Perceptual Development

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Perception is an essentially multisensory process that allows an individual to obtain meaningful information about the surrounding environment. Perception operates in combination with an organism's ongoing actions and, therefore, is an active process by which an individual acquires adaptive behaviors and rich, internal representations. Importantly, at birth, perceptual systems are relatively immature, and individuals are relatively naïve about their world. As development proceeds, perceptual systems mature and help shape an individual's cognitive skills and knowledge. In this entry, we present two essential facets of perceptual development: first, basic principles that characterize the changes in perceptual abilities early in life; and, second, the current understanding of *how* factors both internal and external to the individual (e.g., genes and types of sensory experience) interact during development and how these interactions give rise to new perceptual skills.

Principles of Perceptual Development

Researchers have used a variety of ingenious methods and measures to study perceptual development in infancy. These include behavioral measures such as head-turning, sucking, and visual fixation, physiological measures such as heart-rate, and neural measures such as event-related brain potentials and functional near infrared spectroscopy (fNIRS). Overall, the findings indicate that perceptual abilities not only grow and improve during early development but are refined through a process of *perceptual narrowing* whereby some abilities paradoxically decline.

Perceptual Growth--Increasing Resolution and Specificity. Many perceptual abilities are defined in terms of their precision, that is, the veridicality of the percepts they yield, given the sensory input. For example, visual acuity is 20/640 at birth, which means that an infant must be no more than 20 ft from a stimulus in order to see it as clearly as an adult can see it from as far away as 640ft! Of course, visual acuity improves rapidly over the first few months of life as do many other basic skills, including the perception of motion, color,,frequency, and pitch. Higher-level perceptual abilities also improve. A notable example is object completion. Often, individuals receive incomplete visual input for an object because another object is occluding it. Despite this, most people can “fill-in” the missing sensory information and identify the partially-occluded object. In contrast, newborn infants do not complete the object (even when it is a simple one), whereas 3-4 month-old infants begin to do so.

Perceptual Narrowing. Despite the general improvement in perceptual ability in infancy, younger infants exhibit seemingly *better* perceptual abilities than older infants do. For example, 6-month-old English-learning infants can discriminate phonetic contrasts in their native language as well as they do in a non-native language (e.g., English and Hindi). By 11 months of age, however, they only discriminate the native-English contrasts. This kind of perceptual narrowing also has been demonstrated in infant perception of other-race faces. At 3 months, infants can discriminate between other-race faces and between same-race faces, but by 9 months they only discriminate between same-race faces. Finally, 6-month-old infants can perceive the intersensory unity of same- and other-species faces and vocalizations whereas 8-month-old infants only perceive the unity of same-species faces and vocalizations. Overall, narrowing leads to a paradoxical decline in responsiveness to non-native inputs and a concurrent emergence of perceptual expertise for ecologically-relevant inputs, such as native language and same-race faces.

It has been theorized that there may be a developmental advantage to beginning life with a relatively coarse and broadly-tuned perceptual system. Such a system gives infants access to only a subset of the perceptual information available to adults. For example, poor visual-contrast sensitivity results in infants obtaining information about only the most salient luminance differences, such as the contrast of the white sclera and the dark pupil of the human eye, when observing others. Similarly, young infants respond primarily to low-level but foundational sensory attributes, such as synchrony, intensity, duration, and movement. Although such limitations constrain and limit the information that infants can process and encode, such information is sufficient to specify the basic organizational features of the world. As noted in various forms of the *Less Is More hypothesis* proposed by Newport and by Oppenheim, Turkewitz and Kenny , attention to low-level attributes of objects in the environment can guide processing resources to key aspects of the sensory input, thereby bootstraping the acquisition of knowledge.

How Does Perceptual Development Occur?

Development is a process characterized by complex, dynamic interactions among internal factors (e.g., genes, hormones, nervous system, etc.) and external factors (those in the environment). Therefore, nature and nurture both matter and profoundly interact with each other. Exquisite descriptions of how perceptual development unfolds abound in the field, whether conceived of as stages (e.g., the developmental theories of Piaget) or, more recently, as interrelated developmental events. A recurrent finding is that different abilities, be they perceptual or cognitive, exhibit distinct developmental trajectories. For example, the development of stereoscopic vision does not proceed at the same pace as the development of visual motion perception and, within the latter, the development of global motion perception has a different developmental trajectory and sensitivity to experience than does the perception of local motion. The proposal that development proceeds at a different pace for different perceptual skills has become a general principle that applies not just to perceptual but also cognitive development.

Timing of Experience. The same experiences, when encountered at different points in life, can have dramatically different effects. For example, changes in the tactile and verbal abilities of blind individuals critically depend on whether the individual became blind early or later in life. Early-blind individuals, who are typically defined as losing visual input before 2 years of age, exhibit enhanced tactile and verbal skills resulting from a reorganization of the visual cortex. These effects are not found in later-blind individuals even when they have been deprived of visual input for as long as early-blind individuals have. This suggests that the timing of visual experience during development is critical to the functional reorganization of the primary visual cortex and that maximal effects are delimited by a *sensitive period*. In other words, a developing system is most responsive to experience at specific time points during the life span of the individual. .

Perceptual systems can be reshaped beyond the sensitive period, however. A crucial demonstration of this principle comes from the development of ocular-dominance columns in the visual cortex. Classic studies demonstrated that perturbation of visual input early in life, as in the case of amblyopia, has a dramatic effect on the development of the columns, whereas perturbations later in life have a more subtle effect. As a result, treatment, such as forcing the amblyopic eye to respond by patching the non-amblyopic eye, is less effective in adults than in children. Yet recent research demonstrates substantial plasticity in the adult visual system following altered experiences, such as a prolonged period of total darkness or forcing the amblyopic eye to participate while playing video games. It is now clear that developmental changes outside sensitive periods are possible, albeit in a more-restricted fashion and often requiring special circumstances or experiences.

Altered Experience. Studies of blind and deaf individuals provide striking examples of how altered experience can shape perceptual development. For example, studies of congenitally-blind individuals showed that they possess enhanced auditory attention. Conversely, peripheral-visual attention is enhanced in congenitally-deaf individuals. As with the diversity seen in developmental trajectories, sensory deprivation can produce complex patterns of behavioral change, with improvements in some skills and deficits in others. Of course, deprivation of a specific type of input rather than of input from an entire sensory modality can also profoundly affect development. For example, studies of neonatal rats raised in zero gravity demonstrated that typical experience with gravity is essential for the development of vestibular and motor functions.

Genes. Striking examples of how genes can influence perception can be found in the study of genetically-engineered mice or naturally-occurring mutations within the genes that code for sensory receptors. For example, there is wide variation in different individuals' responses to scents and tastes. Natural genetic variations can explain whether one finds a scent pleasant or offensive as a function of which odor receptors are expressed during development. Unfortunately, the role of genes in higher perceptual skills is not as clear because of the levels of complexity that arise between gene expression and human behavior. For example, twin studies have shown that monozygotic twins exhibit more-closely-correlated face perception and language perception skills than do dizygotic twins. Although interesting, such findings are difficult to interpret because of the complex and fully bidirectional relationship between gene expression and environmental factors. Nonetheless, recent studies of epigenetics offer hope for elucidating these relations.

Overall, it is now clear that the development of perceptual systems and their neural underpinnings is shaped by the dynamic and complex interactions between the current state of the individual (which includes that individual's genetic endowment), her or his past history and experience, and the individual's current environment. Developmentally-relevant factors operate simultaneously at many levels of organization, including the genetic, hormonal, neural, behavioral, and environmental. The current challenge for developmentalists is to unpack the *mechanisms* underlying the co-actions of all these factors and determine how they give rise to specific developmental outcomes.

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Recommended Reading

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