity in perception would be indicated by group improvement or deterioration. If a perception showed stability, individual children who displayed relatively high levels of perception at one point in time would display relatively high levels at a second point later in time. Instability in perception would be indicated by children’s changing in their relative positions through time. Continuity and stability—central constructs in developmental science—describe related, but conceptually and statistically independent, realms of development (Bornstein & Suess, 2000; Hartmann, Pelzel, & Abbott, Chapter 3, this volume; McCall, 1981; Roberts, Walton, & Viechtbauer, 2006; Wohlwill, 1973). Developmentalists are concerned, moreover, with the question of *why* development has occurred. Developmental changes in perception could be attributable to (a) neural, anatomical, or sensory maturation; (b) changes in attention; (c) alterations in motivation or improved task performance; (d) learning and experience; or (e) combinations and interactions of all of these. Despite the fact that they are sometimes conceived as either—or contributors to developmental theories, nature and nurture inevitably and invariably interact through time. That is, perceptual development is influenced by organismic maturation in conjunction with specific effects of experience.

The potential ways in which the forces of nature and nurture possibly interact to influence the course of development can be conceptualized in a simple but comprehensive manner. Figure 6.1 shows different possible courses of development of a perceptual structure or function before the onset of experience and the few possible ways experience may influence eventual perceptual outcome afterwards (Gottlieb, 1981). Experience operates through modification, enrichment, or deprivation. How does experience (or the lack thereof) interact with
biology to affect the course of perceptual development? First, there is the possibility that a perceptual structure or function is undeveloped at the onset of experience, but can be induced or suppressed by relevant experience; without such experience, the structure or function is presumed never to emerge (see Figure 6.1). Second, a perceptual structure or function may develop partially before the onset of experience, after which experience could operate in one of three ways: Relevant experience could facilitate further development or attune the structure or function; experience could maintain the structure or function at the partial level of development attained before the onset of experience; or, in the absence of relevant experience or the presence of experience that suppresses the structure or function may be lost. (Of course, experience per se may not be altogether necessary where the perceptual structure or function would continue to mature as a reflection of the genetic blueprint.) Third, a perceptual structure or function could develop fully before the onset of experience, after which it requires experience only to be maintained; without relevant experience or with suppressing experience, the structure or function may be lost.

The topics in perceptual development to which scientists have historically devoted their attention are those that require answers to descriptive as well as to theoretical questions. The degree to which similarities among human beings are guided by biological or structural identities is difficult to specify, as is the degree to which differences among human beings reflect anatomy or ecology or tuition. Cultural studies of perception (which we review later) reveal clear developmental differences as well as similarities. For this reason perceptual studies often serve as models for other developmental and psychological processes.

![Figure 6.1 Possible developmental outcomes given different levels of perceptual development before the onset of experience and different experiences afterward. From Aslin (1981) after Gottlieb (1981).](http://www.psypress.com/developmental-science-9781848728714)
From a developmental point of view, the study of perception from young adulthood through old age poses relatively few methodological challenges because mature individuals can readily be instructed to report about or to behave in ways that communicate validly about their perceptions. In childhood and especially in infancy, however, the communication barrier throws up a fundamental impediment to perceptual study. Moreover, infants are motorically incompetent, and infants and young children are subject to state fluctuations and are inherently unreliable reporters. As a consequence, our knowledge of early perception must be inferred from reports and behaviors of varying, and usually impoverished, fidelity and credibility. Studies of perceptual development in the early part of the life span are therefore especially challenging. Moreover, perceptual research must be especially vigilant. We see the world—literally and figuratively—through adult eyes. Children do not. They see the world through child eyes. What looks like one thing to us may look quite different to a child, and it can be a gaffe to misattribute our perceptions to the child.

Two main paths to studying perceptual development, neuroscience and behavior, and several techniques within each, have been utilized. For purposes of comparison, the methodologies we review are ordered along a hypothetical continuum roughly in terms of the strength, from low to high, of inference about perception that they permit.

Despite important differences among methodologies, virtually all techniques developed to study perception have been engineered to address a surprisingly small number of perceptual questions. One question has to do with whether the observer detects the presence of a stimulus—in the psychophysicist’s terms, whether the stimulus surpasses an absolute threshold. A second question has to do with whether the observer detects differences between perceptible stimuli—whether the stimuli surpass a difference threshold. Physically nonidentical stimuli that are still not discriminated give evidence of being treated similarly or categorized. Furthermore, some investigators elect to study naturally occurring, usually complex stimulation, whereas others elect to study stripped down stimulus variation along isolated dimensions. As usual, the scientific questions that motivate the research best dictate the nature of the stimuli used as well as the methodology chosen to study them.

The Neurosciences Path

Investigations of perceptual development that have adopted the techniques of contemporary neuroscience approach their subject of study via assessments of the central and autonomic nervous systems (Johnson, Chapter 4, this volume).

Central nervous system. Research efforts related to perceptual development focused on the central nervous system (CNS) have adopted four general techniques—neurological anatomy, single-cell and intercellular physiology, and aggregated cortical electrical activation as well as central function. Questions asked at the level of anatomical investigation concern the structural ontogeny of the perceptual apparatus, with a view to defining its relation to function. A presumption of this research strategy is that structure (anatomy) is necessary for function (perception), and so understanding function is, in a sense, enriched by a knowledge of underlying structure. On occasion, perceptual theorists turn this argument on its head and postulate the existence of structures based on observed functions; for example, the ability of newborns to discriminate shapes, orientations, and colors implies that some part or parts of the geniculo-striate pathway of the brain must be developed at birth. Note, however, that structure is necessary but not sufficient for function: Babies have legs but do not walk. Thus, insofar as inference about perception is concerned, evidence based on anatomical structure alone is very weak.
The second technique of neuroscience investigation has focused more narrowly on the development and specificity of individual neurons and interneuronal connectivity in different sensory systems. Neurophysiological recordings of the brain reveal that individual cells code diverse specific characteristics of the environment. Some so-called “trigger features” of environmental stimulation to which individual neurons in the visual system, for example, have been found to be sensitive include wavelength of light, orientation of form, and direction of movement (Livingstone & Hubel, 1988). Neurons at higher regions of the brain show sensitivity to more complex stimuli. Barlow (1953) first used the term bug detectors based on his work in the frog, and Lettvin, Maturana, McCulloch, and Pitts (1959) proposed the term grandmother cell (Gross, 2002) to describe neurons that respond best to hypercomplex stimuli such as faces and hands (Gross, Bender, & Rocha-Miranda, 1969; Gross, Rocha-Miranda, & Bender, 1972). Although it is exciting and provocative, several questions render this area of research of limited value and suggest that these findings need to be viewed with caution when used to explicate perceptual development. For example, although single neurons show sensitivity to individual properties of environmental stimulation, their actual role (if any) in perception is still largely undefined. Furthermore, as virtually all studies of single units have been conducted in infrahuman species (e.g., cat or monkey), the direct relevance or applicability of single-unit studies to human perception remains open to question. Finally, an intriguing challenge to perceptual development is whether single neurons are innately sensitive to their trigger features, their sensitivity reflects experience, or (as is probable) the developmental interaction of the two.

The third and fourth research techniques into CNS contributions to perceptual development most directly address intact human beings and derive from aggregation and neuroimaging, tools that permit simultaneous examination of structure and function of the brain (Johnson, Chapter 4, this volume; Nelson, Thomas, & De Haan, 2006). They include the electroencephalogram (EEG) and event-related potential (ERP) and magnetic source imaging that taps electrical activity at the scalp that is a byproduct of underlying neuronal activity. The geodesic sensor net, for example, applies as many as 128 electrodes to the scalp surface (Tucker, 1993) for the purpose of identifying patterns of neural activity that may be time-locked to a stimulus (Figure 6.2A). For example, responsiveness to speech sounds has been studied in infants still in the first year of life using ERPs (Rivera-Gaxiola, Silva-Pereyra, & Kuhl, 2005). Reynolds and Richards (2005) made a close examination of ERPs in relation to underlying brain structure in infants 4.5, 6, and 7.5 months of age. They identified different underlying neural mechanisms for different aspects of information processing. Spatial independent components analysis of the electroencephalogram and “equivalent current dipole” analysis revealed putative cortical sources of the ERP components in areas of prefrontal cortex and anterior cingulate cortex (as in Figure 6.2B).

The fourth kind of neuroscience technique includes positron emission tomography (PET) and functional magnetic resonance imaging (fMRI; Figure 6.3). These two approaches provide spatial indications of brain metabolism and activity. Studies using fMRI with infants as young as 2 months reveal the involvement of different neural systems in response to speech (Dehaene-Lambertz, Dehaene, & Hertz-Pannier, 2002).

Widespread use of imaging techniques can lead not only to a greater basic science understanding of structure–function relations in perception, but also to more accurate diagnoses of problem states and enhanced efficiency in assessment and treatment. For example, a neuroscience approach has proved valuable for the light it sheds on atypical development. Electrical responses have been used to diagnose deafness at birth (Figure 6.4): If the newborn does not respond to sound, such responses can indicate whether or not brain pathways are intact.

Autonomic nervous system. A second set of neuroscience techniques widely applied to
FIGURE 6.2  (A) An infant wearing a high-density EEG sensor array (the geodesic sensor net). The elastic net contains 128 individual sensors for recording scalp EEG and ERP signals. Photo courtesy of Electrical Geodesics, Inc.  (B) A source localization solution for ERPs that were collected when participants were hearing the speech sound /ba/ (Brain Electrical Source Analysis, MEGIS Software GmbH). The markers represent modeled locations of signal generators and their corresponding axes of charge polarity. Courtesy of S. Key.

FIGURE 6.3  A 10-year-old normal, healthy child about to be tested in a study of working memory involving fMRI. An overhead projector (not seen) projects visual images onto a screen at the foot of the table. A mirror directly above the child’s head allows him to see these images. The child has a button box (containing nonmagnetic material) in his hand, and during the study (when the child will be in the scanner itself), he will push buttons that correspond to task demands (e.g., push a button that corresponds to a position of a light on the screen). Courtesy of C. Nelson.

FIGURE 6.4  A newborn being tested for hearing. Photo courtesy of T. Hellbrügge.

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gaining information about perception has followed a path through monitoring autonomic nervous system (ANS) reactions in perceptual tasks. Cardiac and cardiorespiratory measures, such as heart rate, heart rate variability, and respiratory sinus arrhythmia (RSA), reflect orienting, sustained attention, and state changes in infants and children (Bornstein & Colombo, 2010).

These measures have proved to be particularly useful in research in perception because they are sensitive to changes in attentional state. They are also important indices of individual differences in children’s capacity to regulate state of arousal and respond appropriately to environmental demand (Bornstein & Suess, 2000; Porges, 1995, 2001, 2003). For example, heart rate has been not only used as a measure of orienting but also to distinguish phases of attention in information processing (Colombo, 2001; Colombo, Richman, Shaddy, Greenhoot, & Maikranz, 2001; Richards, 2003, 2004). In this research, heart rate is measured during stimulus presentation. According to Richards (2004), heart rate changes systematically as an infant looks at a stimulus, and these changes correspond to different phases of attentional engagement. An infant’s heart rate decelerates during orienting, shows sustained deceleration during sustained attention, and increases at the end of sustained attention. There is evidence that infants’ information processing occurs primarily during phases of sustained attention (Frick & Richards, 2001; Richards, 1987, 2003).

Despite these several virtues, the contributions of neuroscience to understanding perception proper are limited, factors other than those under experimental scrutiny can influence responses, and perceptual understanding based on these techniques requires high degrees of inference. As noted, that a cortex exists or that a stimulus presented to the sensory system creates an identifiable and even consistent pattern of electrical activity at the cortex does not guarantee that the stimulus registers in a perceptually meaningful way for the observer. Some ANS measures fare somewhat better in this regard, but they still do not provide convincing evidence of conscious perception as the body may respond in the absence of stimulation giving rise to psychological awareness. Moreover, a basic principle of this approach is that many factors influence these kinds of responses, and thus there is almost never an exact one-to-one correspondence between a physiological index and a psychological state (Kandel, 2007). Access to conscious perceptual function is achieved only through behavioral report.

The Behavioral Path

To assess perceptual life in infancy, in childhood, or in maturity on surer footing, developmental scientists have invented or adapted a wide variety of behavioral techniques. The first of these methods, historically, relied on naturally occurring behaviors, such as looking patterns and facial expressions. Other methods involve infants’ preferences and learning.

Naturally occurring behaviors—looking patterns and actions. Kessen, Haith, and Salapatek (1970) argued that it ought to be possible to assess visual function at birth simply by “looking at infant looking.” These investigators photographed the reflection of a stimulus in the cornea of the baby’s eye and tracked eye movements. They assumed that perceiving is in some degree implied in fixating a stimulus—voluntary visual orienting so as to bring a stimulus into the line of visual regard—and that where a baby looks indicates visual selectivity and, hence, visual perception. Until their studies, basic questions, such as whether or not newborn babies even see, went unanswered. In the decades since, many experimenters (e.g., Haith, 2004) have advanced on the logic of their inquiry and its methodology (Figure 6.5).

With advances in motor development, infants become increasingly capable of intentional action, and researchers use these actions to assess perception. For example, Ruff (1990) observed that infants’ mouthing objects decreased over the second half of the first year,
whereas their fingering and more precise forms of manipulation both increased (accompanying the further development of fine motor coordination). Infants also vary their exploratory activities to match the object being explored. When Ruff systematically changed the nature of an object (once the infant had the chance to explore the object in some detail), the infant in turn changed patterns of tactual exploration so as to maximize acquisition of information about the new object. For example, infants responded to a change in shape by rotating and fingering the object more and transferring it more often from one hand to the other, but they responded to a change in texture only by fingering the new object more.

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6. PERCEPTUAL DEVELOPMENT

Other actions used to study perception are reaching (see Figure 6.6; e.g., Yonas & Hartman, 1993) and crawling and walking (see Figure 6.7). For example, infants will reach to the closer of two objects, indicating that they see the difference in depth between the two, and infants will crawl rather than walk down a steep incline or across a waterbed, indicating that they perceive the characteristics of the surface they are walking on and so adjust their actions accordingly (Adolph & Berger, Chapter 5, this volume).

Preference. Fantz (1958, 1964) argued that, if an observer looked preferentially at one stimulus over another in a choice situation, irrespective of the spatial location of the two stimuli, the observer’s preference could be taken to indicate detection and discrimination. Today Fantz’s argument is the bedrock of the many popular and productive developmental research techniques. Consider the study of visual acuity as an example.

Studies of visual scanning indicate at a minimum that young observers see something when they look at patterns, but do not reveal how well they see. To study visual acuity, Fantz, Ordy, and Udelf (1962) capitalized on the observation that infants prefer to look at heterogeneous over homogeneous patterns. They posted pairs of patterns for infants to look at, in which one member of the pair was always gray and the other an alternation of black and white stripes that varied systematically in width. (The two stimuli were always matched in overall brightness.) As pattern is consistently preferred, the stripe width that fails to evoke a preference is the one that marks the limit of the observer’s ability to tell stripes from the solid gray. (At some point, stripe width becomes so fine as to fade into homogeneity.) Preferential looking has been used to investigate a wide variety of perceptual abilities in infancy, especially in pattern vision and in color vision (Bornstein, 2006, 2007; Ruff & Rothbart, 1996). This technique has also been adapted to explore smell and taste (e.g., Steiner, 1977).

Demonstrable preferences provide evidence for absolute and discriminative thresholds; unfortunately, the preference paradigm suffers from a major shortcoming. The failure to observe a preference is ambiguous with respect to the observer’s ability to detect or to discriminate stimuli. This is a nontrivial methodological drawback, and for this reason many investigators have turned to paradigms that draw even more actively on demonstrative behavioral acts of infants and children to study absolute and difference thresholds in perception. Among the most widely used paradigms are conditioned head rotation and habituation–recovery.

Conditioned head rotation. An experimental paradigm that successfully taps into perceptual development is conditioned head rotation (Werker et al., 1998). In this form of learning, the reinforcement of a voluntarily controlled motor activity results in its being repeated. The child sits on the mother’s lap, otherwise unencumbered, and with a loudspeaker to one side. When a sound (e.g., tone or speech syllable) is played through the speaker and the child responds by orienting to it, the child is rewarded by activation of cartoons or a colorful mechanical toy co-located with the speaker. Using this procedure developmental psychoacousticians have charted the growth of basic sound perception capabilities—detection of sounds of different frequencies, discrimination among frequencies—as well as the growth of responsiveness to complex sounds that specify speech (Saffran, Werker, & Werner, 2006).

Habituation–recovery. Conditioned head rotation provides reasonably reliable data about perception because infant observers actively, voluntarily, and definitely respond and thereby directly “communicate” their perceptions to the experimenter. An equally clear and reliable technique, and one that has been adopted widely in experimental studies of perception in the first years of life, is habituation–recovery (Bornstein, 1985; Bornstein & Colombo, 2010). This procedure has the advantages that it draws minimally on motor ability and that it
FIGURE 6.6 The fine-tuned nature of infants’ ability to link perception and action. Top: The infant reaches for an object that is within reach. Bottom: The same infant leans forward to make contact with a more distant object. After Yonas and Hartman, 1993.

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can and has been used to investigate perception in every modality; for purposes of this exposition, vision serves as an example.

In habituation, an infant is shown a stimulus, and the infant’s visual attention to the stimulus is monitored. Typically, when placed in an otherwise homogeneous environment, an infant will orient and attend to a stimulus on its initial presentation. If the stimulus is available to the infant’s view continuously or if it is presented repeatedly, the infant’s attention to the stimulus will diminish. This decrement in attention, called *habituation*, presumably reflects two component processes: the infant’s developing a mental representation of the stimulus and the infant’s continuing comparison of whatever stimulation is present with that internal representation. If external stimulus and mental representation match, and the infant knows the stimulus, there is little reason to continue to look; mismatches, however, maintain or even evoke the infant’s attention. A novel (and discriminable) stimulus, introduced in a test after habituation to a now familiar stimulus, typically reexcites infant attention to “recover” to the infant’s initial level of looking. Habituation to familiarity and recovery to novelty have proved to be versatile and fruitful testing methods in developmental studies, permitting investigators the possibility of assessing many aspects of early perception. In vision, developmental researchers have used habituation–recovery to address classic questions about the perception of form, orientation, location, movement, color, and more complex events such as the appearance and disappearance of objects.

**Conclusions**

Our understanding of perception, its bases, and its development has been enhanced considerably by studies of the central and autonomic nervous systems and by active behavioral choice and learning. Techniques from neuroscience are valuable as objective and sensitive measures of perception, but the inferences we can make about perception from behavioral methods are stronger. In the next sections we illustrate the wealth of information about perceptual development gleaned from these methodologies.
PERCEPTUAL DEVELOPMENT IN INFANCY, CHILDHOOD, ADULTHOOD, AND OLD AGE

Prolegomena

As noted above, the study of perceptual development has largely focused on infancy and early childhood. This is so for several reasons. First, as we learned, perceptual study as a whole was motivated by philosophical debate. To study perception was to address epistemological controversies, and so to study perception effectively was to do so near the beginning of life before much experience had accrued. Second, by early childhood perception of the world (although certainly not interpretation) was thought to be reasonably mature and stable. Thus, most of the “action” in perceptual development was believed to take place very early in life. The sensory systems function and provide us with highly sophisticated information, systematically and forever eradicating the myth of the perceptually incompetent infant. The exciting and sometimes startling observations about infant perception made in the second half of the twentieth century do not mean that newborn perceptual capacities are fully developed, however; even if rudimentary function is present, qualitative sophistication is often still lacking. Third, after infancy, cognitive factors (including language mediation) play increasingly integrated roles in perception, and so distinguishing perceptual processes per se from other associated mental acts becomes problematic. On this account, the “perceptual plateau” of adulthood was often excluded from studies of perceptual development, with two important exceptions: One is when ontogenetic comparisons were called for; and the other is studies of aging. Today, the picture of perceptual development is changing for two main reasons. First, continuing research into cognitive neuroscience shows that the brain after birth is not a static organ (as once believed), but is plastic to new experiences throughout the life course. Second, demographic changes in the population associated with the increasing longevity of the “baby boom” generation have drawn more attention to aging in general and specifically to perceptual factors in aging. In the life-span view we adopt here, we address perception in infancy and childhood as well as in adulthood and old age.

Anatomical Beginnings

The course of anatomical development of the sensory systems has received more than modest attention, leading to the conclusion that human beings are reasonably well prepared to perceive in many modalities once extrauterine life begins. By the second trimester of prenatal life, the eye and the visual system, the ear and the auditory system, the nose and the olfactory system, and the tongue and the gustatory system are well on their way to being structurally and functionally mature. In general, two principles of development appear to characterize sensory system development. Within systems, maturation tends to proceed from the periphery to the central parts of the brain, so that, for example, the eye differentiates structurally and reaches functional maturity before the visual cortex (Conel, 1939/1959; Nelson, Thomas, & De Haan, 2006), and the electroretinogram before the cortical event-related potential (Barnet, Lodge, & Armington, 1965; Lodge, Armington, Barnet, Shanks, & Newcomb, 1969). Across systems, different senses tend to achieve functional development in sequence (Gottlieb, 1981): cutaneous, gustatory, olfactory, auditory, and finally visual. Turkewitz and Kenny (1982, 1985) argued that this staggered program of development has biopsychological advantages for reducing mutual competition among systems for ambient stimulation, and thereby allowing for eventual heightened sensory organization and integration.

Perhaps the two most important developments at the intercellular level involve biochemical neurotransmission and reorganization among neurons. In the first 2 years of life, proliferation
of synapses—the connections across neurons—proceeds to the point at which there are up to 10,000 connections per cell (Kandel, 2007). This over-proliferation results in a chaotic and immature pattern of multiple intercellular connections (Huttenlocher, 2002). A second wave of overproduction occurs just prior to puberty. Synaptic “pruning” or elimination begins around 1 year of age and again around 13 years of age. At both times, initial chaotic patterns are gradually replaced by more efficient and streamlined systems of central nervous information transmission (Bergström, 1969). Thus, in infancy a discrete stimulus that excites the immature system is likely to result in a diffuse tonic or global response, whereas in maturity interconnections are orderly, and the same discrete stimulus produces a phasic response that is exact in time and parallel in space. Consider how children respond to a loud clap of the hands. Early in life, such auditory stimulation elicits a whole body shudder, for example. Later, the same clap will produce a quick and efficient turn of the head. CNS development at the intercellular level is characterized generally by differentiation and growth of specificity (Purves & Lichtman, 1980).

The Five Senses in Early Life: Touch, Taste, Smell, Hearing, and Sight

**Touch.** We know from everyday experience that soothing pats can quiet a fussy infant, whereas the DPT shot invariably causes an infant distress. Infants are sensitive to the location of a touch and may also feel pain when the tactile stimulus is severe. Alert newborns will turn toward a stimulus that touches near their mouth or a puff of air on their cheek (Kisilevsky, Stach, & Muir, 1991). Newborns also show differential responses to invasive and noninvasive procedures soon after birth: infants react to invasive procedures with a common facial expression composed of lowered brows, tightly shut eyes, nasolabial furrow, open lips, and a cupped taut tongue suggesting that they feel pain from invasive procedures (Craig, Whitfield, Grunau, Linton, & Hadjistavropoulos, 1993; Grunau, Johnston, & Craig, 1990).

**Taste.** Taste is a primitive sensory system that is developed early and of significance to survival. Psychophysical research has led to broad conclusions that four basic qualities (and their combinations) together compose taste experience: sweet, salt, sour, and bitter. Tastes are very powerful stimuli in learning: As most people know, a single experience of nausea associated with a particular taste is sufficient to cause a long-lasting or even life-long aversion to that taste (Garcia & Koelling, 1966). Newborn babies, even those who have tasted nothing but amniotic fluid, appear to discriminate among sensory qualities that signify different tastes and give evidence that they prefer certain tastes to others (Ganchrow & Steiner, 1984; Ganchrow, Steiner, & Daher, 1983). Taste discrimination is organized at a primitive level of the brain; it appears in anencephalic babies (those born without a cortex). Thus, it comes as no surprise that newborn babies show differential reactions to different tastes. Steiner (1977) gave newborn infants sweet, sour, or bitter substances to taste, and he photographed their gustofacial reactions—all prior to the very first time any of the babies ate. Figure 6.8A shows the results. A sweet stimulus evoked an expression of satisfaction, often accompanied by a slight smile and sucking movements. A sour stimulus evoked lip-pursing, often accompanied or followed by wrinkling the nose and blinking the eyes. A bitter stimulus evoked an expression of dislike and disgust or rejection, often followed by spitting or even movements preparatory to vomiting. Oster (2005) observed that 2-hour-old neonates produce different facial responses to sweet versus non-sweet tastes as well as to salty, sour, and bitter tastes. Infants discriminate within, as well as between, these taste categories: Sweeter sucrose solutions elicit fewer and longer bursts of sucking separated by longer pauses than do less sweet solutions (Crook, 1987).
Smell. Odor is another primitive sensory system that develops early. Newborns possess a keen ability to detect and discriminate odors (Engen, 1982; Porter, Balogh, & Makin, 1988), perhaps approaching mature levels (Schaal, 1988). Steiner (1977, 1979) documented neonates’ nasofacial reactions to odors placed on cotton swabs held beneath the nose: Butter and banana elicited positive expressions; vanilla, either positive or indifferent expressions; a fishy odor, some rejection; and the odor of rotten eggs, unanimous rejection (see Figure 6.8B and C). Breast-fed and bottle-fed infants only 12 to 18 days of age were systematically compared for their olfactory recognition of mother, father, and stranger. Babies were photographed while exposed to pairs of gauze pads worn in the underarm area by an adult on the night previous to the test, and the duration of infant preferential orienting to one or another of the gauze pads was recorded. Only breast-feeding infants oriented preferentially and exclusively to their own mothers’ scents, thereby giving evidence that they discriminate among odors and prefer that of mother. (Infants did not recognize their fathers preferentially; nor did bottle-fed infants recognize their mothers.) This pattern of results suggests that, while they are breast-feeding, infants are exposed to, and apparently learn, unique olfactory signatures (Porter & Levy, 1995). Goubet and her colleagues (2002; Goubet, Rattaz, Pierrat, Bullinger, & Lequien, 2003) showed that learning odors, such as vanilla, occurs rapidly in both preterm and term infants, and the presence of a familiar odor during a medical procedure has a calming effect.

FIGURE 6.8 Gustatory and olfactory sensitivity in newborn babies. (A) Infants’ gustofacial response to the taste of sweet (left column), sour (middle column), and bitter (right column). Infants’ nasofacial response to the smell of (B) vanilla and (C) raw fish. After Steiner, 1977.
Femandez and Bahrick (1994) assessed whether 4-month-olds could learn an arbitrary object–odor pairing. Girls (but not boys) increased their looking to a target object that had previously been paired with a cherry odor when the object was presented in the presence of the cherry odor but not in the absence of the odor. These findings point to memory for odors and the potential for a prior experience with an odor to influence infants’ later responses. In another study, 3-month-olds learned to kick to control the movement of an overhead mobile in the presence of an ambient odor. Infant retention was assessed 1, 3, or 5 days later. During the retention test, the olfactory context was either the same odor, a different odor, or “no odor.” At 1 day, infants exhibited retention when tested in the presence of the same odor; infants in the no odor condition exhibited partial retention, whereas memory retrieval was completely disrupted for infants tested in the presence of the different odor. After the 3- and 5-day intervals, all groups showed forgetting (Rubin, Fagen, & Carroll, 1998).

**Hearing.** We have a fairly good understanding of early auditory perception, i.e., hearing (Saffran et al., 2006). How loud does a sound have to be to be heard? For adults, the amount of energy defining the auditory absolute threshold varies with the frequency of the sound: The least energy is required around 1,000 Hz, and more energy is required at both lower and higher frequencies. Virtually the entire audible frequency spectrum (from 200 to 19,000 Hz) has been mapped in children of various ages and compared with that of adults (Trehub & Schneider, 1985). Infant thresholds for noise (as opposed to pure tones) vary substantially with frequency; they are higher than those of adults for low frequencies (200 Hz), approach adult levels for middle frequencies (1,000 Hz), and are again higher than those of adults at very high frequencies (10,000 Hz). Furthermore, hearing at low and high frequencies nearly continuously improves during the first 20 years of life, with sensitivity to high frequency maturing first (Schneider, Trehub, Morrongiello, & Thorpe, 1986; Trehub, Schneider, Morrongiello, & Thorpe, 1988, 1989). Changes in ear structure, nervous system maturation, and experience could account for increasing developmental sensitivity.

Young children also clearly discriminate among sounds of different frequencies. Five- to 8-month-old babies tell apart tones differing by only about 2% in frequency in the 1,000- to 3,000-Hz range (where adult frequency discrimination is about 1%); infant thresholds are twice those of adults at lower frequencies (250–1,000 Hz), whereas they are virtually the same as those of adults at higher frequencies (3,000–8,000 Hz; Werner & Bargones, 1992). Fagen et al. (1997) investigated the role of a complex auditory context (music) on retrieval. They trained 3-month-olds in the presence of a musical sequence (either a classical or jazz piano piece) and then tested infants for retention 1 or 7 days later in the presence of either the same or a different musical pattern. Infants displayed l-day retention regardless of which music was played during the l-day test. At 7 days, however, retention was seen only when the music being played during the retention test matched what the infant had heard during training.

A vital function of hearing for the young infant involves perceiving speech. Newborn babies prefer speech that has been filtered to mimic what they heard in utero over matched complex non-speech sounds, and babies will even work (by sucking more frequently and harder) to present themselves with speech sounds but will not do so for complex non-speech (Vouloumanos & Werker, 2007a, 2007b). Cortical imaging techniques show more activity in left-hemisphere “language” areas when babies are exposed to regular speech but activity in both the left and right hemispheres when babies are exposed to the same speech played backwards (Pena et al., 2003). By the middle of the first year infants discriminate most acoustic differences that signal phonologically relevant speech contrasts in language. In addition, infants perceive phonemes (units of meaningful speech) as equivalent when they are spoken by male and female talkers and, thus, differ in fundamental frequency; and within the first year infants are able to parse the speech stream into smaller units—phrases, words, and
syllables. For example, infants prefer pauses placed between clauses rather than pauses placed within clauses; they rely on stress patterns and sequential regularities (the ordering of phonemic segments) to separate phrases into words; they divide words into syllables; and they detect statistical relations between neighboring speech sounds after relatively little experience with new sound combinations (Saffran et al., 2006).

**Sight.** Eye scan patterns signify that infants from the first days of life actively orient to visual information in the environment, and not only do such patterns reveal what babies look at, but looking patterns develop and are distributed differently over different visual forms. Even in the first hours after birth, infants tend to scan the parts of faces or geometric forms that contain information (usually high-contrast features such as along the contours of figures) in lieu of scanning randomly about the background or over the central part of a figure (Haith, 2004). Generally speaking, visual scanning relates systematically to the content and structure of scenes examined (Figure 6.5). It is likely that these patterns of attentional bias limit some aspects of visual scenes that younger infants actually detect. For instance, one investigation of feature learning and discrimination revealed a failure among young infants to process elements appearing inside a salient outer boundary even though they were able to discriminate patterns on the basis of those external contours. It is possible that such constraints serve a functionally beneficial role in reducing the amount of sensory information that younger infants must process with their more limited cognitive resources.

Color is an intellectually impressive and aesthetically attractive kind of information. Infants see colors and seem to do so pretty well. Darwin (1877) speculated on his own children’s color vision in the 1870s, but real progress toward understanding the development of color vision only began in the 1970s. Studying color vision is particularly formidable technically (Bornstein, 2006, 2007): For example, hue, brightness, and saturation, the major components of color, covary so that whenever a color changes, its hue, brightness, and saturation are normally changing. To distinguish hue alone, which is proof of color vision, it is necessary to match hues in brightness and saturation or make brightness and saturation differences between the hues unrelated. With adults, this is relatively easy, as there exist formulae to relate the amount of change or difference in hue to the amount of change or difference in brightness and saturation; alternatively, adults can match colored stimuli for brightness and saturation directly. In babies, however, the precise relation between brightness or saturation and hue was for a long time unknown, and babies cannot be asked to match brightnesses or saturations. As a consequence, an understanding of early color vision begins with proper controls, and then proceeds to test discrimination, preference, and organization of hue. The development of color vision right after birth has not been studied extensively. Yet infants 3 months of age and older are acknowledged to possess basically normal color vision (Teller, 1998). Moreover, by 4 months of age infants perceive the color spectrum as organized qualitatively into categories of hue (Figure 6.9; Bornstein, Kessen, & Weiskopf, 1976; see also Franklin & Davies, 2004). Preverbal infants categorize the visible spectrum into relatively discrete basic hues of blue, green, yellow, and red, which are similar to those of adults, even though infants, like adults, can also discriminate among colors within a given category (Bornstein, 2006, 2007).

If newborn gustatory and olfactory acuities are highly developed, visual acuity—the level of detail that can be distinguished in a visual scene—is rather poor at birth. Infants begin life “legally blind,” around 20/400. Improvement is linear and quick, however, reaching adult levels by about 8 months of age (Norcia & Tyler, 1985). Nonetheless, young infants’ acuity does not severely limit their perception. They may not be able to read a book, but they can discern objects in their environment and most properties of those objects.

Infants’ perception of form is relevant in this connection. The fact that an observer scans
an angle of a triangle, and even resolves contour well, does not mean that the observer perceives the triangle as a “triangle.” For some time, the problem of form perception in early life proved remarkably resistant to resolution because almost any discrimination between two forms (a triangle from a circle) could be explained as discrimination on some simpler, featural basis (as between an angle and an arc) without whole-form perception being implicated. Because visual object recognition requires form perception, infants’ recognition performance offers clues to their perception of form. In one such study, 5-month-olds were familiarized to a simple, novel object by either a series of images depicting a single view of the object or a series depicting different views around its vertical axis (Mash, Arterberry, & Bornstein, 2007). Infants in the single-view group failed to recognize the same object when inverted, but infants seeing multiple views did recognize the object when inverted. A control experiment confirmed that infants were capable of discriminating subtle shape differences in the stimulus objects. Because such performance requires an initial extraction of 3D form, these findings indicate that infants are capable of combining discrepant static views into a cohesive representation of an object’s 3D visual form. This kind of research provides converging evidence that babies, still only in the first year of life, can perceive form qua whole form.

Objects are specified not only by their form but also by their coordination in space, that is, by their orientation, location, and movement. Physical space extends outward from the central ego equally in all directions, yet perceived orientation is not uniform: For adults, vertical

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holds a higher psychological status than does horizontal, and horizontal is generally higher in status than is oblique (Bornstein, 1982; Essock, 1980). For instance, we accept the statement that “5° is almost vertical” as truer than the statement that “vertical is almost 5°.” Vertical is the reference point for orientation (Wertheimer, 1938). Studies of detection, discrimination, and preference suggest that this hierarchy among orientations exists in early life for artificial geometric forms as well as for more meaningful patterns like the human face, and for static as well as for dynamic forms (Bornstein, Ferdinandsen, & Gross, 1981; Held, 1989; Leehey, Moskowitz-Cook, Brill, & Held, 1975). Young babies also seem able to discriminate orientation, not only in telling vertical and horizontal apart: They can resolve finer differences involving only obliques (Bornstein et al., 1981; Bornstein, Gross, & Wolf, 1978; Slater, Morison, & Somers, 1988).

Location in depth is also an important spatial dimension, and there are numerous cues available for depth perception. Three types of stimulus information specify depth—binocular, kinetic, and static–monocular cues—and infants appear to develop sensitivity to these types of information at different times. Binocular information is available by virtue of the fact that human beings have two eyes. This information consists of the convergence angle of the two eyes and stereopsis (the disparity between the two slightly different images of the visual world each eye receives). Binocular convergence yields information about close-up distances and serves as a reliable source of information about depth by 5 months (von Hofsten, 1974) or possibly earlier (Granrud, 1987; Slater, Mattock, & Brown, 1990). The onset of sensitivity to binocular disparity emerges around 4 months of age (Fox, Aslin, Shea, & Dumais, 1980; Held, Birch, & Gwiazda, 1980), and infants who show disparity sensitivity demonstrate improved spatial perception (Yonas, Arterberry, & Granrud, 1987a).

Young infants’ depth perception is also supported by sensitivity to kinetic information. There are several kinetic cues. When an object comes directly toward us on a “hit path,” we normally move out of the way to avoid the impending collision, and babies as young as 1 month of age consistently show a defensive response (e.g., they blink) to approaching objects (Nanez & Yonas, 1994). Another kinetic cue occurs during movement when closer surfaces are perceived to occlude more distant ones, called accretion and deletion of texture: Sitting in a moving car, we notice that the nearby billboard “moves” in front of and partially covers the more distant hill. Five-month-old babies use this kind of information to perceive the relative ordering of surfaces in depth (Granrud et al., 1984).

Sensitivity to a third type of depth information, static–monocular depth pictorial cues, appears to develop after sensitivity to binocular and kinetic information. When normal conditions of viewing are degraded, as in the case when distances are great or a single eye is looking at a nonmoving single point of observation, we may still perceive depth. Seven-month-olds, but not 5-month-olds, respond to a number of static–monocular depth cues, such as shading, interposition, familiar size, relative size, texture gradient, and linear perspective (Yonas, Arterberry, & Granrud, 1987b; Yonas & Granrud, 2006). Height-in-the-picture-plane may be the only type of static monocular depth information used by infants at 5 months of age (Arterberry, 2008).

Movement of objects also contributes information about their position, shape, and integrity (Kellman & Arterberry, 2006). Perception of objects naturally occurs in the context of their movement, and from such perceptions observers appear to pick up information about movement as well as about objects (Butterworth, 1989). This information “pickup” permits recognition of the same object regardless of its motion, and recognition of a particular movement regardless of the object that is moving (Gibson, 1979). On this account, object and movement perception are separate abilities but closely intertwined. Motion perception is cued by several types of information, including retinal image motion, retinal image displacement, and observer motion; even young infants show sensitivity to motion (Aslin & Shea, 1990;
Dannemiller & Freedland, 1991). They will look more at moving versus stationary versions of the same stimulus (Slater, Morison, Town, & Rose, 1985), locking on to moving heads and blinking eyes (Samuels, 1985). Ruff (1985) habituated babies to a series of objects, each one of which moved the same way (say, from side to side), and then tested them with a novel object moving in the familiar (side to side) motion and with a novel object moving in a novel way (say, from side to side and rotating). Infants at 3½ months discriminated side to side from side to side plus rotation, and by 5 months infants discriminated side to side from rotation alone, rotation from oscillation around the vertical, and left versus right rotation.

In addition to their form and spatial dimensions, patterns and objects in the environment are also specified, identified, and distinguished by surface features. Which features do infants attend to in determining the identity of objects? Wilcox (1999) examined infants’ use of specific object properties in an object individuation task. She measured infants’ looking time to hiding events in which objects’ visual features were switched when briefly hidden (say, a change in the color of a ball from red to blue), assuming that longer looking indicates detection of the switch. Failure to detect switches in particular features would suggest that infants do not focally attend to those features when tracking individual objects through such events. Wilcox found that 4-month-olds attended to both the shape and the size of objects when identifying them after the event had begun, but only after 11 months did they attend to the objects’ surface features of pattern and color. Mash (2007) observed individuation by color in infants as young as 9 months when they were also provided with correlated haptic cues to object identity, a finding that provides clues to infants’ emerging ability to combine information from different senses into coherent representations of distinct objects.

By now it is clear that infants discern the patterns, forms, and objects that they see around them. What is less clear is how they extract coherent, organized forms from an otherwise crowded environment. This question has guided perceptual research across all age groups, and some of the most enduring solutions are found among the Gestalt laws of organization. Gestaltists argued for innate, systematic constraints on the grouping of image primitives in the perception of visual scenes (Wertheimer, 1958), but only more recently have these principles been tested in infants. Quinn and colleagues examined whether manipulating the similarity of contiguous elements in stimulus arrays affected the perceptual organization of those arrays for infants. They found that infants at 3 months could organize arrays by lightness similarity (light vs. dark elements; Quinn, Burke, & Rush, 1993), but that the ability to do so on the basis of form similarity (x elements vs. o elements) did not emerge until closer to 7 months of age (Quinn, Bhatt, Brush, Grimes, & Sharpnack, 2002). These and related studies are consistent with the notion that at least some basic organizational principles guide the extraction of form information very early in life, but not necessarily with the Gestaltist position that these principles are present at birth.

Conclusions. The emerging picture of the beginnings of perception is one of substantial, if incomplete, competency relatively early in life. Young infants start life with a repertoire of abilities that are refined as they grow older. This refinement may result from further maturation of the perceptual systems and development of complementary systems (such as motor skills), experience, or their interaction. The infant perceptual system is by no means simply a small version of that of the adult. Even though quite functional, infants experience limitations that most adults do not. Yet, even infants’ stripped-down version of perception consists of sensitivities that lead to veridical perceptions that are useful to the immature organism. Infants are sensitive to motion-carried information before other types of depth information; acuity is best at distances where important information is usually located (12 inches away where parents’ faces are most likely to be found); likely encountered tastes (sweetness) are discriminated earlier than less likely encountered tastes (bitterness); sounds at decibel levels

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around the average speaking voice are detected more easily than are whispers. Infants are adapted to take advantage of the most useful information in their environment, and it is possible that further perceptual and related developments build on this initial high-quality information (Kellman & Arterberry, 2006).

**Perception in Childhood**

The study of perceptual development after infancy is less motivated by age-old questions, such as the nature–nurture debate, and substitutes a practical emphasis. Many applied investigators have expressed interest in perceptual development in childhood for its relation to children’s performance in school, for example. The significance of developmental questions in perception is brought home when children begin to learn how to read. Visual and auditory abilities (beyond verbal capacities) are persistently implicated in reading performance (e.g., Fisher, Bornstein, & Gross, 1985; Johnston, Anderson, Perrett, & Holligan, 1990; Kavale, 1982; Rayner, 1998; Solan & Ficarra, 1990; van Kleeck, 2003) as are other individual differences in young children such as temperament (Pellegrini & Galda, 2003). For example, individual differences in children’s attention affects the quality of picture book reading (Karrass, VanDeventer, & Braungart-Rieker, 2003; Ortiz, Stowe, & Arnold, 2001; Sénéchal, Cornell, & Broda, 1995). Picture book reading between an adult and a child involves “an attentional state during which the child and partner share a site of interest, such as an object or an event, in their immediate surroundings” (Adamson & Chance, 1998, p. 16). The ability to produce and comprehend rapid speech has been supported by nearly 10,000 generations of natural selection. However, writing and reading have arisen in just the past 5,000 years, and adaptation to these tasks is supported by only 250 generations of natural selection. Thus, it is not surprising to find that so many children have trouble learning to read and are diagnosed as “dyslexic” (Booth, Perfetti, MacWhinney, & Hunt, 2000). Another applied topic is the perceptual developmentalist’s perennial interest in children’s artistic abilities (Golomb, 2004) and perceptual substrates of children’s musical skills (Deliège & Sloboda, 1996; Lynch, Eilers, & Bornstein, 1992; Wilson, Wales, & Pattison, 1997). A further practical side to the study of perceptual abilities is children’s attention to and awareness of dangers posed by the environment (Lis, Venuti, & de Zordo, 1990; Plumert, Kearney, & Cremer, 2007), and the potential influences of entertainment technology (e.g., TV and video games) on children’s perceptual proclivities and abilities (Green & Bavelier, 2003). In American homes, the television is on approximately 6 hours a day on average. Rideout, Vandewater, and Wartella (2003; Vandewater et al., 2005) examined the impact of “heavy-television” households on reading in 756 children aged 0 to 6 drawn from a nationally representative sample. Two-thirds of 0- to 6-year-olds (65%) live in homes where the TV is on half the time or more, even if no one is watching, and one-third (36%) live in “heavy” TV households, where the television is left on “most of the time” or “always.” As a whole, 0- to 6-year-olds average about an hour a day of TV watching (1:05), plus another 38 minutes a day watching videos. Regardless of their age, children from heavy-television households watched more television and were less likely to read.

Perceptual development in childhood generally involves increasing efficiency, as in the abstraction of invariants (constant stimulus features) from the ever-changing environmental array. Both speech and color perception in children give evidence of tuning, which refers to the broadening of categories and reciprocal sharpening of boundaries between them: Zlatin and Koenigsknecht (1975) found that boundaries between speech categories sharpened between 2 and 6 years of age, and Raskin, Maital, and Bornstein (1983) found that boundaries between color categories sharpened between 3 and 4 years of age. The Gibsons (E. J. Gibson, 1969, 1982; J. J. Gibson, 1979) asserted that perceptual life begins as diffuse, and through experience differentiates, becoming ever more selective and acute. They demonstrated
increasing perceptual differentiation of form in children aged 6 to 11 years (Gibson & Gibson, 1955). Other work shows that as children age, they become better able to deploy visual information as, for example, in maintaining postural stability (Schmuckler, 1997) or navigating through space (Newcombe & Huttenlocher, 2000). In childhood, we learn to look for what is distinctive and helpful versus what is irrelevant to perception.

One aspect of perception that changes over the course of childhood, and that is linked to growth in selective attention, is the nature of dimensions that underlie perception of complex stimuli. Objects and patterns can typically be described with distinct visual dimensions such as size, color, and texture. Although adults readily select and attend to the individual dimensions that compose visual objects—say, the shape of an apple as opposed to its color—young children tend to perceive objects and patterns more holistically. This trend in development reveals itself in studies of visual classification in which participants of different ages are asked to classify patterns that vary in only two different dimensions. Whereas children younger than 5 tend to classify such patterns on the basis of their overall similarity, older children and adults are much more likely to classify patterns on the basis of either one dimension or the other (Smith & Kemler, 1977). Using similar task conditions, Mash (2006) examined children’s visual classification of object images instead of the simpler patterns used previously. With object stimuli, 5-year-olds directed their perceptual analysis to local parts, whereas 8-year-olds and adults integrated visual object elements more holistically with development. Together, such findings suggest that as children get older, they gain increasing control over the distribution of their attention to perceptual attributes.

Studies of perception in childhood offer special challenges because, for example, considerations of perceptual development after infancy are often bound up with the growth of language and cognition. From infancy to adulthood, children acquire ever-greater cognitive skill, in domains ranging from reasoning to mathematics to wayfinding. Many theorists believe that a small number of general processing mechanisms are implicated in children’s performance across a wide range of tasks (e.g., Case, 1998; Demetriou & Valanides, 1998). Such global mechanisms are not specific to particular tasks or domains but are, instead, fundamental characteristics of the developing information-processing system; good candidates include processing speed (or efficiency) and working memory. Like the speed of a computer’s central processing unit, processing speed denotes the amount of time required for a person to execute fundamental cognitive processes. As children process information more rapidly, they use working memory more effectively, which in turn allows them to solve problems and reason more successfully. Processing speed therefore influences cognitive development directly (by allowing processes to be performed more rapidly) and indirectly (by increasing the functional capacity of working memory). As children’s general processing mechanisms develop, it becomes increasingly difficult to separate how children perceive the world from how they act on it and what they know about it. Although sensory abilities may mature by puberty, more comprehensive perceptual functioning has not; young children grow continually in integrating perceptions with verbal descriptions and conceptions of the world (Pitchford & Mullen, 2003; Smith, 2003). Selective attention, visual integration of shape, and speed of visual information processing vary among children, but all nevertheless generally increase across childhood, reaching whatever their adult asymptote will be around the onset of adolescence (Gerhardstein, Kraebel, Gillis, & Lassiter, 2002; Kail, 2003).

Even seemingly straightforward studies of perceptual development often involve cognitive processes. An illustration is Lee (1989), who asked 4- to 14-year-olds simply to copy line drawings of tables. It turned out that children’s copying errors related to their knowledge that lines “represent” a table rather than to any difficulty in “drawing” lines per se. Children made few errors when copying lines when they did not know what the lines represented, but they made more errors when copying lines that were component parts of drawings of a table. In
other words, even in a simple copying task children’s cognitions influenced their perceptions. Language is likewise inextricably entangled with perception. It could be that perception precedes language developmentally and forms a basis on which language is built; or, it could be that perception depends on understanding the world, itself intimately involved with language categories and social interactions (Smith, 2003). Marks, Hammeal, and Bornstein (1987) investigated the development of cross-modal correspondences between perceptual dimensions of pitch and brightness, loudness and brightness, and pitch and size using purely perceptual and purely verbal stimuli in children aged 3½ to 13½ years. The youngest children easily matched pitch and brightness, and loudness and brightness, showing that perceptual similarities between hearing and vision are evident even to very young children, and they did so in the perceptual realm (with actual lights and tones) earlier than they did in the verbal realm (rating the word “sunlight” brighter but not louder than the word “moonlight”). Only older children, however, consistently recognized similarity between pitch and size. This difference in developmental timetables accords with the view that some similarities (e.g., pitch–brightness and loudness–brightness) are intrinsic characteristics of perception (characteristics based, perhaps, on common sensory codes), whereas others (e.g., pitch–size similarity) may be learned (perhaps through association of size with acoustic resonance properties). Consistent time lags across tasks pointed to a developmental priority of the perceptual over the linguistic system.

Alongside what appear to be biological changes that underlie perceptual development, unique experiences that children have also influence the early development of perceptual abilities. For example, off the west coast of Thailand, the island preserves of Ko Surin, Ko Poda, and Ko Phi Phi in the Andaman Sea are home to a tribe of so-called “sea gypsies,” the Moken. These people dive to harvest clams, sea cucumbers, and other marine foods. Without goggles or other aids, sea gypsy children routinely spot even the smallest shellfish. Swimming normally presents a problem for human vision because water has essentially the same density as does the fluid inside the eye, so underwater light bends as it enters the eye, resulting in the blurry vision known to all swimmers. Moken children and European children have the same visual acuity on land, but Moken children have better than twice the underwater resolving power of European children—a level of underwater acuity previously thought to be impossible in humans. Mokens shrink the size of their pupils, the round black aperture through which light enters the eye, 22% smaller than the minimum seen in Europeans. Moken apparently learn this adaptive skill in childhood and do not simply inherit it as an inborn reflex (Gislen, Dacke, Kroger, Abrahamsson, Nilsson, & Warrant, 2003).

The importance of perception to children—even older children in school—however underresearched, cannot be overestimated. Consider children’s sometimes surprising level of comprehension and interpretation of basic drawings. Constable, Campbell, and Brown (1988) investigated secondary schoolers’ understanding of biological illustrations in textbooks. Both the features of objects depicted and the number and type of conventions used posed significant difficulties for children through their adolescence. Similarly, children demonstrate significant difficulties reading maps, which has implications for wayfinding and spatial representation (Liben, Kastens, & Stevenson, 2002).

Perceptual Stability and Change in Adulthood

Perception is often thought of as stable from later childhood through adulthood, until the pesky effects of aging begin to make themselves felt. In fact, cross-sectional studies of perception show developmental continuity in some spheres, but discontinuities in others. In perceiving symmetry, for example, Bornstein (1982; Bornstein et al., 1981) found that young infants preferred and processed vertical better than horizontal better than oblique, Bornstein and
Stiles-Davis (1984) found that among 4- to 6-year-olds vertical symmetry possesses the highest perceptual advantage (e.g., in discrimination and memory), then horizontal, and then oblique, and Fisher and Bornstein (1982) also found vertical and horizontal to be special vis-à-vis oblique in adults.

The window of modifiability in perceptual adaptation appears to open early in life, so that organisms can prepare quickly, efficiently, and optimally for the particular ecology in which they develop. This is not to say that structural or functional change in maturity does not occur; special experiences can effect both structural and functional changes pertinent to perception. Gould, Reeves, Graziano, and Gross (1999; Gould, Vail, Wagers, & Gross, 2001) demonstrated hippocampal neurogenesis in the adult macaque but noted that new cortical neurons, like all new neurons, tend to have a transitory existence, perhaps related to a role in learning (Gould, 2007; Gross, 2000; Leuner, Gould, & Shors, 2006). The human brain adapts to moment-to-moment changes in experience even in adulthood and with unsuspected speed. The brain may have networks of silent connections that underlie its plasticity, and rapid reorganized responses to sensory information reflect rewiring in the brain or the growth of new connections through short-term plasticity mechanisms. The visual cortex changes its response almost immediately to sensory deprivation and to new input (Dilks, Baker, Liu, & Kanwisher, 2009). The capacity to change is a fundamental characteristic of the nervous system and can be seen in even the simplest of organisms, such as the tiny worm Caenorhabditis elegans that has only 302 cells.

One of the most intriguing questions in neuroscience concerns the ways in which the nervous system modifies its organization and ultimately its psychological function throughout an individual’s lifetime. Adults who speak tone languages (such as Mandarin Chinese) process pitch with greater accuracy than do adults who speak non-tone languages (such as English): They can repeat a word on the same note or begin a song on the same note (Deutsch, Henthorn, & Dolson, 2004), and they are more likely to possess absolute pitch (Deutsch et al., 2004). The Eguchi method is used around Japan to teach perfect pitch to very young children (claiming a success rate of almost 100 percent for those who start before they are 4 years old). At home, the parent instructs by playing the C chord a few times every day, and the child, sitting where he or she cannot see the keyboard, raises the red flag. After some weeks, a second chord and flag are added. Now the child has to raise a yellow flag for an F major chord, and the red for a C. Eventually all the white-key chords are associated with colored flags, then all black keys. The child names the chord only by its color. Training is not effective after 8. (There is a test of perfect pitch at www.acoustics.org/press/157th/deutsch3.htm.) Furthermore, language experience and early musical training appear to interact: Early trained musicians with absolute pitch are more common among speakers of tone than non-tone languages (Deutsch, Henthorn, Marvin, & Xu, 2006). Behavioral changes in function are often associated with maturation, learning, and memory; however, behavioral changes also imply changes in properties or organization of neural circuitry that underlies the behavior (Kandel, 2007). Conversely, nervous system changes induced by experience imply corresponding change in function. In order to drive a traditional black cab in London, drivers have to gain what is colloquially referred to as “the knowledge”—an intimate acquaintance with the myriad streets in a 6-mile radius of Charing Cross. Mastery can take up to 3 years of hard training, and three-quarters of those who embark on the course drop out. Taxi drivers given MRIs by Maguire et al. (2000) had a larger hippocampus compared to controls. The hippocampus is a part of the brain associated with navigation in birds and animals. Moreover, the hippocampus was larger in taxi drivers who spent more time on the job. Another example of such structural change was provided by Elbert, Pantev, Weinbruch, Rockstroh, and Taub (1995), who used magnetic encephalography (MEG) to map the somatosensory cortex of adults with and without experience of playing a stringed instrument (e.g., guitar or violin).
The area of the somatosensory cortex in musicians that represented the fingers of the left hand (the hand requiring greater fine motor learning, as it is used on the finger board) was larger than the area represented by the right hand (which is used to bow), and larger than the left-hand area in nonmusicians. Adult human brains appear to reorganize themselves based on particular experiences, in these cases musical training and taxi driving. Thus, the healthy adult human brain has the capacity for local plastic changes in structure in response to environmental experiences and demands.

Moving from purely structural change to structure–function relations that reflect specific or unique experience, Tsunoda (1985) developed a behavioral method to evaluate cerebral dominance: He asked adults to tap out a rhythm fed to one ear as he provided the other ear with a half-second-delayed variable-intensity feedback. At some intensity level, the feedback disrupts perception, and the person can no longer tap out the correct rhythm. When the two ears are compared, a performance advantage emerges for the ear with greater resistance to disruption, and ear advantage indicates contralateral hemispheric dominance. Tsunoda examined laterality for all sorts of stimuli, including many basic parameters of language. He showed that predominantly right-handed individuals possess the expected left-hemisphere processing advantage for language stimuli (e.g., consonant–vowel and consonant–vowel–consonant combinations) and the expected right-hemisphere advantage for processing steady-state vowels. With Japanese adults, however, Tsunoda found a left-hemisphere processing advantage for steady-state vowels; that is, Japanese process vowels as verbal sounds in the left hemisphere. Tsunoda also used independent electrophysiological confirmation of this hemispheric difference between Japanese and Western people. Japanese is a vowel-rich language: Like English, Japanese has five major vowels, but vowels alone and in combinations can uniquely constitute words in Japanese. For example, え means “picture,” お means “tail,” いい means “good,” and あお means “bluish”; vowels can be used as phrases and whole sentences, too: おい おおい means “concealing old age,” あおお おお おお means “he seeks love,” and おおお おおお おおお おおお means “the courageous king conceals his tail when he goes out.” Simply put, these vowels are not pure sounds in Japanese, but signify meaning, and they are processed in the language-dominant hemisphere in Japanese people. Notably, second- and third-generation Japanese speakers of foreign languages, as well as Asians of other nationalities, consistently give Western right-hemisphere patterns of responses. Thus, experience with language rewires brain dominance patterns and influences function.

In overview, changes in the cortex likely reflect the differential sensitivity and plasticity of the brain to experience, and changed cortical structures pave the way for enhanced perceptual performance in related and relevant tasks. Although the brain was once regarded as a rather static organ, it is now clear that the organization of brain circuitry is constantly changing as a function of experience. Brain structure and behavior can be influenced by myriad factors, including an unexpectedly wide range of prenatal and postnatal experiences.

**Perception in Old Age**

Many structures and functions in the body deteriorate from their peak performance in early adulthood, although not all do (Birren & Schaie, 1990; Schneider & Rowe, 1990; Stevens, Cruz, Marks, & Lakatos, 1998). Corso (1987) noted that many anatomical and physiological characteristics of the visual system decline with age; for example, the size of the useful visual field, distance acuity, dynamic and static sensitivity, color perception of blue and green, and depth perception (Fozard, 1990; Greene & Madden, 1987; Knoblauch, Vital-Durand, & Barbur, 2001; Matjucha & Katz, 1993; Sekuler & Ball, 1986). Hearing thresholds change, and in old age there is considerable hearing loss at frequencies that result in speech hearing difficulties (Strouse, Ashmead, Ohde, & Grantham, 1998; Wallace, Hayes, & Jerger, 1993).
Less than 1% of individuals 17 to 20 years of age fail to discriminate odor qualities, whereas nearly 50% of individuals 65 to 88 years of age fail to do so, and, even among the half of elderly who discriminate odors, performance in odor identification is worse than that of younger people (Doty, 1993; Schemper, Voss, & Cain, 1981). Happily, deterioration is not a rule of aging. Taste, which like smell plays an important part in enhancing the quality of life as well as in alerting us to danger, constitutes a telling contrast. Taste receptor cells have relatively short life spans and are constantly replaced; we happily retain our sense of taste in aging.

When perceptual function is observed to decline in old age, the significant question turns on cause: Is nervous system degeneration and organ impairment or diminished psychological judgment involved? Some types of poor performance in old age seem clearly to reflect underlying neural or sensory change. For example, conduction velocity of nerve fibers slows approximately 15% between 20 and 90 years of age, and simple reaction time to lights and sounds concomitantly lengthens 50% over the same period (Bromley, 1974). Some changes reflect anatomical factors. The lens of the eye grows like an onion over the course of the life span, adding layer upon layer. Each layer is pigmented, and so as the lens grows, light must traverse more and more absorptive material before it reaches the retina to be effective in vision. Lens pigment selectively absorbs short-wavelength light, causing perception of blue to systematically attenuate in old age (Bornstein, 2006, 2007). Finally, attention continues to play an important role in perception in later life. Attention is prerequisite to cognition and central to the continued success of many important kinds of behavior. Detailed studies of divided, switching, sustained, and selective attention have (with exceptions of more complex tasks) failed to support popular beliefs that older adults undergo a “global reduction in attentional resources” and that, in consequence, perceptual efficiency and cognitive processes are broadly compromised (Salthouse, Rogan, & Prill, 1984; Somberg & Salthouse, 1982). Some performance declines in old age may reflect a combination of CNS or anatomical deterioration along with adverse changes in judgment.

The question of cause leads to a caveat. Before ascribing differences in perceptual performance to aging processes per se, researchers need to take alternative factors into consideration, such as distracters and context. Moreover, beliefs about perceptual and cognitive limitations in older adults may undermine performance (Chasteen, Bhattacharyya, Horhota, Tam, & Hasher, 2005). In studying perceptual processes in the aged, investigators must always also show sensitivity to broader effects associated with age per se versus effects of specific neural or sensory disorders.

A survey of adults 18 to 100 years of age revealed that five dimensions of visual function become increasingly problematic in aging: visual processing speed, light sensitivity, dynamic vision, near vision, and visual search (Kosnik, Winslow, Kline, Rasinski, & Sekuler, 1988), and 50 years is the average age at which these visual functions begin to change noticeably (Johnson & Choy, 1987). Whatever their cause, changes in perception with aging have implications for everyday life. For example, postural stability depends on visual and auditory information processing (Tanaka, Kojima, Takeda, Ino, & Ifukube, 2001), and falls are a common hazard among the aged. Driving is another example. At night, drivers over age 60 need to be more than 75% closer to highway signs before correctly identifying them than drivers under age 25 (Sivak, Olson, & Pastalan, 1981), and older drivers are less accurate in estimating vehicular motion (Schiff, Oldak, & Shah, 1992), two of many perceptual impairments that doubtlessly factor into the rates of vehicular accidents in older drivers (Marottoli et al., 1998; Owsley, Ball, Sloane, Roenker, & Bruni, 1991). More than 20 states require drivers 70 years or older to pass vision and road tests before they can renew their licenses. Happily, Fozard (1990) pointed out that many perceptual failings of old age are amenable to remediation (with eyeglasses, training, and so forth).
The Life Span Approach to Perception

Insofar as life-span study, as a comprehensive approach to development, entails its own theories and methods, life-span approaches of perceptual development do the same. Some (nurture) theories propose that perceptual development reflects primarily changes in knowledge and experience over the life course (Roth, 1983), whereas other (nature) theories point to life-span changes in biological mechanisms (Kail & Salthouse, 1994; Salthouse, 1991). In addition, both these theories of life-span perceptions point to \( \sim \) shaped efficiency and performance functions, development being most active early and late in the life cycle (Brodeur, Trick, & Enns, 1997). However, one can reasonably expect that specific perceptual structures and functions will follow a diversity of developmental trajectories over the life course.

The questions often asked after infancy are also normally specific to a target age group such as school-age children or teens. As a result, a cohesive story of perceptual development across the entire life span is often difficult to piece together. One notable exception is face perception, a topic that has been investigated in infants, children, and adults alike. From the earliest moments of life, infants respond to face-like stimuli differently from other stimuli (Johnson & Morton, 1991). For example, newborns will follow a schematic face farther than a scrambled face (Johnson, Dziurawiec, Ellis, & Morton, 1991), suggesting that there is something special about facial structure. By 3 days of age, infants recognize the face of their mothers based on visual cues alone, even if they have seen the mother for as little as 5.5 hours during those 3 days (Bushnell, 2001), and newborns show a preference for attractive faces (Quinn & Slater, 2003). As human babies grow (and improve in their acuity), the internal features of faces become more prominent (Turati, Macchi Cassia, Simion, & Leo, 2006). Five-month-old infants can discriminate between a face with typical spacing of the eyes and the eyes and mouth from a face with exaggerated spacing between features (Bhatt, Bertin, Hayden, & Reed, 2005). The privilege for face-like stimuli continues throughout development, and specific deficits in face processing, but not in the processing of other objects, are linked to damage in specific neurological regions (Hadjikhani & de Gelder, 2002). This pattern across the life span has led some to suggest that face processing is in some way different from the processing of other objects due to either an innate mechanism or quickly learned expertise (e.g., Farah, Rabinowitz, Quinn, & Liu, 2000; Gauthier & Nelson, 2001; Johnson, Chapter 4, this volume). The ability to recognize facial identity is critical to culturally appropriate responses to kin, same-gender versus opposite-gender strangers, and so forth (Werker, Maurer, & Yoshida, 2009). At the same time, we need to be skilled at recognizing and discriminating facial expressions, which even young infants are (Bornstein & Arterberry, 2003), as well as other changeable aspects of the face, such as direction of gaze and sounds being spoken that transmit socially relevant information such as threat and acceptance (Johnson, Chapter 4, this volume; Werker et al., 2009).

The study of face perception across the life span has revealed both developmental continuities and discontinuities. One example of continuity has to do with configural face perception. When we look at a face we process many features in relation to each other, called configural or holistic processing (e.g., the nose in relation to the brow), rather than each feature in isolation (e.g., just the nose). One way to test whether a stimulus is perceived configurally or featurally is to present the stimulus upside down. Inverted presentation has all the same features but disrupts configural processing. For example, adults’ reaction time and accuracy suffer when they must recognize upside-down faces, and these are much larger differences than are seen for upside-down objects (Freire, Lee, & Symons, 2000; Malcolm, Leung, & Barton, 2005; Mondloch, Geldart, Maurer, & Le Grand, 2003; Mondloch, LeGrand, & Maurer, 2003). Infants, children, and adults process faces configurally rather than featurally: Even if there are slight differences among children and adults in the degree to which a face is processed
configurally, when familiarized to upright faces all age groups show better recognition when tested with upright faces than with inverted faces (Mondloch, LeGrand, & Maurer, 2002; Cashon & Cohen, 2004). Configural face processing appears to be tuned by peoples’ experience with upright faces. Adults are more sensitive to spacing differences in human than in monkey faces even when the physical differences are identical (Mondloch, Maurer, & Aloha, 2006).

An example of discontinuity in development pertains to perceptions of gender and ethnicity in faces (Kelly et al., 2007; Leinbach & Fagot, 1993). Infants and young children have difficulty perceiving the gender of faces when superficial cues such as hair, makeup, and clothing are removed or covered (Leinbach & Fagot, 1993; Poulin-Dubois, Serbin, Kenyon, & Derbyshire, 1994). Adults, in contrast, are quite good at determining gender (or other facial indicators) relying only on subtle differences in the structure of the face (Bruce et al., 1993), and the most useful cue appears to be the distance between the eye and the eyebrow (Campbell, Benson, Wallace, Doesbergh, & Coleman, 1999). It is not surprising that young children may not home in on this cue for determining gender because they may not yet have achieved gender constancy, which depends on the irrelevancy of superficial features (e.g., you are still female if you have short hair). Development of gender perception may also require a certain level of experience once gender constancy is achieved. Children do not reach adult levels of expertise in recognizing individual faces until adolescence (Bruce et al., 2000; Mondloch et al., 2002, 2003). For example, up to at least 10 years, children are not as good as adults at recognizing a face previously seen from a different point of view (Mondloch et al., 2003). Moreover, even adolescents differ from adults in how they read emotional expressions on a face as well as in the parts of the brain underlying that reading. Yurgelun-Todd (2002) scanned teens and adults using fMRI at the same time as she asked them to report about the emotion on a series of faces. Adults identified one emotion as fear, but many teenagers saw something different, such as shock or anger. Adults also used a recently evolved brain system, the prefrontal cortex, which plays a role in self-regulation. Teenagers use a different part of their brain when reading the images. Teens activated the amygdala, a brain center that mediates fear and other “gut” reactions, more than the frontal lobe. (Among older and older teens, brain activity during this task shifted to the frontal lobe.)

Next, we consider the roles of biology and experience in perceptual development more broadly.

THE ROLES OF BIOLOGY AND EXPERIENCE IN PERCEPTUAL DEVELOPMENT

All human beings are believed to be endowed with roughly the same perceptual anatomy and physiology, so it is reasonable to expect that most perceptual structures or functions are essentially universal and that all human beings begin life on much the same perceptual footing. How do varying experiences, say rearing circumstances, influence perceptual development? In many ways our perceptual systems appear to be unperturbed by normal (if large) variation in environmental stimulation. For example, children and adults from rural villages in New Guinea (Kennedy & Ross, 1975), Ethiopia (Deregowski, 1977), and Ghana (Jahoda, Deregowski, Ampene, & Williams, 1977), where representational arts were unknown, reportedly identify or recognize immediately two-dimensional realistic representations of three-dimensional objects. Infant studies support this nativist view (Dirks & Gibson, 1977), as does a study of a 19-month-old Western child whose parents exposed him to and named a wide variety of toys and other solid objects, but who was never told the name or meaning of any picture or depicted object and was generally deprived of seeing pictures (Hochberg & Brooks, 1962). When first tested at almost 2, the child could recognize objects portrayed by

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two-dimensional line drawings and photographs. In addition, some functions are stable across the life span (such as visual search; Plude, Enns, & Brodeur, 1994), and perceptual features might universally affect other cognitive processes. For example, Malt (1995, p. 117) reviewed evidence to show that many cultures spontaneously categorize entities into recognizable life-form groups (e.g., mammals, fish, and birds) on the basis of their “universal, perceptual features.”

As noted earlier, spatial processing is a core component of visual perception, and researchers have documented numerous age-related improvements in the spatial processing of visual information (e.g., Newcombe & Huttenlocher, 2000; Piaget, 1954). The most explicit accounts of development in this domain have come in the form of neural field models that specify how spatial accuracy in visual processing varies with interactions among layers of neural fields (e.g., Simmering, Schutte, & Spencer, 2008). Consistent with some of the same core assumptions, Mash, Quinn, Dobson, and Narter (1998) found that physical maturation of the visual system accounted for group differences in infants’ perceptual organization of spatial relations, while group differences in postnatal visuospatial experience did not convey a measurable effect on performance. Other discussions of maturational effects on visual perception have been motivated by the neurophysiological finding that cortical visual streams segregate in processing an object’s identity versus its affordances for action (e.g., Milner & Goodale, 1995). If different pathways process different aspects of the visual environment, different processing capacities may differ in developmental status (Bertenthal, 1996; Mareschal & Johnson, 2003).

There can be little doubt, however, that experience, or a lack thereof, also plays important roles in maintaining, facilitating and attuning, and inducing sight, hearing, smell, taste, and touch. Some perceptions are plastic to experience, and we consider several examples.

**Individual Experience: Binocular Disparity Sensitivity, Configural Processing, and Categorization**

Binocular disparity sensitivity underlies binocular depth perception, as described earlier. The onset of sensitivity to binocular disparity in children in the United States occurs on average between 14 and 16 weeks of age (Fox et al., 1980; Held et al., 1980). To more clearly understand the development of binocular disparity, Held and his colleagues (Birch, Gwiazda, & Held, 1982; Held et al., 1980) measured disparity sensitivity in infants each week between 10 and 30 weeks of age. The onset of disparity sensitivity is shown in Figure 6.10 for 16 children. Several patterns emerge in these individual graphs: (a) onset of sensitivity is typically rapid, (b) onset occurs at different times for different infants, and (c) at least one infant (see JG) does not begin by 30 weeks. Combining this work with knowledge of development of anatomical structures, the development of disparity sensitivity appears to be a biologically programmed process that is reliant on a specific type of experience, namely, fusion of the two eyes. Without this type of experience within a particular time period, the neural structures for binocular vision do not develop and binocular sensitivity is compromised (e.g., Banks, Aslin & Letson, 1975; Gwiazda & Birch, 2001). A similar longitudinal assessment of sensitivity to pictorial depth cues was conducted by Yonas, Elieff, and Arterberry (2002). Their results revealed variation in the age of onset of depth perception specified by texture gradients and linear perspective, which also suggests a role for experience in the onset of this type of depth information.

Maurer, Lewis, Brent, and Levin (1999) examined the time course of experience in the development of visual acuity by studying infants who were deprived of patterned visual input because they were born with a dense cataract in one or both eyes. Following an average of 3.7 months of visual deprivation, these infants were surgically treated by removal of the affected
lenses and by insertion of contact lenses that enabled them for the first time to focus images on their retinas. Tests of visual acuity that were administered within 10 minutes of initial insertion of the new lenses revealed newborn-like acuity among all infants regardless of age. Remarkably, follow-up tests revealed modest but very reliable improvement in visual acuity after just 1 hour of focused visual input. Children who were finally treated after years of delayed visual input could recognize facial expression, follow direction of eye gaze, and identify faces; these tasks all relied on featural processing (Geldart, Mondloch, Maurer, de Schonen, & Brent, 2002; Le Grand, Mondloch, Maurer, & Brent, 2001). However, children treated for bilateral congenital cataracts did not develop configural face processing (Le Grand, Mondloch, Maurer, & Brent, 2004), and they were poor at detecting differences in visual acuity.


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between faces in the spacing of features and recognizing the identity of a face across changes in orientation (Geldart et al., 2002; Le Grand et al., 2001; Le Grand, Mondloch, Maurer, & Brent, 2003). Early visual experience appears to be required for the later development of configural face processing. A final example of the effects of individual experience on face processing illustrates an enhancement rather than a degradation in perception. Children who have been abused and live in homes with high levels of anger and physical violence are faster in recognizing anger than those who have not been abused. Moreover, the speed of recognizing anger is correlated with the level of anger or hostility in the child’s environment (Pollak, Messner, Kistler, & Cohn, 2009).

In addition to its sustaining effects in basic sensory processes, infants must also utilize visual experience to form stable representations of the objects and object kinds that they encounter in routine daily life. A large number of studies have demonstrated infants’ ability to perceptually categorize exemplars of familiar classes, but very few have controlled infants’ actual experience with exemplars prior to their participation in laboratory tasks. Bornstein and Mash (in press) used novel stimulus objects comprising two shape/color categories in a study of 5-month-olds’ perceptual categorization. One group of infants was shown images of the objects from one category or the other every day at home for 2 months prior to participating in a laboratory categorization task with the same objects. Another group of infants participated in the laboratory task without the prior stimulus experience at home. Although infants in both groups categorized the stimuli, only those in the second group demonstrated any category learning during the task. Infants in the first group categorically organized the experience they had acquired at home, and utilized it systematically in a novel context outside their home.

Cultural Experience: Audition and Speech Perception

Some of the most interesting examples of cross-cultural research informing us of nature–nurture influences on perception come from the auditory and speech perception literatures. We consider two examples, one focusing on hearing loss in the elderly and one on speech perception early in life.

Audition and aging. Auditory sensitivity (as we learned earlier) is measured by assessing absolute thresholds for sounds of different frequencies. In aging, deterioration in auditory sensitivity is common: In essence, elderly people require more energy to hear certain frequencies than do younger people. As Figure 6.11A shows, among Americans hearing loss in aging is more pronounced at higher frequencies. One prominent and straightforward explanation for this finding has been that aging entails the natural and regular deterioration of anatomical and neural mechanisms that subserve hearing. An alternative hypothesis is that exposure to noise over the course of the life span cumulates and deleteriously affects perception of high frequencies. How can these nature and nurture explanations be adjudicated?

Additional data help; first, from individuals in cultures with other noise histories and, second, from individuals in American society who have contrasting life histories of exposure to noise. As Figure 6.11B shows, older American women experience less hearing loss than do older American men; and Sudanese Africans, who show no gender differences in hearing with age, sustain less hearing deterioration than do Americans of either gender. It could be, however unlikely, that genders and races differ biologically in the integrity or susceptibility of their auditory apparatuses to aging. However, contrary to the initial biological deterioration hypothesis, gender and culture data suggest that physiological aging alone is probably not the sole factor in hearing loss. The data on elderly American men exposed to different amounts of noise over the course of their lifetimes further support an interpretation rooted in experience.

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Findings from this third research source—effects of noise history—reinforce the view that hearing loss in old age perhaps relates more to level of exposure to noise and less to natural physiological deterioration, just as cultural experience affects perception by improving processing of faces from one’s own ethnic group than those from other groups. The three research programs together supplement the original descriptive evidence with explanatory evidence and invest greater credence in nurture. Of course, the fact that noise history selectively affects high frequencies indicates that nature and nurture interact. Indeed, Tokyo police...
have availed themselves of this fact to fight crime. In Kitashikahama Park in Adachi Ward, neighborhood teenagers, probably from a local junior high school, were defacing property. Authorities rented a British-made Mosquito MK4 Anti-Vandal System and screwed it into a wall not far from park toilets. The device emits a high-pitched, highly irritating whine that has a frequency above 17,000 Hz. Most adults cannot hear it, but teens can. Seven days a week, the whining begins at 11 p.m. and continues until 4 a.m. Video surveillance cameras that monitor park buildings attest that Kitashikahama Park empties out.

**Infant speech perception.** Another illustration of the ways nature and nurture interact in perceptual development is provided by a single perceptual domain in which multiple pathways of development have been explored. This domain is a narrow but important one in speech perception (Saffran et al., 2006).

Sounds are essentially different sine-wave frequencies produced simultaneously, and speech is the complex array of different frequencies produced at different intensities over time. Spoken language abstracts particular subsets from the universe of all possible speech sounds (phonetics) and invests some with meaning (phonemics). One dimension along which certain phonemes in many languages are distinguished is their voicing. Differences in voicing are perceived when a speaker produces different frequencies of sound waves at slightly different times. In voicing, a sound like /b/ (pronounced “ba”) is produced by vibrating the vocal cords and producing higher frequencies before or at the same time the lips are opened and low-frequency energy is released—/b/ is a voiced phoneme. By contrast, for sounds like /p/ (pronounced “pa”) the vocal cords do not begin to vibrate higher frequencies until some time after the lips release lower frequencies—/p/ is a voiceless phoneme. Thus, high-frequency components of a sound may precede low-frequency components, low- and high-frequency components may begin simultaneously, or high-frequency may follow low-frequency. The relative onset times of low and high frequencies cue phonemic perceptions. Physically, the relative onsets of low- and high-frequency components of a sound vary continuously with time; however, adults perceive differences in voicing more or less categorically. That is, although we can distinguish many differences in relative onset times of low- and high-frequency sounds, we classify some different sounds as equivalent while discriminating others. English distinguishes voiced–voiceless /b/–/p/. Of course, different people say /b/ and /p/ in different ways; yet adult listeners seldom misidentify particular speech sounds, as they employ implicit category definitions to allot a given sound to either the /b/ or the /p/ category. Cross-language research has revealed that adults hear one, two, or at most three categories of voicing: prevoiced, voiced, and voiceless. Categorical perception means that, across a nearly infinite spectrum of minute discriminable possibilities, only a small number are functionally distinguished, and they are distinguished by nearly all peoples despite wide language differences.

Many researchers speculate that phenomena so ubiquitous, consistent, circumscribed, and significant in human behavior as perceptual categories of speech sounds might have a biological foundation. To test this assumption, Eimas, Siqueland, Jusczyk, and Vigorito (1971) sought to discover whether preverbal human infants perceive acoustic changes in voicing categorically, that is, in a manner parallel to adult phonemic perception. These investigators arranged to ask infants some simple same–different questions about their auditory perceptions using the habituation–recovery paradigm. They found that 1- and 4-month-olds behaved as though they perceived speech sounds in the adult-like categorical manner: Babies distinguished examples of /b/ from /p/, but not examples of two different /b/bs. That is, babies categorize variations of sounds as either voiced or voiceless long before they use language or presumably have extensive experience in hearing language. This result seemed to suggest that categorical perception is innate. Returning to Figure 6.1, it would seem that

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categorical perception of phonemes closely fits the topmost developmental function: It is fully
developed at the onset of experience and might require language experience for maintenance
purposes only.

However, the experiment does not conclusively rule out roles for maturation or experience
in perceptual development. After all, the infants who participated in the Eimas experiment
were born into monolingual English-speaking families in which the voiced–voiceless distinc-
tion they discriminated is common (as in baby vs. papa), and fetuses hear and process sounds
from outside the womb (e.g., DeCasper & Spence, 1986) so that even 1-month-old babies
have months of experience with the language. In a follow-up study, monolingual English or
Spanish newborns were examined using a procedure in which their sucking controlled how long
English or Spanish language was played to them (Moon, Cooper, & Fifer, 1993); During the
last 6 minutes (of 18 minutes), the infants sucked more to hear their native language
than the nonnative language. This is evidence for an experience-specific newborn preference.
Newborns (up to 4 days old) also prefer to hear their mother’s voice (Decasper & Fifer, 1980), a
preference that likely reflects prenatal exposure and learning because it is selective to the
mother’s, not the father’s or a stranger’s, voice (Kisilevsky et al., 2003). It could be that
categorical perception is partially developed at the onset of experience and then its continuing
development is facilitated or attuned by early experience. This is the middle course in
Figure 6.1. It could even be that categorical perception is undeveloped until the onset of
experience, and that experience in hearing language over several months of prenatal devel-
opment and months of postnatal development quickly induces these sophisticated auditory
perceptions, following the bottom course in Figure 6.1.

Although surveys of the world’s languages show that only three categories of voicing are
common, not all languages use all categories. Eimas et al. (1971) tested only an English-
language category in their babies. Several researchers have since provided data indicating that
infants born in different places possess some or all of the same categories, although the adults
in their cultures do not. Lasky, Syrdal-Lasky, and Klein (1975) found that 4- and 6-month-
olds in Spanish-speaking (Guatemalan) monolingual families discriminated the English
voice–voiceless sound contrast that is close to, but not the same as, the Spanish one. Likewise,
Streeter (1976) found that Kenyan 2-month-olds from families that speak Kikuyu categorized
the English voicing contrast that is not present in Kikuyu as well as a Kikuyu prevoiced–
voiced contrast that is not present in English. Spanish- and Kikuyu-speaking adults perceive
(although they do not use) the universal English voicing contrast, but they perceive it only
weakly. The phoneme inventory shows other differences among languages. Young Japanese-
learning infants can discriminate contrasts that are used in English but not in Japanese; young
English-learning infants can discriminate consonant contrasts that are used in Czech, Hindi,
Nthlakampx, Spanish, and Zulu (Werker et al., 2009).

The rise or persistence of perceptions, even in the absence of relevant experience, probably
reflects their foundation in the natural, resilient psychoacoustic properties of the auditory
system. Perhaps general experience with the wide range of sounds produced in the natural
environment is sufficient to maintain sensitivities that are native to the perceptual apparatus.
By the end of the first year of life, long before many infants have even acquired their first
word, speech perception capacities have been modified to match the properties of the sound
structure of the native language. Nor are these kinds of effects unique to speech. Infants and
adults are noticeably better at recognizing a face if the face is from their own ethnic group
than from another ethnic group (e.g., Kelly et al., 2007; Meissner & Brigham, 2001), and this
effect obtains for Africans, Japanese, Koreans, Chinese, East Indians as well as European
Americans and African Americans. The effect appears to be the product of experience with
faces from other ethnic groups, and its strength depends on the level of exposure to people of
other ethnicities (Hancock & Rhodes, 2008).

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Conclusions. The influences of nature and nurture are integrally entwined. Yet assessment of their differential contributions is critical to understanding the life-span ontogeny of perceptual processes. An additional benefit of developmental investigations derives from information they afford regarding prevention: In the auditory illustration, whereas descriptive evidence alone strongly implicates biological deterioration, alleviation might best be achieved, for example, through specialized hearing aids for the elderly; the explanatory evidence, which derives from diverse biological and experiential comparisons in development, points to more productive intervention strategies that would effectively obviate sensory deterioration and hearing loss in the first place.

Such research also will determine the limits of a specific ability’s plasticity as well as which experiences are most influential in its expression. Overall, our physical and perceptual experiences appear sufficiently common to render our perceptions more or less similar. When contingencies vary sufficiently, however, perceptions are sure to follow (Cole & Packer, Chapter 2, this volume).

Differential cultural experience has even been found to affect children’s and adults’ understanding of perception itself (Lillard, 1998). In the European American weltanschauung, people are believed to possess five senses (sight, hearing, smell, taste, and touch), each sense providing a different kind of information about the world. Even European American children know this by age 3, asserting, for example, that to know a toy dinosaur is red they would have to see it (Pillow, 1989). Not all cultures subscribe to this European American view: The Hausa (Nigeria) linguistically mark only two senses: Gani refers to sight only and is not used to denote knowing or understanding, and Ji refers to hearing, smelling, tasting, and feeling in the sense of knowing (Ritchie, 1991). These must be cultural differences in emphasis because Hausa certainly distinguish the smell of cooking from hearing an airplane overhead. Cultures also vary in terms of how they rank the senses: Vision predominates among European Americans, but for the Ongee (South Pacific) olfaction predominates (Pandya, 1987, as cited in Lillard, 1998), for the Hausa taste is the most important sense (Ritchie, 1991), and for the Suya (Brazil) hearing is: European Americans say “I see” to mean “I know” or “I understand,” whereas the Suya say “I hear” (Seeger, 1981). Again, the different preferences are likely a matter of different cultural emphasis, rather than perceptual ability or acumen (although they might be), and this cultural variability moves us away from biological determinism.

CONCLUSIONS

We take in information from the world through our senses, and we begin to make sense of the world through our perceptual systems. Perception is among the oldest and most venerable fields of study in psychology and among the most closely tied to psychology’s origins in philosophy. Studies of infancy constitute the bulk of research in perceptual development, and studies of perceptual development have in the past constituted the bulk of research on infancy. However, perceptual development is a lifelong process, even if much of perceptual development in childhood and after is bound up with more comprehensive and overarching developments in cognition. Human beings begin life with perceptual capacities primed to acquire information and knowledge that is requisite to survive in their ecology. Specific experiences interact with developing sensitivities to induce, maintain, or attune perception to optimally match those ecological requirements.

In recent years, the perceptual secrets of infants and young children—formidable and intractable as they once seemed—have given way to a variety of ingenious procedural techniques. Research shows that even the very young of our own species perceive beyond simply

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sensing. But several traditional and important questions about perceptual development are still open, left unanswered even by the wealth of research amassed in recent decades. Moreover, many startling revelations that spring to mind even from our simplest introspections continue to spark curiosity about perceptual development. How do we move so effortlessly from sensing patterns received and transduced at the surface of the body to perceiving objects and events in the real world? How is a world that is constantly in flux perceived as stable? As context is so influential in perception, how does selective attention to signal and figure develop in coordination with selective elimination of noise and ground? How do perceived objects come to be invested with meaning?

The development of perceptual capabilities should not be viewed as isolated events. The study of perceptual development naturally spills over into studies of neural, motor, cognitive, language, emotional, and social development, as chapters in other parts of this textbook attest. Perception needs to be understood in terms of a systems model, that is, a unifying conception of different components mutually influencing one another (Thelen & Smith, 1994). Development in this perspective is dynamic in the sense that the organization of the system as a whole changes with maturity and the acquisition of new experiences. Moreover, as one subsystem emerges, the change brings with it a host of new experiences that influence and are influenced by changes in related systems. Thus, change is not only dynamic but also thoroughgoing, taking place at many levels in the system and affecting many other levels of the system at the same time.

The study of perception across the life span has widely acknowledged practical implications, in its relevance to social and emotional development and to education and medicine. Physical and social stimulation are perceptual stimulation, and many aspects of emotional and social development depend initially on perceptual capacity. Specific examples abound—from the neonate’s perception and consequent ability to read facial expressions (Bornstein & Arterberry, 2003) to the toddler’s acceptance of photographs to mediate separation stress from parents (Passman & Longeway, 1982) to the role of attention and perceptual interpretation in normal personality (Achenbach, 1992; Enns & Burak, 1997).

In the past, experimental traditionalists have expressed reluctance at adding a developmental perspective to the formal study of sensation and perception, psychophysics, and the like—developmental science often being treated as a different field—and the experimental study of sensation and perception was confined largely to adults and to infrahuman animals. Today, research progress with infant, child, and aged populations demonstrates the broadly informative contribution of the developmental view. Knowledge of the developmental perspective is now regarded as essential by all enlightened students of perception.

Perceptual development could serve as a model of developmental studies, one as good as that of any field described in this textbook. It encompasses important questions of philosophy and methodology, and it confronts all of the overarching theoretical and empirical issues in developmental study. Some perceptual capacities are given congenitally and function stably with growth, whereas other perceptual capacities develop and change from infancy through maturity. This ontogenesis, in turn, has several possible sources: Development may be genetically motivated and transpire largely on the élan of maturational forces, or it may be experiential and in the main respond to the influences of the environment and of particular life events. At one time or another, the éclat of each of these possibilities has been championed. Modern studies have informed a modern view, however, that perceptual development doubtlessly reflects the complex transaction of a diversity of biological and experiential forces. Through their systematic efforts at studying perception from infancy through maturity, developmental scientists have determined that basic mechanisms help to impose perceptual structure, but that perceptual development is also determined and guided by a transaction of these structural endowments with self-constructed or environment-provided experience.
Thus, neither nativism nor empiricism holds sway in contemporary views of life-span perceptual development; rather, biology and experience co-determine how we first come—and continue—to perceive the world as we do.

REFERENCES AND SUGGESTED READINGS


6. PERCEPTUAL DEVELOPMENT


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