Perceptual Development

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Glossary

Accretion and deletion of texture – The covering and uncovering of surface texture by one surface that is closer than the other.
Binocular disparity – A binocular depth cue that utilizes differences in the retinal image projected to each eye.
Binocular information – Perceptual information based on two eyes.
Convergence – The amount of rotation of the eyes in order to fixate a distant object.
Externality effect – Infants' propensity to attend to external contours of a compound figure.
Gestalt principles of perceptual organization – A number of principles described by Gestalt psychologists to account for the perception of spatial configuration.
Habituation – Method used to test infants' perception that relies on declining levels of attention with repetition and infants' responsiveness to novelty.
Kinematic information – Perceptual information based on motion, either of objects or observers.
Motion parallax – A depth cue based on the fact that closer objects move faster across the retina than farther ones.
Optical expansion – The change in size of surface texture that results when an object moves closer.
Other-race effect – The ability to recognize faces more easily if they are of the same race as the perceiver.
Perception – The use of the senses to acquire information or knowledge about the external world.
Person constancy – Recognition of the same person across changes in location, viewpoint, and the like.
Sensation – The registration of stimulation of a sense organ such as the eye.
Static-monocular information – Information based on a stationary viewing of distant scenes or close scenes with one eye. Also called pictorial depth cues.
Strabismus – Misalignment of the eyes.

Introduction

Perception is the use of the senses to acquire information or knowledge about the external world. Questions of perception can be asked at a basic level, such as how the five senses respond to external stimulation, or at a higher level, such as how do we determine depth or object shape. Questions of development focus on what capabilities humans have at the beginning of life and how the growing child comes to achieve adult levels.

Much of the research on perceptual development has focused on the first year or so of life, in part to answer intriguing questions about the roles of biological mechanisms and experience in directing development. Historically, the debate has centered on whether an ability is inborn (innate) or whether it emerges after birth as the result of specific experiences. This debate has been termed the nature–nurture controversy, and it has pervaded how we attempt to understand the mechanisms underlying perceptual development.

Two general views of perceptual development provide examples of the nature–nurture controversy. One view – termed constructivism – emphasizes the construction of perception through learning. For the constructivist view, the starting point is trying to make sense of sensations. In every day experience, our senses are bombarded with stimulation, and the perceiver's task is to make meaning of this stimulation. Over time, the young or naïve perceiver begins to bring order to this barrage of information. A prediction for development based on this view is that development of perception is protracted and likely to be reliant on specific experiences. A second view – termed ecological – starts at a very different point. The basic premise is that the perceiver is awash in information, not meaningless stimulation, and humans evolved (even the youngest perceivers) to pick up this information. Predictions for development based on this view are that some abilities may be present at birth and those that emerge later are based on a fine-tuning of perceptual processes rather than the emergence of those processes. One limiting factor that is not directly addressed by these views is biological maturation. Some abilities are not present at birth due to physical maturation of perceptual systems, such as vision. Thus, a complete story of perceptual development takes into account, physical maturation, the role of experience, and a developing sensitivity to information.

Topics related to perceptual development, such as visual development, auditory development, development of touch, and intermodal perception, are found elsewhere in this volume. Here we will focus on the perception of objects – physical and social objects. First we will cover how we know where objects are (depth perception) and then we will discuss various aspects of objects, including their three-dimensional (3D) shape, events between objects, and aspects of social objects, specifically faces.

Depth Perception

Our understanding of depth perception in infancy began with the first study conducted in the late 1950s by Eleanor J. Gibson and Richard D. Walk. They used an apparatus called the visual cliff. The visual cliff is a glass table with a board bisecting it. Under half of the table a checkered cloth is right against the surface. Under the other half of the table, the cloth is on the floor. When lit properly, the glass surface cannot be seen; thus, from the center board, there appears to be a shallow side and a deep side. Gibson and Walk placed infants between the ages of 6 and 14 months on the center board and looked at whether they would crawl over the shallow and deep sides. Avoiding the deep side was taken as a sign of depth perception. Of the 36 infants tested, 27 crawled over the shallow side. Of the 27, 24 did not crawl over the deep side. Later, using heart rate as a measure researchers found that infants as young as 1 month of age perceive a difference between the deep and shallow side of the visual cliff. As infants were lowered down to the glass surface of the deep and shallow sides, their heart rate changed in different directions – it increased over the shallow side and it decreased over the deep side.

These initial visual cliff studies documented depth perception in the first year of life. Later studies addressed what information infants may use for perceiving depth. Adult perceivers have access to three different types of information for depth perception – kinematic information (or motion-carried information), binocular information, and static-monocular information (or pictorial depth cues).

The study of the development of depth perception in infancy has relied heavily on spatially appropriate behaviors, of which one example is avoiding the deep side of the visual cliff. Another spatially appropriate behavior is 'reaching'. Infants, when they detect a depth difference, reach for the closer of two objects, even when the difference is only a few centimeters. In a number of experiments, infants' reaching has been used as a measure of their perception of depth. Often, when infants do not show sensitivity, the first question asked is whether the apparent lack of sensitivity is due to the method used to assess it. It is possible that the infants' motoric abilities are not developed enough for infants to demonstrate their existing perceptual abilities. Consequently, additional studies relying on methods other than reaching, such as habituation paradigms, have provided converging evidence for the developmental time table presented below.

Kinematic Information

Kinematic information is available when either the perceiver or object(s) are moving. One example is accretion and deletion of texture. All objects and surfaces have texture (see **Figure 1**(**a**) for examples of different textures). When one object moves in front of another, the texture on the farther object is covered up. This appearance (accretion) and disappearance (deletion) of texture provides adults with the ordering of surfaces in depth, and infants too are able to use this information at least by 5 months of age.

Another kinematic depth cue is the expansion and contraction of texture elements (optical expansion). When a surface or object approaches a perceiver, the texture elements expand and when a surface or object moves away from a perceiver, the texture elements contract (optical contraction). The direction of expansion and the rate of expansion provide information about whether the surface is approaching or receding and how fast. Infants as young as 4 weeks react defensively to approaching surfaces suggesting early sensitivity to distance information provided by optical expansion.

A third kinematic cue to depth is motion parallax. Motion parallax pertains to the differences in motion across the retina exhibited by objects located at different distances. For example, when driving in a car through a rural area, the rails of a nearby fence pass by much more quickly than the distant hills. Little is known about when infants are sensitive to motion parallax information, but it is predicted to be within the first 5 months of life given infants' early sensitivity to other types of kinematic depth information.

Binocular Information

Binocular depth perception relies on the fact that we have two eyes. When we look at an object with two eyes, we adjust our eyes to place the image of the object on our fovea, the region where acuity is best. The amount we have to move our eyes together, or converge them, is information for distance. Infants as young as 3 months appear to use convergence for perceiving depth.

A second binocular depth cue is called binocular disparity. This cue uses information available at the retinal level. Because our eyes are separated, the images of objects fall at different locations on the retinas of the left and right eyes. The visual system is able to fuse these two

Figure 1 Several examples of static-monocular depth information. (a) Most surfaces have texture (compare the bench with the grass and the gravel). We assume that texture on the same surface is equal in size; thus, parts of surfaces with larger texture elements are perceived as being closer than parts of surfaces with smaller texture elements. (b) The parallel sides of the path appear to converge in the distance, illustrating the depth cue of linear perspective. (c) Patterns of light and shade provide delineation of the tree bark, and the hole is specified by areas of darkness. (d) The cylindrical cement benches decrease in size with distance, providing the depth cue of relative size. For people who regularly walk this river path, the cement benches and their size is familiar, thus providing access to the depth cue of familiar size. The depth cue of interposition is illustrated by the bridge (it overlaps part of the building behind it signaling that it is closer) and the trees (they overlap part of the wall). (b) Photographs courtesy of M.K. Arterberry.

views and use the difference or disparity between them to determine the object's location in depth. Infants become sensitive to binocular disparity starting around 16 weeks of age on an average, and they quickly are able to detect very small amounts of disparity.

Visual experience appears to be necessary for sensitivity to binocular disparity to develop. Misalignment of the eyes, a condition called strabismus commonly referred to as 'cross-eyed', results in inadequate overlap of the two retinal images, and many with this condition do not develop binocular sensitivity. Corrections can be made to such misalignments (usually as early as 6 months of age), and the earlier they are done, the better the resulting sensitivity to binocular disparity.

Static-Monocular Information

Although binocular depth cues provide very accurate depth information, they are only functional within a viewing distance of 3 m. Also, about 10% of the population does not have access to binocular disparity due to misalignment of the eyes or other problems with the visual system. Luckily, there are multiple sources of depth information, and we have already discussed one class of information that does not rely on two eyes – kinematic cues. A second class of information is called static-monocular depth information because these cues are available under static conditions, and they do not require both eyes or for the observer/objects to be at close distances. This information is also referred to as pictorial depth cues because many of them were described by Leonardo Da Vinci for portraying depth in a painting. These cues include shading, interposition, familiar size, relative size, texture gradients, and linear perspective (see **Figure 1** for naturally occurring examples and further explanation of each cue).

Numerous studies conducted by Albert Yonas and his colleagues have investigated the onset of sensitivity to static-monocular depth information by isolating these depth cues from other sources of information. For example, in a study on shading, infants were shown a photograph of a bump and a dent. When 7-month-olds viewed this photograph with one eye (the other was covered with an eye patch), they reach significantly more to the bump. When infants viewed the photograph with two eyes, they reached equally to both the bump and the dent, a finding that was not surprising because binocular information overrides static-monocular information. Five-month-old infants did not reach more to the bump than the dent when viewing the displays with one eye. These findings suggest that 7-month-olds were sensitive to the depth cue of shading for perceiving the layout, but 5-month-olds were not. This same pattern – 7-month-olds but not 5-month-olds showing sensitivity – was found for a number of static-monocular depth cues.

Developmental Trajectories

The foregoing discussion of depth perception suggests a progression in the emergence of depth sensitivity – earliest sensitivity to kinematic information, next to binocular information, and finally to static-monocular depth information. Recent work, however, has provided two challenges to this lock-step story. The first is several studies with 3-month-olds. Using a preferential looking procedure, infants have shown sensitivity to several static-monocular depth cues (such as shading and line junctions) that specify depth to adults. These studies in themselves do not demonstrate depth perception in young infants, but they open the possibility that use of static-monocular depth information may be available to infants younger than 7 months of age. A second challenge is the nature of development. Most of the work on depth perception has been done using cross-sectional designs. The few short-term longitudinal studies that have been conducted (both with binocular depth information and static-monocular depth information) suggest that the emergence of sensitivity shows strong individual differences. For example, some infants show sensitivity to static-monocular depth information as early as 22 weeks of age, whereas others do not show it until much closer to 32 weeks of age.

Object Perception

Perception of objects can take place at several levels. For example, we may perceive 2D features of objects (called 'pattern perception'), such as their surface characteristics (e.g., the stripes on a zebra) or spatial relations among objects (e.g., a zebra is to the left or right of a horse). We may also perceive objects' 3D structure (e.g., the girth of a zebra's body). Pattern perception and 3D object perception are independent, yet complementary processes, and together they help us perceive objects, their surfaces, and the spaces between them.

Pattern Perception

Infants show preferences for certain types of patterns. For example, a bull's eye will be attended to more than horizontal or vertical stripes. In addition, infants show a processing advantage for vertically symmetrical patterns compared to horizontally or obliquely symmetrical patterns, and they are able to process patterns both at the local level (the individual elements that make up the pattern) and global level (the overall pattern). In addition, young infant's attention is directed to edges and contours. For example, if 1-month-olds are shown a compound figure, such as a square inside a triangle, they will not notice if the square is changed to a circle. They will, however, notice a change in the triangle. This finding, called the externality effect, disappears by 4 months of age, and it was originally explained by infants' preference for external features of forms, namely the edges. Being biased toward edges is a good strategy for parsing the visual world into units because edge information informs us about boundaries between objects and surfaces. One finding, though, suggests that infants' attention is not always captured by external features. If the interior shape moves, 1-month-old infants will notice the change in shape. Apparently motion trumps edges and directs young infants' attention to the interior of a compound figure.

Infants at an early age also appear to be sensitive to the configuration of patterns, such as diamond being above or below a horizontal line. Infants (3–4-month-olds) show sensitivity to above and below and left and right as long as the targets (e.g., diamonds) do not change across trials. By 6–7 months, infants generalize the spatial relations of above and below, and left and right across targets, but not the spatial relation of 'between'. By 9–10 months, infants appear to have an understanding of 'between' across target variation. These findings suggest a developmental trend in infants' perception of configuration. Early infants perceive configural relations among objects but do not generalize the configurations to other objects. With age, the ability to generalize emerges as does the complexity of the relations they are able to perceive.

3D Object Perception

Information available for depth perception is also available for perceiving 3D objects. We can perceive an object's structure by using binocular information, we can see the contours of an object by attending to shading information, we can determine which object is in front of another one by using interposition information or accretion and deletion of texture under conditions of motion, and we can determine the shape of an object from motion. A popular method for studying infants' 3D object perception is the habituation paradigm. In a typical experiment, an infant is shown repeated presentations of an object. Once attention decreases, the infant views the same object in a novel orientation and a new object. If the infant recognizes the new object as new, he/she should look at it longer than to the new orientation of the old object. Several studies have assessed infants' sensitivity to different types of information for perceiving 3D shape. For example, 2- and 4-month-old infants are able to recognize the shape of rotating or oscillating objects when they view solid 3D objects, when they view wire figures, and when they view random dot displays. A solid 3D object is the most like infants' everyday experience with objects. As the object rotates, infants would have available a number of cues for shape, including the kinetic transformations at the edges, changes in shading, and the availability of key parts, such as a corner that come available as the object fully rotates. Infants also perceive the 3D shape of a moving wire figure, a finding that suggests that the transformation of the contours in the absence of surface information is sufficient for 3D shape perception. Finally, the fact infants perceive 3D shape in kinetic random dot displays demonstrates that infants can create the edges and surfaces of a 3D object from the relative motion of surface texture. Infants' perception of shape based on binocular information is likely to appear with the development of stereopsis, around 4 months of age. In addition, infants are able to transfer information about object shape across sources of information. Four-month-olds habituated to a dynamic image of a 3D object can recognize the object when its shape is specified by binocular information.

Partly Occluded Objects

An important task for perceivers is to perceive the 3D structure of objects, even if they are not fully visible (in other words, partly occluded). The environment is cluttered, and more often than not we perceive partly occluded objects (see **Figure 2(a)**) yet we experience them as if we perceived them fully. One task for infants is to figure out which parts of the partly occluded objects go together. A simplified version of this task is a straight rod behind a block (see **Figure 2(b)**). Gestalt psychologists provided a good starting point for potential principles for solving this task. These principles of organization include common fate (things are grouped together if they move together), good continuation (straight or smoothly changing contours comprise the same unit), good form (interpretation of input is biased to see symmetrical, simple forms), similarity (parts that look the same are grouped together), and proximity (nearby things are grouped together). When viewing the rod and block in **Figure 2(b)**, we can see several principles in operation. The two ends of the rod are the same color and shape (similarity), the visible ends of the rod can be interpolated across the block to create a straight line (good continuation) and parsing the image into a rod and block, rather than a single object with strange projectiles, creates

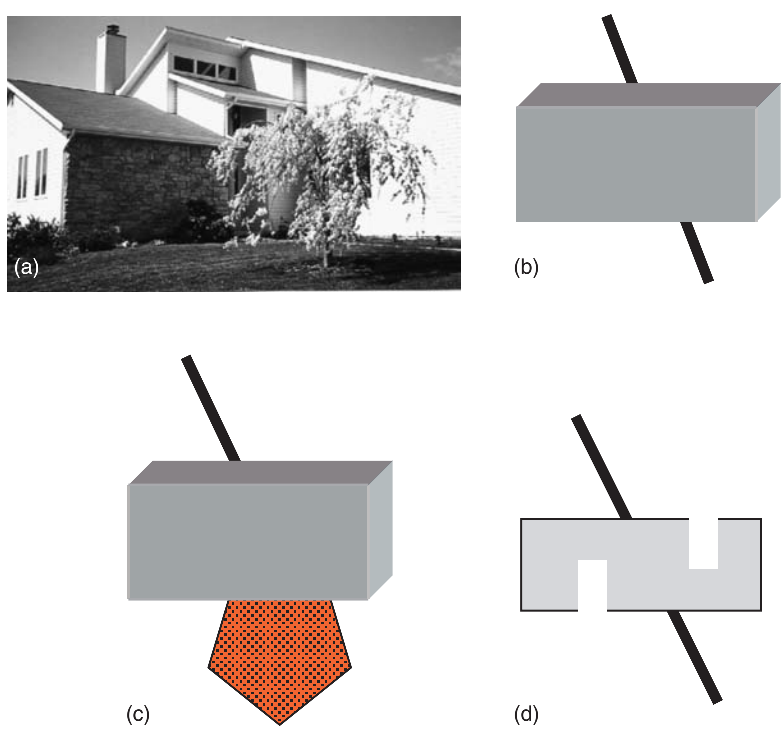

Figure 2 Examples of: (a) a naturally occurring, partly occluded object: (b) a block occluding a rod; (c) a rod block occluding a rod-blob; and (d) a 2D display of a rod covered by a block. As the rod moves behind the block, parts of the rod are visible in the gaps.

two simple forms (good form). If the visible ends of the rod moved in a rigid fashion, we would have the additional principle of common fate.

Studies of infants' perception of partly occluded objects often have used displays like the rod and block depicted in **Figure 2(b)**. In a typical experiment, infants are habituated to a rod occluded by a block. Following habituation, the block is removed and infants view a complete rod and a broken rod. If infants perceived the rod as complete in the habituation phase, they should look longer at the broken rod in the test phase. When the rod translates behind the block, in the *x*-, *y*-, or *z*-axis, 4-month-old infants look longer at the broken rod at test, suggesting that they perceived the partly occluded rod as complete behind the block. This is the case even when some of the Gestalt principles are clearly violated, as in **Figure 2(c)**. When the rod and block are not moving, infants provide no evidence that they can tell that the rod is a complete object behind the block; following habitation to a stationary rod, infants look equally to the broken and complete rod. Similar results are found when the block moves and the rod remains stationary. Thus, motion of the occluded object appears to be a key variable for perception of object unity, and motion overrides other static cues.

Further work has demonstrated that infants as young as 2 months also perceive the rod as a single unit under conditions of rod motion and when (1) the block is narrower than the size tested with 4-month-olds or (2) there are gaps in the block showing more of the rod as it moves behind the block (See **Figure 2(d)**). A curious finding is that newborns appear to perceive a moving occluded rod as broken. Following habituation to a rod moving behind a block, they look longer at the 'complete' rod, suggesting that newborns perceived the rod as broken during the habituation phase. This finding is striking because it implies that babies begin life perceiving their world inaccurately, and the very young infant's first introduction to the world is fragmented. A world based on solely visible surfaces and objects would be a multicolored and multitextured mosaic from which relations among objects may be difficult to discern.

Shape and Size Constancy

Another task in object perception is recognizing an object's shape or size despite changes in orientation or location. Objects move and we move around objects. At any one time the projection of the object on the retina will be different from any other time if the observer or object is moving. The ability to perceive shape across orientations is called shape constancy, and the ability to perceive size across changes in distance is called size constancy.

Achieving size constancy requires relation information about the size of the retinal image and the distance of the object. Consider the example illustrated in **Figure 3**. The same-sized object located at different distances from the perceiver will project different sized retinal images, and different sized objects located the same distance from the perceiver will project different sized retinal images. The task for the perceiver is to differentiate these two conditions, and he/she uses distance information and the size of the retinal image to determine the real size of the object. Shape constancy works the same way, only different orientations of the object result in differently shaped retinal images (e.g., a square tilted forward projects a trapezoidal retinal image). Relying on distance information to determine the object's orientation, the perceiver determines whether he/she is seeing different objects or the same object from different perspectives.

Size and shape constancy have been documented in newborn infants. For example, in one study, infants were habituated to a small cube positioned at various distances across six trials. Following habituation, infants viewed a large and small cube, positioned so they both had the same retinal size. Infants in this condition looked more to the large cube (the novel sized object) than the small cube, suggesting that they recognized the size of the small cube as being the same across all presentations and

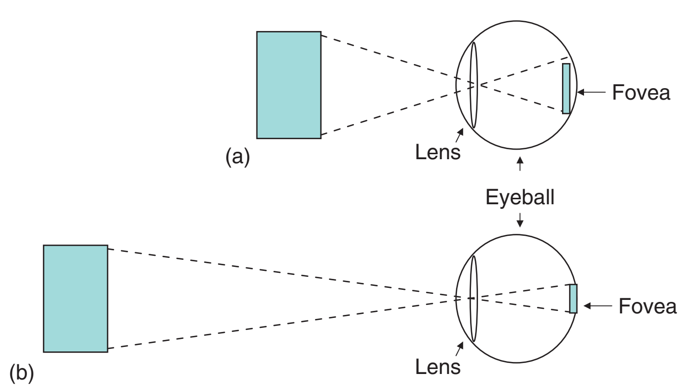

Figure 3 Schematic diagram of the relation between size and distance of an object and its retinal image. In (a) and (b), the image of the object is focused by the lens on the back of the eyeball (over the fovea). The image in (a) is larger than in (b) because the object is physically closer.

the large cube as one they had not seen before. A similar procedure was used to test shape constancy. The findings of both lines of research suggest that infants within several hours of birth have size and shape constancy.

Event Perception

Perceivers are rarely inactive. Even looking around the room while sitting on a couch is 'action'. Normal perception is bound up with ongoing action – action of the perceiver and the objects around him/her. Many of these actions and interactions can be described as events. Here we consider two events – biomechanical motion and causality.

Objects and perceivers move and the resulting patterns of motion provide information about the object. We have already seen several examples in our earlier discussions of perception of 3D object shape and partly occluded objects. People are also important moving objects, and they create distinctive patterns of motion because they are nonrigid (often called biomechanical motion). Nonrigid objects have points whose separation in 3D space changes over time. Consider the movement of a human hand. As the fingers close and open, the distance between the fingertips and the palm changes. One way to assess sensitivity to biomechanical motion is with the use of point-light displays. With point-light displays, a person or any other moving object is filmed in the dark with spots of light at key joints or intersections. These point-light displays are perceived as a coherent motion pattern, which adults readily identify as a human walking (or dancing, doing pushups, and the like). Infants as young as 5 months of age provide some evidence of perceiving a human form in point-light displays, suggesting sensitivity to biomechanical motion.

Perhaps one of the simplest events among objects is when one object moves toward a second object, contacts it, and the second object is physically displaced. Infants' perception of this type of launching event has been studied by several researchers in order to assess infants' appreciation of causality. There are two important components to a successful launching event. The objects need to touch (a spatial component), and the object needs to start moving within a reasonable time after contact (a temporal component). Typical experiments manipulate one or both of these variables to assess infants' sensitivity to these features. For example, infants may be shown a delayed-launch event in which the second object starts to move but only after a delay after contact. Infants also may be shown a noncausal event in which the first object stops short of contacting the second object, but the second object starts to move after the first one stopped. Finally, some researchers have manipulated variables that are not crucial for the perception of causality (such as changing the objects across events) to assess infants' generalization of the events.

The results show a developmental progression in infants' perception of causality. When shown simple events, namely events in which the objects roll and do not change across repeated presentations, 6.5-month-olds are sensitive to causality in launching events. By at least 10 months, infants attribute specific agents to the causal event. In other words, they attend to the object that caused the launching, and they dishabituate if the object is changed during the test phase. In more complex events, such as when balls bounce instead of roll, 10-month-old infants do not attend to the causality of the event. Thus, infants' perception of causality is present within the first year of life, and it matures across this time period.

Face Perception

Perhaps the most important class of objects in the infants' world is people. It is not surprising, then, that face perception is one of the oldest topics in infant perception, beginning with the writings of Charles Darwin in 1872 on facial expressions, and it continues to be one of the most researched topics today. No fewer than 92 papers were published between 2000 and 2006! Key questions pertain to how early in life infants perceive faces and the information infants obtain from faces.

Preferences for Faces

Early research in infants' face perception was concerned with the question of when infants perceive faces; and, in particular, when they know that faces have a particular set of features arranged in a particular way. One of the earliest studies in infant perception showed that they prefer face-like displays (see **Figure 4**(**a**)) over other patterned stimuli, such as a checker board (**Figure 4**(**b**)), and often infants will show a preference for a face with the features arranged correctly over a scrambled face (**Figure 4**(**c**) and **4**(**d**), respectively). Perceiving a face, particularly perceiving the internal details to recognize a face or to discriminate a scrambled face from a schematic face, requires a certain level of visual resolution on the part of the perceiver. There are several findings that suggest that newborn infants have the requisite visual resolution: Infants just a few hours old are able to recognize their mothers from unfamiliar females as long as her hairline is visible, and they show a preference for faces that adults rated as attractive over faces rated as unattractive. Recently, researchers have documented the other-race effect in infants. The other-race effect was first identified in adults and it refers to the difficulty in recognizing faces of people who are not of the same race as the perceiver. The other-race effect has been documented in infants as young as 3 months of age in two ways: (1) infants show a spontaneous preference for faces of the same race and

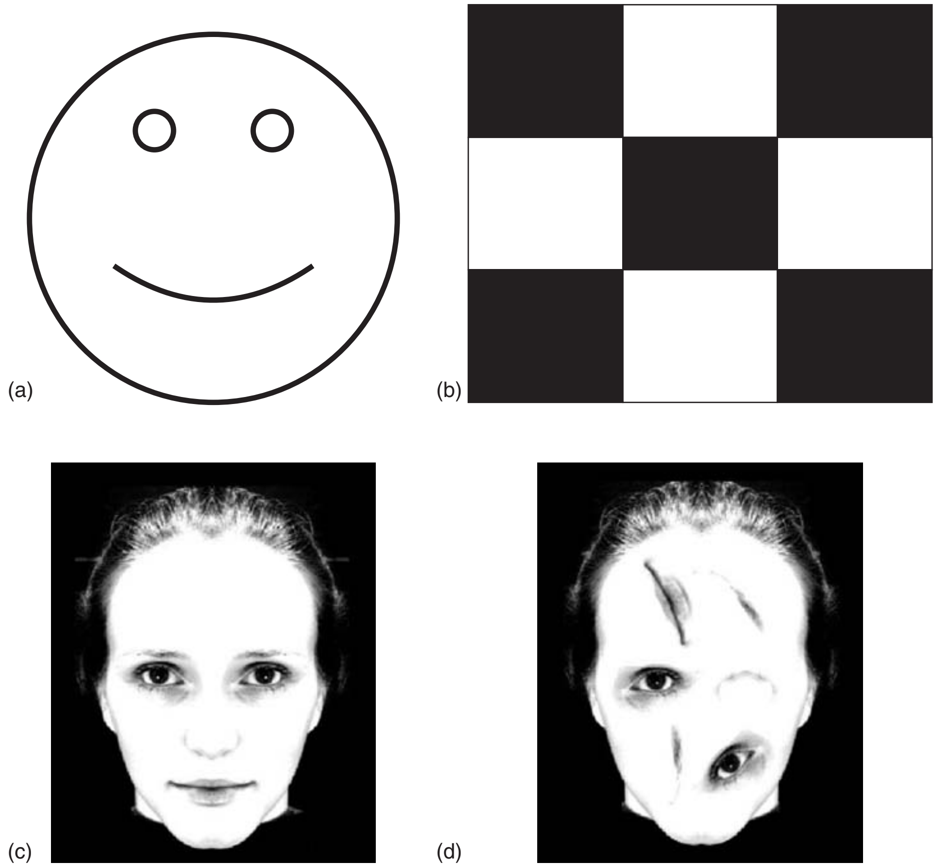

Figure 4 Examples of stimuli that could be used to test infants' preferences for faces: (a) a schematic face; (b) a checkerboard; (c) a face with the features in the correct place and (d) a scrambled face. (c, d) Photographs are courtesy of S.M. Jones.

when (2) habituated to a single face, infants have difficulty recognizing the face at test if the face is of another race. Newborns, on the other hand, do not show the other-race effect. Together, these findings document impressive early sensitivity to faces.

Perceiving Specific People, Gender, and Facial Expressions

Beyond the newborn period, infants are sensitive to facial information that may be useful for recognizing specific people, perceiving characteristics of people, and for non-verbal communication. The ability to recognize a person across different views, or person constancy, is an important skill because faces (and people in general) are dynamic objects. Faces exhibit differing expressions, and infants have the opportunity to view faces from different perspectives. In order to recognize key people in their environment, it is necessary for infants to be able to perceive the constancy of a person despite such differences. One-month-old infants recognize familiar faces (their mother but not a stranger) in different views, such as frontal and three-fourths views but not in profile, and infants recognize faces across differing intensities of an emotional expression at least by 5 months of age. By 7 months, infants' face processing appears to be disrupted if the face is upside down, suggesting that with experience, infants come to process faces as whole units (called configural processing) rather than based on the individual features (called featural processing). Inverting a face disrupts adults' ability to process faces as a configuration with interrelated elements, and the same may be true for infants by 7 months. The timing of this inversion effect is consistent with infants' motor development. Most children can sit independently by 7 months, and it is possible that their experience with faces becomes more limited to upright views than at earlier ages.

In addition to recognizing particular faces, infants may use information contained in faces to categorize people into groups, such as male and female. Perception of gender by adults can be based on superficial cues, such as hair length, facial hair, and/or makeup or on structural cues, such as the distance between the eye and brow. Infants' perception of gender has been assessed in the context of categorization tasks. Infants are shown either male or female faces and are tested with a novel face of the same gender and a novel face of the opposite gender. Infants categorize gender by 9 months of age with the aid of superficial features (stereotyped hair length and clothing); however, they only seem to do it in one direction. That is, when habituated to male faces, infants looked significantly longer to the female face in the test phase but infants habituated to female faces did not look longer to the male face, as would be predicted if they had categorized the gender of the faces. This finding is consistent with other face processing or categorization studies, and the evidence is mounting that when it comes to face perception, infants develop an expertise for female faces before male faces. This may be due to the nature of infants' early experience with people. Infants who have female primary caregivers show preferences for female faces. The more rare infants who have male primary caregivers show preferences for male faces.

Faces also convey information about emotional states via facial expressions. Facial expressions may play an important role in communication for the nonverbal infant, and infants have the opportunity to experience a variety of facial expressions. Moreover, similar expressions appear in child–adult interactions across cultures. Consequently, perception and discrimination of emotional expressions becomes crucial in order for infants to be engaged social partners. Infants between 5 and 7 months of age show evidence of discrimination of the facial expressions of happiness, anger, fear, and surprise. Moreover, they are able to categorize one or more of these expressions across different people. For example, 5-month-olds who are habituated to different intensities of smiling, from a slight upturning of the mouth to a full toothy grin, modeled by four different females, will look significantly longer to a fearful expression modeled by a fifth female rather than a new intensity of smiling modeled by a sixth person. This suggests that they categorized the facial expression of smiling and treated the new smiling exemplar as fitting within that category.

Mechanisms for Face Perception

Infant face perception provides a nice example of the intersection between biological predisposition (or innate ability) and experience. Researchers have made considerable progress chronicling what infants perceive when viewing a face or a set of faces; however, less clear is the mechanism(s) underlying these abilities. There is strong evidence that infants come predisposed to attend to faces. Some claim this predisposition could be the result of an innate representation for faces, whereas others claim it could be the result of a quick learning process. Recent advances in neuroimaging and electrophysiological techniques have provided researchers with the opportunity to identify areas of the nervous system that are involved with face perception. Key areas that have been identified are the middle fusiform gyrus in the right hemisphere for perception of upright faces and the amygdala for perceiving facial expressions. Work with nonhuman primates have identified face-responsive cells in the inferior temporal cortex. Explanations for the development of face perception abilities in infants have, to greater and lesser degrees, been linked to these physiological findings.

Several proposals have been put forth. One is that face processing in infants shows a right hemispheric advantage with implication of the fusiform gyrus. These areas develop more quickly in the right hemisphere than in the left, and experience with faces contributes to the specialization of this area for face perception. A second explanation is that there are two processes, Conspec and Conlern, each subserved by different mechanisms. Specifically, Conspec is a subcortical process involving the superior colliculus and that Conlern is a cortical process involving the primary visual cortex. The later emergence of Conlern is due to maturational constraints of these areas.

The third possibility relies on speech perception as a model. In this proposal, face perception abilities initially are responsive to a wide variety of face-like stimuli, including faces from other species, and these abilities are tuned with age as a result of specific experiences. As reviewed elsewhere, the development of speech perception begins with some specific skills – infants recognize their mother's voice, and they discriminate a range of speech sounds. More impressive is the fact that young infants are able to discriminate speech sounds that adults in their environment cannot. The ability to discriminate non-native speech contrasts diminishes with exposure to language, and infants' speech perception abilities are generally tuned to their linguistic environment by 10–12 months of age. In other words, there is a perceptual window that narrows throughout the first year of life depending on experience. This third possibility suggests a similar fine-tuning of face perception abilities. For example, young infants are better than adults in recognizing faces of monkeys, and this advantage decreased across the first year of life. Moreover, infants do not initially show an other-race effect nor an inversion effect and this may be due to the need for specific experiences to fine-tune the system. Further support for this idea comes from studies of children and adults who were born with cataracts: Visual deprivation during the first 7 weeks of life due to congenital cataracts resulted in significant and apparently permanent impairment in face processing later in life.

Clearly, more work is needed to flesh out the underlying mechanisms of face perception. One commonality among all the explanations is a role for experience and its timing.

Conclusion

Infants are surprisingly competent in their perception of the world around them. Their perceptual abilities are not at the same level of adults, not at birth nor by the end of the first year of life. It might be best to characterize them perceptually as a stripped down adult. They have basic capacities that allow them to perceive things that are important to them, such as where objects are and what the objects look like.

Much of the work in infant perception is inferential in nature. From measuring attention levels or watching where infants reach, researchers draw inferences about the information infants are using and/or the nature of their perceptual experience. A limitation of this methodology is the interpretation of null findings. While it is tempting to conclude that infants lack the ability under study or that they are limited in some way in their perception, researchers can never really know. Because most methods are inferential and because they require some type of response from the infant (e.g., attention or reaching), it is possible that researchers have not found the appropriate task to document the presence of the ability rather than the ability being absent. Thus, conclusions based on the lack of a difference always have to be made cautiously. As new methodologies are developed, it would not be surprising if earlier competencies are revealed.

See also: Attention (00013); Auditory Perception (00015); Concepts and Categorization Skills (00043); Exploration and Curiosity (00058); Face Perception (00059); Habituation and Novelty (00074); Intermodal Perception (00086); Learning (00092); Motor/Physical: Manual - Perception and Action (00105); Nature vs. Nurture (00107); Perception and Action (00119); Perception: Music (00106); Preverbal Development (00131); Speech Perception (00154); Self Knowledge (00139); Sensory Processing Disorder and Sensory Modulation (00142); Taste and Smell (00159); Touch and Pain (00165); Vision Disorders/Visual Impairment (00168); Visual Perception (00169).

Suggested Readings

Bornstein MH, Arterberry ME, and Mash C (2005) Perceptual development. In: Bornstein MH and Lamb ME (eds.) *Developmental Psychology: An Advanced Textbook,* 5th edn., pp. 283–325. Mahwah, NJ: Lawrence Erlbaum Associates.

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Relevant Websites

http://www.cdc.gov – Centers for Disease Control and Prevention – Child Development.

http://www.cfw.tufts.edu – Child and Family Web Guide.

http://www.zerotothree.org – Zero to Three.