ommended Readings

Sociocultural Theories of Development


ain, M. (2001). The social context of cognitive development. New York: Guilford. Guavin argues that social processes involved in the mechanisms of learning, she reviews evidence for this position in the domains of attention, memory, problem solving, and planning.


omasello, M. (1999). The cultural origins of human cognition. Cambridge, MA: Harvard University Press. Tomasello argues that humans possess a unique ability for cultural learning, and that this ability allows them to pool their cognitive resources with other members of their social group.


A 4-month-old girl is shown two movies with their screens side by side. In one movie, a woman is playing peekaboo. She repeatedly hides her face with her hands, uncovers it, and says, “Hello baby, peekaboo.” In the other movie, a hand holds a stick and rhythmically strikes a wood block. The experimenter plays either the sound track with the woman saying “peekaboo” or the sound track with the drum beat, but not both at the same time.

Somehow, the 4-month-old knows which sound track goes with which visual sequence. She demonstrates this knowledge by looking more at the screen that displays the movie that goes with the sound track than at the screen showing the other movie.

Spelke (1976) found that almost all 4-month-olds behave as the girl in this story did. Of the 24 infants she tested, 23 looked for more time at the screen with the appropriate video accompaniment than at the alternative. Apparently, even in their first half year, infants connect sights and sounds in meaningful ways.

This example is representative of current findings about perceptual development in a number of ways. The children in the study were less than 6 months old. The investigator used a simple experimental procedure, yet asked a fundamental question about human nature: Are infants able to integrate sights with sounds from very early in life? The results of the study showed greater perceptual abilities in young infants than might have been expected.
This chapter has two central themes. First, perceptual functioning reaches adultlike or near-adultlike levels remarkably rapidly. Even newborns can see, hear, and integrate information from different sensory systems, and these abilities continue to develop rapidly during the first year. Second, perception and action are closely connected, and this connection is present from infancy. Perception provides children with information that they use to guide actions, and actions generate perceptual information for the developing child.

**Perception and human nature.** The study of perceptual development raises fundamental questions about human nature. How does biological inheritance contribute to the ways in which people perceive the world? How does experience contribute? Above all, how do biological and experiential factors interact?

Empiricist philosophers such as John Locke and George Berkeley suggested that perceptual abilities are learned. Infants might at first experience the world in terms of isolated lines and angles. Gradually, they learn that these lines and angles constitute objects. Later still, they learn to infer properties of the objects, such as how far away they are, by noting the relation between how the objects look and how long it takes to crawl or walk to them. The impoverished initial endowment that these philosophers envisioned led the great early psychologist William James (1890) to hypothesize that infants experienced the world as a "great blooming, buzzing confusion."

Other theorists, such as J.J. and Eleanor Gibson (e.g., E.J. Gibson, 1969; E.J. Gibson & Pick, 2006; J.J. Gibson, 1979), hypothesized that perceptual abilities that are essential to survival are built into the infant. They noted that, like all animals, humans evolved in an environment of objects and events, and they need to perceive these objects and events accurately to survive. Further, survival requires that animals' actions be guided by their perceptions. For example, children might need to perceive whether the terrain in front of them can be walked on (solid ground) or not (water or a cliff), so that they can choose an appropriate and safe action. Therefore, the Gibsons hypothesized that perception and action are closely linked.

The Gibsons' theory did not focus solely on biological factors—they also emphasized the importance of learning in perceptual development. In their view, perceptual learning is a process of learning to detect information that is available in the environment. With experience, there are changes in infants' abilities to detect and interpret such information. At the same time, as infants develop, there are changes in the actions that they need to perform and in the movements that they can make. Thus, the Gibsons' view of perceptual development recognizes both biological and experiential factors, and emphasizes the linkage of perception and action throughout development.

Subsequent research has revealed a picture much more like that posited by the Gibsons than like that proposed by the empiricists. Even in the first months, infants seem to experience a world of objects and events that is similar in important ways to that experienced by adults (Kellman, 1988; Slater, Mattock, & Brown, 1990). All current theories recognize that people are biologically prepared to perceive the world in certain ways, and that many important perceptual capabilities are present at birth. All current theories also recognize that experience contributes to the development of perceptual abilities.

Subsequent research also has supported the view that perception and action are closely connected from the beginning of life (e.g., Bertenthal, 1996; Bertenthal & Clifton, 1998; Thelen, 1995). For example, when infants see a ball rolling in front of them, they sometimes move their hands to intercept it. Rather remarkably, they reach not where the object is when they begin the reach, but rather toward where it will be by the time their hands arrive (von Hofsten, 1993).

The linkage between perception and action is evident at the neurophysiological level as well as at the behavioral level. The visual system includes two main subsystems. One, the *ventral system*, which carries information in large part to the temporal cortex of the brain, is specialized for recognizing and representing the visual world. The other, the *dorsal system*, which carries information largely to the parietal cortex, is specialized for using perceptual information to guide action (Goodale & Milner, 1992; Milner & Goodale, 1995). Aspects of both systems are functional in the first half year of life (Johnson, Mareschal, & Csibra, 2001).

The linkage between perception and action makes complete sense if one thinks about why we perceive the environment in the first place. For any organism that moves, perception provides the information needed to act effectively in the environment. It allows us to stay in touch with a constantly changing world. There is a reason why plants don't see anything; it would do them no good because they cannot move beyond the limits of their roots anyway. In contrast, for animals that can move, sensory systems such as vision and hearing help meet the basic needs of obtaining food and avoiding predators.

**The task of perception.** We perceive the world through a number of sensory systems: vision, audition (hearing), gustation (taste), olfaction (smell), and a few others. Regardless of the particular sense being considered, however, the task of perception can be thought of in terms of the need to accomplish three functions: attending, identifying, and locating. **Attending** involves determining what in a situation is worthy of detailed processing. **Identifying** involves recognizing what we are perceiving. **Locating** involves specifying how far away the perceived object or event is and in what direction relative to the observer. All of these functions are performed with the goal of effectively guiding action.

An example may help to highlight the distinctions between and interrelations among the three functions. If you are in a jungle and a tiger is charging, you need to orient your attention toward the tiger, to identify it as a tiger, and to locate how far away it is. A blur of motion in the periphery of the eye might stimulate initial attention to the tiger. More careful and focused attending would
presumably follow, leading to identification of the moving object as a tiger. Yet more careful attention would follow, specifying the location of the tiger as nearby and rapidly approaching. Information gained through attending, identifying, and locating would then be used to inform a decision about whether to climb a tree, hide, or pray. Thus, attending, identifying, and locating all serve the goal of guiding an appropriate course of action.

Although people perceive the world through a number of senses, we rely most heavily on sights and sounds. Therefore, this chapter focuses primarily on the development of vision and audition (hearing), as well as on the ways in which information from these and the other senses is integrated. The final section focuses on how perceptual information is used to guide action. The chapter focuses primarily on infants and toddlers, because many of the most important changes in perception occur very early in development. The chapter’s organization is outlined in Table 5.1.

### TABLE 5.1 Chapter Outline

| I. Vision |
| A. Attending to Visual Patterns |
| B. Identifying Objects and Events |
| C. Locating Objects |

| II. Hearing |
| A. Attending to Sounds |
| B. Identifying Sounds |
| C. Auditory Localization |

| III. Intersensory Integration |
| A. Attending |
| B. Identifying Objects and Events |
| C. Locating |

| IV. Chronological Summary |

| V. Perception and Action |
| A. Perception Guides Action |
| B. Actions Generate Perceptual Information |

| VI. Summary |

### Vision

To understand the development of visual perception, it is helpful to understand a little about the mature visual system. Visual perception ordinarily originates with light being reflected from, or emitted by, an object in the environment. The light impinges on the eye and progresses through the cornea and pupil to the lens (Figure 5.1). The lens bends the light rays to project a focused image on the light-sensitive retina behind it. Change in the shape of the lens that brings the object into focus is known as accommodation.

The retina includes two types of photoreceptor cells (receivers of light): the rods and the cones, which are so named because of their shapes. The cones are concentrated in the fovea, which is a small, approximately circular area near the center of the retina, where vision is the most acute. The cones respond differently
to different wavelengths of light, and comparing the outputs of different types of cones enables color vision. Cones require relatively strong stimulation, so they are used primarily for day vision. In contrast, the rods are responsive even in dim light, so they are used for night vision. The rods are located in the periphery of the retina, and they are absent from the fovea.

From the retina, information is relayed to the brain by way of the optic nerve. The visual cortex of the brain registers the information and integrates it with previous information to form a representation of the visual scene.

This description provides the framework within which visual development occurs. But it also leaves open many questions. For example, is the development of visual perception primarily due to changes in the eye or to changes in the parts of the brain that process input from the eyes? Does the early immaturity of the brain mean that subcortical structures within the visual system (the retina, optic nerve, midbrain, etc.) initially play a larger role in perception than they will later? Is perception direct, in the sense of depending only on currently perceivable stimuli, or do previously formed memories also influence it?

Although people have long wondered about these questions, only recently has substantial progress been made in answering them. One important reason for this recent progress is the development of experimental methods that allow infants to demonstrate their visual competence. Infants cannot verbally describe how they see the world. They also cannot follow instructions, thus ruling out almost all conventional methods for studying perception in adults and older children. To learn about infants' perceptual capacities, then, it was essential to identify some behavior that reflected the capacities. An incredibly mundane-seeming behavior—eye movements—provided the key to revealing the perceptual world of the infant. Infants move their eyes and turn their heads to look directly at what interests them. Such actions are based on perception, because perceptual information is used to identify objects that might be worth a closer look.

Researchers have developed two primary methods for studying infant visual perception, and both capitalize on the fact that infants turn their heads toward what interests them: the preferential-looking paradigm and the habituation paradigm. In the preferential-looking paradigm, two objects or events that differ in only one way are displayed side by side, and the researcher examines whether infants consistently look more at one of them. If they do, they must perceive the difference. For example, if infants are repeatedly shown a red ball and an otherwise identical gray one, and they consistently look at the red ball, they must perceive the difference in color.

The habituation paradigm is based both on infants' propensity to look more at objects that interest them and on the fact that, like older individuals, infants grow bored with objects that are presented repeatedly. The paradigm includes two phases. First is the familiarization phase, in which an object is presented repeatedly. When infants no longer look at it much, a new object that differs in some specific way is introduced. If infants show renewed interest in the new object, they must perceive a difference between the two. These simple methods have allowed researchers to make great progress in answering fundamental questions about how infants perceive the world.

**ATTENDING TO VISUAL PATTERNS**

From birth, infants look at some objects and events more than others. These preferences may be crucial to development. Cognitive growth will presumably be more rapid if infants orient to informative parts of the environment rather than to uninformative ones. But how informative should informative be? Objects and events that are too far beyond infants' current knowledge of the world may be impossible for them to understand.

Cohen (1972) made an important distinction between attention-getting and attention-holding properties of stimuli. The idea is that gross physical characteristics of objects attract initial attention, but the objects' meaningfulness determines whether attention persists. Cohen suggested that the same attention-getting properties continue to influence perception throughout life, but that attention-holding properties change with age and experience. Movement grabs the attention of adults as well as infants, but infants and adults differ considerably in what they find interesting enough to be worth sustained attention. In the next sections, we first consider attention-getting properties, and then attention-holding ones.

*The orienting reflex.* When people see a bright flash of light or hear a sudden loud noise, they orient their attention to it even before they identify what it is. This orienting reflex seems to be present from birth. It is adaptive in helping people react quickly to events that call for immediate action.

The orienting reflex can be controlled by the cortex, but more typically it is controlled by subcortical brain regions. This conclusion emerged from a study of an anencephalic infant (an infant born without a cortex) (Graham, Leavitt, Strock, & Brown, 1978). The anencephalic infant showed an orienting response when novel stimuli were presented. The infant also habituated to familiar stimuli. That is, as shown in Figure 5.2, the infant's heart rate, which initially showed a large decrement five to seven seconds after a speech sound (a typical orienting response), stopped showing this response after six exposures to the sound. Since this infant did not have a cortex, its abilities to orient and habituate prove that cortical activity is not needed for these processes to occur. Subcortical mechanisms must be sufficient for both.

Especially intriguing, the pattern of orienting and habituating in Graham et al.'s 1-month-old anencephalic infant actually was precocious. It was typical of a 2-month-old normal infant. Graham et al. concluded that very early in development, cortical activity may hinder rather than facilitate orienting, and that this was why the performance of the newborn anencephalic infant was unusually advanced.
Overt and covert deployment of attention. Quite often, when someone's attention is attracted by an object or event, they turn to look at it. In these cases, attention is reflected in overt behavior. Other times, however, people look at one thing but their minds are on something else entirely. In these cases, attention is being deployed covertly.

Determining whether infants can attend to something different from what they are looking at has taken considerable ingenuity. However, Johnson, Posner, and Rothbart (1994) devised a way to do so. They exposed 4-month-olds to a training procedure in which the appearance of a diamond in the periphery of one side of their field of vision usually meant that an interesting beeping, rotating, multicolored wheel would appear a half second later on the other side. The diamond was on the screen too briefly for the infants to make an eye movement to look directly at it, and infants rarely looked at the side with the diamond before the wheel appeared. However, on some trials, the colorful wheel appeared just after the diamond had appeared on the opposite side. If infants were attending to the side with the diamond, but not looking there, they presumably would be especially quick to move their eyes to the opposite side where the wheel would appear. This is exactly what happened. Thus, even though the 4-month-olds were not looking directly at the diamond, they were attending to it, demonstrating that they were capable of covert as well as overt attention.

Rules for scanning the environment. Even in their first days of life, infants do not just orient to attention-grabbing objects that appear in their visual fields; they actively seek out interesting stimulation. Haith (1980) suggested that newborns act as if they know the following five rules for finding the interesting parts of their environments:

1. If you are awake and alert, and the light is not too bright, open your eyes.
2. If opening your eyes reveals darkness, scan the environment intensively.
3. If opening your eyes reveals light, scan the environment broadly.
4. If you find an edge, stop scanning broadly and continue scanning around the edge. Cross the edge and look at the other side if you can.
5. When you are scanning near an edge, reduce the range of fixations perpendicular to the edge if there are a lot of contours in the area.

Acting in accord with these rules helps infants find some interesting aspects of their environments, but may result in their missing others. In particular, it may lead to infants scanning the edges of objects to the exclusion of their interiors. For example, as shown in Figure 5.3, 1-month-olds scan the external

FIGURE 5.2 Orienting response of an infant born without a cortex. The curves indicate changes in the infants' heartbeat rate after he heard someone talk. On the first trial, there was a large decrease in the infant's heartbeat rate 5 to 7 seconds after the word was pronounced. This was a typical orienting-response pattern. By the sixth trial, there was little change in heartbeat rate. Thus, the infant habituated to the sound despite not having a cortex. (Adapted from Graham, Leavitt, Strock, & Brown, 1978).

FIGURE 5.3 Visual scanning of a person's face by 1- and 2-month-olds (after Salapatek, 1975). The concentration of horizontal lines on the chin and hairline of the face on the left indicated that the 1-month-old focused on the external contours. The concentration of horizontal lines on the mouth and eye of the face on the right indicated that the 2-month-old focused on internal features as well.
contours of faces and the eyes, but not until 2 months do infants examine other
ternal features (Haith, Bergman, & Moore, 1977; Salapatek, 1975).

These age-related changes in scanning patterns, as well as other changes in
infants’ attention, appear to be due in large part to the relative rate of matura-
tion of the visual cortex and the subcortical visual structures (Bronson, 1974).
Scanning can be controlled either by the visual cortex or by subcortical struc-
tures, such as the superior colliculus. The subcortical structures are more mature
at birth and therefore seem to play a larger role in directing attention in the first
months than they do later. This leads to the infants’ attending more to the out-
lines of objects, such as faces, and high-contrast areas such as the eyes, because
subcortical mechanisms are especially sensitive to the visual information in these
areas.

Several types of evidence support the view that subcortical mechanisms
play an especially large role in directing attention in the first month or two. One
is the anatomical immaturity of the visual cortex at birth. It is unclear that this
part of a newborn’s brain is sufficiently developed to direct choices of where to
look. A second source of evidence is that in newborns, subcortical areas, in par-
ticular the midbrain, are known to be strongly involved in deploying attention
so as to avoid returning to locations that were focused on immediately before
(Valenza, Simon, & Umilta, 1994). Third, as the cortex matures during the first
year, success on a variety of attentional tasks that would seem to require corti-
cal involvement becomes possible, and analyses of brain activity during these
tasks show increasing metabolic activity in cortical areas such as the parietal
lobe (Chugani, Phelps, & Mazziotta, 1987; Posner, Rothbart, Thomas-Thrapp, &
Gerardi, 1998). Thus, many sources of evidence converge to suggest that there is
a shift from a subcortical dominance to later increasing cortical involvement
in the deployment of visual attention. Note that this does not imply that there
is no cortical involvement in visual attention in early infancy, but only that sub-
cortical mechanisms are dominant.

Stimulus complexity. What qualities of objects and events hold an in-
fant’s attention beyond the initial attention-drawing occurrence? One attention-
holding property appears to be moderate stimulation. Given a choice between a
moderately bright object, a very dim object, and a very bright object, even 1- and
2-day-olds prefer the moderately bright one (Lewkowicz & Turkowitz, 1981).
Even more striking, when the infants are stimulated by a loud noise just before
such objects are presented, their preference shifts to the dim object. Maurer and
Maurer (1988) suggested that this was due to the infants’ trying to modulate the
total amount of incoming stimulation; the loud noise and the dim light together
provided a moderate level of stimulation. In keeping with this interpretation,
Maurer and Maurer found that simultaneously increasing the amount of stimu-
lation in each of three sensory modalities (sight, sound, and touch) by a small
amount had the same effect on infants’ attention as increasing one of them
(sound) by a large amount.

In addition to preferring moderate stimulation, infants also prefer to look at
moderately complex objects, rather than at ones that are extremely simple or
extremely complicated. Of course, the meaning of moderate complexity changes
as the infant develops. Situations that seem moderately complex to a 2-month-old
often seem simple to a 6-month-old. These observations have led to the formul-
lation of the moderate-discrepancy hypothesis: Infants are most interested in looking at
objects that are moderately discrepant from their existing capabilities and knowl-

Several findings seem consistent with the moderate-discrepancy hypothe-
sis. As infants grow older, they increasingly look at more complex stimuli. For
example, in studies in which infants are shown checkerboards, 3-week-olds spend
more time looking at 2-by-2 than at 8-by-8 boards; in contrast, 14-week-
olds prefer the more complex 8-by-8 boards (Brennan, Ames, & Moore, 1966).
The familiarity of the specific pattern also influences preferences. When initially
shown 2-by-2 and 24-by-24 checkerboards, 4-month-olds preferred the simple
2-by-2 boards. After repeated exposure to both boards, however, the infants pre-
Again, as the children’s ability to deal with complexity increased, they preferred
more complexity.

Part of the appeal of the moderate-discrepancy hypothesis is that it sug-
gests a mechanism of great potential importance for all aspects of cognitive de-
velopment. If people are programmed to orient toward material that is just
beyond their current understanding, they continually will be pulled toward
more sophisticated attainments. If there were 10 possible levels of understand-
ing in an area, they would first attend to the material that could be grasped with
the simplest level of understanding, then to the material that could be grasped with
the next more complex understanding, and so on. They spontaneously
would choose the optimal sequence of experiences for learning, and thus would
effectively regulate their own development. Because it is difficult to measure in-
fants’ knowledge, however, it also is difficult to know what is moderately dis-
crepant from it. Thus, at present, the moderate-discrepancy hypothesis has more
the status of an intriguing possibility than of a scientifically validated law.

Expectations. Infants are oriented toward the future, as well as the pres-
ent, from the first days outside the womb. For example, expectations about the
future state of the world are what allow them to reach for moving objects where
the objects will be, rather than where the objects are when they begin reaching
(von Hofsten, 1993).

At least by the time infants are 3 months old, they also form expectations
about where interesting events will occur, and they use these expectations to
guide their looking. This was learned in a series of studies in which the location
at which an interesting picture would appear varied either in a regular alternate-
ing sequence (left-right-left-right . . . ) or in an unpredictable sequence (Canfield
minute of exposure to a regular alternating pattern, 3-month-olds detected the pattern and used it to anticipate where the pictures would appear next. That is, they were more likely than infants who saw the irregular sequence of locations to look left after the picture appeared on the right, and vice versa.

Three-month-olds also form expectations about more complex patterns of events. For example, they were shown sequences in which the interesting picture’s location varied in a 2/1 pattern (LRLRR...) or in a 3/1 pattern (LRLRLRR...). The 3-month-olds detected these patterns and used them to guide their looking, just as they had with the alternating sequence. In contrast, 2-month-olds gave no evidence of forming expectancies about these patterns. Thus, the expectations that infants form change with development.

**Summary.** What, then, can we conclude about development of visual attention during infancy? Certain events, such as loud noises, bright lights, and changes in the environment, attract the attention of newborns, just as they do with adults. Even in the absence of such events, newborns scan the environment in ways that lead them to attend to the most important information. For example, their eyes focus on the contours of objects rather than on internal details. They can attend to locations covertly, even when their eyes are focused elsewhere. Infants’ attention also is guided from early in life by a preference for moderate degrees of stimulation and by the expectations they form.

**Identifying Objects and Events**

How do infants identify the objects and events that they see? Infants’ visual acuity and the movement and color of objects all contribute. Further, people seem to be equipped especially well to identify evolutionarily important stimuli, such as faces and human motion. This section focuses on how each of these factors contributes to our identification of objects and events.

**Visual acuity.** The single capability that is most crucial for identifying objects and events is the ability to discriminate them from the ongoing flux of visual stimulation. One component of this ability is visual acuity, or vision for fine detail. Visual acuity enables people to see clearly the similarities and differences among stimuli. Typically, the Snellen chart, which hangs in every optometrist’s office, is used to measure visual acuity. The letters you can read from 20 feet away are used as the reference point. If you can just read at 20 feet the letters that a person with “normal” vision can read at 150 feet, your vision is said to be 20/150.

Infants’ visual acuity cannot be measured by asking them to read the letters on a chart. However, their preferences for looking at one object rather than another can yield similar information. Almost all infants would rather look at alternating black and white stripes than at undifferentiated gray fields. By showing infants a gray field on one side and a set of stripes on the other, and examining whether the infants look more toward the stripes, researchers have been able to determine how much space between stripes (spatial frequency) infants need to see the difference.

Results obtained via this technique indicate that newborns see objects at 20 feet as well as adults with 20/20 vision see them at about 660 feet (Courage & Adams, 1990). Their acuity therefore is about 20/660. Average acuity improves to about 20/300 for 2-month-olds, 20/160 for 4-month-olds, and 20/80 for 8-month-olds. The 20/80 acuity at 8 months is about as good as that of an adult who could see better if she wore glasses but would not usually bother to do so. To give a qualitative sense of what a young infant’s vision is like, Figure 5.4 illustrates the finest level of stripes that most 1-week-olds can discriminate from a gray field at a distance of 1 foot (Maurer & Maurer, 1988). It is enough to see the outlines of objects, but not their details.

Differences between infants’ and adults’ pattern vision are present not just in the absolute sensitivity, but in where the greatest sensitivity is. One-month-olds’ sensitivity is greatest at very low spatial frequencies (widely separated stripes). Over the next few months, sensitivity becomes best at progressively higher spatial frequencies (stripes closer together). This means that 1-month-olds...
are maximally sensitive to very coarse outlines; after this, optimal vision is found with increasingly detailed patterns. What these changes mean for infants’ ability to see a woman’s face is illustrated in Figure 5.5.

The development of visual acuity depends on experience with the visual world. This has been shown in infants who were born with cataracts that prevented visual input. Such cataracts are typically removed in the infants’ first 6 months of life, and after the surgery the infants are fitted with contact lenses so that they can receive appropriate visual input. Immediately after the surgery, infants’ acuity is no better than that of newborns. However, acuity improves rapidly, even in the first hour after the surgery, and this improvement continues over the following month (Maurer, Lewis, Brent, & Levin, 1999). Thus, visual experience appears to be crucial for the development of visual acuity.

Motion. Young infants’ attention is drawn to moving objects (Volkmann & Dobson, 1976), and their sensitivity to motion increases with age (Dannemiller, 2000; Roessler & Dannemiller, 1997). Even newborns have some ability to track moving objects smoothly, but this ability is initially limited to objects that are large and that move slowly (Dayton & Jones, 1964; Dayton et al., 1964). For smaller or faster-moving objects, young infants’ eye movements are much less smooth. They typically fixate at the location where the object used to be for a second or two after it has moved away, and then jerk their eyes forward to a position roughly, but often not precisely, in line with the object’s new location. With age, infants become better able to smoothly track moving targets using both head and eye movements (Aslin, 1981; von Hofsten & Rosander, 1996, 1997). The development of smooth visual tracking coincides with the development of sustained attention to visual stimuli (Richards & Holley, 1999).

The propensity to attend to motion exemplifies the subtle and varied ways in which our perceptual system has evolved to help us adapt to our environment. In the world in which people evolved, moving objects could represent threatening predators, enticing prey, or any number of significant events. Attending to moving objects was, and continues to be, useful for survival.

The fact that motion attracts our attention also is useful because it helps us identify objects. Intuitively, it might seem that identifying moving objects would be more difficult than identifying stationary ones. However, after analyzing the information available in the physical environment, J.J. Gibson (1966) noted that movement provides critical data about properties of objects that persist throughout the movement, such as that all parts of the object move together. Thus, infants might find it easier to perceive the unity of different parts of a single object (though not its details) if the object is moving.

Subsequent research supported this analysis. Infants’ perception of objects as single entities appears to be based in large part on information provided by movement (Kellman & Short, 1987; Kellman & Spelke, 1983). For example, 3-month-olds perceive objects as separate if they move independently, but not if the same objects are stationary (Spelke & van de Walle, 1993). Thus, motion not only attracts infants’ attention, it also helps them identify what they are seeing.

Color. Adults can perceive wavelengths of light ranging from roughly 400 to 700 nanometers (nm). We see particular wavelengths as particular colors. For example, we perceive wavelengths of 450–480 nm as blue, 510–540 as green, 570–590 as yellow, and 615–650 as red. Although we see some wavelengths as mixtures (for example, 500 nm is perceived as bluish-green), we see most as unambiguously one color or another.

Color is a domain in which humans demonstrate the phenomenon of “categorical perception.” In categorical perception, differences between categories (such as green and yellow) seem greater than differences within a category (such as differences among various shades of yellow), even when the physical differences are identical (in this case, the differences in wavelength between the green-yellow pair and the yellow-yellow pair). Categorical perception has been demonstrated in a variety of domains, including perception of speech sounds (Eimas, Siqueland, Jusczyk, & Vigorito, 1971) and perception of facial expressions of emotion (Ekman & Magee, 1992; Pollak & Kistler, 2002).

Because speakers of different languages label colors differently, anthropologists have speculated that the division of the wavelengths into color categories
is culturally relative; that is, people in different cultures would perceive the boundaries between colors in different places. Research in infant perception and other areas, however, has indicated that this view is false. For example, Bornstein, Kessen, and Weiskopf (1976) repeatedly presented 4-month-olds with a particular wavelength until they lost interest and stopped looking at it. They then presented one of two alternative wavelengths that were equally far from the original, now “uninteresting,” wavelength in physical terms. However, at least to adults, one of the new wavelengths looked like a different color than the original wavelength, whereas the other looked like a different shade of the same color.

Infants looked at the alternative that adults saw as the different color more than at the one adults saw as the different shade of the original. It has since been found that even newborns show such discriminations for some colors (Adams, 1987), and that 1-month-olds discriminate colors across the entire spectrum (Clavadetscher, Brown, Ankrom, & Teller, 1988). Thus, like adults, infants display categorical perception of color, and they place the boundaries between colors at the same places that adults do. Strikingly, this ability is in place long before infants learn the color names. These results, together with identification of cells that respond differently to different colors (DeValois & DeValois, 1975) and observations that people all over the world classify the same wavelengths as being the best examples of particular colors (Berlin & Kaye, 1969), indicate that our biological makeup plays a critical role in color perception.

Social perception. Attention to the faces of mothers, fathers, and other people has been hypothesized to play a unique role in infant development. From the first months, infants prefer looking at faces over most other objects. Until recently, however, it was unclear whether this preference was due to the infants seeing the faces as faces or to other properties of the faces that attract infants’ attention. Babies like many characteristics of faces: symmetry, high contrast, movement, and sound. Thus, liking for the individual features, rather than perceiving that faces are faces, might explain the fact that infants like looking at them.

A compelling study by Dannemiller and Stephens (1988), however, established that at least by 3 months, faces as such are special for infants. Groups of 6- and 12-week-olds saw the computer-generated stimuli depicted in Figure 5.6. Although stimuli A and B differ only in having their contrast reversed, adults see Figure A as much more face-like. At 6 weeks, infants looked at the two figures equally often; by 12 weeks, however, they strongly preferred the more face-like Figure A. They do not show any change toward preferring Figure 5.6C over 5.6D, thus demonstrating that the change toward preferring the face-like Figure 5.6A is not simply due to 12-week-olds preferring pictures with thick dark edges or a dark shape in the middle. Thus, 12-week-olds seem to identify faces as faces and to look at them at least in part for that reason.

Younger infants also like looking at faces, and the faces need not have the detail of real faces to attract their attention. They just need two blobs approximately where the eyes would be and another blob where the mouth would be. Thus, newborns track the stimuli in Figure 5.7A and B more than the stimuli in Figure 5.7C and D (Johnson & Morton, 1991). Similarly, in a recent study, newborns with a mean age of 53 minutes old preferred looking at the face-like configuration of blobs in Figure 5.7B to its inverse, Figure 5.7C (Mondloch et al., 1999). However, the same group of newborns showed no preference between the positive-contrast and negative-contrast stimuli shown in Figure 5.6A and B.

Taken together, the findings suggest that there may be an innate mechanism that directs newborn infants’ attention toward faces. The mechanism appears to operate with a fairly crude initial representation of faces, because it does not differentiate between face-like stimuli with positive and negative contrast. In the first month after birth, infants follow moving faces with their eyes more than they do most other moving objects (Johnson & Morton, 1991). This attention to faces provides infants with input for learning in detail what a face looks like.

The tendency to track moving faces declines sharply between 4 and 6 weeks after birth, a time when a number of subcortically-based reflex-like behaviors decline in frequency. By 3 months, infants track each of the four stimuli in

\[ \text{Perceptual Development} \]

\[ \text{Perceptual Development} \]

\[ \text{FIGURE 5.6 Stimuli presented to infants by Dannemiller and Stephens (1988). Despite A and B being identical except for the reversals of the black and white shading, A looks more face-like to adults and attracts more attention from 12-week-olds. The same infants had no preference between C and D, indicating that their preference for A was due to their perceiving its facelike quality, rather than generally preferring stimuli with thick, dark borders.} \]
Perceptual Development

Why might infants (and adults) prefer the particular faces they do? A large part of the explanation seems to be that faces are perceived as attractive to the degree that they fit a prototype of an average face. This prototype can be approximated by taking black and white photos of a large number of faces, averaging the shadings of each pixel within the pictures, and using the averaged values to create a composite face. Rather than generating faces that are average in attractiveness, this procedure creates faces that adults rate as being more attractive than almost any actual face, and that infants look at more than almost any actual face (Langlois, Roggman, & Musselman, 1994). These faces are average in their physical characteristics but not in their attractiveness to infants or adults.

There is evidence that infants do indeed abstract prototypes when they view human faces. After being familiarized with a set of eight faces, 6-month-old infants responded to an averaged face, which they had never seen before, as if it were familiar (Rubenstein, Kalkanis, & Langlois, 1999). Based on this finding, it seems likely that infants rapidly abstract a prototype face from their experiences with faces shortly after birth. Thus, it appears that newborns’ initial representation of the human face is enriched by early experience with individual faces (Slater & Quinn, 2001).

In fact, early visual experience appears to be required in order for skill at face perception to develop normally. This issue has been investigated in infants who were born with cataracts that prevented visual input, and who had the cataracts removed in their first 6 months. Even when tested more than nine years later, children who had been deprived of visual input until 2 to 6 months of age showed subtle deficits in face perception compared to control participants (Le Grand, Mondloch, Maurer, & Brent, 2001). Thus, visual experience in the first few months appears to be essential for the normal development of face perception.

Human motion. Infants also are attracted to human motion. Even 4-month-olds look longer at displays of lights that to adults look like a cartoon of a person walking than at an equally numerous set of randomly placed lights, in which the individual lights show similar motions to those of matched lights in the “walking person” (Bertenthal, 1993). The attraction appears to be fairly specific to human motion: 4-month-olds do not show similar interest in displays that to adults look like walking four-legged spiders (Bertenthal & Pinto, 1993).

Infants’ ability to discriminate varieties of human motion is surprisingly sophisticated. By 3 months of age, infants discriminate between light displays that to adults look like walking and running, and by 5 months of age, infants are sensitive to higher-order properties of human motion, such as variations in the symmetrical patterning of the limbs (Booth, Pinto, & Bertenthal, 2002). It seems likely that the perception of biological motion involves both initial representations that have been shaped by evolutionary forces, and knowledge learned from experience seeing people move (Bertenthal, 1993).
A more complex version of the box-and-cylinder display was too difficult for 4½-month-old infants to interpret (Needham & Baillargeon, 1997). However, a brief experience with one of the objects enabled them to do so. After they viewed either the box alone or the cylinder alone for 5 seconds, infants correctly interpreted the box and cylinder as two objects (Needham & Baillargeon, 1998). Thus, knowledge gained through experience also plays a role in infants’ perception of objects from a very early age.

**Summary.** Infants’ visual acuity improves considerably in the first six months and beyond. Even in the first month, infants see the outlines of objects quite clearly, as well as some high-contrast interior detail. They also seem to see the same qualitatively distinct colors as adults do. Both faces and human motion attract and hold infants’ attention. Surprisingly, infants prefer to look more at faces that adults consider attractive than at other faces. Thus, preferences that were once thought of as purely the product of culture-specific values turn out to emerge so early in infancy that they almost certainly reflect biological predispositions as well.

In addition to biological predispositions, knowledge is an important component of infants’ abilities to identify objects and to discriminate them from one another. Infants begin to utilize configural, experiential, and physical knowledge for these purposes in their first half-year of life.

**Locating Objects**

In addition to identifying objects, infants also need to locate them in space if they are to reach for them or move toward them. Perceiving an object’s location requires perceiving both its direction and its distance from oneself. When the object can be seen, perceiving its direction presents no special problem; determining its distance, however, is more complex. At any one time, the display of light on the retina only specifies height and width, not distance; how can a three-dimensional world be represented in a two-dimensional retinal image? Yet, as noted in Chapter 1, even 1- and 2-day-olds solve the problem; they perceive distance with some accuracy (Slater et al., 1990). In this section, we consider some of the **monocular cues** (cues available separately to each eye) and some of the **binocular cues** (cues available only when both eyes focus on an object) that make distance perception possible.

**Monocular cues to distance.** The cues to distance that can be perceived through one eye working alone fall into two groups: those that rely on motion and those that are present even in stationary scenes. First consider some cues that involve motion. As objects approach us, or we approach them, they fill an increasing portion of our visual field; this is known as **visual expansion**. Similarly, when a person moves his or her head, the retinal images of closer objects move...
faster than those of more distant objects; this is known as motion parallax. A third monocular cue based on motion is occlusion; when one object moves in front of another, the closer object occludes the overlapping parts of the more distant one. Infants seem to use all of these monocular cues based on motion in the first months of life (Arterberry, Craton, & Yonas, 1993).

In contrast, not until 6 or 7 months do infants seem to infer distance on the basis of monocular cues that do not involve motion. These are frequently referred to as pictorial depth cues, since they were originally described by Leonardo da Vinci as ways of conveying relative distance within paintings. One such cue is relative size; other things equal, closer objects will cover more area on the retina. Another is texture; other things equal, closer objects will have a more differentiated surface. A third cue is interposition, which is like occlusion except that the objects are stationary. Five-month-olds do not appear to perceive depth from any of these pictorial cues, whereas each of them is effective in conveying information about depth to 7-month-olds (Arterberry et al., 1993). Thus, use of pictorial depth cues to infer relative distance seems to develop between 5 and 7 months.

**Binocular cues to depth.** Because people’s eyes are several centimeters apart, the pattern of stimulation that impinges on the two retinas almost always differs. This retinal disparity is valuable for estimating the relative distances of two objects in close proximity, or the distances of different parts of an object from one another. The value can be illustrated by going to an unfamiliar location, closing one eye, and trying to estimate which of two objects is farther away. Most people do much worse when they look with only one eye than when they use both.

Stereo, the ability to perceive depth solely on the basis of binocular cues, emerges suddenly at around four months. Individual infants consistently shift within a week or two from clearly not having such binocular depth perception to clearly having it (Figure 5.9). The key change seems to be segregation of neural pathways from the eye to the brain (Held, 1993). Before 4 months, information from both eyes arrives at the same cells in the visual cortex. Rather suddenly, the pathways are segregated so that information from the left eye arrives at some cells and information from the right eye at others. Additional binocular neurons receive inputs from both eyes. The brain detects disparities in the input from the two eyes and infers depth based on the degree of the disparity (the farther the object, the less the disparity).

The fact that stereopsis develops so consistently and so quickly at around 4 months might be interpreted as meaning that its development is due only to maturation. It turns out, however, that visual experience also is crucial. Administering drugs that block the neural activity that would normally occur in response to visual experience results in the segregated neuronal pathways not forming at the usual time (Stryker & Harris, 1986). As often is the case, maturation does not occur in a vacuum. Even developments that are universal and that occur at a fixed age generally require normal experience as well as maturation.

**Summary.** Infants use a variety of cues to determine the distances of objects from themselves. These include monocular cues, available to each eye individually, and binocular cues, available only when both eyes focus on the same point. Monocular cues can be divided into motion-based and pictorial cues. Even 1-month-olds seem to extract information about depth from motion-based monocular cues, but not until about 7 months are pictorial cues effective. This is one more illustration of motion aiding perception, especially young infants’ perception.
The ability to perceive depth on the basis of binocular cues is called stereopsis. It arises quite suddenly at around 4 months of age, apparently based on segregation of the neural pathways connecting the eye and the brain. However, this does not imply that the development of stereopsis is entirely controlled by biological factors—normal visual experience also is crucial.

**Learning**

To understand the development of auditory perception, it is helpful to understand the basics of the auditory system (see Figure 5.10). Sound waves are collected by the external part of the ear, the pinna. From the pinna, sound waves then pass through the ear canal, which leads to the tympanic membrane, or eardrum, which vibrates in response to sound waves. The movements of the eardrum set into motion a chain of three tiny bones called the hammer, anvil, and stirrup. The movement of these bones compresses fluid in the cochlea, and this in turn causes vibrations of the basilar membrane, which is located inside the cochlea. The part of the basilar membrane that vibrates depends on the frequency of the auditory stimulation. The actions of the basilar membrane in turn activate sensory cells, called hair cells, which are connected to auditory nerve fibers. Thus, sound waves enter the ear and initiate a chain of movements that culminate in neural signals in the auditory cortex.

What types of research methods are used to study infants’ auditory perception? Recall that the two primary methods used to investigate infants’ visual perception are preferential looking and habituation. Each of these methods has a counterpart for studying audition. In the head-turn preference procedure, sounds are presented from loudspeakers located to the left and right of the infant.

**ATTENDING TO SOUNDS**

Infants are responsive to sounds even before they are born. When babies in the uterus are exposed to loud sounds, they move around more and their hearts beat faster (Kisilevsky & Low, 1998). By one week after birth, infants hear and respond to a wide range of sounds. When presented with loud noises, they look startled, jerk their limbs erratically, and blink their eyes rapidly if they are open or squeeze them tightly shut if they are closed. Quieter sounds elicit less dramatic reactions. Thus, the newborn auditory system is functional from the first days.

Infants are more attentive to some sounds than others. They appear especially attentive to speech-like sounds. They react most noticeably to sounds in the frequency range (pitch) of 1,000 to 3,000 Hz, the range in which most speech occurs. They also react more to sounds that, like speech, include a range of frequencies, than to pure tones, in which all sound is at a single frequency. This is not due to their being able to hear these tones the most acutely. They detect sounds of higher frequencies at least as accurately (Schneider, Trehub, & Bull, 1979). Rather, these are the sounds that interest them enough to attract their attention. The auditory attention to frequencies in the speech range is reminiscent of the visual attention to faces and human motion—in both cases, infants are predisposed to attend to information that helps them learn about other people.

One sound that infants find especially attractive is that of their own name (Mandel, Jusczyk, & Pisoni, 1995). Already by 4 months, they attend for a greater amount of time to a loudspeaker that is saying their name than to one saying a different name with a similar stress pattern (e.g., Jojo vs. Mimi).

From a very early age, infants also prefer to listen to their native language (Moon, Cooper, & Fifer, 1993). Furthermore, they are able to discriminate between
snippets of different languages, even when both of the languages are unfamiliar. However, for newborns to make the discrimination, the unfamiliar languages must be from distinct language families. For example, newborn French infants can discriminate English from Japanese, but they cannot distinguish between English and German, which have similar rhythmic patterns (Nazzi, Bertoncini, & Mehler, 1998).

IDENTIFYING SOUNDS

Infants show an impressive ability to identify and discriminate between sounds that differ only subtly. Many of the most striking demonstrations of this ability concern speech perception. However, infants also have keen abilities for identifying and discriminating among other sounds, such as musical tones.

Speech. Two-month-olds discriminate between such similar speech sounds as /ba/ and /pa/, /ma/ and /na/, and /s/ and /z/. Their perception of the differences between these sounds appears to be categorical, just as is their perception of the differences between colors. This was originally shown in experiments testing 1- and 2-month-olds’ ability to discriminate /ba/ from /pa/ (Elmas et al., 1971). The two sounds differ only in voice onset time (VOT), the time when speakers begin to vibrate their vocal cords to make a sound. Despite this dimension of timing being continuous, adults hear sounds with VOTs below a certain value as /ba’s/ and otherwise identical sounds with VOTs above the threshold as /pa’s/. —We do not hear any sound as a mixture of /ba/ and /pa/. Apparently 1- and 2-month-olds also perceive the speech sounds categorically. After hearing /ba/ repeatedly, they dishabituate more when they hear a /pa/ than when they hear a different /ba/, one whose VOT is equally far from the original /ba/ but in the opposite direction. Infants have shown similar abilities to discriminate syllables that differ only in the position of the speakers’ lips (/ba/ versus /ga/), their tongues (/a/ versus /i/), and numerous other features (Aslin, Jusczyk, & Pisoni, 1998).

Might these discriminations be due to the particular language infants hear? A study with Guatemalan infants between 4 and 6 months suggests not. The Guatemalan infants were of interest because the Spanish they hear places the VOT boundary between /ba/ and /pa/ at a different place than English and most other languages. In spite of this linguistic experience, the infants dishabituated in a way that indicated that they placed the boundary between /ba/ and /pa/ where most languages do, rather than where their native language does (Lasky, Syrdal-Lasky, & Klein, 1975). Thus, infants may enter the world with sensitivities attuned to particular boundaries.

These predispositions do not persist forever. Although infants are initially sensitive to many contrasts not used in the language they hear, they later lose sensitivity to these features. Werker, Gilbert, Humphrey, and Tees (1981) demonstrated this phenomenon with English- and Hindi-speaking adults and 7-month-olds who were brought up in Canada. The stimuli were two sounds that differed on a contrast that differentiates words in Hindi but not in English. After repeatedly presenting one sound, the experimenter abruptly switched to the other. To get a reward, subjects needed to turn their head to one side when the sound changed. Almost all of the 7-month-olds accurately perceived the change, as did all of the Hindi-speaking adults. However, only 1 of 10 English-speaking adults accurately perceived it. This decline in ability with age is reminiscent of the similar decline with age in the ability to distinguish among faces of individuals of other species (Pascalis et al., 2002).

The beginning of the decline in the ability to perceive contrasts not used in one’s native language coincides in time with the beginning of infants’ ability to speak their native language (Werker & Desjardins, 1995). Both occur at about age 10 months. There are declines in infants’ abilities to perceive many different contrasts at about this time, including three different contrasts used in Zulu but not in English (Best, 1995), a contrast used in English but not in Japanese (Kuhl, 1998), and a contrast used in the Native American language Nhlapakpmx but not in English (Werker & Tees, 1984). The decline continues for the next 8 to 10 years, at which time the ability to discriminate the sounds has diminished to adult levels.

Why does this decline in phonemic discrimination abilities occur? The reason seems to be that in the course of acquiring their native language, children learn to group together sounds that differ physically but for which these differences do not affect meaning (such as the physically different /ba/ sounds studied by Elmas and his colleagues). Consistent with this interpretation, infants show considerably heightened sensitivity to the sound patterns of their native languages in the period just prior to when they lose sensitivity to sound differences that do not matter in their language. Nine-month-olds, but not 6-month-olds (1) prefer listening to words that have sequences of phonemes that are common in their language to ones that are uncommon (Jusczyk, Luce, & Charles-Luce, 1994); (2) prefer listening to words that have stress patterns that are common in their language to ones that are uncommon (Jusczyk, Cutler, & Redanz, 1993); (3) are more likely to integrate novel two-syllable sequences into a single unit (like a word) when the two syllables conform to the stress pattern typical of their language (Morgan, 1996); and (4) are sensitive to similarities in the beginning sounds of syllables (Jusczyk, Goodman, & Baumann, 1999). Thus, increasing sensitivity to the sound patterns of their native languages precedes, and may well cause, decreased ability to discriminate among sounds that are not meaningfully different in the infants’ native language. As is often the case, developmental gains also involve losses (for a wide range of illustrations of this principle, see Bates, 1997).

Speech perception involves much more than the ability to discriminate among sounds. Among the other skills that it requires is identifying the voices of different speakers. Infants as young as 3 days old can identify their mother’s voice, and they prefer it to other voices. DeCasper and Fifer (1980) devised a procedure in which infants could trigger a recording of either their mother’s
voice or the voice of a female stranger by sucking on a special pacifier in different ways. The 3-day-old infants learned how to produce their mother’s voice and produced it more often than the voice of the stranger.

In DeCasper and Fifer’s experiment, none of the infants had spent more than 12 postnatal hours with its mother. Although this experience may explain the preference for the mother’s voice, another possibility is that the preference was based on familiarity with the voice obtained before birth. Evidence supporting this possibility was found in a study in which expectant mothers were asked to read aloud Dr. Seuss’ story The Cat in the Hat each day during the last six weeks of their pregnancy. After the babies were born, an experimenter played a tape recording of the mother reading that story or an unfamiliar one. The babies sucked at a higher rate in response to the familiar story (DeCasper & Spence, 1986).

When adults talk to infants and young children, they often speak in a style known as “motherese,” or infant-directed speech. This style is characterized by high pitch and exaggerated intonations. In a study of German mothers, Stern, Spieker, and MacKain (1982) found that 77 percent of the mothers’ utterances to infants between birth and 6 months of age fell into this category. Subsequent studies have shown that infant-directed speech is used in a wide variety of cultures and language communities (Fernald et al., 1989).

Adults have good reason to use infant-directed speech. Infants as young as 2 days old seem to prefer it. They look longer at a checkerboard pattern when the reward for looking is hearing a tape of a woman speaking simple sentences in infant-directed speech than when the reward is hearing the same woman speaking the same sentences as she would to an adult (Cooper & Aslin, 1990). The extremely early age at which this preference for infant-directed speech is shown suggests that it does not depend on associating a way of talking with other rewards that the mother provides, such as food and comfort. Instead, it seems independent of postnatal experience.

In sum, infants are able to discriminate among speech sounds, voices, and intonation patterns. They also prefer their mother’s voice to that of other women, and they prefer infant-directed speech to adult-directed speech.

**Music.** Infants perceive the distinctions between some types of musical sounds categorically, just as they perceive colors and speech sounds categorically. In listening to the types of sounds made on a violin, adults perceive some as plucks and others as bows. The differences between plucks and bows can be reduced to a single physical dimension known as *rise time*. Two-month-olds discriminate between plucks and bows, but not between stimuli equally discrepant in rise time that adults hear as two types of plucks or two types of bows (Jusczyk, Rosner, Cutting, Foard, & Smith, 1977).

Infants also attend to the pitch of the sounds they hear. They can discriminate between intervals (pairs of tones) that are consonant (pleasant-sounding) and those that are dissonant (unpleasant-sounding) (Schellenberg & Trehub, 1996), and they prefer to listen to pieces that include more consonant intervals (Trainor & Heinmiller, 1998). Thus, infants are sensitive to the relative pitches of adjacent tones.

Infants are also able to encode pitch in absolute terms. Saffran and Griesenbrug (2001) presented 8-month-old infants and adults with a three-minute sequence of tones in which some pairs of tones consistently occurred together. After exposure to the tone sequence, participants were tested to determine whether they had encoded aspects of the sequence in terms of relative pitch (i.e., intervals between adjacent tones) or absolute pitch (i.e., exact tones, such as A and C). The infants’ test examined whether they could discriminate between pairs of tones that had consistently occurred together in the exposure sequence and pairs of tones that had the same relative pitches, but that had not consistently occurred together. If infants encoded the exact tones that they had heard in the exposure sequence, they would show a systematic preference for one or the other of the pair types. However, if infants encoded relative pitch in the exposure sequence, they would choose randomly, since both pair types have the same relative pitches. In fact, the 8-month-olds could make the discrimination, and they preferred the novel pairs. These data indicate that the infants encoded the exact tones that they heard in the exposure sequence.

Adult participants were tested using the same items as infants, but with a forced choice task rather than a preferential listening task. On each trial, the adults were asked to choose the more familiar of the two pairs. Adults’ performance was at chance, suggesting that they had encoded the intervals between adjacent notes, rather than the exact tones. Together with the infant findings, these findings suggest that there is a developmental shift from an early focus on absolute pitch, to a later focus on relative pitch. People can encode pitch in both ways at all ages, but there appears to be a developmental shift in the type of information that is most salient.

There are also other developmental changes in people’s ability to discriminate contrasts in music. As with speech discrimination abilities, music perception abilities become increasingly sensitive to the types of sounds to which infants are exposed in their home environments, and infants’ abilities to discriminate between unfamiliar sounds diminish with time. Lynch and Eilers (1992) presented 6- and 12-month-olds with a brief melody either in the commonly-used major scale or in the rarely-used augmented scale. The melody was presented repeatedly through a stereo speaker until infants were familiar with it. Then, the infants started hearing either the familiar melody or a version of it with one note somewhat off-key. The 6-month-olds discriminated the deviations in both cases; they turned toward the speaker more often when the off-key note was played in either the familiar or unfamiliar scale. In contrast, 12-month-olds’ discrimination skills, and also those of adults, were more limited. They noticed deviations within the familiar scale but not in the rarely heard one. Similar patterns have been shown for infants’ and adults’ perception of mistunings of melodies in familiar Western major scales as compared to unfamiliar Javanese pelog scales. At 6 months, infants discriminated the mistunings for melodies in
both scales, but musically inexperienced adults did not (Lynch, Eilers, Oller, & Urbano, 1990).

The findings raise an intriguing question: Is the similar timing of the narrowing of music and speech perception abilities a coincidence, or does it indicate a general reorganization of the auditory perception system? At present, no one knows.

**AUDITORY LOCALIZATION**

From birth, infants look to the source of sounds. This was first demonstrated by Wertheimer (1961), who performed a simple experiment with his daughter. Immediately after she was born, she sounded a clicker first on one side of the room and then on the other. From the first sounding of the clicker, the daughter turned her head in the direction of the sound. The same result has since been found in larger samples of newborns. The subsequent findings indicate some ability to localize the sounds within the side from which they came, as well as to locate them as being generally to the right or to the left (Morrongiello, Penwick, Hillier, & Chance, 1994). One cue that infants rely on in localizing sound is the difference in the time it takes sounds to reach the two ears, called the **interaural time difference** (Litovsky & Ashmead, 1997).

Infants' auditory localization abilities enable them to use sound to guide their reaching behaviors. By 3 months of age, infants in totally dark rooms will reach for objects that are making sounds (Clifton, Muir, Ashmead, & Clarkson, 1993; Ferris & Clifton, 1988). Infants use sound to infer not only direction, but also distance. At 6 months, infants reached for sounding objects that were 10 cm away, but they did not reach for sounding objects that were 100 cm away (Clifton, Ferris, & Bullinger, 1991).

Surprisingly, newborns seem better able to localize sounds than 2- and 3-month-olds, though not better than 4-month-olds. This pattern of data, which appears in a number of contexts throughout the book, has been labeled a **U-shaped curve**. At first, performance is at a high level, then it drops, then it returns to a high level. The U-shaped pattern is of special interest, because it suggests that different mechanisms are responsible for the same behavior at different points in development. This seems to be the case in auditory localization.

Muir, Abraham, Forbes, and Harris (1979) conducted a longitudinal study in which they repeatedly examined four infants over the first four months of the infants' lives. They found that three infants showed a U-shaped pattern of auditory localization. As shown in Figure 5.11, the infants first showed high levels of head turning toward the side from which the sound came, then showed reduced levels, and then, by about four months, returned to the prior high levels. The decline in the middle was not due to lack of interest in the sounds. Even when an infant's mother or father called the child's name in the midst of a series of rattling sounds, the pattern of head turning did not change.

![Figure 5.11](image)

FIGURE 5.11 Percentage of trials on which four infants turned toward sounds. Infants were tested every 20 days from birth to 120 days (from Muir, Abraham, Forbes, & Harris, 1979).

Muir et al. proposed an explanation much like those proposed by Bronson (1974) and Johnson (1998) to explain U-shaped patterns in infants' visual behavior. They suggested that auditory localization in the first month after birth reflects primarily subcortical functioning. In the second and third months, cortical activity increases, and it replaces subcortical activity as the dominant influence on infants' auditory localization. However, at this point, the cortical activity is not sufficiently well developed to produce highly accurate performance, as the subcortical mechanisms had previously. Only in the fourth month does cortical activity become sufficiently mature to reinstate accurate localization.

The precision of auditory localization improves rapidly between ages 2 and 5 months, and it continues to improve more slowly until infants are roughly a year and a half old (Ashmead, Davis, Whalen, & Odom, 1991). It is probably not coincidental that the rapid improvement occurs during the time when infants'
ability to control their heads is also rapidly improving. Better control allows infants to move their heads more precisely and enables them to learn how to move their heads to the optimal location for hearing (Bayley, 1969; Bertenthal & Clifton, 1998).

Summary. Infants enter the world with substantial auditory capabilities, and the capabilities develop further in the first few months. The capabilities are evident in which sounds attract infants’ attention, in their ability to identify sounds, and in their ability to localize where sounds originate. Sounds with characteristics that resemble speech are especially likely to attract infants’ attention. Like adults, infants appear to process both speech and music sounds categorically. Development of both speech and music perception involves losses as well as gains; toward the end of the first year, infants’ perceptual abilities narrow in a way that focuses them on the types of speech and music that are part of their culture. The ability to localize sounds shows a U-shaped pattern between birth and 4 months. It is best at the two extremes, and is less good in between. A plausible explanation is that subcortical mechanisms produce the initial high level of skill, whereas cortical mechanisms produce similarly good localization beyond age 4 months.

Intersensory Integration

How do infants integrate the information they receive from different sensory systems into a single coherent experience? One plausible developmental path would be that each sensory system first develops independently and then, when all have reached a degree of maturity, they become interconnected. Piaget (1971) proposed just such a theory. Recent investigations of infants’ intersensory integration suggest a quite different picture, however. It now appears that sights and sounds are integrated from birth.

Evidence for intersensory integration has already been presented under other headings throughout this chapter. Intersensory integration plays a role in all three of the major functions of perception: attending, identifying, and locating.

ATTENDING

The orienting reflex exemplifies how intersensory integration influences infants’ attention. Hearing loud noises causes infants to look toward the source of the sound. That is, they use auditory information to guide visual attention.

Just as infants follow looking “rules” based on visual information, so do they follow looking “rules” based on auditory information (Mendelson & Haith, 1976). One such rule is that when you hear a sound, and you are looking somewhere else, look toward the source of the sound. Another rule concerns what to do when you already are looking at the apparent source of a sound. Under this condition, you should center attention closely on that source and shorten the length of your eye movements. The rules seem likely to promote attention to animate objects, such as people and other animals that make noise.

Consistent with these looking rules, when 5- to 7-month-olds hear a voice, they increase their scanning of a face in front of them, particularly the eyes (Haith et al., 1977). This coordination of sight and sound may help infants to associate particular faces with particular voices, a skill that is already present at 3 months of age (Brookes et al., 2001).

Bahrick (1992; Bahrick & Lickliter, 2000) has argued that infants’ attention is especially attracted to information that is presented redundantly across multiple senses, and that is synchronized in time. As a result, infants learn information that is presented multi-modally before they learn information that is available in only one modality. One study of this issue explored infants’ ability to learn about rhythm. Infants learned a specific rhythm (produced by a hammer tapping) more effectively when the event was presented both auditorily and visually than when it was presented in either modality alone (Bahrick & Lickliter, 2000). This bias to attend to multi-modal information may help infants link faces and voices. When people speak, their lips and faces move in a fashion that is synchronized with the sounds in both tempo and duration, and infants’ attention is drawn to such multimodal displays.

IDENTIFYING OBJECTS AND EVENTS

Both sights and sounds are also used to identify objects and events. Recall Spelke’s (1976) study in which 4-month-olds looked more often at the movie in which the visual images were in keeping with the sounds they were hearing (the mother playing peek-a-boo or the drum beat). If the infants were not integrating visual and auditory information in the movie, they would have had no reason to act in this way.

Four-month-olds also integrate tactile (touch) and visual information in identifying objects. In one experiment (Stier & Spelke, 1988), infants first explored with their hands one of two objects: either two rings connected by a rigid stick or the same rings connected by a flexible band. A thick cloth was placed so as to prevent the infants from seeing the object that their hands were exploring. After the infants habituated to handling the object, they were shown visually either the rigidly or the loosely connected rings. The 4-month-olds looked more at the object with the type of connection they had not encountered previously. The demonstration was especially interesting because during the manual-exploration phase, most infants had not touched the connection; they only played with the rings. Thus, their visual identification seemed to be based on their making an inference about the type of object that would produce the observed reactions to their pushing and pulling the rings.
One question that follows from Streri and Spelke’s findings is whether visual experience promotes or hinders manual exploration abilities. To find out, Morrongiello, Humphrey, Tinney, Choi, and Rocca (1994) contrasted the ability to identify objects of congenitally blind 3- to 8-year-olds with that of sighted children of the same ages who performed the task blindfolded. One possibility was that the sighted children would do better, because they had had the opportunity to learn what objects looked like when manual exploration revealed certain properties. Another line of reasoning suggested that the blind children would do better. They would have had to depend more on manual exploration, and might be more skilled at it.

In fact, blind and sighted children were equally skillful in identifying the objects through manual exploration. They were correct on an equal percentage of trials, took equally long to do the exploration, and were equally complete in their explorations. However, the older children were better on all of these measures than younger children. The findings indicate that manual exploration skills improve with age, but that the improvement is due to general cognitive and motoric improvements rather than to specifically visual experience or experience correlating manual and visual information.

**LOCATING**

Studies of infants' auditory localization indicate that vision and audition are coordinated from birth. In most studies of auditory localization, the primary measure of localization is head turns toward the source of the sound. Head turning would not be a useful measure if infants did not look toward the sources of sounds.

Infants' ability to control the location of their own bodies in space also requires the integration of information from multiple senses. It is obvious that vestibular (balance) information is involved in maintaining and controlling posture. Less obvious is the fact that visual information is also involved. The importance of visual information has been documented in studies that utilize a “moving room.” In the moving room, the participant sits or stands on a stationary floor, and the ceiling and surrounding walls move. Infants who have just learned to stand will sway or stagger when the walls move, indicating that they adjust their posture in response to visual information (Lee & Aronson, 1974). Similarly, sitting infants sway their trunks when they see the walls move (Bertenthal & Bai, 1989; Bertenthal, Rose, & Bai, 1997). Thus, vestibular and visual information are integrated in controlling the location of the body in space.

**Chronological Summary**

To gain a larger, more integrated picture of perceptual development, it is valuable to consider what capacities infants possess for vision, hearing, and intersensory integration at different ages in the first year. Table 5.2 lists a number of
perception and Action

Why do humans perceive the world as they do? One reason is that perception provides the organism with information that is necessary for effective action in the world. Action in turn can generate perceptual information, and can improve the quality of information that is already available. Thus, perception and action form an integrated system, in the sense that each influences and contributes to the other.

Perception Guides Action

Perception is necessary to guide actions as basic as controlling posture, and as complicated as obtaining food and avoiding danger. Indeed, it can be said that the purpose of perception is to guide action. This general point is evident in many of the studies that have been discussed so far in this chapter. For example, in the moving room studies, infants used visual perception to guide their postural adjustments to the changes in the room. Similarly, in the studies of reaching in the dark for sounding objects, infants used auditory perception of sounds emanating from the objects to guide their reaching.

Studies of motor performance also highlight the crucial role of perceptual information in guiding actions such as locomotion. Infants who have perceptual impairments show delays in motor development. For example, children who are blind or who have moderate visual impairments have difficulties with balance and postural control, and they experience significant delays in achieving most motor milestones, including sitting, crawling, standing, and walking (e.g., Bouchard & Tetreault, 2000; Prechtl, Cioni, Einspieler, Bos, & Ferrari, 2001). Children who are deaf also show delays in motor development (Dummer, Haubenstricker, & Stewart, 1996) as well as slowed execution of motor movements (Wiegert & Van der Velde, 1983). Thus, both vision and hearing appear to be involved in guiding motor actions.

Actions Generate Perceptual Information

The relation between perception and action is a reciprocal, complementary one. Improvements in perceptual skills allow for more finely tuned actions. On the other side of the coin, action also generates perceptual information. For example, moving the head may make a sound seem louder, and this information may contribute to auditory localization. Similarly, moving in space generates patterns of visual information that may contribute to identifying objects. As J.J. Gibson (1979) put it, "We must perceive in order to move, but we must also move in order to perceive." Movements that are produced in order to generate perceptual information are often referred to as exploratory movements.

If the purpose of exploratory movements is to generate perceptual information, then infants should produce such movements especially often when they need perceptual information to choose a course of action. For example, when infants are presented with a situation in which they must descend a steep slope, they need to decide whether to crawl, slide, or back down. To make this decision, infants gather information using exploratory movements such as patting the slope and rocking back and forth at the brink of the slope. Infants produce more of these exploratory movements on steep slopes than shallow ones, perhaps because the consequence of making a poor decision (falling down) is more serious on steeper slopes (Adolph, 1997). In one study, infants' ability to produce exploratory movements was diminished by having them wear a heavy vest (one with pockets filled with lead). The vest made it more difficult for infants to pat the slope or to keep balance while rocking at the brink of the slope. When wearing the vest, infants made poorer decisions about whether and how to descend the slopes (Adolph & Arolt, 2000).

Because actions generate perceptual information, the development of new abilities for action has important consequences for perceptual development (Bushnell & Boudreau, 1993). Improvements in motor skills make it possible for infants to explore their environments in new ways, and consequently, to generate new sources of perceptual information.

In one study of the links between motor and perceptual development, Needham (2000) examined infants' skills at exploring objects and also examined their abilities to use object features to determine the boundaries between
adjacent objects in a visual display. Infants who more actively explored one set of objects in the first part of the experiment were more likely to discriminate the boundaries between other objects in the second part of the experiment. Needham argued that infants with stronger object exploration skills are able to gather more information about objects, and this information helps them learn to interpret object features.

The onset of crawling is also linked with important changes in many other domains, including social, cognitive, and perceptual skills (Campos et al., 2000). Infants who are able to crawl display better perceptual skills in a variety of contexts than do infants of the same age who are not yet able to crawl. For example, crawlers display more postural compensations in the “moving room” than pre-crawlers, suggesting that they are more responsive to visual information (Higgins, Campos, & Kermoian, 1996). Similarly, crawlers attend more to distant objects than do pre-crawlers (Campos et al., 2000). Thus, gains in locomotor skill are linked with changes in the information to which infants attend.

One task that illustrates the links between motor skill and perception especially well is the visual cliff (Figure 5.12), which was first used by Gibson and Walk (1960). This task involves a clear plexiglass surface on which infants can crawl. One side has a tablecloth with a checkerboard pattern just below the surface; the other side has a tablecloth with the same pattern several feet below the surface. To adults, it looks like the surface falls off sharply at the boundary between the two parts. Infants able to crawl are placed on the “shallow” side, just before the boundary with the “deep” side, and their mothers beckon them to crawl across to them. Seven-month-olds who have been crawling for 6 to 8 weeks often refuse to cross, and their heart rates accelerate (a sign of fear) when they are urged to do so. In contrast, babies of the same age who are not yet crawling do not show similar signs of fear (Campos, Bertenthal, & Kermoian, 1992).

The key to this difference seems to be the experience of self-generated locomotion, rather than experience with crawling per se. In another experiment, a group of pre-crawling infants was given 40 hours of experience with a walker, which allowed them to move around independently by sitting in a seat and pushing with their feet on the floor. The infants given experience in the walker showed greater fear when beckoned to cross the visual cliff, as measured by accelerating heart rates, than infants of the same age who had not been given such experience (Bertenthal, Campos, & Kermoian, 1994). The walker provided infants with a new opportunity for action, and by performing this action, infants gained new information that led them to perceive the apparent drop-off in the visual cliff differently, and therefore to fear it. Thus, the experience of self-generated locomotion appears to be crucial for the development of wariness of heights. Consistent with this view, mammals that can locomote from birth shy away from cliffs from early in life.

Why would self-generated locomotion produce this effect? After all, the infants would often have experienced their parents carrying them from one place to another. Campos et al. (2000) have argued that the key difference between self-produced and other-produced locomotion is in the correspondences among perceptual information gleaned from different sources, including visual information, vestibular (balance) information, and somatosensory (body sensation, such as muscle and joint position) information. When infants are carried, they may not look in the direction of motion (and in fact, they often face in the opposite direction, looking over their parent’s shoulder), so the visual information they receive is often inconsistent with the other information they receive from their bodies, such as vestibular and somatosensory information. Consequently, infants who are carried do not develop consistent expectations about how these different sources of information are related. In contrast, when infants move on their own, these sources of information are systematically related, so infants begin to form expectations about how these sources of information correspond. At the visual cliff, locomotor infants’ expectations about the correlations between visual, vestibular, and somatosensory information are violated, and this leads them to fear making movements over the apparent edge.
The levels of auditory perception shown by young infants are at least as impressive as their achievements in visual perception. Infants are especially attentive to speech-like sounds. This appears due to their being interested in the speech-like sounds, rather than to their being able to detect them more easily than other sounds. By 4 months, they also are interested in some particular sounds, such as their own names.

Infants' identification of both speech and some musical sounds is categorical, much like their color perception. The categorical perception is not attributable to the particular language infants hear; infants may set categorical boundaries at points different from those that appear in their native language. In addition to being able to discriminate between specific sounds, newborns also are able to identify more general speech characteristics. For example, they can discriminate their mother's voices from those of other women. They also show a preference for infant-directed speech, a form of speech characterized by high-pitched sounds and exaggerated intonations.

The development of auditory localization shows a U-shaped function. At birth and after 4 months of age, localization is quite accurate. In the interim, the ability is less acute. The pattern, like infants' pattern of visual attention, may reflect a shift from subcortical to cortical dominance.

Perception and action form an integrated system from the beginning of life, in that perceptual information guides action, and actions provide the organism with perceptual information. The role of perception in guiding action is strikingly apparent among children with perceptual deficits, such as blindness or deafness, who often show delays in motor development. People often produce exploratory actions in order to generate perceptual information, such as touching a shiny surface to determine whether it is slippery. As infants' motor skills develop, they become able to explore their environments in new ways. Thus, gains in motor skills influence infants' abilities to generate and use perceptual information.

Recommended Readings


young infants can detect an off-key note in familiar and unfamiliar scales, whereas older
infants and adults can do so only in familiar
scales.

Fryer, D., Lewis, T.L., Brent, H.P., & Levin,
L.V. (1999). Rapid improvement in the acuity
of infants after visual input. Science, 286,
108–110. Describes the development of visual
acuity in infants who were born with
catacarts that prevented visual input. After
surgery to remove the cataracts, infants were
fitted with contact lenses, and their visual
acuity began to change within hours.

Pascalis, O., de Haan, M., & Nelson, C.A.
(2002). Is face processing species specific
during the first year of life? Science, 296,
1321–1323. Presents evidence for the role of
experience in face perception. Six-month-old
infants are able to distinguish among both
monkey and human faces, but older infants
and adults can do so only for human faces.

6

LANGUAGE DEVELOPMENT

Where you going?
I'm going.
Shoe fixed.
Talk to momny.
Shoe fixed.
See Antho.
Anthony.
Good night.
See morrow morning. (Weir, 1962)

The preceding monologue was obtained from a tape recording of a
2½-year-old talking in his crib before going to sleep. The child's statements
exemplify several key properties of language development. First, they commu-
nicate meaning. It is easy to understand most of what is being said, even though
the phrases are not the ones that older individuals would use. Second, the state-
ments are cryptic. When children first learn to speak, they include only the
essentials. They omit many of the prepositions, articles, adverbs, and adjectives
that lend precision, color, and grammatical structure to the language of older
individuals. Third, the language is internally motivated. No one else was in the
room during Anthony's monologue. Nonetheless, he found talking sufficiently
enjoyable that he spoke anyway.