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CHAPTER 6

Basic Learning and Perception

Key Themes in Basic Learning and Perception

- **Nature/Nurture** What roles do nature and nurture play in learning and perceptual development?
- **Sociocultural Influence** How does the sociocultural context influence learning and perceptual development?
- **Child's Active Role** How does the child play an active role in learning and perceptual development?
- **Individual Differences** How prominent are individual differences in learning and perceptual development?
- **Interaction Among Domains** How do learning and perceptual development interact with development in other domains?

The apartment had suddenly grown terribly quiet. The three other babies and their mothers who had been helping to celebrate Chad's first birthday had departed. Only Tanya, Chad's mother, remained with him as the light faded at the end of the day. Picking up the torn gift wrappings, Tanya reflected on the events of the past year. She thought back to her first glimpse of Chad. She had counted his toes and fingers to make sure all were there. She had wondered aloud, as she first held him, "What do you see? Can you hear me? What are you thinking?" Tanya had vowed to be a good mother, to help Chad learn. As she began to vacuum the cake crumbs from the floor, she wasn't sure she was keeping her promise. She couldn't afford the colorful playland that had beckoned to him at the toy store. She never seemed to have enough money now that Chad's father had moved out. Was it fair for Chad not to have things that delighted him and from which he could learn so much? Chad also sometimes challenged her, and she became angry with him. What was he learning from these kinds of exchanges?

What can a newborn learn or hear, or see or feel? Only thirty or forty years ago obstetricians and pediatricians, and even some psychologists, might have answered, "Very little and perhaps nothing at all" (Haith, 1990). But a far different answer has emerged in recent years. Newborns are already engaging in the lifelong process of learning. Their vision provides enormous amounts of information from which to learn. If newborns can see, can they also hear—for example, a mother's lullaby? Can they identify the subtle smells of their mothers' bodies, feel the prick of a nurse's pin or the pain of circumcision? If the answer to these questions is yes, they also have the potential to learn a great deal about their world right from birth, maybe even before. What had Chad been learning? Being reared in the angular world of city skyscrapers, might he, for example, see and learn in a far different way than a child growing up in a tropical rain forest? How important are these early experiences for his development?

These are precisely the kinds of questions psychologists have often asked. Why? Because learning and perception are fundamental processes by which children come to understand their world. Perception, the interpretation of sensory information from visual, auditory, and other receptors, is the vehicle by which we glean information about the world. Learning, a means of acquiring new skills and behaviors from experience, is an extremely important form of adaptation. Through learning children avoid dangers, achieve satisfactions, and become contributing members of the families, communities, and cultures in which they live. We begin this chapter by discussing basic processes in learning; then we consider sensory and perceptual development in infants and children. These processes serve as the foundation for the more complex aspects of cognitive, intellectual, emotional, and social development examined in the chapters that follow.

Basic Learning Processes in Infancy and Childhood

KEY THEME
Nature/Nurture

Learning permits adaptation to the environment. It helps infants and children to respond to the demands of their physical and social world and to achieve goals and solve problems. Children learn, for example, that a stove can be hot, that hitting a sibling will make their parents angry, and that a symbol of a male on a rest room door signals the right (or wrong) one to enter. What are the basic forms of learning? How early do these important capacities appear? Consider first one of the simplest forms of learning: *habituation.*

Habituation

The gradual decline in intensity, frequency, or duration of a response to the repeated occurrence of a stimulus is known as **habituation.** Even newborns display habituation. For example, they may show less arousal—that is, reductions in heart rate or fewer searching eye movements—as they are shown a colorful toy or hear the same bell ringing over and over. Habituation is thus a simple, adaptive form of learning to ignore things that offer little new information and that, in a sense, have become boring.

The finding that, once babies have habituated to an event, they often display a renewed response to a change in the stimulus indicates that habituation is a form of learning rather than merely fatigue or an inability to continue responding. For example, if touched on the leg instead of the arm or exposed to a sound other than the ringing of a bell, they may become aroused once again. The return of a response is an example of **recovery from habituation** (sometimes called **dishabituation**) and suggests that the baby perceives the new stimulus as different from the old one.

Low-birth-weight, brain-damaged, and younger babies tend to habituate less rapidly than older, more mature infants (Krafchuk, Tronick, & Clifton, 1983; Rovee-Collier, 1987). In fact, as we will see in the chapter titled "Intelligence," an infant's rapid habituation and recovery from habituation to new stimuli is associated with greater intelligence and cognitive capacities in later childhood. Thus, although it is a simple form of learning, habituation may nonetheless be an important process in intellectual development.

Classical Conditioning

As we learned in the chapter titled "Themes and Theories," in *classical conditioning* a neutral event paired with a stimulus that triggers an inborn reaction can begin to elicit a response similar to the one initiated by the original stimulus. Consider a nipple placed in a newborn's mouth; it tends to elicit sucking. The nipple is an **unconditioned stimulus (UCS);** the sucking response is an **unconditioned response (UCR).** After a series of trials in which a neutral stimulus—say, a distinctive odor—is paired with the nipple (the UCS), the odor may also begin to elicit sucking even when the nipple is not present. The odor has become a **conditioned stimulus (CS),** and the sucking response it initiates a **conditioned response (CR).** Table 6.1 summarizes the sequence of steps in classical conditioning for this and other typical examples.

Infants display classical conditioning within hours of birth. Elliot Blass and his colleagues (Blass, Ganchrow, & Steiner, 1984) paired a tactile stimulus, stroking of the newborn's forehead (CS), with the delivery of a sugar solution to the mouth (UCS) that elicited sucking (UCR). Newborns learned to orient and initiate sucking (CR) with stroking of the forehead (CS) alone. Thus, important associations, particularly those surrounding feeding activity, can be acquired through classical conditioning shortly after birth. But some types of classical conditioning are difficult for infants to learn. For example, researchers have not been able to successfully condition infants

habituation Gradual decline in intensity, frequency, or duration of a response over repeated or lengthy occurrences of the same stimulus.

recovery from habituation Reinstatement of the intensity, frequency, or duration of a response to a stimulus that has changed. Also called *dishabituation.*

dishabituation See *recovery from habituation.*

unconditioned stimulus (UCS) Stimulus that, without prior training, elicits a reflexlike response (unconditioned response).

unconditioned response (UCR) Response that is automatically elicited by the unconditioned stimulus (UCS).

conditioned stimulus (CS) Neutral stimulus that begins to elicit a response similar to the unconditioned stimulus (UCS) with which it has been paired.

conditioned response (CR) Learned response that is exhibited to a previously neutral stimulus (CS) as a result of pairing the CS with an unconditioned stimulus (UCS).

TABLE 6.1 Examples of Classical Conditioning

Classical conditioning is learning in which a neutral event (conditioned stimulus), through its association with a cue (unconditioned stimulus) that naturally elicits a reflexlike response (unconditioned response), comes to elicit the same response (conditioned response).

	Step 1 (Stimulus → Response)	Step 2 (Stimulus → Response)	Step 3 (Stimulus → Response)
General Principle	UCS → UCR	CS + UCS → UCR	CS → CR
Example 1	Nipple → Sucking	Odor + Nipple → Sucking	Odor → Sucking
Example 2	Injection Needle → Fear	Doctor + Injection Needle → Fear	Doctor → Fear

younger than three or four weeks to respond to aversive stimuli, such as foot withdrawal at loud noises or a painful prick. Perhaps the youngest infants lack the motor and neural abilities needed to escape noxious events; they must depend on caregivers for protection until they acquire simple locomotor skills for avoiding aversive stimuli (Rovee-Collier, 1987). As infants become older, classical conditioning occurs more rapidly and involves a broader range of stimuli.

positive reinforcement Occurrence of a stimulus that strengthens a preceding response. Also known as a *reward.*

negative reinforcement Removal of an aversive stimulus that strengthens a preceding response.

negative punishment Removal or loss of a desired stimulus or reward that weakens or decreases the frequency of a preceding response.

positive punishment Occurrence of an aversive stimulus that serves to weaken or decrease the frequency of a preceding response.

Operant Conditioning

In *operant* (or *instrumental*) *conditioning,* the frequency of spontaneous, sometimes novel behaviors changes as a result of positive and negative consequences. Put another way, behaviors tend to increase when followed by rewards (**positive reinforcement**) or the removal of aversive events (**negative reinforcement**) and to decrease when followed by the loss of rewards (**negative punishment**) or an aversive outcome (**positive punishment**). The term *positive* in this context indicates that when a behavior occurs, it causes a stimulus event that either increases the rate of the response (reinforcement) or decreases it (punishment). The term *negative* in this context indicates that when a behavior occurs, it leads to the removal of a stimulus that either increases the rate of the response (reinforcement) or decreases it (punishment). Figure 6.1 summarizes these relationships and provides examples of positive and negative reinforcement and punishment.

Operant conditioning can also be observed in infants within the first few hours of birth. For example, newborns will either increase or decrease pressure during sucking when the availability of milk, a positive reinforcer, is contingent on an increase or

Rate of response

Response leads stimulus to be	Increases	Decreases
Delivered	**Positive reinforcement** (Increases behavior by delivering a desired stimulus) Example: Infant says, "cookie" → Mother gives praise	**Positive punishment** (Decreases behavior by delivering an aversive stimulus) Example: Toddler throws toys → Father yells, "Stop it"
Removed	**Negative reinforcement** (Increases behavior by removing an aversive stimulus) Example: Child cleans messy room → Parent stops "nagging"	**Negative punishment** (Decreases behavior by removing a desired stimulus) Example: Teenager out past curfew → Parent grounds teenager

FIGURE 6.1
Positive and Negative Reinforcement and Punishment

Reinforcement leads to an increase in the rate of responding; punishment leads to a decrease in the rate of responding. *Positive* refers to the presentation of a stimulus following a response; *negative* refers to the removal of a stimulus following a response.

a decrease in pressure (Sameroff, 1972). And as with classical conditioning, operant conditioning seems to work best with behaviors important to infants, such as searching for (head turning, mouthing) and obtaining (sucking) food or other stimuli that are comforting. In other words, babies seem to be biologically prepared to learn about some things that are especially important for them.

Visual and auditory events can be especially powerful reinforcers for infants. Babies will work hard, modifying the frequency or rate of sucking, vocalizing, smiling, and other behaviors under their control, to see and hear things. These kinds of stimulation, of course, typically occur in the presence of parents, grandparents, neighbors, and siblings who, as major sources of reinforcers, encourage the baby to become responsive to them.

Research Applied to Parenting

Reducing Sleep Disturbances Through Changes in Learned Behavior

As the last rays of sun disappeared, Tanya shifted her focus to preparing Chad for bed. After putting on his pajamas and playing with him a few more minutes, she rocked him and sang a lullaby before giving him a final hug and kiss. But just as she was about to lay him in his crib, Chad started to cry. Tanya tried to ignore his sobs, but as they intensified to screams, she knew Chad, still wound up from the party, would not go to sleep right away this night. Indeed, he had been doing the same thing for the last several weeks. Why would this evening be any different? Tanya picked him up, played with him a bit longer, and then lay down with him in her own bed until he finally fell asleep. She moved Chad to his own crib later that evening.

Even more distressing for Tanya, however, were Chad's frequent awakenings. Usually, two or three times each night, he would cry so hard that she would have to go through the same bedtime routine until he fell asleep again. Tanya was having difficulty getting the sleep that she desperately needed, and it was beginning to take a toll on her relationship with Chad.

Surveys of parents reveal that somewhere between 10 and 40 percent of infants and young children have difficulty going to sleep or returning to sleep after awakening in the middle of the night (Blampied & France, 1993; Johnson, 1991). Most of

Establishing bedtime routines can help young children prepare for sleep. Quiet activities such as looking at and reading a book together with a parent, as well as the availability of a comforting toy such as a teddy bear, should help these toddlers make the transition from wakefulness to sleep.

these difficulties do not stem from serious developmental problems, but they can become a major challenge for parents as they try to obtain sufficient rest for themselves.

Principles of classical and operant learning can account for most sleep difficulties; they can also provide answers to eliminating the problem. For example, for a variety of reasons, such as illness, teething, or some other discomfort, an older infant or a young child may have considerable difficulty falling asleep. Under such circumstances, parents often—and in such cases, quite appropriately—pick up, rock, or otherwise soothe the child. However, such activities are usually powerful reinforcers that can strengthen fussing, crying, or other attention-getting behaviors. Thus, long after the initial distress has been resolved, a child may still display sleep difficulties at bedtime or after awakening in the middle of the night. The principles of learning suggest a number of steps to take to address this issue (Adair et al., 1992; Blampied & France, 1993; Ferber, 1985):

1. *Provide positive routines in preparation for bedtime.* Older infants and young children need to learn to associate certain cues with preparing themselves for sleep. These should include regular, quiet activities such as reading or gentle rocking about the same time each evening to reduce arousal level and increase expectations—that is, set the stage—for sleep onset.

2. *Arrange for falling asleep in the child's own crib or bed.* Children need to associate certain rooms and other spatial cues with falling asleep. Otherwise, particularly if they awaken in the middle of the night, those cues are not available to help them return to sleep.

3. *Offer comforting resources to substitute for parental attention.* A favorite toy, blanket, or other item may help young children soothe themselves in preparing for sleep. Once such items become associated with falling asleep, they can also be important cues for subsequently promoting sleep if the child awakens later in the night.

4. *Reduce and eventually eliminate parental cues for falling asleep.* Parental attention can be a highly positive reinforcer. Sleep difficulties often arise when parents rock, hold, or otherwise engage their children in trying to get them back to sleep; the parents' presence and falling asleep become a learned association (Ferber, 1985).

Infants less than four to six months of age should not be expected to adopt a sleep schedule. Parents need to follow their young infant's lead, feeding and providing other care and assistance even when tired themselves. However, older infants and young children may need to learn to fall asleep. If soothing and rocking seem to be effective, parents can feel more confident that hunger, pain, or some other problem is not the reason for difficulty in sleeping. In considering learning principles to help reduce sleep problems, Richard Ferber and others suggest that when an older infant or a young child has difficulty, parents implement a progressive *delayed-responding* or "controlled-crying" *technique* to change the association between caregiver presence and falling asleep. If a young child starts to cry after being put to bed, wait a few minutes. Then check to see that she or he is all right and does not need to be fed, changed, or provided with other care; but limit the visit to two or three minutes and to reassuring behaviors other than picking up, feeding, and so forth. Leave while the child is still awake to promote cues for falling asleep without the parent's presence. If crying continues, wait for gradually increasing periods of time before returning and follow the same procedure. On subsequent days, start with gradually longer intervals before confirming that the child is all right.

By sticking to such a schedule, parents promote fewer and less severe sleeping problems (Hiscock & Wake, 2002). Of course, an illness or a significant change in the child's life can upset a child so that sleep disturbances return. But once the immediate problem is addressed, parents may need to reimplement the steps that encourage sleep both for their child and themselves.

Classical and operant conditioning can explain the acquisition of many other behaviors throughout infancy and childhood. Through repeated associations of events and from positive outcomes, including the reinforcing actions of caregivers or "instructors," children become more skilled and proficient in a rich variety of endeavors. Consider the six-year-old learning to write the letters of the alphabet. At first, of course, neither the sizes nor the shapes of the letters are skillfully reproduced, but the teacher may express enormous satisfaction with these early efforts. With practice and as the child's fine motor skills improve, the teacher begins to expect far more legible symbols before granting praise to the student. Precisely these kinds of contingencies are central to *applied behavior analysis,* described in the chapter titled "Themes and Theories."

It is difficult to imagine, however, that habituation, classical conditioning, and the systematic implementation of reinforcers and punishment are the basis for mastering all the vital tasks of childhood. One element that seems to be missing from this discussion so far is children's active roles in observing and interpreting events that occur in their surroundings. As we see in the chapter titled "Themes and Theories," social learning theorists have also considered observational learning an important means by which children acquire many complex social and cognitive skills (Bandura, 1977b). Individuals often learn behaviors important to the community by observing the activities of others, who in turn provide further guidance. Imitation has become an increasingly important element in explaining learning throughout development.

KEY THEME
Child's Active Role

Imitation

When does imitation become possible? How important is this ability in the learning of infants and children? Andrew Meltzoff and M. Keith Moore (1999) argue that even newborns and very young infants imitate a variety of responses, including tongue protrusion, mouth opening, and possibly even facial expressions portraying such emotions as happiness, sadness, and surprise (Field et al., 1982). Although some investigators have been unable to replicate these results, many others, including the authors of one study involving infants from Nepal (see Figure 6.2), report amazing imitative competence in neonates (Reissland, 1988).

More controversial, though, is what the imitative behaviors mean. Piaget (1962), for example, claimed that infants younger than eight to twelve months could imitate someone else's behavior, but only when able to see themselves making these responses. Because babies cannot view their own faces, imitative facial gestures would be impossible, according to Piaget, until after about a year of age, when symbolic capacities emerge. From this perspective, then, facial gestures are stereotyped, rigid responses triggered by or tethered, so to speak, to limited forms of stimulation. For example, perhaps tongue

FIGURE 6.2
Facial Imitation in Newborns

Within an hour after birth, babies in Nepal showed different responses when an experimenter used pursed versus widened lip movements. On the left, the baby broadens his lips in response to widened lips by the model. On the right, the baby exposes his tongue in response to pursed lips by the model. The findings support the highly controversial position that even newborns are capable of imitating facial gestures.

protrusion by a model arouses the infant, which in turn promotes a sucking response that naturally invokes tongue protrusion from the infant (Karmiloff-Smith, 1995). Alternatively, perhaps this behavior reflects an active effort to explore an interesting object available in the infant's visual field (Jones, 1996). In either case, infants could be responding to just one or two types of stimuli and producing a kind of reflexive motor activity that is not really a form of imitation (Anisfeld, 1996).

Meltzoff and Moore (1999) counter that very young infants imitate a variety of responses, modify their imitations to increasingly match the modeled behavior over time, and exhibit their imitations primarily to other people and not to inanimate objects. These arguments contradict the view that such behaviors are simply a fixed pattern of reflexive actions. They propose instead that infants imitate in order to continue interacting with others. In fact, babies as young as six weeks will imitate behaviors of a model up to twenty-four hours later. The infant produces these imitative actions, according to Meltzoff and Moore, to help determine whether the model is the same person seen earlier, that is, as a way to help to identify and communicate with the model. If this interpretation is correct, imitation has an important social-communicative function and signals one of the earliest games babies play to learn about others in their surroundings.

KEY THEME
Interaction Among Domains

Between six and twelve months of age, infants clearly display far more frequent and precise imitations, matching a wide range of modeled behaviors (Kaye & Marcus, 1981; Meltzoff & Moore, 1999). Piaget and others (McCall, Parke, & Kavanaugh, 1977) believed that **deferred imitation,** the ability to imitate well after some activity has been demonstrated, was not possible until about eighteen to twenty-four months of age. Piaget held that deferred imitation, along with pretend play and the emergence of language, provides one of the first major pieces of evidence for symbolic capacities (see the chapter titled "Cognition: Piaget and Vygotsky"). However, as we have already seen, Meltzoff and Moore observed infants as young as six weeks reproducing a model's behavior a day after seeing it.

Other research confirms that deferred imitation can be observed far earlier than Piaget claimed. For example, six-month-olds will remove a mitten from a puppet's hand, shake it, and try to put it back on the puppet after observing this sequence of actions performed by a model twenty-four hours earlier (Barr, Dowden, & Hayne, 1996). Moreover, toddlers as young as fourteen months who see a peer pulling, pushing, poking, and inserting toys in the laboratory or at a day care center will reproduce the behaviors in their own homes as much as two days later when given the same toys and will imitate other novel behaviors as much as a week later (Meltzoff & Moore, 1999). The capacity for deferred imitation, then, appears to emerge much sooner than previously assumed. In fact, the results accord well with research on memory (discussed in the chapter titled "Cognition: Information Processing") showing that infants younger than one year can recognize stimuli hours and even days later.

The findings of imitation at very young ages provide clear and compelling evidence that infants, as well as older children, learn many new behaviors by observing others. In fact, fourteen- to eighteen-month-olds are more likely to imitate an adult's action that is accompanied by the verbal expression "There!"—indicating it was performed intentionally—than an action accompanied by the verbal expression "Whoops!"—implying a mistake (Carpenter, Akhtar, & Tomasello, 1998). This finding suggests that very young children are capable of selectively imitating the deliberate actions of others, an important achievement for learning the more important social and cultural skills valued by other members of the community. Mothers also report that two-year-olds increasingly imitate responsible behaviors such as chores and self-care (pretending to cook, brushing teeth) rather than affective or attention-getting actions such as laughing, sighing, shouting, or pounding (Kuczynski, Zahn-Waxler, & Radke-Yarrow, 1987). Thus observational learning, along with the parent's direct application of reinforcers and punishments, undoubtedly plays a powerful role in the socialization of young children.

deferred imitation Ability to imitate a model's behavior hours, days, and even weeks after observation.

Implicit Learning

Humans, including infants and young children, probably learn in many other ways. **Implicit learning** has become of increasing interest to researchers because it may help to explain the acquisition of some fundamental aspects of knowledge, including language, categories, and procedural routines that accompany many motor behaviors in infants and children. Implicit learning refers to abstract knowledge that is not available to conscious reflection. It is knowledge incidentally acquired from processing structured information; the learning is unintentional. Because much of the stimulation to which we are exposed—for example, the visual-spatial environment and language—is organized by patterns and rules, learning these systematic relationships is important for adaptation to both the physical and social worlds. Essentially, as a result of the frequent covariation of specific features and attributes in experience, we implicitly become sensitive to these patterns or rules. We present a claim for such learning in the chapter titled "Language," in the discussion of how infants might acquire some aspects of linguistic abilities, such as detecting the boundaries of words within the continuous stream of speech sound. Implicit learning may also be a significant aspect of perceptual learning, a topic discussed more fully later in this chapter.

Research by Annie Vinter and Pierre Perruchet (2000) illustrates the concept of implicit learning applied to a motor skills task. When we draw a figure such as a circle, we tend to do so either clockwise or counterclockwise, depending on the position of the starting point. For example, if the starting point is above an imaginary line drawn to connect the positions of approximately eleven o'clock and five o'clock on the circle, we tend to draw it counterclockwise; if below the line, clockwise. Of course, the task requirement of drawing the entire circle is the same no matter which direction is employed. In Vinter and Perruchet's study, children practiced drawing the circle but were instructed at what point to start and in which direction to draw it. Some children received far more experience drawing the circle in the direction opposite to the one they would spontaneously employ. When no longer instructed to draw the circle in a particular direction, they were much more likely to draw it in the direction with which they had more experience. The children (as is true of adults as well) did not realize that they had drawn the circle in one direction more frequently than the other during the practice session. Nevertheless, they continued to display this behavior, a kind of procedural learning, as much as an hour after the practice session. These findings suggest that learning takes place in many contexts and situations of which we are totally unaware and by different mechanisms than those involved in, for example, classical and operant conditioning. In other words, even infants' and young children's behavior could be dramatically influenced and driven by the various kinds of regularities that they experience in their world.

Knowing how to address a revered elder, care for a flock of sheep, read and solve complex mathematics problems, and navigate from one location to another within the city, over mountainous terrain, or between widely dispersed islands are just a few of the many complex skills children acquire that involve various facets of learning. Because learning is exhibited within the confines of a rich context of additional social and cognitive processes, its importance will continue to be evident in our discussion of many other aspects of development.

FOR YOUR REVIEW

- What are the basic principles of habituation, classical conditioning, and operant conditioning? What does recovery from habituation tell us about the habituation process? What are an unconditioned stimulus, an unconditioned response, a conditioned stimulus, and a conditioned response? How do positive reinforcement, negative reinforcement, negative punishment, and positive punishment affect behavior?

implicit learning Abstract knowledge not available to conscious reflection acquired incidentally from processing structured information.

- How can learning principles affect the sleep patterns of toddlers and young children? How might they play a role in the emergence of other acceptable and unacceptable behaviors in children?
- Why is imitation an important component of learning theory? What evidence exists for imitation in early infancy? What is the significance of deferred imitation?
- What is implicit learning?

Sensory and Perceptual Capacities

Although various kinds of learning contribute to mastering new behaviors and enriching each individual's skills and competencies, these depend on other basic processes, including sensation and perception. Tanya's queries about whether Chad could see or hear as she first held her son are the kinds of questions many parents pose to their newborns even as they seem to provide their own answers by vocalizing, making funny facial expressions, touching, caressing, and rocking the baby. Still, the uncertainty remains: what do infants sense and perceive?

Sensation refers to the basic units of information recorded by a sensory receptor and the brain. **Perception** refers to the process of organizing and interpreting sensations. Sensations consist of, for example, registering different regions of brightness or of *contours,* the transitions in dark-light shading that signal borders and edges of elements in a visual array. With respect to auditory input, sensation refers to, for example, being able to discriminate a difference in the intensity or frequency of a sound. Perception, on the other hand, takes place when the infant recognizes his mother's face by sight or interprets a sequence of sounds as a familiar lullaby. Thus, sensations are typically thought to be the building blocks; perception, the order and meaning imposed on those basic elements.

KEY THEME
Nature/Nurture

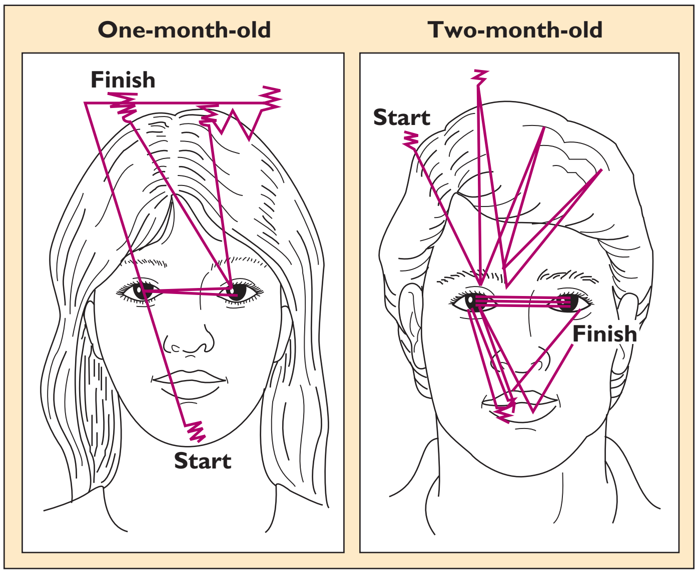
Is the sensory world of the newborn a "big blooming buzzing confusion" caused by a barrage of unorganized sensations, a view proposed by William James (1890) more than a century ago? If so, the young infant would not apprehend objects or meaningful events at first but would acquire the ability to do so only from learning, over a lengthy period of time, which pattern of basic sensory features is associated with a particular perceptual array (Gordon & Slater, 1998). Perhaps, then, as a result of repeated experience with distinctive sensory input, the infant comes to recognize the human face or to perceive how far away an object is located or to hear a sequence of sounds as a lullaby. According to this viewpoint, perceptual development is a *constructive* process, that is, one of imposing sense and order on the multisensory external world.

James and Eleanor Gibson and many of their students offer a strikingly different opinion of the early sensory capacities of infants (Pick, 1992). For them, babies come into the world well equipped to respond to the structure and organization of many stimuli and readily perceive the patterns afforded by objects and other sensory events. Some go even further. According to the *nativist* position, the newborn from very early on has, for example, a set of core principles and mechanisms to process complex visual cues signifying objects and three-dimensional space and to interpret other sensory input (Spelke & Newport, 1998). Of course, even within this framework, experience provides ever greater opportunity to refine knowledge about which properties processed by the senses are stable and important and which can be ignored as relatively uninformative.

Before considering some of the findings bearing on these issues, we can make two broad observations about work on perceptual development. First, vision has been studied far more than any other sensory domain. To some extent, this bias reflects the widespread view that sight provides the major source of information for humans. Vision, however, has also been easier to study than hearing, smell, and other senses. Second, knowledge of sensory and perceptual development in newborns and young infants has expanded far more rapidly than knowledge of their development in older infants and children (Aslin & Smith, 1988). The disparity reflects the efforts of researchers to un-

sensation Basic information in the external world that is processed by the sensory receptors.

perception Process of organizing and interpreting sensory information.



Source: Adapted from Salapatek, 1975.

FIGURE 6.3
Visual Scanning

Using specialized techniques, researchers can often pinpoint the specific features in a visual stimulus at which infants are looking. Here the typical patterns of scanning these facelike stimuli by a one- and a two-month-old have been recorded. Note how the younger infant's gaze tends to be directed to the outer or external regions of the facial stimulus, that is, hair and chin. The older infant's gaze is more frequently directed to inner features such as the eyes and mouth.

cover the earliest appearance of sensory and perceptual capacities, the finding that many important changes in these domains occur in the first few months after birth, and interest in trying to determine whether perceptual abilities are innate or acquired.

Measuring Infant Sensory and Perceptual Capacities

How can we possibly know what babies see, hear, or smell when they are unable to tell us about it in words? Researchers have devised ingenious techniques, some quite simple, to help answer this question. Most of these procedures are based on measures of **attention,** that is, alertness or arousal focused on a specific aspect of the environment. For example, when infants display attentional preferences, that is, look longer at one thing than at another, they are communicating that they perceive differences between visual arrays.

● **Preferential Behaviors** In 1958 Robert Fantz placed babies on their backs in an enclosed, criblike chamber. Through a peephole, he and his colleagues observed how long the babies gazed at different visual stimuli inserted in the top of the brightly illuminated chamber. Observers were able to determine where the infants were looking because the reflection of the stimulus could be seen on the *cornea,* the outer surface of the babies' eyes, as they looked at the objects. Using this method, Fantz (1961) found that one- to six-month-olds attended to disks decorated with bull's eyes, stripes, newsprint, or facelike figures far longer than to solid-colored circles.

The simple methodology encouraged many researchers to study the visual capacities of infants by observing their preferential looking. The procedure has some limitations, however. What can we conclude, for example, when the infant attends to both members of a pair of stimuli for the same length of time? Is the baby unable to discriminate the two, or does she prefer to look at one just as much as the other? Nor can we be certain about what features the infant is processing when gazing at a stimulus.

Despite the limitations, babies often show preferences in what they attend to, and this simple procedure has proven enormously useful in assessing whether they prefer a human face over equally complex patterns; features such as edges, corners, or movement within a visual array; and other patterns or characteristics of visual information. By using special photographic techniques involving infrared lights and appropriate film, researchers can pinpoint specific regions and aspects of a figure at which the baby looks and how she or he inspects a stimulus. Such procedures have revealed, for example, which features of a human face infants are most likely to scan, as Figure 6.3 shows.

attention State of alertness or arousal that allows the individual to focus on a selected aspect of the environment.

Habituation *Habituation* of attention, the simple form of learning described earlier, is another technique that capitalizes on the infant's tendency to prefer looking at some things more than others. Babies shown the same stimulus for relatively lengthy periods or over a series of trials pay less and less attention to it. A change in the stimulus, however, may elicit *recovery from habituation,* or, if the habituated stimulus is paired with one that is dissimilar, the infant may show a preference for the new one, both indicators that the child has perceived a difference.

Examining Research Methods

Habituation Procedures

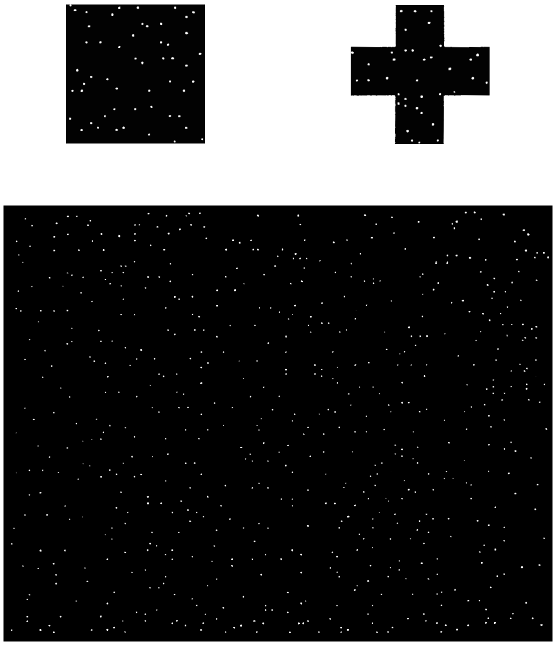
To illustrate the use of a habituation procedure, consider a recent study carried out by Scott P. Johnson and Uschi Mason (2002). They were interested in whether two-month-old infants could detect the illusory shape of a black square or a cross with points of light on the surface when the figure was embedded in an equally black background containing similar points of light (see Figure 6.4). Not surprisingly, when the figures were stationary, not even adults could see the square or the cross; the figure literally fused with the background. However, when the illusory figure moved, the accretion and deletion of the points of light on the background, as well as the relative motion of the points within the shape, "revealed" the appearance of the figure, at least to adults. Would two-month-olds be able to process these same **kinetic cues**—cues provided by changes in the flow of visual elements within the perceptual array—and perceive the illusory shape as well?

To answer this question, Johnson and Mason (2002) presented a series of trials during which either the square or the cross moved along a square path in the center of the background. Not surprisingly, the infants' attention declined over these trials; they habituated to the display. How were the researchers able to measure the babies' attention? The answer, of course, was by having observers watching through peepholes positioned at the side of the monitor on which the displays were presented and recording the amount of time the infants looked at the array before turning away for two seconds. When looking times on trials decreased to less than 50 percent of the time the infant had attended on the beginning trials—a conventional way of assessing habituation—test trials were presented. These test trials consisted of alternate presentations of a gray square and a gray cross of the same size and moving in the same pattern as the shape on the habituation trials.

Would infants show greater looking time at the test pattern that differed from the textured pattern to which they habituated? The answer was yes. If they had been presented the square during the habituation trials, most infants preferred looking at the cross; if they were shown the cross during the habituation trials, most infants preferred looking at the square. In other words, their findings indicated that the infants must have perceived the figure that appeared during the familiarization period, as their attention to the novel shape was greater on the test trials. Could the researchers have reached the same conclusion had the infants shown a preference for the figure that had appeared on habituation trials? Probably yes, although the general finding in research of this type is that infants prefer to attend to novel arrays. What could they conclude if the infants showed no preference for either figure on test trials?

Johnson and Mason (2002) went on to show in additional experiments that infants this young can detect the shape on the basis of either the accretion and deletion of the background points or from the relative motion of the light points. These findings suggest a rather remarkable ability to perceive shape as a result of motion via simple textural cues very early in development; the infants did not need to have boundary information to convey the shape in order to perceive it. The ingenuity of these researchers, along with that of many others relying on a simple habituation procedure, has yielded extraordinary insights into the sensory and perceptual capacities of even very young infants.

kinetic cue Perceptual information provided by movement of objects in the environment or of eyes, head, or body. Important source of information for depth perception.



Source: Johnson & Mason, 2002, p. 24.

FIGURE 6.4
Using Kinetic Cues to See an Illusory Figure

The habituation and recovery from habituation procedures can be used to demonstrate that even very young infants perceive illusory shapes. Johnson and Mason (2002) showed two-month-olds a black background with points of light randomly distributed on it. A square or a cross with the same background and containing similar points of light was imposed on the background to test whether accretion and deletion of the light points in the background, as well as the relative movement of the points of light, were cues that the infants could use to "see" the square or the cross. When not moving, the shapes were undetectable (the square is in the left portion of the background, the cross in the right portion). When only one of the shapes was presented moving within the background, even two-month-olds recognized the figure, as evidenced by their showing greater attention during test trials to the other (novel) figure than to the one shown during habituation trials. Infants could form a coherent percept of the moving figure, even though its appearance was undefined by contour boundaries.

Operant Conditioning More complex forms of learning, such as operant conditioning, can be used to further test an infant's ability to process sensory cues. To receive milk and other tangible rewards, such as interesting visual and auditory patterns, babies will learn to suck faster or slower, turn their heads, look, and perform other behaviors that indicate that they discriminate the arrays.

Operant conditioning procedures figure prominently in research on auditory perception. One procedure, established by Peter Eimas and his colleagues (1971), has proven especially informative. Babies are given a special nipple designed to record their rate of sucking. A baby who sucks energetically or at a rapid rate may be rewarded by hearing some pleasant sound, for example, the consonant-vowel pairing *pa.* After hearing *pa* repeatedly, the rate of sucking typically declines as the infant habituates to the stimulus. What will the baby do when a different sound, such as *ba,* is introduced? Infants as young as one month begin to suck at a high rate again in order to keep hearing *ba.* They can discriminate the new consonant-vowel pair from *pa*; they are already able to distinguish some important sounds that occur in language.

In addition to behavioral methods—preferential looking, habituation, and operant conditioning—physiological measures such as heart rate or the neurological activity of the brain and even the firing of individual neurons can be recorded to clarify the sensory and perceptual abilities of infants (de Haan & Nelson, 1997; Teller, 1998). Fortunately, the results of the various methods often complement one another in providing information about what infants are processing.

Vision

Because newborns have limited motor skills, we are often tempted to assume that their sensory systems—their eyes, ears, noses, mouths, and skin—must be passive receptors awaiting stimulation. But Eleanor J. Gibson and James J. Gibson convincingly argue that perceiving is an active process (Gibson, 1966). "We don't simply see, we look" (Gibson, 1988, p. 5). Even neonates mobilize sensory receptors to respond to stimulation flowing from their bustling environment.

KEY THEME
Child's Active Role

This young infant appears to be attentively examining his mother's smiling face. Such an interesting stimulus undoubtedly helps the baby to make sense of the various features that differentiate the face of the mother from the face of others. Visuomotor and other visual abilities rapidly improve during the first few months of life, and the ability to recognize a caregiver's face is acquired very early in development.

Visuomotor Skills The eye includes a lens designed to refract, or bend, light. The lens focuses visual images onto the *retina,* the back of the eye that houses the *rods,* which are responsive to the intensity of light, and the *cones,* which are sensitive to different wavelengths of light. The lens of the human eye is variable; small, involuntary muscles change its shape so that images of objects viewed at different distances are brought into focus on the retina, a process called **visual accommodation.** When the lens works effectively, we can see things clearly.

Newborns display limited visual accommodation. However, the process improves rapidly to nearly adultlike levels by about three months of age (Aslin, 1987a). Improvements in the physical characteristics of the eye and in paying attention to visual information may contribute to the developmental change (Hainline, 1998). In addition, the *pupillary reflex,* which controls the amount of light entering the eye, is sluggish during the first few months after birth, further reducing the ability to focus (Aslin, 1987a). As a result, infants are unable to see details of stimuli. However, they discriminate best those patterns and objects about eight to twenty inches away, the typical distance of a caregiver's face when holding or feeding the baby.

Eye movements are another essential part of looking. **Saccades,** rapid movements of the eye to inspect an object or to look at something in the periphery of the visual field, are produced within hours of birth (Lewis, Maurer, & Kay, 1978). At first, the saccades are initiated slowly and cover only small distances; neonates must launch a sequence of them to "catch up" to a peripheral target (Aslin, 1993). Saccades typically become more accurate, however, during the first three to four months and continue to improve in accuracy throughout childhood (Fioravanti et al., 1995).

Humans exhibit another pattern of eye movements, **smooth visual pursuit,** which consists of maintaining fixation on a slowly moving target almost as though

visual accommodation Visuomotor process by which small involuntary muscles change the shape of the lens of the eye so that images of objects seen at different distances are brought into focus on the retina.

saccade Rapid eye movement to inspect an object or view a stimulus in the periphery of the visual field.

smooth visual pursuit Consistent, unbroken tracking by the eyes that serves to maintain focus on a moving visual target.

FIGURE 6.5
What the Two-Month-Old Sees

Although adults with normal vision would see a clear image of this individual (A), the two-month-old would perceive the same individual in far less detail as suggested by the photo on the right (B). Acuity in young infants, however, rapidly improves and typically approaches a normal level sometime between about six and twelve months of age.

the eyes were locked onto it. Newborns display only brief periods of smooth pursuit, but its execution continues to improve through six to eight months of age (von Hofsten & Rosander, 1997), when it begins to appear adultlike. The development of both saccadic and smooth visual pursuit eye movements is closely linked to the improving capacity of infants to sustain attention to visual arrays (Richards & Holley, 1999).

In looking for an object, both eyes normally move together in the same direction. Sometimes, however, the eyes must rotate in opposite directions, turning toward each other as, for example, when a person tries to see a fly that has landed on his or her nose. This response, called **vergence,** occurs when fixations shift between far and near objects; otherwise, we would see double images. Vergence occurs irregularly in infants younger than two months, especially when objects are not static and move to different depths (Hainline & Riddell, 1995; Thorn et al., 1994). For example, young babies' eyes may fail to rotate far enough toward each other to converge on a visual target.

Acuity How well are young infants able to see despite their immature visuomotor skills? The question concerns **visual acuity.** One common test of visual acuity, the *Snellen test,* is based on identifying letters or other symbols on a chart twenty feet away. Babies, of course, cannot name letters, so other procedures are used to test their visual acuity. Several methods have been devised, but one that has proven reasonably good relies on preferential looking. As an array of, say, black and white stripes appears more frequently (the stripes become narrower), the pattern becomes more difficult to see, and the stimulus eventually appears gray. Infants unable to detect the stripes quickly lose interest, preferring to attend instead to a pattern they can still detect. By pairing stimuli with different frequencies of stripes and observing preferential looking, researchers can gauge the visual acuity of infants.

Two key findings emerge from the many investigations of visual acuity and *contrast sensitivity,* another more complex measure of visual capacity that takes into consideration ability to discriminate when illumination, orientation, and other aspects of contour also vary. First, even newborns detect contours, although their acuity and sensitivity to contrast is estimated to be about forty times poorer than in children or adults as suggested in Figure 6.5 (Maurer et al. 1999). Second, acuity and contrast sensitivity improve rapidly during the first six months after birth and continue to improve at a slower rate for several years thereafter (Adoh & Woodhouse, 1994; Tschopp et al., 1999). The gain, especially during early infancy, is owed to enhanced visuomotor skills and neural pathways for vision, changes in the shape and physical characteristics of the eye, and greater efficiency in the functioning of visual receptors in the retina.

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Perceptual Abilities in Infants

vergence Ability of the eyes to rotate in opposite directions to fixate on objects at different distances; improves rapidly during first few months after birth.

visual acuity Ability to make fine discriminations among elements in a visual array by detecting contours, transitions in light patterns that signal borders and edges.

KEY THEME
Nature/Nurture

Atypical Development

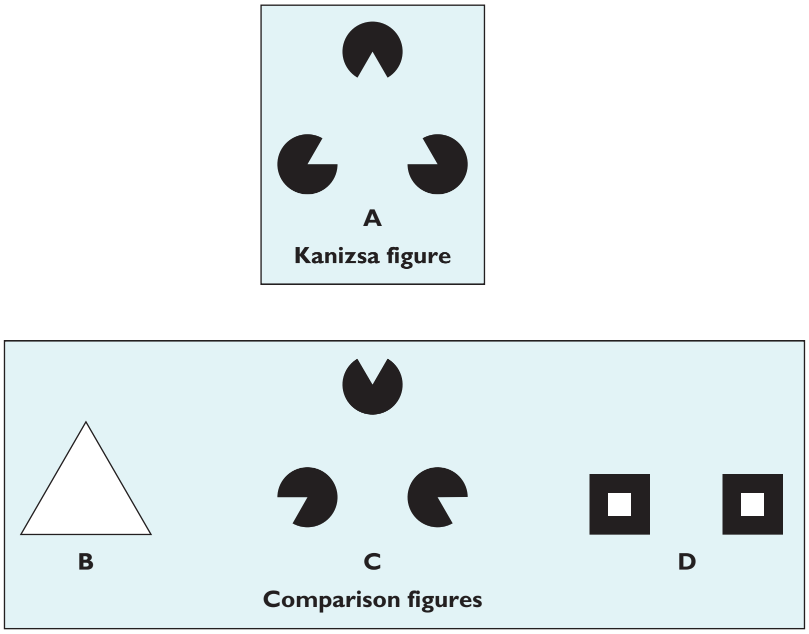
Visual Problems in Infancy

How important is visual sensory stimulation during infancy and early childhood for the development of the normal capacity to see? In the chapter titled "Brain, Motor Skill, and Physical Development," we describe research carried out on young kittens suggesting that early perceptual stimulation was essential for the growth of neurons in the visual receptor areas of the cortex. Although experimental procedures cannot be carried out on human infants, several naturally occurring problems in infancy suggest similar consequences for the development of human visual abilities.

Approximately 1 in every 10,000 babies is born with cataracts, a clouding of part or all of the lens of the eye that impairs the capacity to see patterned stimulation (Sireteanu, 1999). If uncorrected, the baby's visual acuity, as well as other visual abilities, can be seriously impaired. Moreover, if the cataract is located in only one eye, the normal eye will actively suppress whatever responsiveness exists in the affected eye. The result is a lack of improvement in acuity in the affected eye, as well as impairment in depth perception because of the loss of binocular vision. Fortunately, cataracts are often relatively easy to detect. They can be surgically removed if medical resources are available, and substitute contact lenses can be implanted so that visual input will be focused on the retina. When such procedures are followed early in infancy, acuity in the affected eye or eyes improves rapidly, even after only an hour of patterned visual experience, and continues to improve rapidly with an outcome of normal visual development (Maurer et al., 1999).

Perhaps an even more frequent visual problem affecting as many as 5 percent of infants and young children is *amblyopia*, a condition sometimes called "lazy eye." Amblyopia refers to the failure of vision to develop in one eye, again because of suppression of visual input by the other eye. A common cause of amblyopia is *strabismus,* or the inability of the two eyes to display vergence. In many circumstances, strabismus is also relatively easy to detect; the eyes appear misaligned, or the child appears "cross-eyed" because muscles controlling the directionality of one of the eyes may be too strong or too weak. When strabismus is corrected early, normal depth perception and vision again become possible, as the two eyes begin to work together. However, for some infants and young children, the complementary functioning of the two eyes may go awry even without visible evidence of strabismus if, for example, the ability of one eye to focus is better than the other. A child with amblyopia displays the progressive loss of depth perception that vergence provides (Banks, Aslin, & Letson, 1975), and the weaker eye may become functionally blind. Fortunately, many procedures are available to correct such conditions, including patching the stronger eye for a period of time to strengthen the weaker one. If not performed early, preferably in toddlers and especially before the end of the preschool years, the loss of visual capacities can be permanent. However, parents, and sometimes even pediatricians, may not always be aware of these visual problems. Thus caregivers need to take the initiative in ensuring that their infants' and toddlers' vision is evaluated by experts who can conduct relatively simple tests for amblyopia; adequate perceptual stimulation early in development is an essential ingredient to the emergence of normal visual capacities.

Color Perception Can babies also see colors? Once again the answer is yes, at least after a few months of age. Although very young infants may not see a full range of colors, perception of several hues is possible. For example, shortly after birth babies can detect red hues, especially if they are highly saturated, that is, contain relatively few wavelengths of other light (Adams & Courage, 1998). Detection of some hues may even become adultlike by three months of age (Kellman & Banks, 1998; Teller, 1998).



Source: Adapted from Treiber & Wilcox, 1980.

FIGURE 6.6
Infants' Subjective Perception of Form

Infants, as well as adults, perceive the subjective triangular figure (A) even though no contour is present to define it. After becoming habituated to the Kanizsa figure, babies are shown other figures, including a standard triangle formed by visible contours (B), the indented circular figures rotated to eliminate the subjective triangle (C), or a completely different array of stimuli (D). Infants show the least recovery from habituation to the traditional triangle (B), suggesting that they perceived the triangular shape produced by the Kanizsa figure.

Perception of Pattern and Form Few questions fascinate psychologists more than when and how infants recognize patterns and other configurations of visual arrays. Are babies born with the ability to perceive wholes and units? Some researchers think so. Others have argued the more traditional view, that this capacity is acquired only through extensive visual experience; infants become aware of or construct perceptions of integrated, holistic, and meaningful visual figures through repeated opportunities to process contours, angles, shading, and other primary sensory features.

KEY THEME
Nature/Nurture

As we have already learned, very young infants detect contours of visual stimuli, as well as movement associated with contours. Does that necessarily mean that they see a unitary object or pattern? Perhaps not, but evidence suggests that by two or three months of age, babies are likely to see the whole. Furthermore, infants now inspect and analyze the components of complex stimuli, scanning a variety of their visual properties and carrying out a much more deliberate, organized search (Bronson, 1994). A good example of this developmental change is demonstrated by the **externality effect:** infants younger than about two months of age typically focus on the outer contours of a complex stimulus as if caught by this sensory feature, so that little systematic exploration of its internal characteristics takes place. However, older infants tend to scan its internal features as well (Maurer, 1983; Salapatek, 1975). We saw an illustration of the externality effect in the discussion of preferential looking. Babies younger than two months tend to fixate on the outer contours of the face, such as hair or the chin line; older infants much more frequently inspect internal features, such as the eyes or mouth (see Figure 6.3).

KEY THEME
Child's Active Role

Other experiments provide further evidence that babies perceive entire forms and patterns at least within a few months after birth but continue to show improvement in form perception throughout infancy (Kellman & Arterberry, 1998). One especially convincing illustration involves subjective, or gradient-free, contours. Look at the Kanizsa figure shown in Figure 6.6. You should see a highly visible white triangle appearing to stand "above" three black, disklike figures at each of its corners. But closer inspection will reveal that the brain subjectively assumes the triangular form; no contour is present to mark its edges. Infants, perhaps when as young

externality effect Tendency for infants younger than two months to focus on the external features of a complex stimulus and explore the internal features less systematically.

as one or two months and certainly by three to four months, perceive the subjective figures too, another powerful demonstration that perception of form is not always based on a detectable contour (Ghim, 1990; Treiber & Wilcox, 1980). In addition to seeing the illusory figure, infants by eight months of age treat it as residing above the circular elements. When other elements are moving in the array, they are perceived as disappearing "behind" the illusory figure and coming out its other side (Csibra, 2001).

KEY THEME
Interaction Among Domains

Some perceptual patterns are especially significant to the infant. One is the human face. Do even newborns recognize faces, perhaps the faces of their caregivers? Based on the discussion so far, it should not be surprising to learn that by about two months of age infants do assign great importance to the face, attending to it more than to other, equally complex arrays. But an even earlier, perhaps innate preference also makes evolutionary sense, because faces are a vital source of information for social and emotional relationships.

KEY THEME
Nature/Nurture

Some researchers have found evidence that newborns prefer, at least for moving configurations, a facelike image—two eyelike representations above a mouthlike feature—to other arrangements of the same components (Johnson et al., 1991). Mark Johnson and his colleagues (Johnson, 1992; M. H. Johnson et al., 2000) suggest that this inborn preference arises from a fairly primitive subcortical visual system that functions in newborns. Within about two months of age, this primitive system is supplanted by a more sophisticated cortical visual system that explores and discriminates faces from other, equally complex stimuli (Mondloch et al., 1999). The primitive system helps to ensure, however, that the infant gets off to the right start by preferring this extremely important perceptual array. Moreover, newborns display preferences for certain kinds of faces. Alan Slater and his colleagues (Slater et al., 1998) showed babies between one and six days of age pairs of female faces that had been judged by adults as attractive and unattractive. These infants gazed at the attractive faces longer than the unattractive faces. By five months of age, they also prefer looking at pictures of faces with larger eyes, just as do adults (Geldart, Maurer, & Carney, 1999).

When does a baby discriminate his or her mother's face from that of another person? Perhaps within days after birth (Bushnell, Sai, & Mullin, 1989). However, as you might guess, this recognition is based on outer elements, such as hairline or head contours, rather than on a full appreciation of a mother's facial features (Pascalis et al., 1995). By six months of age, differences in brain wave patterns are evident when a baby looks at her mother's face compared with a stranger's face (de Haan & Nelson, 1997). The conclusion is that infants are attracted to and identify significant aspects of the human face early in their development and make rapid strides in perceiving and recognizing this important social stimulus.

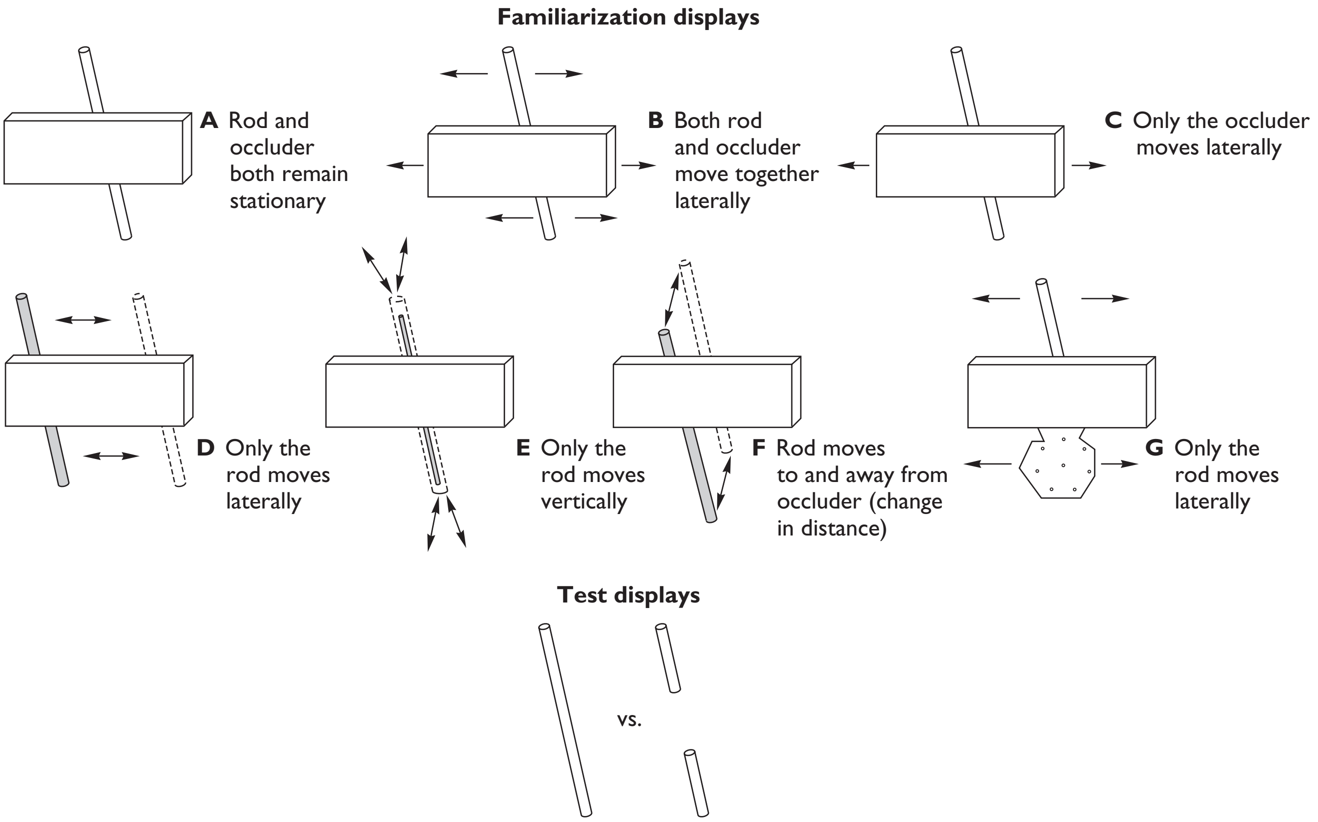
KEY THEME
Child's Active Role

● **Perception of Objects** Much of the visual environment is made up of objects and their surfaces. How does a baby perceive a rattle apart from the table on which it lies or the family dog as distinct from the floor on which it sits? James J. Gibson (1979) argued that the dynamic flow of visual information provided by kinetic cues is essential to this capacity.

Research carried out by Philip Kellman, Elizabeth Spelke, and others supports Gibson's position regarding the importance of kinetic information for perceiving objects, even in infants as young as three months of age (Kellman, 1996; Kellman & Spelke, 1983). Kellman, Spelke, and their colleagues initiated similar studies investigating how a variety of movements associated with an occluded rod influences the infant's inferences about object unity. Figure 6.7 illustrates some of the variations that infants were shown. Babies interpreted the rod as complete, not broken, as long as its two protruding ends appeared to move together in the same direction and independently of the block during habituation trials, even if the two visible ends were of quite different shapes (Kellman & Banks, 1998). If neither the

FIGURE 6.7 Inference of Unity and Coherence

Under some conditions, four-month-olds respond as if they perceived an occluded rod as a single complete figure. Infants are habituated to one of the seven familiarization displays shown here and are then presented with the test displays. After viewing conditions A, B, and C, infants respond to the complete rod in the test display as novel, indicating they perceived the rod in A, B, and C as being broken. When shown conditions D, E, F, or G, however, infants appear to perceive the rod as a connected whole, showing less attention to the complete rod than to the broken rod in the test display. The results indicate that young infants are able to infer unity and coherence for objects. Research suggests newborns do not make these perceptual inferences.



Source: Adapted from Spelke, 1985.

rod nor the block moved, or if the rod and block shifted together in the same direction, or if only the occluding block moved during habituation trials, the infants did not "fill in" the unseen portion of the rod; they treated the stimulus as two short pieces separated by an intervening space. By about six months of age or older infants are more likely to infer a unitary rod when its ends move together in a different direction—for example, when it rotates behind an occluder (Eizenman & Bertenthal, 1998).

Kinetic cues associated with viewing three-dimensional arrays are not the only way for infants to infer object unity (Mareschal & Johnson, 2002). A recent set of studies involved two-dimensional computer-generated figures in which a rectangular surface was displayed on a textured background (much like that shown in Figure 6.4) and appeared to bisect the end projections of a rodlike element. The cues provided by the appearance and disappearance of the dots on the textured background were necessary for infants to infer the unity of the end projections of the rod, as it and the rectangular shape were shown moving independently in the two-dimensional array. However, when the end projections were misaligned so that they did not appear to project toward one another, the infants did not infer their unity as part of a single occluded rod (S. P. Johnson et al., 2000). Thus characteristics of the occluded form, as well as its movement in the textured background, contribute to its perception of connectedness.

KEY THEME
Nature/Nurture

Is the perception of a coherent object possibly innate? Might newborns interpret the rod as being complete as well? Alan Slater and his colleagues think the answer is no (Slater et al., 1996). Under movement conditions in which older infants treat the separated segments as novel, newborns see the complete rod as novel; they do not fill in or make the perceptual inferences about the occluded segment of the stimulus.

Amy Needham (2001) and her colleagues (Needham & Baillargeon, 1998; Needham & Modi, 2000) have argued for yet one other important factor in object perception for infants, especially when perception takes place in a relatively cluttered environment in which many contours and surfaces are intermingled. Such a condition might exist, for example, when the infant is able to see a pacifier stuck among numerous toys in a box or among kitchen utensils in a drawer. Needham suggests that in these circumstances having viewed or manipulated the object as a separate entity at an earlier time is critical. Because the infant has memory for the segmented visual display on the basis of experience with it, he or she is able to perceive it in other contexts. Needham's work, then, points out the role that the infant's emerging cognitive capacities (see the chapters titled "Cognition: Piaget and Vygotsky" and "Cognition: Information Processing") might play in the very young infant's perception. In other words, perceiving an object may stem not only from processing features and characteristics of the external sensory environment but also from what the infant brings to the perceptual task in the form of memory for having interacted with it before.

● **Biological Motion** The role of kinetic cues, and motion in general, for early infant perceptual development is demonstrated in yet another phenomenon known as *biological motion.* Bennett Bertenthal (1993) and his colleagues (Proffitt & Bertenthal, 1990) carried out a series of studies in which infants were shown points of light moving as though attached to the head and major joints of a person walking. Adults who observe the pattern readily interpret the light movement as though it were someone walking. In other conditions, the pattern of lights was inverted or an equivalent amount of motion was shown but with the lights scrambled so that the motion did not simulate the appearance of a person walking. Using attentional and habituation measures, these experiments demonstrated that by the time infants have reached three to five months of age, the "walker" has taken on special meaning to them compared with other patterns of light motion.

● **Depth Perception** From our earlier discussion of visual problems in infancy, it should be apparent that, in addition to seeing to the left and right and above and below, babies see depth or distance. Yet visual images are recorded on the retina in two dimensions. When and how do we acquire the ability of depth perception? One source of information is *binocular vision.* Sensory information differs slightly for each eye. The ability to fuse the two distinct images to perceive a single object is called **stereopsis,** a capacity that improves markedly during the first four months after birth. Stereopsis provides clues to depth as effectively for six-month-olds as for adults (Fox et al., 1980; Held, Birch, & Gwiazda, 1980).

Still other sources of information about depth and distance are available to infants. A classic series of studies involving the **visual cliff** suggests that kinetic cues are among them. The visual cliff consists of a large sheet of glass bisected by a relatively

stereopsis Ability to perceive a single image of an object even though perceptual input is binocular and differs slightly for each eye; significant source of cues for depth perception.

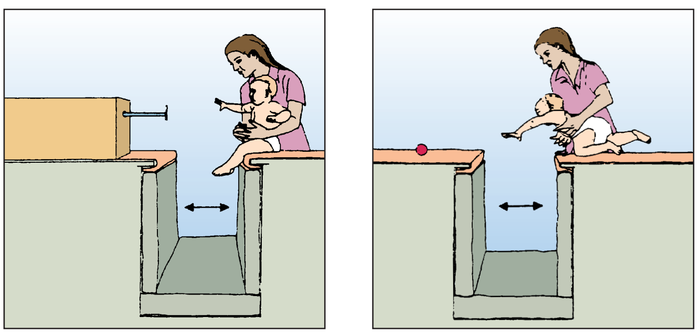
visual cliff Experimental apparatus used to test depth perception in which the surface on one side of a glass-covered table is made to appear far below the surface on the other side.

narrow plank. A patterned surface is placed immediately under the glass on one side, but much farther below it on the other side. Richard Walk (1968) found that an infant old enough to crawl can usually be coaxed to cross the shallow side but was much less likely to crawl over the deep side. The kinetic cues provided by their own head and body movements signaled depth; the babies showed the same response regardless of whether they could use one or both eyes.

Even babies too young to crawl react to the shallow and deep sides of the visual cliff differently. When placed face down on the glass surface, two- to three-month-olds become quieter, are less fussy, and show a greater decrease in heart rate on the deep side than on the shallow side (Campos, Langer, & Krowitz, 1970). Such reactions suggest that infants have not yet associated anxiety or fear with depth and find the visual information provided by the deep side more interesting than that on the shallow side. In fact, depth cues may already influence attention at birth, because newborns prefer looking at three-dimensional objects to looking at two-dimensional figures (Slater, Rose, & Morison, 1984).

Surprisingly, however, learning to avoid a drop-off occurs relatively independently when babies are acquiring the ability to sit, crawl, and walk. Karen Adolph has observed infants as they attempt to either reach across or crawl over a gap and as they attempt to negotiate crawling or walking down a steeply inclined surface (Adolph, 1997, 2000). Whereas infants may avoid reaching across a gap that would cause them to lose their balance and fall from their seated position, they may readily attempt to crawl across a gap that is far too wide for them to avoid falling (see Figure 6.8). Similarly, even though they may have learned to safely crawl down an inclined plane, they seem to have to relearn the dangers of that same slope when beginning to walk. Although infants may perceive depth, awareness of the risks accompanying it does not transfer to the acquisition of later postural and motor milestones. Instead, infants need to learn to coordinate their perception of depth with safe actions for negotiating their surroundings as each new kind of postural and motor ability is acquired.

Finally, other cues, collectively described as *pictorial,* signal depth in photos or two-dimensional arrays. Pictorial cues include relative size (near objects appear larger), shadows, interposition of surfaces (one surface hides another), and linear perspective (lines converging toward a horizon), as well as the surface contour cues depicted in Figure 6.9. Infants begin to use many of the cues to identify nearer configurations by about five to seven months of age (Kellman & Arterberry, 1998; Sen, Yonas, & Knill, 2001; Yonas & Owsley, 1987). Thus infants respond very early on to an abundant array of cues signaling depth and the three-dimensionality of objects. Many aspects of visual development during infancy are summarized in the Visual Development chronology.



A **B**

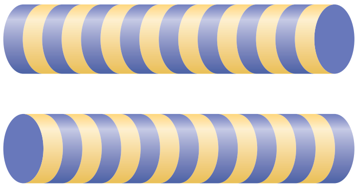
Source: Adolph, 2000, p. 292.

FIGURE 6.8
Avoiding a Risky Fall

Although infants at a very young age can perceive depth, their understanding of its consequences has to be relearned to fit the postural limitations associated with different motor skills. An infant may resist leaning too far to reach an attractive object located across a gap when sitting (A). However, that infant may readily try to crawl across a gap of a similar width and would fall if not caught by the experimenter (B). Similarly, in learning to locomote down an inclined plane, the child seems to have to relearn that he or she will fall down a steep slope that he or she can successfully negotiate when crawling. Coordinating perceptual information with permissible actions has to be relearned with each motor milestone in development.

FIGURE 6.9
Surface Contour as a Cue Implying Depth

Objects with certain kinds of markings can produce the illusion of depth in a two-dimensional array. One end of one of the cylinders in each pair shown here appears to be closer than the other, depending on the pattern of surface contours. When shown these two-dimensional arrays, infants seven months of age also process this kind of pictorial depth cue; they are more likely to reach toward the end of the cylinder that looks closer. Five-month-olds do not consistently reach to the apparently closer end; these surface cues do not yet provide a source of information about depth for them. These and other findings indicate that infants begin to use a variety of pictorial cues to interpret depth in the layout of two-dimensional visual arrays at around five to seven months of age.



Source: Sen, Yonas, & Knill, 2001, p. 168.

FOR YOUR REVIEW

- What is the difference between sensation and perception?
- How are attention and other behavioral and physiological responses used to investigate infant sensory and perceptual capacities?
- What limitations exist in infant visual accommodation, saccadic eye movements, smooth visual pursuit, vergence, and other visuomotor capacities? How quickly do these achieve adultlike ability?
- What kinds of visual problems are found among infants? Why is the correction of these problems important in infancy or early childhood?
- What is the ability of infants to perceive color?
- How early do infants see patterns and forms in the visual world? What is the externality effect? What is the developmental course of infant perception of faces? When can an infant distinguish the faces of caregivers from the faces of others?
- How early and what kinds of cues can be used by infants to perceive objects in their world? What is meant by the perception of biological motion?
- How early and what kinds of cues can be used by infants to perceive depth? What evidence exists to indicate that its perception does not always produce appropriate responses to the dangers associated with depth?
- Why do developmental psychologists no longer believe the infant's visual world is simply a "blooming buzzing confusion?"

Audition

Just as opinion once held that newborns are blind, so did it assert that newborns are deaf (Spears & Hohle, 1967). However, the fetus is listening well before birth. Brain wave patterns, heart rate changes, and activity level observed on ultrasound scans reveal responses to vibroacoustic stimulation (Kisilevsky, Hains, & Low, 1999; Kisilevsky & Muir, 1991). Low-frequency sounds, the kind that are produced in human speech, are detected by the fetus sometimes as early as twenty-three weeks of age (Kisilevsky & Low, 1998; Lecanuet, 1998). Sensitivity to a wide range of sounds at lower and lower intensities increases dramatically during the remainder of the prenatal period (Hepper & Shahidullah, 1994).

KEY THEME
Nature/Nurture

Persuasive evidence that fetuses hear also comes from several studies indicating that newborns prefer to listen to the sounds they heard before birth. Anthony DeCasper and Melanie Spence (1986) asked expectant women to read aloud a passage from Dr. Seuss's *The Cat in the Hat.* Women read the passage twice a day during the last six weeks of pregnancy; their fetuses were exposed to the story for a total of about three-and-a-half hours before birth. Two or three days after birth, the babies listened to either the same passage or a new story while outfitted with a special pacifier that recorded rate of sucking. Depending on rate of sucking, the recording of the story would turn on or off. When newborns heard *The Cat in the Hat,* they changed

CHRONOLOGY: *Visual Development*

Newborn

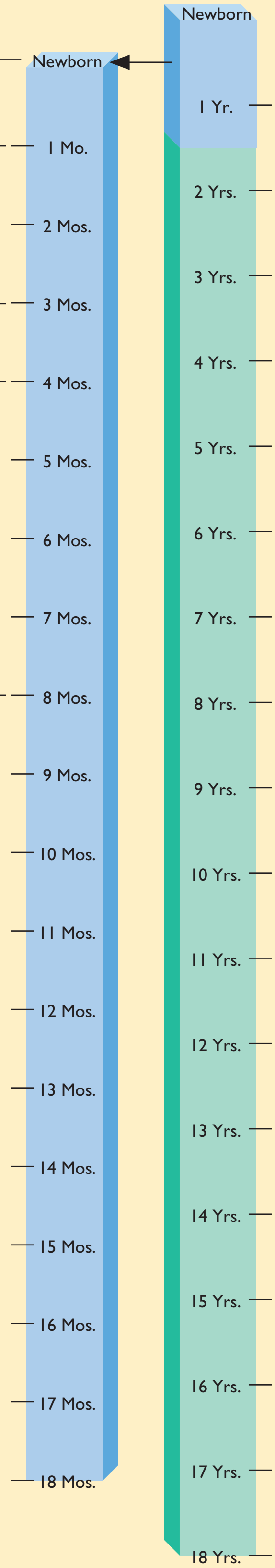
- Shows minimal accommodation; limited, sluggish saccades; incomplete vergence.
- Detects contours, but acuity and contrast sensitivity remain relatively poor.
- Prefers attending to highly visible contours, angles, features in motion, and three-dimensional over two-dimensional stimuli.
- Exhibits externality effect.

1–3 Months

- Shows accommodation; near normal adultlike vergence.
- Smooth visual pursuit emerges.
- Discriminates cues to depth.
- Responds to rapidly expanding visual images.
- Explores internal as well as external features of stimuli.
- Recognizes shape of simple figures and more detailed patterns and objects.
- Prefers attending to increasingly complex patterns, including those with facelike organization.
- Detects basic colors.
- Infers “subjective” contour if defined by movement cues.

4–8 Months

- Exhibits stereopsis.
- Saccadic eye movements become larger, more rapid, and accurate.
- Shows adultlike smooth visual pursuit.
- Acuity and contrast sensitivity approach normal.
- Displays fear of depth on visual cliff.
- Discriminates many pictorial (two-dimensional) cues to depth.
- Distinguishes symmetrical from asymmetrical patterns.
- Processes “subjective” contours even if arrays are static.
- Perceives occluded objects as wholes.
- Becomes responsive to “biological motion.”



This chart describes the sequence of visual development in infancy based on the findings of research. Children often show individual differences in the exact ages at which they display the various developmental achievements outlined here.

their rate of sucking to listen to it but did not do so for the new story. Some kind of learning about the Dr. Seuss story apparently took place prenatally.

What precisely does the fetus hear, and what is it learning from these exposures? We are not really sure. As newborns, infants prefer to listen to their mothers' voice rather than the voice of a stranger (DeCasper & Fifer, 1980), especially the lower frequency sounds associated with their mother's voice (Spence & Freeman, 1996). Because the mother's body tissue and bones are very good conductors of sound, the newborn already has had considerable exposure to characteristics of the mother's speech (Lecanuet, 1998). However, the fetus can also learn something about the cadence of sound as well. After expectant women in France repeatedly recited a rhyme from the thirty-third to thirty-seventh week of their gestation period, changes in fetal heart rate in response to the rhyme revealed that the fetus differentiated it from another novel rhyme even when recited by someone else (DeCasper et al., 1994).

Controversy: Thinking it Over

Should the Fetus Undergo a Sensory Curriculum?

Many prospective parents are eager to assist their child's development in any way they can. That desire extends to the fetus as well. An expectant mother, as we saw in the chapter titled "Prenatal Period and Birth," can initiate many practices that will foster healthy development during pregnancy. But with the advent of public awareness about the auditory and learning abilities of the fetus has come a new type of training that some parents have adopted to promote development, this time in terms of giving their infants a psychological head start.

What Is the Controversy?

With the finding that the fetus has sensory capacities, a new kind of "curriculum" has entered the caregiving market. This one involves the planned and regular exposure of the fetus to patterned sounds—simple ones, such as a heartbeat or drumbeat, or complex auditory and vibroacoustic events, such as classical or other kinds of music; sometimes even words, numbers, and letters are steadily relayed to the fetus via a belt worn by the expectant woman. Such technological gadgetry is really only one example of such efforts; others may expose the fetus to "daily lessons" in music or other forms of sensory stimulation via other means. Does this practice give the newborn a head start in life by stimulating intellectual processes or by arranging a relaxing and comforting continuity to its world after birth? Could it have some negative consequences?

What Are the Opposing Arguments?

Some claim that this kind of early stimulation can have lasting beneficial effects on cognitive development, literally helping children to become smarter. Others suggest that these early memories promote emotional stability as well, a kind of "security blanket" in the form of a soothing environmental context for the infant, who is experiencing many additional stresses in negotiating the new world after birth. Countering these views is the concern about whether such extra stimulation, especially if too intense, might actually damage delicate sensory organs that are just beginning to function. For example, low-frequency sounds emanating from outside the womb are somewhat amplified for the fetus (Richards et al., 1992), and expectant women exposed to noisy workplaces or rock concerts sometimes report considerable activity in their fetuses. No one really knows what level of sound intensity the fetus might be exposed to by an enthusiastic prospective parent. Could such experiences, then, disrupt sleep patterns that occur prenatally, overstimulating and discomforting the fetus with the potential outcome of disrupting normal brain development?

What Answers Exist? What Questions Remain?
At this time, despite some claims to the contrary, no scientific studies have demonstrated that a prenatal sensory curriculum promotes cognitive, creative, or any other form of intellectual development. Nor is there any evidence supporting its potential benefits for emotional or social development. It would be extremely difficult to conduct experimental research that could show that development is enhanced by a sensory curriculum rather than by some other characteristic of parenting activity practiced either before or after the birth of the baby. Perhaps, if there are benefits, they may be as much for the prospective parents as for the baby. Gently talking to the fetus and reserving and organizing time for it may provide a kind of prelude to the type of attention and schedule that the infant will very likely demand after birth. And listening to music may be good for adults as well. But one thing all agree on, even those who champion a sensory curriculum, is that moderation is essential (Van De Carr & Lehrer, 1996).

Hearing Little research exists on exactly how well babies hear immediately after birth. Physiological measures taken from the auditory brain stem suggest that responsivity is nearly adultlike for some frequencies, especially those in the middle range, of sounds that humans can detect (Sininger, Doyle, & Moore, 1999). However, work using attentional and behavioral measures with older infants reveals marked improvement in most auditory skills throughout the first few months. Certainly by about six months of age, babies are able to detect and discriminate numerous features of sound, such as its frequency and intensity, almost as well as do adults (Aslin, Jusczyk, & Pisoni, 1998).

Not all babies, however, are able to hear at birth. Deafness and other hearing disabilities strike an estimated one to three out of every thousand infants born in the United States (Stein, 1999). That translates into perhaps as many as 20,000 infants each year who are hearing impaired. Lower rates are found in some Western European nations such as France (Baille et al., 1996), but higher rates are found in many other regions of the world. New screening techniques—for example, physiological measurements of neural activity in the auditory brain stem—can be used with infants to detect the possibility of hearing loss. Auditory screening is often administered to those infants born at risk in families with a history of hearing impairment or to those exposed to cytomegalovirus and other diseases or drugs known to affect hearing. However, auditory screening of infants is not universal in many countries, including the United States and the United Kingdom, despite the known benefits of early intervention (Joint Committee on Infant Hearing, 2000; Kennedy, 2000). In fact, congenital hearing impairment is detected in only about half of the infants who have the impairment in the United States during the first year of life (Eilers & Berlin, 1995).

KEY THEME
Individual Differences

Sound Localization and Patterns of Sound Shortly after birth babies display **sound localization,** the ability to locate a sound in space, by turning their heads or eyes in the direction of the sound. This early ability, which may be reflexive, declines during the first two months and then reemerges at about four months of age in the form of a more deliberate search for sound (Field et al., 1980). Ability to locate the precise position from which a sound originates markedly improves throughout infancy and into early childhood (Ashmead, Clifton, & Perris, 1987; Morrongiello, Fenwick, & Chance, 1990). By six to eight months of age, infants also begin to appreciate the distance from which a sound emanates. At this age, babies hearing a sound in the dark produced by an object beyond their reach are less likely to attempt to retrieve it than an object producing a sound that is within their reach (Clifton, Perris, & Bullinger, 1991).

In every culture that has been observed, caregivers sing to their infants (Trehub, Unyk, & Trainor, 1993). Can babies distinguish music from noise? Might they even have a preference for some kinds of music? Two- and three-month-olds do recognize changes in tempo (the rate at which sounds occur; Baruch & Drake, 1997) and in

sound localization Ability to determine a sound's point of origin.

intervals between brief bursts of sound that denote simple rhythmic change (Demany, McKenzie, & Vurpillot, 1977). Between six months and one year of age, they also begin to distinguish between more complex rhythms and patterns of sounds (Clarkson, 1996; Morrongiello, 1984). For example, at eight months of age babies recognize changes in short (six-note) melodies, including a transposition in key and the shift to either a higher or a lower frequency of a single note in a sequence (Trehub, Bull, & Thorpe, 1984; Trehub, Thorpe, & Morrongiello, 1985). Surprisingly, under some circumstances eight-month-olds are able to keep track of absolute pitch better than adults (Saffran & Griepentrog, 2001).

In addition to detecting differences between sound patterns, infants show clear preferences for certain auditory events. Perhaps because of its voice quality or tempo, they prefer to listen to a song or lullaby directed by an adult to another infant over the same song or lullaby of the adult singing alone (Trainor, 1996). In fact, four-and-a-half- to six-month-olds can boast of some budding capacities as music critics! Carol Krumhansl and Peter Jusczyk (1990) chose short passages of Mozart minuets and introduced brief pauses at locations judged by adults to be either natural or awkward places for a musical phrase to end. Babies preferred looking at a loudspeaker that played only natural versions of the music to those passages that played unnatural versions of the Mozart selections. Other research has shown that infants prefer the original passages of Mozart minuets over versions in which the intervals between sequences of notes have been altered to create a more dissonant, less pleasing sound, as heard by adults (Trainor & Heinmiller, 1998). In addition, after hearing two Mozart sonatas daily over several weeks' time, seven-month-olds can distinguish these from other Mozart sonatas, even when tested two weeks later (Saffran, Loman, & Robertson, 2000).

WHAT DO YOU THINK?

Is There a "Mozart Effect"?
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Babies are indeed sensitive to rhythmic and melodic contour. Hemispheric asymmetries in responsiveness to melodic changes (a left-ear/right-hemisphere advantage), as well as to speech sounds (right-ear/left-hemisphere advantage), are found in many young infants just as they are observed in adults (Balaban, Anderson, & Wisniewski, 1998). Moreover, the ability to detect satisfying musical phrasings may be important not only for appreciating music but also for the phrasing and sound rhythms that commonly underlie speech. The Auditory Development chronology summarizes some of the early abilities displayed in this domain.

Speech Research on infants' hearing abilities has often been conducted to answer another question: how soon do babies perceive human speech? The ability to interpret speech sounds as meaningful elements of language probably begins in the second six months of life. That developmental story is discussed in the chapter titled "Language." However, can even younger infants discriminate speech sounds?

The smallest unit of sound that affects the meaning of a word is called a **phoneme.** Phonemes are surprisingly complicated bursts of acoustic energy. For example, a difference of less than one-fiftieth of a second in the onset or transition of a frequency of sound is enough for adults to discriminate the distinctive phonemes /*p*/, /*b*/, and /*t*/ in the sounds *pa, ba,* and *ta.* (Linguists use slashes to identify the phonemes of a language.) Are infants able to hear the differences? Indeed they are. In fact, before six months of age babies distinguish all the important sounds in any of the hundreds of languages spoken around the world (Werker & Desjardins, 1995).

KEY THEME
Nature/Nurture

From these findings, some who study language acquisition argue that babies are born with a "speech module," an innate capacity to detect and process the subtle and complicated sounds that make up human language (Fodor, 1983). The complexity of language acquisition, according to this view, requires a specialized ability because the cognitive skills of infants and young children are so limited. Another view is that phoneme discrimination hinges on general auditory capacities, capacities not limited to processing speech sounds or even necessarily unique to humans but that infants are able to exploit quite early in development.

phoneme Smallest unit of sound that changes the meanings of words.

What evidence exists for either of these positions? Two research findings lend support to the view that speech perception involves special language-oriented

CHRONOLOGY: *Auditory Development*

Newborn

- Recognizes auditory events that were repeatedly produced by the woman when fetus was still in utero.
- Discriminates mother's and stranger's voices.
- Localizes sound reflexively.

1–3 Months

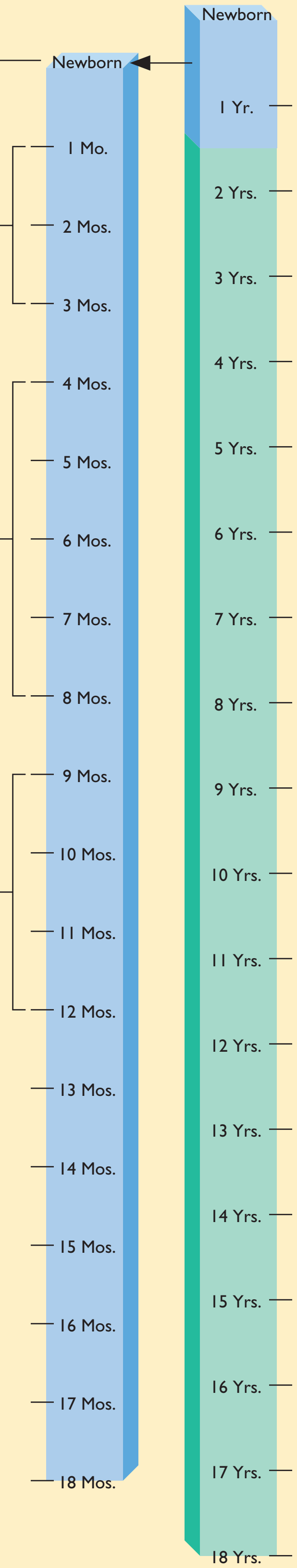
- Recognizes simple auditory patterns.
- Discriminates many, if not all, basic sounds used in language.
- Makes deliberate efforts to locate sound, an ability that continues to improve throughout early childhood.

4–8 Months

- Detects and discriminates high-frequency tones nearly as well as, sometimes better than, children or adults; ability to detect low-frequency tones continues to improve throughout childhood.
- Recognizes melodic rhythms, transposition in key, note changes, phrasing in music.

9–12 Months

- Begins to lose some phoneme discriminations if not heard in native language.



This chart describes the sequence of auditory development in infancy based on the findings of research. Children often show individual differences in the exact ages at which they display the various developmental achievements outlined here.

mechanisms. The first comes from the extremely complex relationship between the acoustic properties of phonemes and their perception. For example, the /*b*/ phoneme in the words *beak* and *book* are quite different acoustically, although people treat the sounds as equivalent. Researchers argue that the absence of a simple set of rules for signaling the phoneme /*b*/ in the two words makes the presence of a special mechanism for speech perception highly likely (Kuhl, 1987).

A second finding is based on **categorical perception,** the classification of sounds as the same even when they differ on some continuous physical dimension, except when on opposite sides of a critical juncture. For example, the English consonants /*b*/ and /*p*/ in the sounds *ba* and *pa* differ only in voice onset time (VOT), the period during which the vocal chords begin to vibrate relative to the release of air by the vocal apparatus. Small changes in VOT are typically not heard as more or less like *ba* or *pa.* Instead, English speakers hear only *ba* as long as VOT continues to fall on one side of the categorical boundary and only *pa* when it falls on the other side. But if the difference in VOT crosses a critical point, the phoneme boundary, the two sounds are readily distinguishable. Infants as young as one month already demonstrate categorical perception for many different speech sounds (Aslin, 1987b; Kuhl, 1987).

Researchers remain uncertain about whether babies are born with a special sensory mode for speech (Aslin, Jusczyk, & Pisoni, 1998). Categorical perception can be observed with some sounds other than those found in speech. Monkeys, even chinchillas, also distinguish speech sounds categorically (Kuhl & Miller, 1978; Kuhl & Padden, 1983), a finding that further argues against a specialized innate ability to process phonemes in humans.

KEY THEME
Sociocultural Influence

Regardless of what accounts for phoneme perception, younger infants appear to be more sensitive than older infants to phonemes found in languages other than their own (Best et al., 1995; Werker & Desjardins, 1995). In one study, six- to eight-month-olds reared in an English-speaking environment could readily discriminate among phonemes used only in Hindi, whereas eleven- to thirteen-month-olds had more difficulty with this task (Werker & Lalonde, 1988). Adults can regain the lost discriminations only with considerable practice or under highly restricted listening conditions (Werker, 1989). Thus it does not appear that we completely lose the capacity to make these discriminations. Instead, toward the end of the first year of exposure to speech, our auditory and, perhaps, our attentional and cognitive functioning undergo a reorganization that limits our sensitivity to the sounds not utilized in the language we hear (Lalonde & Werker, 1995). As with vision, psychologists have often been surprised at the many competencies infants display with respect to their auditory abilities.

Smell, Taste, Touch, and Sensitivity to Pain

Developmental researchers have given far less attention to smell, taste, and the *cutaneous senses*—the receptor systems of the skin responsible for perceiving touch, pressure, pain, and temperature—than to vision or hearing. Each of these senses also functions shortly after birth and furnishes crucial adaptive and survival cues for the baby. Smell, for example, may be critical for determining what is edible and may also be involved in early attachment to the caregiver.

KEY THEME
Nature/Nurture

categorical perception Inability to distinguish among sounds that vary on some basic physical dimension except when those sounds lie at opposite sides of a critical juncture point on that dimension.

● **Smell** Facial expressions, changes in rate of respiration and blood flow in the brain, and approach-avoidance activities involving head turning are just a few of the responses indicating that newborns detect odors. Do babies turn up their noses at the unpleasant smell of rotten eggs? Can they detect the food-related smells of fish, butter, banana, or vanilla? They most certainly can (Steiner, 1979). Moreover, newborns become increasingly sensitive to these and other smells during the first few days of life (Marlier, Schaal, & Soussignan, 1998).

Parent-infant recognition occurs by odor among many species of animals. Can human infants identify their caregivers this way as well? Again, the answer is yes. By five days of age infants turned their heads longer in the direction of a breast pad that had been worn by the mother than to an unused one. By six days of age, infants also preferred a pad obtained from their own mothers to one from an unfamiliar mother (MacFarlane, 1975).

Can other family members also identify their infants on the basis of odor? Indeed, within the first few days of birth and after brief contact, not only mothers but also fathers, grandmothers, and aunts can recognize newborn kin by their smell alone. In other words, humans may inherit some family olfactory signature about which they are sensitive or learn very quickly (Porter, Balogh, & Makin, 1988).

Taste Receptors for the basic tastes of sweet, sour, salty, and bitter, located mostly on the tongue, develop well before birth; the fetus may already taste as it swallows amniotic fluid. Facial expressions and rate of sucking reveal that newborns can also discriminate tastes (see Figure 6.10). Sweet stimuli, for example, elicit a relaxed facial expression resembling a smile; sour stimuli produce lip pursing or a puckered expression; and bitter stimuli elicit mouth opening as though expressing disgust (Steiner, 1979).

Innate preferences for some tastes may help infants to meet nutritional needs and protect them from harmful or dangerous substances. Preferences can, however, be modified by experience. For example, babies fed sweeter fluids in the first few months after birth ingest more sweet water at six months of age than babies not given this experience (Beauchamp & Moran, 1982). The desire for salt in a specific food may

KEY THEME
Nature/Nurture

FIGURE 6.10 Discriminating Tastes

Babies produce different facial expressions depending on what they taste. The first column shows the resting faces of three newborns. Column 2 shows the same babies after they received distilled water—their expressions show very little change. After sweet stimulation, the babies' facial expressions are more positive and relaxed, resembling a smile or licking of the upper lip, as shown in column 3. However, their mouths become more pursed after sour stimulation (column 4) and more arch-shaped after bitter stimulation (column 5).

also be established early in infancy (Beauchamp & Cowart, 1990; Sullivan & Birch, 1990). Infants can detect flavors from their mothers' milk as well—for example, garlic, alcohol, and vanilla—an ability that might familiarize them to the foods common to their families and cultures (Mennella & Beauchamp, 1996). Although learning appears to be important in the emergence of odor and taste preferences, we should emphasize that until about two years of age, children will put just about anything into their mouths. Thus among the most important things they must learn is what *not* to taste (Rozin, 1990).

Touch and Temperature Skin contains more than one hundred types of receptors sensitive to touch, pressure, temperature, and pain (Reisman, 1987). As we see in the chapter titled "The Prenatal Period and Birth," even the fetus responds to touch. In the newborn, stimulation can also elicit a variety of reflexes (see the chapter titled "Brain, Motor Skill, and Physical Development"). And just as caregivers recognize their babies by odor shortly after birth, so can they recognize them by touch. After only sixty minutes of contact, mothers and fathers can identify their infants on the basis of stroking the backs of the babies' hands (Bader & Phillips, 1999; Kaitz et al., 1992; Kaitz et al., 1994). This ability, which may be adaptive in encouraging caregivers to be responsive to their offspring, is another illustration of the sensory communication that can facilitate social interactions between infant and caregiver.

KEY THEME
Interaction Among Domains

A difficult problem for newborns, particularly premature infants, is regulation of body temperature (Moffat & Hackel, 1985). Cooling awakens babies, makes them more restless, and increases their oxygen consumption, responses that facilitate heat production. Because many newborns are unable to sweat or pant, exposure to high temperatures produces reddening skin, less activity, and more sleep, events that decrease heat production and assist heat loss (Harpin, Chellappah, & Rutter, 1983). When warm, babies also assume a sunbathing position, extending their extremities, perhaps a good clue for a caregiver who is trying to decide whether a baby is too warm (Reisman, 1987).

Sensitivity to Pain Heel pricks, circumcision, and other medical procedures involving newborns and young infants have come under increasing scrutiny in recent years because of concerns about the pain they may cause. Historically, newborns experiencing such invasive procedures were rarely given pain reduction medication (Ramenghi et al., 1996), and even major operations on very young infants were carried out with little or no effort to diminish pain. Why was this the case? The answer is that newborns were believed to have neither the neurological capacity to experience pain nor the ability to remember it. An additional concern was the potential negative side effects of pain medication on an immature organism.

Today we know that brain centers involved in the detection of pain are well developed prenatally and that behavioral responses (crying, facial expressions, etc.) consistent with the discomfort associated with pain are readily displayed by preterm and other newborns (Anand et al., 2001). Moreover, evidence has been gathered to suggest that exposure to painful circumstances early in infancy can lead to lasting changes in the endocrine and immune systems and to continued behavioral sensitivity to pain later in development (Porter, Grunau, & Anand, 1999; Taddio et al., 1995). And although medications may be an important part of efforts to manage pain, offering sucrose or the opportunity to engage in nonnutritive sucking and even exposure to music during minor operations have comforting effects for infants in painful situations (Anand et al., 2001; Joyce, Keck, & Gerkensmeyer, 2001).

Intermodal Perception

We have considered the development of seeing, hearing, and other senses in isolation from one another, but, of course, most objects and events bombard us with multiple sensory inputs. The sight of a cup provides information about how to shape the mouth to drink from it. The toddler who hears his mother's voice from another room expects to see her when he walks into that room. We often perceive these experiences as integrated and coordinated, and draw perceptual inferences because of the typical relationships observed from multimodal stimulation. Sometimes, of course, we can be fooled by all these correlated experiences: a good ventriloquist really does make the dummy appear to be talking!

How does the capacity to integrate several sensory inputs, referred to as **intermodal perception,** begin, and how important is it for development? One traditional view is that input received via the various senses is initially unimodal, that is, the senses function separately and independently. Only after repeated multimodal experiences, this argument runs, do babies come to recognize the correlations among various sensory inputs. Thus intermodal perception involves, for example, learning that when objects are shaken, some rattle and make a noise but others do not; that material that feels soft can also look soft; and that a square-looking peg will not fit into a round-looking hole. According to this viewpoint, intermodal perception stems from *integration* or *enrichment* by the repeated association of sensations from two or more modalities. Alternatively, from a more Piagetian perspective, it is the outcome of constructing multisensory schemes from correlated sensory experiences (Lickliter & Bahrick, 2000).

But others have suggested that some intermodal perception is already possible at birth (Gibson, 1982; Gibson, 1979). According to this perspective, a primitive unity

KEY THEME
Nature/Nurture

This toddler appears to be enjoying both the visual and tactual effects of playing with the water leaking from the flower pot. In fact, it would not be too surprising if she even began to taste it as well, although a caregiver might quickly discourage this behavior. Infants and young children experience events through multiple sensory modalities. At a very early age, they expect things to look, feel, taste, or sound in a particular way based on the information received from just one of these modalities.

intermodal perception Coordination of sensory information to perceive or make inferences about the characteristics of an object.

exists among the senses in early infancy, and with development and experience, **perceptual differentiation,** the ability to distinguish information coming through each particular sensory modality, occurs. A related aspect of this point of view is that important sensory information is often *amodal,* that is, not tied to a particular sensory modality but shared across two or more of them. Examples of amodal characteristics of sensory input are temporal synchrony, that is, the correlated onset and offset of stimulation that can occur between two or more sensory modalities (e.g., hearing someone begin and stop speaking while simultaneously seeing their lips start and stop), and tempo and rhythm, common components of both auditory and visual experience.

Some researchers believe that the ability to process amodal properties is especially important for early perceptual development (Bahrick & Lickliter, 2000; Lewkowicz, 2000). For example, Lorraine Bahrick and Robert Lickliter (2000) suggest that the intermodal redundancy that characterizes temporal synchrony attracts the infants' attention to patterns of stimulation that belong together and that it, along with other amodal properties, is among the earliest perceptual cues they process. As a consequence of the attentional bias, infants also begin to learn about other arbitrarily correlated properties and qualities of objects and events, such as the voice that belongs to a particular parent, the bark that signifies the family's pet dog, or the verbal label for a particular color. Some go so far as to claim that this kind of learning begins very shortly after birth (Slater et al., 1999). But regardless of how early it begins, this perspective emphasizes that both differentiation and integration of intermodal properties cannot be ignored as important components in perceptual development very early in infancy.

● **Sight and Sound** To determine whether infants link visual and auditory events, Elizabeth Spelke (1976) developed a simple procedure in which four-month-olds could look at either of two films shown side by side. At the same time, the infants could hear a soundtrack coming from a speaker located between the two viewing screens. The soundtrack matched events in one of the two films, for example, an unfamiliar woman engaged in a game of peek-a-boo or someone playing a percussion instrument. Would infants pay more attention to the film synchronized with the soundtrack? Spelke found this to be the case, at least when the percussion sounds could be heard.

Four-month-olds can match other auditory-visual cues as well. In one study babies were shown two films, one depicting wet sponges being squeezed, the other two blocks being clapped together (Bahrick, 1983). When the babies heard a squishing sound, they attended more to the film showing the sponges; when they heard a banging sound, they attended more to the film of the rigid blocks. Before four months of age, they also infer that a sound made by one object or multiple objects hitting a surface extends to other, somewhat similar visual arrays containing one object or multiple objects (Bahrick, 2002). Five-month-olds even link sounds such as an auto or a train coming or going with concordant visual progressions of approaching and retreating movement (Pickens, 1994; Walker-Andrews & Lennon, 1985).

Experience may have permitted the three- to five-month-olds to learn about these relationships. However, other research suggests that newborns quickly master the association between a sound and a visible toy. After seeing a toy presented in several different locations and making a particular sound for brief periods of time, neonates displayed increased attention if the sound originated apart from the toy or if it accompanied a different toy (Morrongiello, Fenwick, & Chance, 1998). Thus even newborns possess some kind of amodal process that guides and unifies sensory information from separate senses such as hearing and vision (Kellman & Arterberry, 1998).

perceptual differentiation Process postulated by Eleanor and James Gibson in which experience contributes to the ability to make increasingly finer perceptual discriminations and to distinguish stimulation arising from each sensory modality.

Intermodal perception in infants extends to social information and relationships as well. For example, three-and-a-half-month-olds are likely to look at that parent, seated to one side, whose voice is coming from a speaker centered in front of the baby (Spelke & Owsley, 1979). By six months of age, babies hearing a strange male or female voice recite a nursery rhyme look longer at a face of the same sex than at a face of the opposite sex (Walker-Andrews et al., 1991). In addition, babies are able to match the maturity of a face with its voice; they look more at the face of an adult or a child, depending on who is heard talking from a central speaker (Bahrick, Netto, & Hernandez-Reif, 1998).

Intermodal cues can influence perception in some perhaps unexpected ways. Speech perception, for example, may be greatly affected by what a person sees. Harry McGurk and John MacDonald (1976) played videotapes of an adult uttering simple syllables such as *ba ba.* Sometimes, however, the video picture was synchronized with another sound, such as *ga ga.* Three-year-olds through adults often reported hearing something quite different, for example, *da da* or another utterance. By five months of age, babies also recognize auditory-visual correspondence, attending more to facial expressions articulating sounds that match than facial expressions that do not match what they hear (Meltzoff & Kuhl, 1994; Rosenblum, Schmuckler, & Johnson, 1997).

Sight and Touch By six months of age, infants who explore an object with their hands alone can recognize it by sight alone (Pineau & Streri, 1990; Rose, Gottfried, & Bridger, 1981; Ruff & Kohler, 1978). But coordination of some visual and tactile information exists much earlier when the mouth is used to explore objects. In one experiment, one-month-olds showed greater visual attention to a hard rigid object or a soft, deformable object, depending on which they had been given time to suck (Gibson & Walker, 1984). Other research reveals that infants five months of age exhibit intermodal perception between proprioceptive and visual cues deriving from self-movement. Infants showed differential attention to point light displays (similar to those used in studying sensitivity to biological motion) depending on whether the display mirrored the motion produced by the movement of their own hidden legs or the noncontingent movement of the legs of another infant (Schmuckler & Fairhall, 2001).

Babies can even be surprised by a discrepancy between vision and touch. Emily Bushnell (1981) showed infants a solid object within a box. Its location was distorted by mirrors. When babies reached for it, they touched another object that differed in size, shape, and texture. Infants younger than nine months failed to investigate the novel object actively or search for the one they could see, but older infants did both. Thus there is substantial evidence that infants before a year of age make inferences about their world based on intermodal perception.

FOR YOUR REVIEW

- What evidence exists to show that the fetus can detect vibroacoustic stimulation? Are there advantages or disadvantages to exposing the fetus to auditory stimulation?
- What are the basic auditory capacities of the infant, and what sound patterns do they prefer to listen to? How does sound localization develop?
- What arguments exist for or against the view that infants possess an innate capacity to detect phonemes?
- Can newborns and very young infants discriminate smells, tastes, touch, and temperature differences? Can they feel pain?
- How does intermodal perception develop? What evidence exists to show that infants recognize the correlation between visual and auditory information as well as visual and tactual cues?

Perceptual Development Throughout Childhood

Richard Aslin and Linda Smith (1988) have noted a predicament facing anyone interested in learning about perceptual development after infancy. As research has increasingly documented sophisticated abilities in newborns and infants, the importance of studying perceptual development at older ages appears to have faded. Nonetheless, researchers do find evidence of improved sensory processing during childhood (Ellemberg et al., 1999; Tschopp et al., 1999).

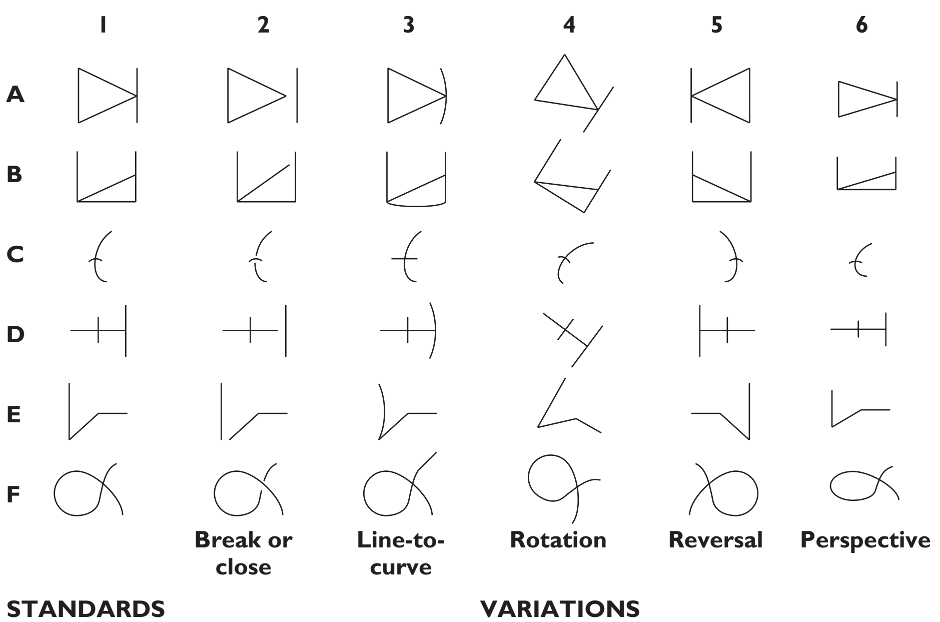
KEY THEME
Interaction Among Domains

Perception also becomes more difficult to investigate without considering at the same time the child's developing attentional, linguistic, and cognitive skills. These factors may contribute to the observation that perceptual skills become more focused, organized, and confined to the meaningful and important features of the environment; in other words, perception becomes increasingly efficient with development. Eleanor Gibson (1969, 1982, 1988) has outlined a view of perceptual learning to account for these kinds of findings.

Perceptual Learning

Eleanor Gibson's theory of perceptual learning emphasizes three changes with age: increasing specificity in perception, improved attention, and more economical and efficient acquisition of perceptual information. Much of the infant's first year is spent learning the sensory properties of objects, the spatial layout of the infant's world, and the perceptual repercussions of his or her actions. But perceptual learning continues. For example, children acquire new kinds of visual discriminations when they learn to read. They must begin to pay attention to consistencies and variations in letters and text.

Eleanor Gibson and her colleagues (Gibson et al., 1962) created different sets of letterlike figures such as those shown in Figure 6.11. One member of each set was designated a standard, but each set included variations of that standard. A straight line, for example, might be redrawn as a curved line, the standard rotated or reversed, a break introduced in a continuous line, or the line's perspective changed by tipping or elongating some aspect of the figure. Children four through eight years of age



Source: Adapted from Pick, 1965.

FIGURE 6.11
Sensitivity to Perceptual Differences

Column 1 gives different letter-like forms used as standards in a sorting task. Columns 2 through 6 display various transformations of each standard. Four- to eight-year-olds, when shown a stack of the figures and asked to select only those identical to the standard, commit relatively few errors on variations that involve a break in the figure, presumably because the distinction is important for identifying many objects, as well as alphabetic symbols. With increasing age, errors involving rotation, reversal, and line/curve variations decrease substantially because, according to Eleanor Gibson, children who are beginning to learn to read must pay attention to these features of the stimuli. Errors involving perspective remain high at all ages, perhaps because the transformation is not important for identifying either objects or letters of the alphabet.

were shown a stack of each set of figures and asked to pick out only those identical to the standard.

Children made many more errors for some kinds of variations than others. Children of all ages seldom confused the standard with versions that contained breaks, perhaps because these features are important for identifying objects in the environment, as well as letters of the alphabet. On the other hand, older children did substantially better than younger children in discriminating rotations and reversals and line/curve transformations, presumably because children who are learning to read must begin to distinguish such variations. Finally, children of all ages found it difficult to discriminate changes in perspective from the standard, a variation that can and normally should be ignored for identifying both physical objects and letters of the alphabet.

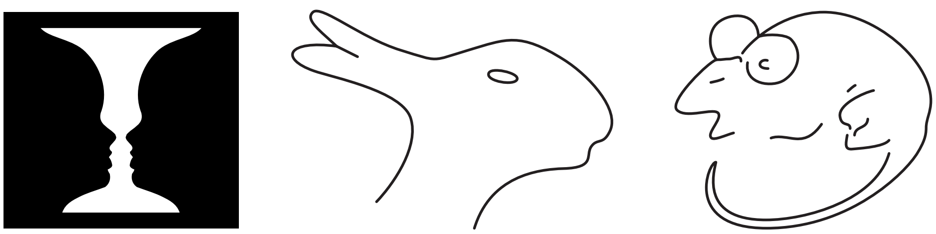
Eleanor Gibson believes the age-related improvements in performance on this activity do not come about by reinforcing children to make the discriminations. In fact, when asked to classify the letterlike forms over a series of trials, children showed steady improvement in sorting without any feedback about their accuracy. Gibson argues that through repeated exposure to and inspection of letters of the alphabet, children are afforded the opportunity to recognize certain critical features distinguishing such figures, an example of the powerful influence of implicit learning discussed earlier.

Still other changes are evident in perceptual development. Young children, for example, have difficulty making precise and systematic judgments about the similarity of objects based on a single dimension or attribute (Smith, 1989). Preschoolers might put a red rubber ball with a slightly smaller ball of pink yarn because the overall appearance of the two is similar, whereas older children are likely to lump the red rubber ball with a white foam ball on the basis of their being the exact same size. Preschoolers also do not perceive the two distinctive interpretations that typically can be given to ambiguous figures (see Figure 6.12). Even after looking at an ambiguous figure for a long period of time, children less than about five years of age fail to see the figures reverse as do older children and adults (Gopnik & Rosati, 2001). Perhaps cognitive limitations in organizing perceptual information and in understanding that arrays can have multiple meanings is a factor in the difficulty young children have with these kinds of perceptual tasks.

Experience and Perceptual Development

How do experience and inborn sensory capacities interact to determine perception? Throughout the history of psychology this has been an important question, and it continues to be so as medical and technical advances provide opportunities to compensate for some kinds of sensory disabilities. For example, blind children can perceive the existence of distant objects, presumably from changes in auditory cues they receive while moving about (Ashmead, Hill, & Talor, 1989). As a consequence, blind infants are now being fitted with sonic devices to help them hear echoes to signal the direction, distance, and other qualities of objects.

FIGURE 6.12
Perceiving Ambiguous Figures



Source: Gopnik & Rosati, 2001, p. 176.

What do you see in these ambiguous figures? If you look at each figure long enough, you will most likely see (in one or the other order) a vase and two people looking at each other, a duck and a rabbit, and a rat and an old man with glasses. In fact, your perception of the figures may often shift back and forth between the two interpretations. If you did not see both initially, you will readily detect them when told about the two possible representations. However, children less than five years of age seem unable to see more than one representation even when told about the alternative interpretation. Cognitive limitations associated with attributing multiple representations to a stimulus may be a factor in seeing both aspects of the ambiguous figures.

KEY THEME
Sociocultural Influence

The effects of these efforts with blind children are still to be demonstrated, but we can be sure of one thing from research we discussed earlier that showed evidence for sensitive periods in the development of vision: experience is extremely important for maintaining many perceptual capacities. Experience also helps to explain cross-cultural differences in perception. Environments around the world differ in their degree of "carpenteredness" (Segall, Campbell, & Herskovits, 1966). In most urban, technically advanced societies, houses are constructed on rectilinear principles, which involve perpendicular and right-angle dimensions. Even the layouts of roads and other artifacts of the environment often follow these principles. In other environments, such as in Oceanic and many African cultures, walls and roofs may be curved, and straight lines and angular intersections may be few.

In one study, field workers administered several optical illusions, such as the Müller-Lyer and horizontal-vertical illusions whose effects depend on straight lines that intersect, to samples of children and adults in Africa, the Philippines, and the United States (Segall et al., 1966). The researchers theorized that individuals living in a carpentered environment, who often see rectangular intersecting contours, would be more susceptible to these illusions than people living in noncarpentered environments. In fact, their results conformed to their prediction. In a related set of findings children and adults in cultures with minimal formal education, little experience with pictures, or artworks that incorporate few depth cues are unlikely to perceive pictures or photos in three dimensions (Pick, 1987). Thus the ways in which children and adults interpret their sensory environment can be greatly affected by cultural opportunities, a finding that fits well with the conclusion that perception is influenced by experience.

FOR YOUR REVIEW

- What kinds of developmental changes are accounted for by Gibson's perceptual learning theory?
- What aspects of objects do children have difficulty perceiving?
- How might cross-cultural factors influence perceptual development?

These children in the Sudan receive their education in front of a round schoolhouse. Does a child who grows up in a culture in which linear perspective is uncommon, as in many parts of Africa and island regions in the Pacific Ocean, perceive things differently than a child who grows up in an environment filled with straight lines, right angles, and many opportunities to see distances based on orderly linear cues?

CHAPTER RECAP

Summary of Developmental Themes

■ **Nature/Nurture** ***What roles do nature and nurture play in learning and perceptual development?***

We cannot help but be impressed by the remarkably adaptive resources immediately available to infants for gaining knowledge of their environment. The basic mechanisms of learning—habituation, classical and operant conditioning, and perhaps even imitation—are ready to influence behavior at or shortly after birth. A newborn's sense organs are sufficiently developed to provide rudimentary capacities to see, hear, feel, taste, and smell, and often function even before birth. We have also seen, however, that sensory and perceptual capacities improve substantially as a result of experiential fine-tuning. Thus the environment plays an early and powerful role in determining which capacities are acquired and maintained.

■ **Sociocultural Influence** ***How does the sociocultural context influence learning and perceptual development?***

Experiences the culture provides—the behaviors that are reinforced and punished and opportunities to observe others engaged in work, play, and social interactions—have substantial effects on what a child learns. Although formal instruction and education assist learning in some societies, in all cultures the actions of caregivers and other models provide plentiful opportunities for children to gain knowledge of what is socially accepted and expected. Specific cultural demands, such as discriminating the printed word, and culturally related physical layouts, such as carpentered environments, may have considerable bearing on perceptual development.

■ **Child's Active Role** ***How does the child play an active role in learning and perceptual development?***

Mechanisms of learning typically do not emphasize an active role for the child. Yet what the child learns certainly affects the kinds of interactions she or he will experience and opportunities for further learning. In this sense, the knowledge and skills a child possesses actively contribute to further social interactions, learning, and development. With respect to perceptual development, Eleanor Gibson's theory highlights the important role the activity of the child, including visuomotor and other sensorimotor mechanisms, plays in perceptual development. Children construct perceptions of whole, multisensory arrays at an early age, and their perceptual learning increasingly reflects deliberate and organized exploration of the environment.

■ **Individual Differences** ***How prominent are individual differences in learning and perceptual development?***

All normal children are equipped with the basic capacities to learn and perceive. But individual differences are built on those capacities as each child experiences various role models, educational practices, cultural conventions, and other phenomena unique to his or her circumstances. What the child learns establishes the knowledge base on which he or she displays a rich variety of accomplishments and skills. Accompanying these achievements may also be different ways of using the senses and perceiving the environment that contribute to the individual's unique view of the world.

■ **Interaction Among Domains** ***How do learning and perceptual development interact with development in other domains?***

Learning plays a substantial role in almost every aspect of development. The child learns social skills, acceptable ways to express thoughts and feelings, techniques to achieve academic and occupational success, and numerous other behaviors. The child who learns about the alphabet, about having to sit quietly in the classroom, about when and when not to speak to an adult, or about behaviors effective in hunting, shepherding, domestic, or other activities of the culture can be expected to achieve social status, prestige, and other resources that will benefit development in many other domains. Furthermore, gains in perception are substantially influenced by physiological and neural advances. Rapidly improving intellectual and motor skills introduce demands for making new perceptual discriminations (such as reading) that, once mastered, lead to further progress in cognitive, social, and other domains.

Summary of Topics

Basic Learning Processes in Infancy and Childhood

- Learning includes mechanisms that permit adaptation to the environment. Many forms of learning are already evident in infancy.

Habituation

- *Habituation* refers to the gradual decline in responding as a result of repeated exposure to an event, a basic form of learning that helps in orienting to new information in the environment. Increased attention to new information following habituation indicates *recovery of habituation.*

Classical Conditioning

- Classical conditioning involves the pairing of a neutral stimulus with one that naturally elicits a response. The neutral stimulus then begins to elicit the response as well.

Operant Conditioning

- Operant conditioning involves the delivery or removal of a reinforcing or punishing stimulus so that behaviors preceding the stimulus increase or decrease.

Imitation

- Imitation plays a major role in socialization, as well as in the acquisition of knowledge. Caregivers and tutors often rely on observational learning to assist children in the acquisition of a wide range of behaviors.

Implicit Learning

- Implicit learning takes place as a result of unintentionally abstracting patterns and rules that often organize the structure of physical, linguistic, and social information.

Sensory and Perceptual Capacities

- *Sensations* refer to the basic units of information recorded by the various receptor systems and the brain; *perception* refers to the organization and interpretation of these sensations.
- Although all of the senses operate at birth and, in some cases, well before, debates exist concerning the roles that nature and nurture play in their continued development.

Measuring Infant Sensory and Perceptual Capacities

- Researchers rely on infants' *attentional* preferences, habituation and recovery of habituation to familiar stimuli, learning, and other physiological indicators to provide evidence that they are able to discriminate objects and events.

Vision

- Vision involves actively looking and seeing. Although infants possess some capacities at birth, they typically show rapid advances within the first six months in *accommodation,* the ability of the lens of the eye to focus visual input on the retina; *saccadic* eye movements, shifts of the eye to attend to visual targets at different locations; *smooth visual pursuit,* the tracking of a slowly moving object; and *vergence,* the capacity to orient both eyes toward an object at different distances.
- *Visual acuity,* the ability to discriminate contour and fine details, is limited in newborns but improves rapidly. However, cataracts, or clouding of the lens, or the failure of both eyes to focus together, if left uncorrected, can result in the failure of visual acuity to improve and loss of stereoptic depth perception.
- Color vision and *stereopsis*, the ability to see depth as a function of the slight discrepancy in the images available to the two eyes, normally are evident shortly after birth.
- Newborns do not examine visual patterns systematically and are often attracted to the more salient external features that show high contrast (the *externality effect*) or movement. Within a few months, they engage in more systematic exploration of visual arrays. They prefer attending to the human face and show signs of this preference for certain features shortly after birth. Their perception of the unity and coherence of objects is enhanced by kinetic cues and prior experience with the stimuli.
- Depth information is provided to infants by *kinetic cues,* the differential flow of optic information that derives from self-induced movement or as a result of movement among arrays in the visual field and stereopsis. Infants process depth provided by pictorial cues beginning about five to seven months of age.

Audition

- The ability to hear exists prenatally, undergoes substantial improvement during the first few months after birth, and continues to improve throughout childhood. Some kinds of auditory information experienced prenatally are remembered after birth. These observations have led some parents to provide regular vibroacoustic experiences in the form of music or other sounds to the fetus. At the present time, no research has shown long-term benefits to the child, and some believe that potentially negative consequences can occur under some conditions of exposure.
- Newborns demonstrate *sound localization,* the ability to determine the location from which a sound emanates, and this capacity undergoes improvement over the following months. Auditory perception of patterns of sound is displayed early, and infants show a preference for listening to musical patterns that conform to acceptable phrasing.
- Infants can detect *phonemes,* the basic unit of sound used to differentiate the meaning of words in languages. However, by the end of the first year, as a result of exposure to only a subset of these sounds, they often discriminate only those phonemes heard in their own language. This observation, along with evidence of *categorical perception* for phonemes, has given rise to theoretical debates about whether speech sounds are processed by special acoustic mechanisms available only to humans or by more general auditory processes.

Smell, Taste, Touch, and Sensitivity to Pain

- Newborns discriminate basic tastes and pleasant and unpleasant smells. Behavioral and other responses indicate that the newborn can feel pain.

Intermodal Perception

- Babies also display *intermodal perception,* the ability to integrate information arising from more than one sensory modality. However, the role that learning plays in this capacity is uncertain. Some amodal properties of stimulation, information common to more than one sensory modality such as temporal synchrony, may be highly salient to young infants and assist in their acquiring an understanding of the correlations that exist among the various sensory properties of objects and events.

Perceptual Development Throughout Childhood

- Compared with the extensive research carried out on infants, relatively few investigations of perceptual development have been carried out on children.

Perceptual Learning

- Research based on Eleanor Gibson's theory of perceptual learning has revealed that perception becomes more focused, organized, and confined to the meaningful and important features of the environment with development.

Experience and Perceptual Development

- Perceptual learning may have an important bearing on observations of some cultural differences in perception of the environment.