

Infant Perception and Cognition

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II. Infancy

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## Infant Perception and Cognition

Research on infant perception and cognition has grown exponentially over the past four decades. In most respects, this explosion of research has led to spectacular advances in knowledge and appreciation of infants and their abilities. However this same growth has also led to conflicting theoretical views, contradictory conclusions, and even heated exchanges between investigators – all of which seem to make a coherent picture of infant perceptual and cognitive development difficult, if not impossible to achieve. One goal of this chapter is to cut through some of the extravagant claims and rhetorical arguments to examine in some detail what the evidence really indicates. We shall approach this task from an information-processing point of view by continually asking two interrelated questions: (1) How are infants actually processing the information in their environment? and (2) In what way does that processing change with age and/or experience? Fortunately when one takes this approach, an organized and reasonably consistent picture of infant perception and cognition emerges. Furthermore, a number of domain general propositions, such as those mentioned below in the section on “Information Processing”, seem to help in explaining both infants’ information processing at a given age and how that processing develops over age. In this chapter we shall both describe these information-processing principles and, when possible, use them as a convenient tool for organizing the many findings on numerous topics within the domain of infant perception and cognition.

### Infant Perception versus Infant Cognition

Before discussing the findings in the area of infant perception and cognition, the first step should be, at least, to make some crude attempt to define what we mean by

“infant perception and cognition.” The reader may have noticed our tendency so far to treat infant perception and cognition as a single domain rather than as two distinct entities. Even that issue is unclear and debatable. Some, such as Mandler (1992, 2000), overtly assume that infant perception and cognition are two distinct domains with little communication between them. Under this view, infant perception may be seen as including lower level, automatic processes such as noticing the features of objects and responding in terms of those features. Infant cognition, on the other hand, may be seen as involving higher level, conceptual processes such as making inferences about the functions or meanings of objects. Others, such as Quinn and Eimas (2000), argue that both are aspects of a single domain and that they differ more in degree than in kind.

Our opinion falls closer to Quinn and Eimas’ than to Mandler’s. We also see the difference between perception and cognition to be more a matter of degree than of kind. Whether one is dealing with perceiving size constancy - perceiving the actual size of an object seen at different distances – or understanding the meaning of a complex causal event in which one object pushes another object across a table, it is the nature of the underlying relationship that must be perceived or understood. In size constancy, the underlying relationship is the size of one object relative to the object’s distance or to the size of other objects; in the causal event, it is the movement of one object in space and time relative to the movement of the second object. Some relationships may be perceived automatically and effortlessly; others require a more active comparison. But from an information-processing perspective, they all can be understood in terms of sets of relationships. Our task is to describe the nature of these relationships and how they contribute to some overall organization or information-processing hierarchy.

Historical Antecedents

We begin by considering some historical antecedents of the current popularity of research on infant perception and cognition. Certainly interest in infants and what they can perceive and understand has existed for centuries. Classic debates by philosophers such as Locke versus Rousseau exist in modified form to this day. Biologists' and psychologists' biographies of their own babies, such as Teidemann, Preyer, Darwin, and Piaget provided important insights into their infants' reactions, although they often were less than totally objective accounts (see Kessen, 1965). More objective experiments on infants' responsivity to stimulation occasionally appeared in the early 1900s. For example, McDougall (1908) reported finding differential infant fixation times to stimuli varying in color. Blanton (1917) was one of the first to find that infants will pursue a moving stimulus visually, and Irwin (1941) found that changes in light intensity produced modifications in an infant's activity.

Somewhat later, in the 1950s and 1960s, studies began to appear that measured heart rate and sucking measures, as well as visual fixation. Both auditory (e.g., Bridger, 1961) and olfactory (Engen, Lipsitt, Lewis, & Kaye, 1963) stimulation were found to produce changes in heart rate in newborn infants. Furthermore, these studies also showed that repeated presentations of these stimuli led to habituation of the response. A group of Russian investigators (Bronstein, Antonova, Kamenskaya, Luppova, & Sytova, 1958) presented auditory, olfactory and visual stimuli to infants under one month of age. They found suppression of sucking to all three types of stimulation and habituation of the suppression over trials. Often infants were presented with repetitions of a bright light or 90 db white noise. Many of these studies examined what Sokolov (1963) had referred to

as the “orienting reflex,” a pattern of physiological and behavioral changes to the presentation of a novel stimulus. There were several reports that infants exhibited both an orienting response and a decline in that response - habituation - with repeated presentations of the same stimulus. According to Sokolov, habituation of the orienting reflex reflected a form of memory, a point that would be picked up in the 1970’s when studies of infant memory first became popular.

These studies, and many similar ones, demonstrated that infants - even very young infants - were sensitive to stimulation from a number of modalities and, perhaps, that they even had some memory of that stimulation. Yet these studies did very little to address more interesting questions about how that stimulation was processed or remembered. This may, in part, be due to the complexity of the methods involved; in order to conduct these experiments one needed rather elaborate and expensive recording equipment as well as a team of investigators to monitor that equipment and the infant.

### Modern Techniques for Assessing Infant Perception and Cognition

#### Infant Visual Preference

Two seminal studies, conducted independently on essentially the same topic, both published in 1958, radically reduced the potential complexity of the experimental method and led to a dramatic change in the nature of research on infant perception and cognition. Berlyne (1958) measured the visual fixations of three to nine month old infants. On each trial, two black and white checkerboard patterns that differed in brightness or complexity were placed on a display board in front of each infant. An observer, who could not see the patterns, called out the direction of gaze of the infant which allowed Berlyne to determine to which pattern the infant first fixated. One of Berlyne’s findings was that

infants' first looked at a complex pattern, such as a checkerboard with many squares, more than at a simple pattern, such as a checkerboard with few squares.

At the same time Fantz, known to many as the founder of modern research on infant perception, began a series of studies (Fantz, 1958, 1961, 1963, Fantz, Ordy, and Udelf, 1962) on infants' visual preferences. Patterns, such as checkerboards with differing numbers of squares, vertical stripes of different thicknesses, and drawings of regular versus scrambled faces were shown to infants two at a time. Fantz' procedure was a methodological advance over Berlyne's in that because of the placement of the infant in a testing chamber, the experimenter could actually see a reflection of the stimulus on the infants' cornea. Also, Fantz measured total looking time rather than just the direction of first look. Among Fantz' findings were that infants tend to prefer patterned surfaces to uniform surfaces and complex patterns to simple patterns.

Both Berlyne's and Fantz' studies represented real advances over previous research in the field. Their innovations included demonstration of a simple, reliable, inexpensive technique for measuring infant visual attention, systematic manipulation of the stimuli presented to infants, and examination of differences in the pattern of visual attention over age. Their technique capitalized on what may be considered infants' "natural preferences" for some stimuli over others and has come to be called "the visual preference paradigm".

The visual preference paradigm is still a very popular technique. Numerous studies by many investigators over the past 40 years have used some version of this visual preference paradigm to examine topics ranging from infant visual acuity, to pattern

perception, preferences for complexity, and even face perception. Several of these topics will be discussed in greater detail later in this chapter.

### Novelty Preferences and Habituation

The visual preference technique works well when infants have a “natural” preference for certain stimuli, that is, when from the outset, infants have the tendency to look longer at some stimuli rather than others. When this occurs, not only we can infer that infants have a preference for one stimulus to another, but also that infants can discriminate between those stimuli. However, many cases exist in which infants do not display an initial preference, yet investigators need to know if the infants can discriminate between the stimuli. In such cases, investigators often rely on a paradigm that combines the visual preference technique with habituation. Once again, the field is indebted to Fantz for leading the way. In 1964, Fantz reported a study in which infants were shown two magazine pictures simultaneously, side by side, and the infants’ looking times to the pictures were recorded. As trials progressed the picture on one side remained the same, but the one on the other side changed from trial to trial. Over the course of the experiment, infants gradually came to look more and more at the side with novel pictures.

This preference for novelty has become the underlying basis of the most widely used research tool for investigating infant perception and cognition - the infant visual habituation paradigm. Although many variations of this paradigm exist, a prototypical example would be to repeatedly present one visual stimulus until an infant’s looking time habituates to some criterion level, such as 50% of the infant’s initial looking time. Novel and familiar test stimuli would then be presented to see if the infant looks longer at (i.e., recovers to) the novel ones. Doing so indicates the infant can differentiate between the

novel and familiar stimuli, even though initially the infant may not have had a “natural” preference for one over the other.

As we shall see later in this chapter, the infant visual habituation paradigm has been used for over three decades to investigate basic and esoteric questions related to infant perception, attention, memory, language acquisition, object knowledge, categorization, and concept formation. Differences in habituation and/or recovery have been reported between normal and aberrant infants and both habituation rates and preferences for novelty appear to be moderately correlated with later IQ.

As simple and straightforward as infant preferences for novelty and habituation appear to be, the situation is actually more complicated. Many people assume infants always have a preference for novelty. In reality, several studies have shown that a preference for familiarity often precedes a preference for novelty. Furthermore, this early preference for familiarity seems to be stronger in younger infants. It is also stronger the more complex or difficult the information-processing task is for the infant.

Hunter and Ames (1988) have summarized these conditions. According to them the time it takes for an infant to be familiarized to a stimulus, that is show a novelty preference, depends upon both the age of the infant and the complexity of the stimulus. For example, the familiarity preferences for older infants (e.g., those over 6 months of age) should be very brief compared to those for younger infants (e.g., those under 6 months of age) and within an age group the familiarity preferences should vary according to stimulus complexity. The bottom line is that if younger infants are repeatedly shown very simple stimuli, or if older infants are shown moderately complex stimuli, both groups are likely to produce the classic monotonically decreasing habituation curve. On

the other hand, if infants at either age are shown dynamic moving scenes involving multiple objects, they are likely to prefer familiar scenes prior to preferring novel ones. Therefore, it becomes important in such studies to habituate all infants to a relatively stringent criterion and to include both familiar and novel stimuli at the end to test that the infant indeed prefers novelty. Unfortunately, many infant habituation studies today do not adhere to these procedures.

### Other Techniques

Several other techniques have also been used to investigate questions related to infant perception and cognition. In some, infants play a more active role such as crawling, walking, or reaching. In others, physiological measures such as heart rate or cortical evoked potentials rather than behavioral ones are assessed. Although some of these techniques are unrelated to visual preference and habituation, others are more related than one might first assume. For example, infant operant conditioning is often used and has many similarities to visual habituation (e.g., Bower, 1966a). In these studies, infants are first conditioned to respond to one stimulus and then tested with novel stimuli that vary in some systematic way from the conditioned stimulus. The logic is similar to that in habituation studies. In habituation, responses are artificially decreased to one stimulus. Discrimination is assessed by determining if that decrease generalizes to other stimuli. In conditioning, responses are artificially increased to one stimulus and discrimination is assessed by determining if that increase generalizes to other stimuli.

A variety of conditioning studies have also been used to investigate infants' perception of speech (e.g., Eimas, Siqueland, Jusczyk, & Vigorito, 1971), all of which relate either to visual preferences, visual habituation, or both. Such studies have

frequently used a high amplitude sucking procedure in which infants first are conditioned to suck to hear a sequence of speech sounds. That procedure continues until their sucking habituates, at which time the speech sounds are changed and recovery of sucking is assessed. Many more recent studies of infant speech perception and early language ability have turned to visual attention as the measure (e.g., Jusczyk & Aslin, 1995). For example, infants may learn to look at a specific location to hear a particular sound. Then a new sound is introduced and changes in looking time are assessed. Interestingly, just as in the visual perception literature, some disagreement exists as to whether the infants should look longer or shorter when a novel stimulus is presented. We cannot list all possible techniques that can be used to assess infant perception and cognition, but as we have described, many are related, either procedurally or logically, to two very important techniques - infant visual preferences and visual habituation.

### Theoretical Perspectives

Several theoretical perspectives have been influential in directing research on infant perception and cognition over the past forty years. It is impossible to adequately represent any of these viewpoints in just a single chapter. Indeed some of them require entire books to explain them adequately. Certainly Piagetian theory, Gibsonian theory, Dynamical Systems, and Connectionist Modeling fall into this category. Others are more approaches to studying infant development than they are complete theories. They make certain assumptions and predictions and use certain research techniques to investigate those predictions, but they probably do not qualify as formal theories. Nativism, Cognitive Neuroscience, and Information-Processing tend to fall into this category. Brief descriptions are provided below for each of these theoretical perspectives. It should be

understood that each description is merely a cursory overview. Any real understanding requires reading much more, including the references provided with each description.

### Piagetian Theory

The one researcher who has had the longest, and many would say the most profound, impact on the field of infant cognition and perception is Piaget. Originally a biologist, Piaget developed a theory of cognitive development by observing his own children's behavior on certain tasks during infancy and childhood (e.g., Piaget, 1927; 1952; 1954). For many years, psychologists in the United States disregarded Piaget's theory because his research methods were considered imprecise and his ideas about cognition were in conflict with the Behaviorist's zeitgeist of the day. However, that position began to change as comprehensive reviews of Piaget's theory became available in English (e.g., Hunt, 1961; Flavell, 1963). As the reader will see, the modern infant cognition researcher often uses Piaget's theory and observations as a springboard for further ideas and research.

Piaget's view of infant development is that infants develop an understanding of the world, that is, an understanding about objects, space, time, and causality by interacting with the environment (Piaget, 1954). Borrowing from the field of biology, Piaget (1952, 1954) believed that infants develop through the processes of assimilation and accommodation. Piaget also believed that development is stage-like and discontinuous. Furthermore, the infant, according to Piaget, is as an active learner who is motivated to learn about the world, but cognitive development, like other aspects of development, represents an interaction between maturation and learning.

Piaget specified four major periods corresponding to different ages of the developing child. The first period of Piaget's theory of cognitive development, the Sensorimotor Period (Piaget, 1954), describes infants from birth to around 18 – 24 months of age, or about the age that language first appears. During this period, infants are thought to go through six stages starting from interacting with the world strictly with innate reflexes (Stage 1) to using mental representations for acting on the world (Stage 6). Topics examined by Piaget include the development of infants' understandings of time, space, causality, and the permanence of objects.

Many modern developmental researchers agree with Piaget's view that the child is an active learner, but disagree with his view that development is discontinuous, or stage-like. Theoretical positions, such as information-processing and the connectionist view of development, are similar in some ways to Piaget's view in that both emphasize the role of learning and experience to help explain developmental changes and both can be considered constructivist theories. Like Piaget, both assume developmental change is a building block process that starts small and gradually becomes more elaborate or sophisticated. Other, more nativist views, believe Piaget was much too conservative about infants' developing abilities. They claim he underestimated the ability of the infant. Some modern researchers believe that because Piaget's method of research was not truly experimental, his findings were not generalizable. His findings are sometimes criticized for erroneously focusing too much on the child's competence at a very specific task that may or may not reveal the child's true understanding of the world (e.g., Baillargeon, Spelke, & Wasserman, 1985; Bower, 1974). Nevertheless, Piaget is revered today by

many infant cognition and perception researchers and is appreciated for his ingenuity and his insights into the mind of the infant (See Flavell, 1963).

### Gibson's Ecological Theory

Not all theories of development rely so much on the developing mind of the infant. For example, Gibson's ecological approach to the study of infant perceptual development places emphasis on the environment and infant's abilities to detect important information from the world. Her view is based primarily on two key issues: (1) the infant's ability to discover new affordances - ways upon which an environment lends itself to be acted, and (2) the infant's ability to differentiate - parse out invariant information from the world. As infants act in the world, they differentiate information in their environment and discover affordances. With this new understanding of the world around them, their actions in the world change.

According to Gibson, perception and action are closely related for the infant and much Gibsonian research examines that relationship (Gibson, 1995). For example, it has been found that an infant may tumble down a slope the first couple of times he approaches such a surface. Soon the infant begins to understand that one affordance of the slope, compared to other surfaces, is that it may cause tumbling (Adolph, Eppler, & Gibson, 1993a). Another example is Gibson and Walk's (1960) classic work on infants' perception of depth, known as the "visual cliff" experiment. In this study, it was found that infants would not crawl across a table that appeared to have a drop off, or cliff, in the middle. Gibson and Walk saw this as evidence that infants of crawling age had enough experience with depth to know that it could afford danger. (For a more detailed

discussion of this theory and related research, see the review by Adolph, Eppler and Gibson (1993b).

### Dynamical Systems

Another theoretical view that emphasizes the close relationship between perception, cognition and action is dynamical systems. In a recent set of books, Smith and Thelen (1993) and Thelen and Smith (1994) attempt to unify recent advances in dynamical systems theory with research in developmental neuroscience and behavioral development. They argue that development can best be understood in terms of complex non-linear systems that are self-organizing. Developmental changes tend to be described in the language of physical non-linear systems, that is attractor states, phase transitions, and stability versus fluctuations of the system. This view, with its emphasis on mechanisms of change, is clearly opposed to nativist explanations. Although, to date it has been applied most successfully to issues of motor development, its advocates are attempting to apply it to perceptual and cognitive development as well. As we shall see, it also has important elements in common with connectionist modeling.

### Nativism

A persistent theoretical debate throughout the entire history of developmental psychology has been nativism versus empiricism. Nowhere is it more apparent than in modern day infant perception and cognition. A chief spokesperson for the nativist position is Spelke. According to Spelke, infants are endowed by nature with capacities to perceive and understand objects and events in the world (Spelke 1985). This “core knowledge” includes an understanding of partially and fully occluded objects, the ability to reason about physical properties of objects such as continuity and solidity, an

understanding of number, and knowledge of physical causality. Spelke and others, most notably Baillargeon, have argued that human infants are more competent than others, such as Piaget, had believed. To bolster their claims they have provided considerable evidence based upon ingenious variations of infant habituation and visual preference methods. In some of these variations, infants must not only perceive events involving one or more objects but must make inferences when a portion of those events is hidden behind an occluder.

Needless to say, this viewpoint has been controversial. Many believe the nativist assumptions about the competencies of young infants are unwarranted. In fact, they question whether such assumptions can even be considered explanations. Recent debates on the pros and cons of nativism have appeared in the literature between Spelke (1998) versus Haith (1998) and Baillargeon (1999) versus Smith (1999). Furthermore, empirical research on some of these topics is beginning to show that simpler explanations can account for the apparent cognitive sophistication proposed by the nativists. Some of the research both for and against the nativist viewpoint will be described in later sections of this chapter.

### Connectionist Modeling

The connectionist modeling approach stands in sharp contrast to the nativist approach. The most complete description of the application of connectionism to development has been published in a recent book entitled “Rethinking Innateness” (Elman et al., 1996). Whereas nativism assumes infants come prewired with certain core knowledge, connectionists reject this form of innateness. They argue that at all levels, molecular, cellular, and organismic, interactions occur between organisms and the

environment. A more appropriate meaning of innateness is that the outcome is constrained to some extent at each of those levels. These constraints operate on the type of representation, the architecture, and the timing of the developmental process being considered. Comparisons, sometimes real, sometimes metaphorical, are made between the structure of the brain and computerized connectionist networks. So, for example, just as brains include neuronal synapses and specific areas, connectionist models include patterns of connections and types of units or levels. Connectionist models also include nonlinear learning rules that may lead to emergent, stage like properties and thus are quite compatible with a dynamical systems approach. Many early models were developed to counter the prevalent nativism of linguistic theory. Modelers tried to demonstrate that what some assumed were innate rules of language could be approximated through experience by connectionist models. Recently connectionism has spread to simulations of infant perception and cognition. New models are appearing on infant categorization (Mareschal & French, 2000), object permanence (Munakata, McClelland, Johnson & Siegler, 1997) speech perception (Schafer and Mareschal, 2001) and rule learning (Shultz & Bale, in press). The adequacy of these models is still being hotly debated (Marcus, G. F. 1999a, 1999b) but there is no doubt that these models are presenting a challenge to the view that infants possess innate knowledge structures.

### Cognitive Neuroscience

Developmental neuroscience is an area that has grown substantially over the last ten to twenty years. Like dynamical systems and connectionist modeling, its users attempt to make links between development of the brain and development of behavior associated with perception and cognition. Whereas previous approaches to ties with brain

development have been somewhat metaphorical, developmental neuroscientists attempt to measure brain development directly and then relate it to cognitive development. However, finding the answers to questions about brain development and cognitive development in infants is not such a straightforward business. Procedures that may be useful to study the link between brain and cognition in older children may not be appropriate for studying this link in infants. For example, PET (positron emission tomography) and F-MRI (functional magnetic resonance imaging) methods may work fairly well with children and adults, but these are considered too intrusive for use with infants (Johnson, 1997). The methods most often used to study the developing brain in infants are EEG's (electroencephalography), ERP's (event related potential), and animal models (for a review of studies on infant perception and attention see Johnson, 1996).

### Information-Processing

The information-processing approach contains elements of some of the other approaches described previously. Like Piaget, proponents of the information-processing approach believe that perceptual and cognitive development is constructive. According to one view, at least, the emphasis is on infants learning to process the relationship among properties to form the whole (Cohen, 1988; 1991; 1998; Cohen and Cashon, 2001b). Young infants are able to process simple perceptual properties of objects such as color, form, shape before they can process objects as a whole. As in Piagetian theory, development is also hierarchical. From an information-processing perspective what counts as a unique whole at one age can serve as a property or element of a larger or more complex whole at an older age. So once infants perceive or organize perceptual properties into unique objects they can treat objects, themselves, as properties of larger

wholes and look for relationships between objects in dynamic events involving multiple objects. One such relationship is causality and infants can distinguish causal, direct launching events, from non-causal events. At a later point in development even these causal events can become elements in more elaborate event sequences.

Recently this approach has been summarized by a set of 6 propositions (Cohen & Cashon, 2001b):

1. Perceptual/cognitive development follows a set of domain-general information-processing principles.
2. Information in the environment can be processed at a number of different levels of organization.
3. Higher (more holistic) levels can be defined in terms of the types of relationships among lower (parts) levels.
4. Development involves progressing to higher and higher levels.
5. There is a bias to initiate processing at the highest level available.
6. If an information overload occurs (such as when movement is added or when the task involves forming a category), the optimal strategy is to fall back to a lower level of processing.

Much like connectionist modeling and dynamical systems, and unlike nativism, the information-processing approach emphasizes the role of experience, learning, and non-linear changes in development. In fact attempts are currently underway to produce a connectionist model that follows the 6 propositions listed above (Chaput & Cohen, 2001). Along with other approaches, visual attention and habituation are frequently used to assess infant information-processing. In contrast to other approaches it also emphasizes

changes in attention and memory over age. An information-processing perspective has often been used in studies of individual differences in preterm versus full-term infants or normal versus aberrant infants as well as long term predictions of later intellectual ability (e.g., Fagan, 1984; Bornstein and Sigman, 1986).

### Infants' Perception of Properties of Objects

We begin by considering three classic topics in perception that have also been studied extensively in infants, form perception, color perception, and perceptual constancies. If space permitted we could have included many other topics that have also been investigated in infants including the perception of sound, touch, odor, and motion. Although our selections are not exhaustive, they are representative of the type of questions being asked about infant perception and its development. They also serve as a reasonable starting point for our progression from topics which most would agree are clear examples of infant perception to topics which fall more into the category of infant cognition.

#### Form Perception

Form perception in infants is usually studied with 2-D or 3-D static figures or shapes that have well-defined contours (Slater, 1995b; Slater & Johnson, 1998). The issue most often investigated in form perception is whether infants will respond to the “component parts” of a shape or to the figure “as a whole” (Slater, 1995b; Slater & Johnson, 1998). However, making this distinction experimentally is not always easy. For example, Slater, Morison, and Rose (1983) found that newborn infants can discriminate between the outlines of the shapes of a triangle, a square, and a cross. Is this form perception? Perhaps not. In fact, in one of the earliest form perception studies with

infants, Salapatek and Kessen (1966) found that when newborns scanned a large triangle, they only scanned a small portion near the apex. To count as clear evidence of form perception, it is important to show that infants are discriminating between these shapes based upon more than just a portion of their outlines, or some other component of the figure. It also must be shown that infants process the figure “as a whole.” As Banks and Salapatek (1983) discussed (see also Slater, 1995b), it is very difficult to obtain unambiguous evidence of form perception because there are often simpler, perceptual explanations for results with infants. Thus, even topics as basic as form perception must deal with issues about part vs. whole processing that are central to the “information-processing” approach mentioned earlier.

Fortunately, there are ways to examine this experimental issue. In one such study, Cohen and Younger (1984) investigated developmental differences in the perception of angles by 14- and 6-week-old infants and were able to get clear evidence of form perception in the older infants. Cohen and Younger (1984) tested whether infants would process the parts of the angle, that is, the orientations of the lines, or whether they would process the whole angle, that is, the relationship between the lines. After habituating infants to one angle, they presented variations that either changed the line orientations but not the angle, or the angle but not the line orientations. Their results indicated a developmental shift in the manner that infants process angles, and perhaps other simple forms. The younger infants seem only able to process the line orientations, or the independent parts of the angle; whereas the older infants are able to process the relationship between the lines and process the angle as a whole form.

Slater, Mattock, Brown, and Bremner (1991) conducted a similar set of experiments with newborns. In the first experiment, newborns were found to behave similarly to the younger, 6-week-old infants in the Cohen and Younger (1984) study. Not surprisingly the newborns in Slater et al. (1991) responded to a change in line orientation and not to a change in the angle. In a second experiment, Slater et al. (1991) investigated whether newborns could process the angle independently of its orientation. In this experiment, newborns were familiarized either to an acute or an obtuse angle presented in six different orientations, much like a category study. Infants were then tested on an acute and an obtuse angle, one of which was familiar and the other novel, both in novel orientations. Slater et al. (1991) found that the newborns showed a novelty preference for the novel angle. Slater (1995b) suggested that this could be evidence of form perception in newborns, although he acknowledged that it may not be unambiguous evidence.

One important alternate interpretation has been referred to as the “blob theory” (Slater et al., 1991). This interpretation rests on the notion that at the apex of an angle a low frequency “blob” is formed, and the size of the blob will vary depending on the size of the angle. When newborns discriminated between the acute and obtuse angles in Slater et al. (1991) test, they may have been responding to the difference in relative size of the blobs and not actually to the angle itself. If this is the case, then the results would be consistent with a developmental progression in the perception of angles, whereby newborns respond to the size of the apex (the blob), 6-week-olds respond to the independent lines of an angle, and 14-week-olds respond to relationship of the lines of the angle or the “form” of the angle.

Slater and Morison (as cited in Slater, 1995b) also found evidence for a developmental progression in form perception. In this experiment, newborns, 3-month olds and 5-month olds were tested on whether they could extract the general shape from a series of figures that varied only slightly from one another in design or texture. After being familiarized to six exemplars of a shape, infants were tested on a novel exemplar of the familiar shape and a novel shape. By showing infants slight variations of the same shape, the experimenters were able to see if infants could form a category based on the overall form of the shape. If infants were, in fact, able to form this category, then one would expect infants to show a novelty preference for the novel shape. This is exactly what the 3- and 5-month old infants did; however the newborns did not show the preference. These results fit nicely with an information-processing approach and provide further support that form perception may develop over time.

### Color Perception

Our knowledge about infants' color perception has grown considerably in the last 25 years (for a review, see Teller and Bornstein, 1987). Before that time, the results of research conducted on infant color perception were somewhat ambiguous. It was never clear in these early experiments whether infants were discriminating between different hues, or some other aspect of color such as brightness or intensity.

In 1975, several researchers invented clever tasks to show that infants younger than 3 months of age can discriminate stimuli that vary in hue, not just brightness. For example, Peeples and Teller (1975) tested 2-month-old infants on a hue preference test and found that they could discriminate a red hue from a white hue, independent of brightness. More recently, Adams, Courage, and Mercer (1994) tested infants shortly

after birth and found that newborns could discriminate red from white, but not blue, green, or yellow from white. However, as Kellman and Arterberry (1998) concluded, by about 2 to 3 months of age infants seem to have very similar color vision to adults and can discriminate between many colors.

So, within the first 2 to 3 months of life, infants appear to be sensitive to the same spectrum of color as adults. But, do infants view the boundaries between colors in the same way as adults? Adults will group a range of colors into “blue” and another range into “green” etc. In other words, do infants, like adults, organize colors into distinct categories? Bornstein, Kessen, and Weiskopf (1976) tested this question with 4-month-old infants. They habituated infants to a stimulus of a certain hue, or wavelength. Then, the infants were tested with the same stimulus, a stimulus of a different wavelength but from the same color category, and a stimulus of a different wavelength that was considered by adults to be in a different category. If infants dishabituated to both novel stimuli, one would conclude that they must have responded to the wavelength and not the color categories. However, Bornstein et al. (1976) found that infants dishabituated only to the stimulus that adults considered to be in a different color category. Thus, infants not only perceive colors at an early age, they also seem to organize them into roughly the same color categories as adults.

From an information-processing viewpoint, it is interesting that, like form perception, even infants' color perception appears to go through a developmental pattern whereby infants begin by processing information at a lower level, and then, later, they integrate that information and process it at a higher level. In the case of color perception, infants first gain the ability to discriminate between colors (around 2- to 3-months of age)

and then later, building upon that ability, are able categorize colors (around 4-months of age). We will see something, again, that looks very much like categorization with infants' perception of shape and size constancy, which will be presented in the next section.

### Perceptual Constancy

Artists are taught to be conscious of the way they see the world and to create visual illusions such as size, perspective, and distance on the canvas. For example, to create the illusion that an object is farther away, an artist will simply draw the object higher and smaller on the page than an object that is meant to be up close. Similarly, adults have little difficulty making sense of the environment and understanding the illusions created on our retina. For example, you would have no trouble recognizing this book as the same book whether you saw it inside on your desk under fluorescent lighting or outside in the bright daylight. You would not be fooled by the different perceptual characteristics of the book due to the different illuminations and would effortlessly understand that it is the same book. Furthermore, you would perceive the book as the same despite its change in location or orientation. This ability to identify an object as the same despite a perceptual transformation is known as perceptual constancy.

One question that researchers have asked is whether young infants see real objects, as adults do, or retinal images of objects? For example, how would an infant make sense of seeing a teddy bear from across the room and then seeing the same teddy bear up close? Would the infant respond to the objective characteristics of the teddy bear and recognize the two images as the same teddy bear, or would the infant respond to the different sized images on the retina and perceive the bears as two distinct objects, one much larger than the other? If infants perceived the two images as the same, as adults

would, we would say that infants have size constancy, that is, despite the fact that the retinal image of the close teddy bear may be twice as large as the retinal image of the distant teddy bear, the objective size is still preserved.

The notion of constancy can also refer to shape constancy, which is the ability to perceive an object as being the same despite changes to its orientation or slant. For example, if an infant saw a rectangular block from the frontal view and then saw it at a 45-degree angle, would the infant know that it was the same block? In other words, would the infant, like an adult, understand that despite the change in slant both objects are the same rectangular block? Or, would the infant perceive only the retinal image of these two objects and treat these two as different shapes, one as a rectangle and one as a trapezoid?

Size Constancy. Piaget and Inhelder (1969) adhered to the position that infants first respond to the retinal images of objects and believed that infants did not get size constancy until 5 or 6 months of age. They based this belief on the finding that if one taught infants to reach for a large box, the infant would continue to reach for that box even though it projected a smaller image on the retina than a box that was closer and smaller in real size.

Bower, however, challenged the traditional view of size constancy and was one of the first researchers to test its claims empirically. In several experiments (e.g., Bower, 1966b), he used an operant conditioning paradigm to investigate whether young infants based their responses to an object on that object's real size, retinal size, or distance. Bower (1966b) found that infants generalized their response based upon both the objective size and the object's distance, but not retinal size. Thus, he had evidence that

infants younger than 2 months of age do not rely on the retinal size of objects and can respond on the basis of an object's real size and distance.

Day and McKenzie (1981) continued the work on infant size constancy using a habituation paradigm, a completely different technique from Bower's operant conditioning experiments. They also found evidence for size constancy in infants as young as 18 weeks of age. Subsequently two independent research laboratories tested newborns in a habituation paradigm and both found evidence of size constancy (Granrud, 1987; Slater, Mattock, & Brown, 1990).

Shape Constancy. In addition to studying size constancy in infants, Bower also used his operant conditioning technique to study shape constancy. In one experiment with 50- to 60-day-olds, he trained infants on a rectangle that was slanted at a 45-degree angle, which created a retinal image that looked like a trapezoid. He then looked for a generalized response to: 1) a rectangle at a frontal view (new retinal image, same objective shape, new slant); 2) a trapezoid at a frontal view (same retinal image, new objective shape, new slant); and 3) a trapezoid slanted at a 45-degree angle (new retinal image, new objective shape, same slant). Bower found that infants generalized their response to the rectangle presented at a frontal view. This result indicates that the infants responded to the objective shape of objects and not the shape of the retinal image or the slant of the objects.

Caron, Caron, and Carlson (1979) also addressed the issue of shape constancy in young infants, but did so in several studies using a habituation paradigm. Their results supported Bower's finding that young infants perceive the objective shape of objects and do not rely solely on the retinal image of those objects. In fact, in a more recent

habituation study, Slater and Morison (1985) also found evidence of shape constancy in newborns.

Constancy As a Relationship Between Features.

In sum, the evidence suggests that young infants do not rely solely on the retinal image of objects and are capable from birth, or shortly thereafter, of understanding size and shape constancy. How is it that infants are able to understand these constancies and respond to more than the retinal image of objects at birth? The key may be that all constancies require an understanding or appreciation of relational information. To return to the examples in the beginning of this section, the reason this book outdoors is not perceived as brighter is because relative to other objects, it is not brighter. Furthermore, the reason why an infant would perceive the teddy bear up close and far away as the same bear is because the size is constant relative to the distance of the object. The up close bear may appear two times as large but it is also two times as close as the distant bear. Thus, the relationship between size and distance has remained the same. It is these constant relationships to which the infants must be sensitive.

Being sensitive to the relationships among things in the world is a necessary requirement for understanding the world around us. From our information-processing perspective, understanding relationships is the central principle around which infant perceptual and cognitive development proceeds. Throughout this chapter, we will demonstrate that as infants get older, the types of relationships they process, understand, and remember become more complex and abstract. In that sense the ability to understand size, shape and other constancies become building blocks from which infants learn about first objects and later events in the world about them.

Even some types of constancies may be more cognitively demanding or require more conscious attention to relationships than others. One of these may be object constancy, which is an understanding that despite a significant physical transformation of an object in space and/or time, it is the same object. An example would be understanding that the bottle now on it's side but seen previously standing up, is the same bottle, or, recognizing the back of mother's head is the same person who is normally seen from the front. One could go a step further. What if the object or person was not visible at all? For example, consider an infant who hears her mother's voice in the other room and is able to identify that voice as her mother, or, an infant who recognizes that the toy under the table as the same toy she had in her hand before she dropped it and lost sight of it. This extension of object constancy has been examined in great detail in the infant cognition literature by Piaget and many other investigators under the heading of "object permanence." Since the development of an understanding about objects has played such a prominent role in investigations of infant cognition we shall devote considerable space to it in the next section of this chapter.

### Infants' Understanding of Objects

#### Object Permanence

When people think about what infants know about objects, the concept of object permanence, or understanding that an object continues to exist in the world even though it is hidden or cannot be seen, often comes to mind. There is the general misconception that infants acquire this concept at 8 or 9 months of age. The misconception arises in part because most people think of object permanence as a unitary concept that infants have or do not have at a particular age.

Because one of the most dramatic developments in object permanence, reaching for and obtaining an object that is totally hidden, occurs around 8 or 9 months of age, this is when many assume infants acquire object permanence. However, for Piaget, obtaining a hidden object is only one intermediate step in a long sequence of accomplishments that infants must master during their first two years of life (Piaget, 1952; 1954). Obtaining a completely hidden object is characteristic of the onset of Piaget's Stage 4 (9 to 12 months). However, infants at Stage 3 (1 1/2 to 4 to 5 months), although not yet able to retrieve a completely hidden object, are able to retrieve an object that is only partially hidden. And, even though Stage 4 infants can retrieve a completely hidden object, if an experimenter subsequently hides the object under a second cloth, infants at this stage will commit what is known as the "A not B error." They will mistakenly go to the first cloth to retrieve the object (for more discussion on the A not B error, see Diamond, 1991; and Haith & Benson, 1998).

Infants at Stage 5 (12 to 18 months) no longer make this error and will correctly retrieve the hidden object from the correct cloth. However, according to Piaget (1954), Stage 5 infants still do not completely have the concept of object permanence for they are fooled by "invisible displacements." If an experimenter shows an infant an object and then places the object in a small box before hiding it under a cloth on the table, the Stage 5 infant will not look for the hidden object at its final destination. An infant who does successfully retrieve an object under this circumstance is considered by Piaget to be in Stage 6 (18 to 24 months) and to have completely mastered the object concept. (For more discussion on the development of the object concept see Diamond, 1991; and Haith & Benson, 1998)

Object Unity.

More recent research has extended the work of Piaget and considered other questions about infants' understanding of objects. Kellman and Spelke (1983), for example, investigated the role of coordinated movement of an object parts in infants' perception of "objectness," or the perception of object unity. In this classic study, they habituated 4-month-old infants to a display in which a partially occluded rod moved back and forth behind an occluder. They were then tested on two displays without the occluder. In one test, infants saw a complete rod that moved back and forth, and in the other they saw just the two rod parts that resembled portions visible during habituation. The infants dishabituated to the two rod parts, but not to the solid rod indicating to Kellman and Spelke (1983) that the parts were novel, and thus that they must have perceived the two moving parts during habituation as a single complete rod. This result according to Kellman and Spelke, indicates that the infants perceived object unity even under conditions of partial occlusion. It is interesting to note that the perception or inference of an object under conditions of partial occlusion at 4-months of age would be consistent with Piaget's Stage 3 behavior. It therefore would be of interest to test younger infants to see if, in fact, this ability to perceive or infer a unified object develops during the first few months of life.

Several researchers have, in fact, attempted to replicate this object unity study with younger infants. Slater, Morison et al. (1990) conducted a similar study with newborns and found a very different set of results from those reported by Kellman and Spelke (1983). Slater, Morison et al. (1990) found that instead of dishabituating to the two rod parts, newborn infants dishabituated to the complete rod suggesting that they

were perceiving the rod parts as separate items rather than as the top and bottom of a single unified object. More recently, researchers have replicated Kellman and Spelke's findings with 2 month olds and have found that they dishabituate to the rod parts display in the test if the occluder is rather narrow (Johnson & Nañez, 1995). Collectively, research on object unity shows that infants are not born with the ability to perceive two parts of a moving, partially occluded object as one object, but that this ability develops over at least the first 4 months of age.

In fact, such a conclusion fits within an information-processing framework by showing once again a developmental change from processing parts to processing wholes. It seems clear from research on object unity and other related topics that well before 7 months of age, infants are capable of perceiving "objectness", that is of perceiving those characteristics that indicate a single unified object exists. From our earlier discussions on form, color, and constancy, it is equally clear that also well before 7 months of age infants perceive many characteristic features of an object. However, as research described in the next section will indicate, young infants still lack the ability to distinguish one object from another. This ability has been called object individuation or object segregation and estimates about when it develops range widely from 4 or 5 months of age to 12 months of age.

### Object Individuation

The ability to distinguish two objects as distinct entities is what researchers refer to as object individuation or object segregation. Depending on the procedure used, there are reports that infants can individuate objects at 12-, but not 10-months of age (Xu & Carey, 1996), or in some cases as young as 5-months of age (Needham, 2001; Wilcox,

1999). Xu and Carey (1996) employed an “event-mapping” procedure, as it is referred to by Wilcox and Baillargeon (1998), in which infants were shown an event and then tested on two events, one that was considered “consistent” and another that was considered “inconsistent” with the first event. Specifically, infants initially saw one object move behind an occluder from the left, then a different object emerge from behind the occluder and move to the right. The authors reasoned that if infants understood that there were two objects in the original event, then they should look longer at the inconsistent event, that is, the display with one object. They found that the 12-month olds, but not the 10-month olds, looked longer at the one object display. Based upon these findings, Xu and Carey concluded that these older infants understood that there were two objects present in the event and had successfully individuated the objects.

However, studies with younger infants suggest that they too, under certain circumstances, can individuate objects. In a very recent set of studies, Needham (2001) gave infants exposure to an object prior to presenting two test events that involved an object similar to the prior-experience-object, but varying on some feature such as texture (Experiments 1 & 2), orientation (Experiment 3), and color (Experiments 4, 5, & 6). One test event can be described as “two objects-move-together.” In this event the two objects which are touching and move together could be perceived as either one or two separate objects. The second test event can be described as “one-object-moves.” In this event the object remains stationary so it should be obvious that there are two distinct objects. Needham reasoned that if infants attended to the featural characteristics of the prior-experience-object and its equivalent in the test was similar enough, then infants should still show signs of individuating the objects in the move-together test event. If, however,

infants did not view the two objects as similar, then presumably that prior experience with the first object would not help the infants to individuate the objects in the test display. In this case infants would not be expected to show a difference in response to the two test events. Needham (2001) found that 4.5-month-olds could use texture and orientation, but not color cues, to help them individuate the objects in the test displays.

In addition to these findings a study by Wilcox (1999) showed a developmental progression in what featural information can be used to help infants individuate objects. She found that at 4.5-months of age infants can use shape and size, at 7.5-months of age they can use pattern, and at 11.5-months of age they can use color to individuate objects. From our earlier discussions on form and color perception, it is clear that infants in the first 3 months can perceive these characteristics about objects. Furthermore, as the discussion on object unity shows, infants are also capable of perceiving “objectness” (i.e., that something is a separate object) by 2 months of age. So, one may ask why infants cannot consistently individuate objects until possibly 5- or even 10- to 12-months of age? We believe the answer may lie in an information-processing perspective. The ability to individuate objects requires attention to and integration of both featural information and objectness. Thus, object individuation represents another example of a developmental progression from processing the independent features of objects to integrating or relating those features and processing the object as a whole.

### Core Knowledge about Objects

Some theorists believe that infants have sophisticated knowledge about objects, and object permanence, much earlier than others such as Piaget had assumed. In fact, in many of their studies investigating infants’ understanding of objects, an understanding of

object permanence is a prerequisite for the infants. For example, in one experiment on young infants' understanding of object solidity, that is, that one solid object cannot pass through another solid object, Spelke, Breinlinger, Macomber, and Jacobson (1992, Experiment 3) showed 2.5-month olds' events in which a ball rolled from the left end of the stage to behind an occluder. After about 2 s, the occluder was raised to reveal the ball resting against a wall. In the habituation phase, when the occluder was raised, the ball was shown resting on the left side of a wall on the right end of the stage. In the test phase, lifting the occluder revealed two walls, one in the center of the stage and one on the right. In one test event, the ball was found resting against the center wall, which was considered a "consistent" outcome since the wall would have obstructed the ball's path. In the other test event, the ball rested against the right wall, which was considered an "inconsistent" outcome since the ball would have had to go through the center wall to reach the right wall.

Spelke et al. (1992) found that infants looked longer at the inconsistent outcome and interpreted this result to mean that infants as young as 2.5-months of age understand that a ball cannot travel through a solid, center wall to get to the right wall. However, given the fact that the action of the ball took place behind an occluder, to make the interpretation that these very young infants understand object solidity, one also has to assume that these infants understand the ball continues to exist when behind an occluder, in other words that they are operating at least at Stage 4 of object permanence.

Recent evidence with 8-month-old infants and animated events, however, suggests a simpler explanation for this apparent sophisticated cognitive ability by infants. It is possible the infants were simply responding to changes in the perceptual cues of the

events such as the duration of movement or the presence of a wall to the left of the ball (Bradley & Cohen, 1994). In another, similar set of experiments on infants' understanding of solidity, Cohen, Gilbert and Brown (1996) tested 4-, 8-, and 10-month-old infants. They found that infants had to be at least 10 months of age before they really understood that one solid object cannot pass through another solid object.

If this conclusion is accurate, once again it fits within the information-processing framework. As we have mentioned, there is evidence that infants first learn about the independent features of objects by about 4 months, and then integrate these features into a whole object by about 7 months. The next step developmentally would be for infants to understand the relationship between objects, in this case, to understand that one solid object cannot pass through another solid object. It makes sense to us that the ability to understand object solidity may not develop until approximately 10 months of age, given that infants would first have to be able to individuate and segregate individual objects.

Another type of relationship between objects would be a causal relationship, the simplest version of which would occur in what has been called a "direct launching" event. In this type of event one moving object hits a second moving object causing the second object to move. Several studies have now been reported on infants' perception or understanding of causality in these type of events. Once again as predicted by an information-processing view, when realistic objects are being used, infants don't perceive the causality until approximately 10 months of age. See Cohen, Amsel, Redford, and Casasola (1998) for a review of this literature.

In addition to Spelke and her colleagues, Baillargeon has also reported a large body of research suggesting that infants are precocious (for reviews, see Baillargeon,

1995; 1999). In one of her most well-known set of studies, she reported that infants as young as 3.5-months old understand that an object continues to exist when it is out of sight (Baillargeon, 1987; Baillargeon, Spelke, & Wasserman, 1985). Her procedure was very different from the traditional Piagetian object permanence task. Instead of relying on an infants' ability to reach for a hidden object, she, like Spelke, relied on infants' looking times to possible and impossible events.

The procedure involved familiarizing infants with a screen that rotated 180 degrees back and forth, from a position of lying flat on the front part of a stage to lying flat on the back part of the stage. Infants were then tested on a possible and an impossible event, both of which involved the presence of an object, such as a yellow box, placed in the path of the rotating screen. In the possible event, infants saw the box resting on the stage before the start of the first rotation. The screen then rotated back and forth, as it did in the familiarization event. Each time it rotated back it hid the object from the infant. Furthermore, the screen stopped rotating at 112 degrees when it appeared to make contact with the object, and then rotated back toward the infant once again re-exposing the object. The impossible event was similar to the possible event, except that the screen rotated a full 180 degrees appearing to go magically through the space that should have been occupied by the box. (There was actually an experimenter behind the stage who removed the box so that the screen could complete its rotation. As the screen rotated toward the infant again, the experimenter replaced the box on the stage in time for the infant to see the box once again resting in the screen's path.)

Baillargeon (1987) found that 4.5-, and some 3.5-month-old infants, looked longer at the impossible event. She interpreted this finding to mean that the infants

“understood that (a) the object behind the screen continued to exist after the screen rotated upward and occluded it and (b) the screen could not move through the space occupied by the object” (p. 662). She based these interpretations on several assumptions: (1) infants normally have a novelty preference during the test phase, (2) infants would perceive the impossible event as familiar because the amount of rotation in this event is the same as the amount of rotation in the familiarization event, (3) infants would perceive the possible event as novel because the amount of rotation is novel, and (4) if infants looked longer at the impossible event, which should be perceived as familiar, it must be for reasons other than novelty; it must be because they understood object permanence and object solidity and were observing a violation of both concepts.

However, as with Spelke et al. (1992), recent evidence suggests a simpler, perceptual explanation of Baillargeon’s (Baillargeon, 1987; Baillargeon, Spelke, & Wasserman, 1985) “drawbridge” results. We have already mentioned the problem of a familiarity effect in habituation/familiarization studies. Along those lines, one alternative interpretation is that the infants in Baillargeon’s studies were not fully habituated and thus, did not have a novelty preference during the test phase, as she assumed. The results of these more recent studies, which varied familiarization time or used more stringent habituation criteria, support the interpretation that infants looked longer at the “impossible” event because it was familiar, not because it was impossible (Bogartz, Shinskey, & Schilling, 2000; Cashon & Cohen, 2000; Schilling, 2000; see also Bogartz, Cashon, Cohen, Schilling, & Shinskey, 2000).

The findings that 3.5- to 4.5-month olds understand object permanence (Baillargeon, 1987) and that infants as young as 2.5-month old understand object solidity

(Spelke et al., 1992) stand in stark contrast to Piaget's reported ages and stages. Thus, if one assumes that explanations like Baillargeon's (1987) and Spelke et al.'s (1992) are correct regarding infants' early understanding of object permanence, that explanation has to be reconciled with the fact that under standard object permanence techniques, infants do not show evidence that they understand an object exists when completely hidden until at least 8- or 9-months of age.

The prevailing explanation for this discrepancy is that younger infants understand that hidden objects continue to exist, but they fail to reach for those objects in a standard Piagetian task because they have difficulty with means-end actions (Baillargeon, 1987; Baillargeon, Spelke, & Wasserman, 1985; Bower, 1974; Diamond, 1991). In other words, infants may have trouble coordinating two actions to obtain a goal, in this case, removing the cloth and then reaching for the object. However, once again, recent evidence suggests that infants do not have a means-end deficit. A couple of recent studies, for example, have shown that infants do not have the same reaching problem when the object is behind a transparent obstacle compared to an opaque obstacle (Munakata, McClelland, Johnson, & Siegler, 1997; Shinskey, Bogartz, & Poirer, in press). Taken together, these more recent results uphold previous findings that infants younger than 8- to 9-months of age fail to search for hidden objects, not because they lack a means-end skill, but because they have yet to understand that objects continue to exist when they are hidden.

### Face Perception

A considerable amount of research has been conducted on infants' perception of faces over the past 40 or so years (see Maurer, 1985 for review). There is no question that faces are important stimuli for infants. Infants see faces often and use them to help

identify others, interact with others, and learn about the world. It may seem odd to some that we have included a section of face perception within a section devoted to objects. However, one issue that arises in the study of infants' perception of faces is whether infants view faces as something special or they perceive faces in the same way they perceive other complex objects (see Kleiner, 1993 for discussion). Nativists often argue that faces are a unique class of objects and that the way in which newborns process a face is quite different from the way in which newborns process non-face stimuli (e.g., Fantz, 1961; Morton & Johnson, 1991). Empiricists, however, regard face perception quite differently. They argue that the way in which we process a face is brought about through experience; at least in the beginning, faces are no different from other objects (e.g., Banks & Ginsburg, 1985). In this section, we shall review some of the literature regarding the issue of infants' preference for facelike over non-facelike stimuli followed by a discussion on how infants' process faces and how that processing may change with age.

Research on infants' perception of faces has produced conflicting results with respect to the question of whether faces are special to infants. Whether newborns have an innate preference to look at faces over other stimuli is still unresolved (for discussions see Easterbrooks, Kisilevsky, Hains, & Muir, 1999; Maurer, 1985). Visual tracking studies with newborns have shown that neonates will follow, with their eyes, a facelike pattern farther than a non-facelike pattern (Goren, Sarty, & Wu, 1975; Johnson, Dziurawiec, Ellis, & Morton, 1991; Maurer & Young, 1983). However, preferential looking paradigm studies have provided a different picture. Fantz and Nevis (1967) found that, in general, newborns preferred to look at patterned stimuli, such as a bull's-eye and a schematic face, to plain stimuli, and a schematic face to a bull's-eye; however, they did not find a

preference for a schematic face over a scrambled face. In another preferential looking study, Maurer and Barrera (1981) found a preference for a facelike pattern over scrambled faces at 2 months of age, but not at 1 month of age. Johnson, Dziurawiec, Ellis, & Morton (1991, Experiment 2) replicated Maurer and Barrera's findings with 5- and 10-week-old infants in a preferential looking paradigm and Goren, Sarty, & Wu's with newborns in a visual tracking task.

It may seem odd that the evidence suggests that newborns have a preference for faces, but that this preference disappears by 2 months of age. One possible explanation for the discrepancy, posited by Morton and Johnson (1991) and Johnson and Morton (1991), is that two different testing methods were used that may tap into two different processes of face recognition in place at different ages. The first mechanism they describe is CONSPEC, a subcortical device in the brain of the newborn that contains the information about the structure of a face. CONSPEC is believed to attract infants' attention to stimuli with the same structural information as faces, which would account for newborns' preferential tracking of faces. The second mechanism, CONLERN, is thought to take over by the second month. It is assumed to be a cortical structure that is involved in learning about the conspecifics of a face. This mechanism is believed to help in the recognition of individual faces.

If Morton and Johnson are correct that infants have an innate representation of the structure of faces, then we could certainly conclude that faces are special. However, evidence from other studies raised doubts about this conclusion. The results of studies on infants' visual scanning patterns of faces and non-face stimuli have revealed similar scanning patterns and developmental trends for faces and non-face stimuli alike, which

suggests that faces may not be special to infants (see Salapatek, 1975 for discussion). Several researchers have reported finding that infants tend to scan mostly the external contour of a face in the first month of life; whereas in the second month, infants tend to scan the internal features (Bergman, Haith, & Mann, 1971 as cited in Salapatek, 1975; Maurer and Salapatek, 1976; Salapatek, 1975). This developmental shift in the scanning pattern of faces has also been found in infants' scanning pattern of non-face stimuli (Salapatek, 1975).

A number of investigators have examined the development of infants' face processing over the first year of life and whether that processing is similar to or different from the development of object processing. Previous findings with 4- and 7-month-olds have shown that the younger infants process the independent features of line drawn animals, but that the older infants are sensitive to the correlations among features (Younger & Cohen, 1986). More recently, we have been investigating whether this developmental shift from parts to whole processing would also be true in 4- and 7-month-old infants' processing of faces as well. It has been found that adults process upright faces as a whole, but inverted faces in a piecemeal manner. Therefore, we also examined the effect of orientation. Half of the infants saw all upright faces and the other half saw inverted faces.

Some of the results were expected, others were surprising. The 7-month-olds behaved as expected, that is, they responded to upright faces as a whole, but inverted faces in a piecemeal fashion (Cohen & Cashon, 2001a). The 4-month-olds, however, behaved in a totally unexpected manner. In one sense they appeared to be more advanced than the 7-month-olds, or even adults. Not only did these younger infants process a face

as a whole when it was presented upright, but they also processed it as a whole when it was presented in an inverted orientation (Cohen & Cashon, 2000)! One possible explanation for this finding currently under investigation is that an upright facial orientation may not be as important to infants at 4-months of age. They undoubtedly receive a considerable amount of exposure to faces in a variety of orientations, perhaps much more so than at 7-months when they are stronger and tend to view the world from an upright position.

### Infant Categorization

Categorization is a fundamental cognitive ability. It allows us to group together objects and events in the world and to respond equivalently to items that may be perceptually quite different. Infants as well as adults must be able to categorize to some degree. Consider what life would be like for infants if they could not. No two experiences would be identical, learning would be non-existent, and anticipating the regularities in the world would be impossible. As Madole and Oakes (in press) have stated it a bit more conservatively, “The ability to categorize may be especially important in infancy when an enormous amount of new information is encountered every day. By forming groups of similar objects, infants can effectively reduce the amount of information they must process, learn and remember...” (p. 1).

But how can one determine if infants, particularly young, preverbal infants, are able to categorize? Fortunately that problem was at least partially solved in the late 1970’s by a modification of the standard habituation paradigm. Instead of habituating infants to repeated presentations of a single item, infants could be habituated to a series of perceptually distinct items that all were members of the same category. If in a subsequent

test, infants remained habituated to a novel example from that habituated category, but not to a novel non-category item, they would be demonstrating the ability to categorize. In other words, they would be responding equivalently to items that were perceptually distinct.

Cohen and Caputo (1978) were among the first to use this procedure. They tested three groups of 7-month-old infants. One group was habituated to a single, repeated presentation of a photograph of a toy stuffed animal. A second group was habituated to pictures of different stuffed animals, and a third group was habituated to pictures of unrelated objects. All three groups were then tested with the picture of a new stuffed animal and a multicolored arrangement of flowers. The first group dishabituated to both test items. They had not formed a category. The third group did not even habituate. But the second group, the one that had seen different members of the “stuffed animal” category, dishabituated to the flowers but remained habituated to the new stuffed animal. They demonstrated that they were responding on the basis of the stuffed animal category.

Early demonstrations, such as the stuffed animal example above, have been followed by other attempts to assess infant categorization using a variety of techniques including habituation and novelty preference, sequential touching, operant conditioning and even imitation with infants over one year of age. In fact an explosion of research on infant categorization has occurred in the past two decades and several reviews of this literature are available. (e.g., Cohen & Younger, 1983; Hayne, 1996; Madole & Oakes, 1999; Quinn & Eimas 1996, Younger & Cohen, 1985). In reviewing this literature we shall consider three significant questions regarding infant categorization: At what age can

infants categorize; what is the content of infants' categories; and finally, what information processing changes underlie infant categorization?

The Earliest Age Infants Can Categorize

Considerable evidence is now available that infants can categorize during the second half of the first year of life. In addition to the previously mentioned study with pictures of stuffed animals, several studies report infant categorization of faces (e.g., Cohen and Strauss, 1979; Strauss, 1979) of 3D as well as 2D representations of animals (Younger and Fearing, 1998), and even adult gender categories (Leinbach & Fagot, 1993). Other studies have reported that as early as 3 or 4 months of age, infants can distinguish cats from dogs (Quinn, Eimas, & Rosenkrantz, (1993), and animals from furniture (Behl-Chadha, 1996). In addition if one assumes that perceptual constancies may actually be a form of categorization, then there is evidence that newborns can categorize.

Consider size constancy as an example. In a newborn size constancy experiment infants are habituated to the same object at different distances and then are tested with that same object at a new distance versus a different sized object at an old distance. Assuming that the infant can discriminate among these distances, then the procedure amounts to a typical categorization experiment. The infants have been habituated to multiple examples of discriminably different stimuli (in this case the same object at different distances) and then do not dishabituate to a new example (the object at a new distance) but do dishabituate to a non-example (a new object). Of course as adults we assume a big difference between an instance of "perceptual constancy" which we interpret as different views of one item, and "categorization" which we interpret as a

grouping of similar, but different items. It is a totally unexplored question whether infants make that same distinction and if so, at what age they do it.

### The Content of Infants' Categories

Although many investigators agree that even newborns may be able to categorize, they also agree that the content of those categories changes over age. It is one thing to group together different views of the same object and quite another to group together very different animals into the category of mammal or tables and chairs into the category of furniture. An important issue in this regard is the level at which infants first categorize objects. The traditional view has been that infants and young children form basic level categories, such as dog or chair, and only later form higher-order super-ordinate categories such as animal or furniture (Mervis & Rosch, 1981). Recent evidence with infants (see Quinn & Eimas, 1996, for a review) provides some support for this view. On the other hand Mandler (e.g., Mandler, 2000) has argued just the opposite. She has reported studies in which infants first appear to respond in terms of global categories (e.g., Mandler, Bauer, & McDonough, 1991). Quinn and others have also reported that infants respond more readily to global categories than to basic categories (Quinn and Eimas, 1998; Quinn and Johnson, 2000; Younger and Fearing, 2000).

To complicate matters further, one might assume Mandler would be pleased to find additional evidence supporting a priority of global categories over basic categories. However, she makes an additional distinction, also in dispute, between perceptual and conceptual based representations (Mandler, 2000). She believes the evidence cited above, which is based primarily upon habituation and novelty preference techniques, taps perceptual categories whereas her studies which use manipulation and imitation

techniques tap something independent, conceptual categories. Quinn and Eimas (1996), on the other hand, argue that there is a continuum between the two, with perceptual categories gradually developing into more abstract conceptual categories.

### Information Processing Changes in Categorization

One of the difficulties in deciding between global versus basic levels or perceptual versus conceptual processing is that these distinctions are based upon the presumed content of the categories from the experimenter's point of view. Just because infants distinguish between animals and vehicles, for example, does not mean the infants necessarily are operating at a global or super-ordinate level. In fact Rakison and Butterworth (1998) have shown that in the case of toy animals versus toy vehicles 14- and 18-month-old infants are actually responding to legs versus wheels. Much younger infants can distinguish cats from dogs, but the distinction is based primarily on features located in the face region (Quinn & Eimas, 1996). Consistent with an information-processing viewpoint, there appears to be a developmental progression from processing these features independently to processing the correlation among the features (Younger and Cohen, 1986). In fact, by 10 months of age, attention to correlations among features becomes a major factor both in the formation of categories and in the differentiation of one category versus another (Younger, 1985).

The number and variety of features to which infants attend also increases with age (Madole & Oakes, in press). One non-obvious type of feature that appears to become salient, particularly in the second year of life, is an object's function. For example Madole, Cohen, and Bradley (1994) found that 14-month-olds but not 10 month-olds used functional information (what an object does) in their formation of categories.

Madole, Oakes, and Cohen (1993) also reported a developmental shift from processing form and function information independently at 14 months, to processing the relationship between form and function at 18 months, once again a developmental shift that is consistent with an information-processing view of infant perception and cognition. The increased salience during the second year of life of non-obvious features of objects, such as their function or their animacy (Rakison & Poulin-Dubois, 2001) may account, at least in part, for what appears to be a shift from perceptual to conceptual categorization.

#### Current Trends in Infant Categorization Research

Research on infant categorization is continuing at a rapid pace. Among the most exciting developments are the ties developing to other related areas of developmental and cognitive psychology. One of these is the relationship between infant categorization and infant language development. Lalonde and Werker (1995) for example have shown the close tie between the use of correlated attributes in categorization and the development of speech perception. Waxman (1999) has also reported the importance of language labels on infant categorization. Close ties are also developing between infant categorization and connectionist modeling. Several attempts recently have been reported to simulate infant categorization (e.g. Mareschal and French (2000); Quinn & Johnson, 2000). The most popular approach at present has been the use of simple auto-encoder models although other more complex models are on the drawing board. These early attempts to model infant behavior in a categorization task have been remarkably successful. Future, more extensive, models are likely to lead to interesting predictions as well.

#### Individual Differences

The vast majority of research on infant perception and cognition has been concerned with discovering the abilities of normal infants along with changes in those abilities over age and development. Both theoretical predictions and experimental designs generally have been based upon differences between groups with the goal being to describe and explain how infants in one condition differ from those in another condition, or how one age group differs from another age group. The average performance of these groups is not even the emphasis. It is the optimal performance of infants at a certain age, so that often the behavior of 25% or more of the infants in a study is discarded for some reason. Perhaps it is because the infants were too irritable, or too sleepy, or they did not attend sufficiently, or they did not habituate. In such studies individual differences traditionally are treated as error variance. They are considered primarily as an indication of the degree of experimental control or the statistical power of the experiment.

This overwhelming emphasis on group differences among normal infants does not mean investigators of infant perception and cognition have been totally unconcerned about the value of assessing individual differences in normal populations or in discovering what differences exist between normal and aberrant infants. In fact a frequent argument, often made in significance sections of grant proposals, is that one must first collect data on normal infants before one can determine the most important ways aberrant infants deviate from normal ones. Fagan, a basic researcher of infant attention and memory in the 1970s, has gone considerably further than that. He has developed a clinical screening device, based upon his measure of infant novelty preferences, that he argues should be used to differentiate those infants truly at risk for some long term deficit from those who may seem to be at risk, but really are not (Fagan, 1984).

To be accurate, individual differences in infants' functioning have been of interest to some investigators of infant perception and cognition since the 1970s. That research has come primarily from those focused on differences in infant attention, memory, and information processing. As Rose and Feldman (1990) noted, this research on individual differences can be subdivided into two broad categories: differences between normal versus risk groups and measures of predictive validity, primarily in normal infants.

### Fullterm versus Preterm Infants

The term "at risk" usually refers to infants who are born with some difficulty that may or may not lead to a long-term deficit. The most common group of "at risk" infants are those who are born prematurely with or without additional symptoms. Much of the early research on individual differences in infant perception and cognition compared fullterm versus preterm infants. One of the first such studies was reported by Fagan, Fantz, and Miranda (1971). They tested normal and preterm infants on a novelty preference task from approximately 6 to 20 weeks of age. Their infants were familiarized to one complex black and white pattern and then tested with that pattern versus a novel pattern. A clear difference between the groups was obtained with normal, term infants first showing a novelty preference at 10 weeks of age, but preterm infants not showing a novelty preference until 16 weeks of age. Of more importance from a developmental perspective, was that when the two groups were equated for conceptional age (gestational age plus age since birth) the group difference disappeared. Both groups first showed a strong novelty preference at about 52 weeks of conceptional age. Thus, at least on this one task, maturation seemed to play a more important role than the total amount or type of external stimulation the infants had received.

Others, however, have found differences between preterm and fullterm infants even when conceptional age is equated. Sigman and Parmelee (1974), for example, found that at 59 weeks of conceptional age, fullterms preferred faces to non-faces whereas preterms did not. Unlike the results in the Fagan et al. (1971) study, fullterms but not preterms also displayed a novelty preference. Of course there are many reasons why preterm infants may be delayed compared to fullterm infants. Preterms usually have more serious medical complications; they are more isolated from their parents; they stay in the hospital longer; they tend to be disproportionately male and lower class; the parents tend to have received less prenatal care and poorer nutrition, and so on. Any number of these factors in isolation or combination could be responsible for delays in perceptual or cognitive development.

In another study (Cohen, 1981) three groups of infants were compared at 60 weeks conceptional age. The “severe” group had a number of complications including prematurity, hyaline membrane disease, several had seizures, one had severe hypocalcemia and one had congenital heart disease. In general these infants had suffered considerable prenatal or perinatal trauma but had survived relatively intact. They all also came from lower class family backgrounds. A second group included only fullterm, healthy infants also from lower social class backgrounds. Finally, a third group included only fullterm infants from middle class backgrounds. In this study, low and middle SES groups differed in number of two parent families, years of education, racial background, and place of residence. All three groups were habituated to a picture of a face and then tested with two different novel faces. The middle class group dishabituated to the novel faces (i.e., showed a novelty preference), but neither of the lower class groups did so. It

appeared that factors associated with class status were more significant than prematurity or risk status in this particular study.

Interestingly, Rose, Gottfried, and Bridger (1978) reported a similar finding with one year old infants and a cross modal task. Middle class fullterm infants, lower class fullterm infants and preterm infants were allowed oral and tactile familiarization with a 3 dimensional block. When shown that object and a novel object, only the middle class infants looked longer at the novel object. In a subsequent study, however, using a visual task with simple geometric shapes presented at 6 months of age, lower class full term infants displayed a novelty preference but lower class preterms did not (Rose, Gottfried, and Bridger, 1978). Thus the evidence is mixed with respect to preterm versus fullterm differences. Systematic differences between these groups are frequently reported, but the bases for those differences are not always clear. In some cases the difference appears to be based upon conceptional age or social class. In other cases risk status seems to be implicated more directly.

The differences discussed so far between fullterm and preterm infants have been rather global, fullterm infants dishabituate or show a novelty preference whereas preterm infants do not. But at least one study has gone further to investigate how the two groups differ in their information processing. Caron, Caron, and Glass (1983) tested preterm and fullterm infants on a variety of problems that involved processing the relations among the parts of complex face-like drawings and other stimuli that they presented. They then tested to see if the infants had processed the stimuli on a configural basis (e.g. the overall configuration of a face) a component basis (e.g. the type of eyes and nose that made up

the faces). They found clear evidence that the fullterm infants were processing configurations, whereas the preterm infants were processing components.

Infants with an Established Risk Condition

A distinction is sometimes drawn between infants who are “at risk” for later disability and infants who have an “established risk condition,” such as Down syndrome, cerebral palsy, and spina bifida (Tjossem, 1976). Several studies have established that Down syndrome infants, for example, are delayed relative to normal infants in habituation and novelty preference (e.g., Fantz, Fagan, and Miranda, 1975; Miranda, 1976).

One of the more interesting comparative studies was reported by McDonough (1988). She tested normal 12-month-old infants as well as 12-month-old infants with spina bifida, cerebral palsy, or Down syndrome. The infants were given a category task similar to the one reported earlier by Cohen and Caputo (1978). Infants were habituated to a series of pictures of stuffed animals and then tested with a novel stuffed animal versus a non-stuffed animal (a chair). The normal infants and the infants with spina bifida or cerebral palsy habituated, but the infants with Down syndrome did not. Apparently the presentation of multiple distinct objects was too difficult for them to process. However, in the test, only the normal infants and the infants with spina bifida showed evidence of categorization by looking longer at the non-category item than at the new category member. So even though the infants with cerebral palsy habituated, they showed no evidence of forming the category.

These and other studies that have compared normal with at risk infants provide compelling evidence that the at risk infants perform more poorly on certain tests of

habituation and novelty preference. Additional evidence on these differences is available in edited volumes by Friedman and Sigman (1981) and Vietze and Vaughan (1988). An important question is what these differences mean. Most would assume that habituation and/or novelty preference tests are assessing certain aspects of information processing such as attention, memory, or perceptual organization. But even if some at risk infants perform more poorly during the first year of life, does this performance predict any long-term deficiency in one or more of these processes? Even if some long-term prediction is possible, does that prediction only apply to group differences, such as those between normal and at risk or established risk infants? Or can one also use habituation and novelty preference measures to make long-term predictions of individual differences even among normal infants? This question will be addressed in the next section.

#### Predictive Validity of Habituation and Novelty Preference Measures

An examination of the predictive value of traditional, standardized tests of infant development, such as the Bayley or the Gesell scales, has led to the unfortunate, but definite conclusion that these tests have dubious long-term predictive validity for normal populations (e.g., McCall, 1979; McCall, Hogarty, & Hurlburt, 1972), as well as for populations that include infants at risk (Kopp & McCall, 1982). This lack of predictive validity of traditional tests was at first considered not to be a failure in the tests themselves but simply a reflection of the discontinuity and qualitative nature of change over age in intellectual development from infancy to childhood (McCall, 1981; McCall, Appelbaum, & Hogarty, 1973).

That view became somewhat suspect in the 1980s as studies appeared demonstrating sizable correlations between infant habituation or novelty preference

usually assessed sometime between 3 and 8 months of age, and later IQ - usually assessed between 3 and 8 years of age (e.g., Caron, Caron, & Glass, 1983; Fagan & McGrath, 1981; Rose & Wallace, 1985). Both Bornstein and Sigman (1986) and McCall and Carriger (1993) provide excellent reviews and analyses of this literature. McCall and Carriger (1993), for example, report that across these studies the median correlation between information processing measures assessed via habituation or novelty preference tasks with childhood intelligence is approximately .47, whereas it is approximately .09 between standardized infant tests and later intelligence. Furthermore these high correlations between information processing and later IQ tend to occur even in small samples and with normal populations.

Although many specific measures of infant information processing have been tried, three classes of them appear to be the best predictors of later intelligence (Slater, 1995a). One is preference for visual novelty. Following brief exposure to a visual pattern (usually 5 to 20 sec), the familiar and a novel pattern are presented side by side and the percent responding to the novel pattern is recorded. This percent novelty tends to be positively correlated with later IQ. A second is some measure of habituation rate. Various measures of habituation, such as the total looking time until some habituation criterion is reached or the total number of habituation trials prior to criterion, are sometimes found to be correlated with later intelligence. In general, those who habituate more rapidly tend to have higher IQs. The third is some measure of fixation duration independent of habituation. The measure may be the duration of a look at the outset of the habituation trials, or the duration of the longest look during habituation, or the average duration of a look during habituation. In general, the shorter the look by the infant, the higher the IQ

found later in life. Some have even found systematic individual differences between short and long lookers. For example, it has been found that younger infants tend to look longer at most pictures that they can see clearly than do older infants (Colombo & Mitchell, 1990).

Although most investigators agree that these measures tap some aspect of information processing, it is less clear what the underlying mechanism or mechanisms may be. Most explanations of differences in infants' performances have something to do with differences in encoding or processing speed or the ability to remember old information and compare it to new information. Perhaps the most popular explanation is based upon processing speed. Why speed of processing visual pattern information in infancy should be related to later IQ in childhood is still an open question, although Rose and Feldman (1995) have recently reported that these infancy measures correlate with "perceptual speed" at 11 years of age, even when IQ was controlled.

Whatever the mechanism, correlations in the .4, .5, or even .6 range between measures of infant attention at around 6 months and later measures of IQ at around 6 years, is quite impressive, particularly in light of the failure of standardized IQ tests to predict. But the results are not without controversy. Not everyone obtains such high correlations. Both Lecuyer (1989) and Slater (1995a), for example, point out the "0.05 syndrome" makes it is difficult to publish a paper if your correlations are not significant. Many studies have probably not found a relationship between infant attention and IQ, but they are not counted in summaries or meta-analyses, since no one knows about them. In their meta-analysis of this literature, McCall and Carriger (1993) evaluate three other criticisms that have been raised about the importance of these correlations. First,

habituation and novelty preference measures may not reflect any interesting cognitive process. Second, the infancy measures have only moderate test, retest reliabilities. Third, the small sample sizes used may lead to a prediction artifact. That is, the inclusion of a few extreme scores, perhaps by infants who have known disabilities, can inflate correlations when the sample N is small. McCall and Carriger conclude that although these criticisms have some merit, in the end, they do not negate the fact that even with normal populations the ability to make long-term predictions is impressive.

#### A Specific Information Processing Explanation

Before leaving this section, it might be worthwhile to try to understand these individual differences by referring to the specific set of information-processing propositions mentioned previously in this chapter (Cohen and Cashon, 2001b). First it seems a bit odd that previous explanations have assumed that somehow habituation and novelty preferences are tapping infant “information processing” but they don’t emphasize how infants are actually processing the information or how that processing changes with age. It is not a coincidence that the best predictions seem to result when infants are between about 4 and 7 months of age and they are shown complex, abstract patterns or pictures of faces. That is just the age period when infants should be making a transition from processing those pictures in a piecemeal fashion to processing them holistically. If one makes the additional assumption that processing and remembering something holistically takes less time and resources than processing it one piece at a time, then the following set of results, all of which have been reported, would be predicted.

1. Younger infants should look longer at complex patterns than older infants because the younger ones, who are processing the individual features, effectively have more to process.
2. At 4 or 5 months of age, short looking infants should be more advanced than long looking infants because the short lookers have made the transition to holistic processing whereas the long lookers are still processing the stimuli piece by piece.
3. Optimal predictions should occur in a novelty preference procedure when familiarization times are short. Obviously if familiarization times are long enough, even piecemeal processors will have sufficient time to process and remember all or most of the pieces.
4. Both measures of infant fixation duration in habituation tasks and measures of percent novelty in novelty preference tasks will work equally well. Both are essentially testing the same thing in different ways. Short fixation durations imply holistic processing. Therefore, short lookers should be more advanced than long lookers. Novelty preference tasks work when familiarization times are short. In other words, at the end of familiarization the holistic processor will have had time to process and remember the pattern presented, but for the piecemeal processor much about the pattern will still be novel. Therefore when tested with the familiar versus a novel pattern, the holistic processor should show a greater novelty preference.

Thus, according to this version of the information-processing approach, the correlations with later intelligence occur because the infant tasks are tapping into an important developmental transition in information processing at exactly the right age and

with exactly the right stimuli to assess that transition. Those who develop more rapidly as infants will tend to continue that rapid development and become the children with higher IQs. Whether the developmental progression that is being assessed in infancy is specific to infant perception and cognition or whether it is much more general really has yet to be determined.

Two final points can be derived from this approach. First, it is clear that the piecemeal to holistic transition is hierarchical. It occurs at several different levels at different ages. Therefore one would predict that if simpler stimuli were presented with younger ages, or more complex stimuli such as categories or events involving multiple objects were presented at older ages, one might achieve the same level of prediction that one now finds with complex 2-D patterns in the 4 to 7 month age period. At the very least this viewpoint predicts that the most appropriate stimuli for the infants to process will change systematically with age.

The other point is that the information-processing tasks given to infants might be tapping processing or perceptual speed as some assume, but only in an indirect way. More advanced infants may appear to process the items more rapidly because they effectively have fewer items to process in the same stimulus, not because they are processing each item more rapidly. Once the manner in which infants process information at a particular age is understood, one can design experiments which equate the effective amount of information at different ages to see if older and/or more advanced infants really do process and remember information more rapidly.

### Concluding Comments

As we were contemplating topics to include in this chapter it became obvious that it would be impossible to review all, or even most of the research on infant perception and cognition in the space allotted. Instead we decided to concentrate on a several areas that not only have been very productive over the years but also tend to relate to each other in one way or another. The purpose was to provide some overall organization to the field. Admittedly, that organization is based upon an information-processing perspective, the perspective we believe most adequately encompasses most of the findings, both basic and applied. However, we also included other theoretical perspectives and attempted to show how these perspectives are similar or different from one another. It should be obvious that we relied, almost exclusively, on issues and evidence from infant visual perception and cognition and on techniques designed to address those issues. One could argue that that is where most of the action is these days.

We fully recognize, however, and want the reader to appreciate that many other topics are equally important and exciting. These topics include, but are not limited to, auditory and speech perception, the relationship between perception and action, cross modal perception, the perception of number, the understanding of causality and animacy, the expectation and anticipation of future events, and an understanding of the organization of complex sequences of events. We believe many of the issues addressed in this chapter apply to these topics as well. For example, some of these areas are clearly in the domain of perception and others are much more in cognition; still others fall somewhere in between. Again, nature versus nurture rears its head with respect to these topics as well as to the ones described in more detail in the chapter. Furthermore,

traditional theoretical perspectives have been applied to these topics and to the ones covered in chapter. Like those topics covered in the chapter, we believe more recent theoretical approaches such as connectionist modeling, dynamical systems, and information processing may lead to advances in these topics as well.

One thing is certain. The area of infant perception and cognition is alive and well and making continued progress. Spectacular results and unwarranted assumptions are being replaced by solid evidence. The field is expanding. Topics investigated under the rubric of infant perception and cognition are becoming more and more advanced and the ages being studied are getting older and older. At the same time, investigators of cognitive processes in children are going younger and younger to find the origins of those processes. In some cases, such as in “theory of mind” research, the two fields have met and fruitful collaborations are taking place. Collaborations are also beginning between investigators in infant perception and cognition and those in other apparently quite disparate areas such as sensory psychophysics, cognitive neuroscience, language acquisition, and even artificial intelligence and robotics. It is an exciting and dynamic time. Over the past twenty-five years we have seen exponential growth in research on infant perception and cognition. Given current attempts to apply approaches broad enough to relate basic and applied research, and excursions into collaborations that will add new dimensions to our understanding, continued rapid progress in research on infant perception and cognition is not only likely, it is inevitable.

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