Editorial Essay

How Much Do Babies See And When Do They See It?

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The world of the infant is a blooming, buzzing confusion.

William James

Human development

Over 50 years ago Lawrence K. Frank[1] famously wrote,

I suggest that we try to imagine purchasing a Model-T- Ford and driving it continuously for 20 years, during which period it has been gradually transformed into a Rolls-Royce, despite daily use, a variety of accidents, untold incidents, and the many vicissitudes of travel. However fantastic this may seem, it is scarcely adequate as an analogy for the truly extraordinary sequence of human development, from contraception through to old age… While human development begins with the fertilized egg, it becomes observable only in the infant who undergoes a series of abrupt transitions, shifting from a liquid to an air environment and becoming functionally independent of the mother.

The study of human development has benefited in recent years by the development of new methods and techniques. This has led to ideas that challenge scientists to formulate innovative conceptual models of infant development

Visual responses in the newborn

Is it true that newborns are in a perceptual state of confusion not making sense of the sensory bombardment they face immediately after entering the world? Well, actually not. The visual apparatus in humans is used from birth as an important part of the infant's interaction with the environment. It is a developing sensory modality that at birth is ready to function without prior experience. Eliciting visual behavior in the neonate appears to be positive evidence of central nervous system function.[2] The full-term, and some premature infants, responses to appropriate stimuli can be demonstrated in the delivery room by observing fixation on a contrasting object. When the object is moved slowly it is pursued with the eyes and head for several continuous lateral and vertical movements. The entire organism appears to be involved as the baby responds visually. These pursuit movements differ in intensity, smoothness, and duration from shorter, jerkier optokinetic movements seen with other visual stimulation. The presence of this ability to alert and respond to a visual object in the newborn appears to signify an intactness of the nervous system which is of a higher order than that which is necessary to produce optokinetic responses. Saccadic fixation accuracy, but not latency, develops in the first seven months and its measurement in a clinical setting is practical and potentially useful in the visuomotor assessment of the young infant.[3] As behavioral optometrists we are interested in more than primitive visual functioning and eye movements. Our concern is with higher level perceptual responses in the infant. Are they innate or

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learned? How does the infant develop complex perceptual abilities?

Theories of infant perceptual development

Salapatek[4]reviewed major theorists' ideas regarding infant perception development. The Gestalt school[5] proposed extensive innate organization in perception. Hebb,[6] on the other hand, maintained that the spatial organization and identities of even simple figures and patterns must be laboriously learned. Most other theories lie between these two extremes.

For the Gestalt school figures are innately perceived as separated from ground. Innate tendencies toward figure-ground, primitive unity, and a "good gestalt" or "configuration" sharpen and organize features and distinguish one figure from another, even when they overlap. For the newborn, simple figures such as triangles, squares, and circles are perceived as totalities. The task of the infant is not to discriminate, perceive, or organize such patterns but to learn their significance.

Hebb represents the opposite extreme. He maintained that the only perceptual organization of the visually naïve newborn is the ability to segregate figure from ground and to assign a global coherence or primitive unity to the elements or contour features of this segregated entity. According to Hebb the human newborn confronted with a simple figure, for example a triangle, would perceive: (1) an "amorphous mass" on a ground, and (2) clearly only those pattern features lying in or near the fovea, or the macula. Pattern features stimulating the peripheral retina would not be clearly perceived.

For J.J.Gibson[7,8] and E.J.Gibson[9] the naïve infant apparently perceives at least some of the structure that exists in stimulation from the visual world; structure such as surface texture, transitions in surface texture, and/or some of the distinctive features of objects. The ability to perceive as different- simple two-dimensional figures on a ground, with appreciation of contour features and their arrangement is apparently immediate without experience. However, the perception of depth, e.g. depth at an edge, and the perception of the constancies may be innate but require three dimensional information, e.g. motion or binocular parallax.

Visual perception in human infants

It is difficult to study visual perception in human infants.[10] Direct methods do not work—one cannot ask a neonate what he/she sees since they do not talk. They do, however, initiate limited motor actions and behaviorally and physiologically react to visual stimuli. Indirect assessment methods, such as recording visually evoked potentials (VEP), can become extremely complicated with the data often difficult to interpret. In the VEP, for example, its amplitude depends upon the location of the electrodes; the size, intensity, wavelength, and patterning of the stimulus; the location of the stimulus on the retina; and the subject's visual acuity and state of alertness. Only after all of these influences are understood can we ask what the data show about perception. Researchers use, in addition to VEP, such methods as anatomical analysis, eye tracking, habituation, electro- retinography, electrooculography, corneal reflection, and optokinetic nystagmus.[11] Many of these methods have yielded useful information about visual perception in the infant despite the methodological difficulties. Our knowledge of vision and visual perception in infants has expanded exponentially and excellent research is continuing at a rapid pace.

Visual perception in infants

Not only is the visual system capable of functioning as a sensory system, but perceptual organization , which is reflected in the ability to see an integrated visual pattern as opposed to multiple isolated elements, can be demonstrated. Zuckerman and Rock,[12] for example claim that there is an innate organizing process of visual perception. They maintain that prior organization of perception is necessary before experience can have its modifying or enriching effect and that it is apparent that infants do perceive forms and patterns from a very early age. Vision in infants at birth and later on has been a matter of study for a long time. In a seminal article written over forty years ago, Robert Fantz [13] wrote:

> *It is…reasonable to suppose that the early interest of infants in form and pattern in general, as well as in particular kinds of pattern, play an important role in the development of behavior by focusing attention on stimuli that will later have adaptive significance.*

Meltzoff and Moore[14] demonstrated that infants between 12 and 21 days of age can imitate both facial and manual gestures. Such imitation implies that human neonates can equate their own unseen behaviors with gestures they see others perform. Six years later the same researchers[14] working with newborn infants ranging in age from 0.7 to 71 hours old were tested for their ability to imitate two adult facial gestures: mouth opening and tongue protrusion. The results showed that newborn infants can imitate both adult displays. Three possible mechanisms underlying this early imitative behavior are suggested:

1. Instrumental or associative learning
2. Innate releasing mechanisms
3. Active intermodal matching

It is argued that the data favors the third mechanism.

The goal of most of the published literature on infant visual behavior has been to determine infant visual competence as a function of age and/or to describe precisely the corresponding visual behaviors. It has been recognized that infants only a few minutes old already have the capacity to fixate and follow a stimulus with their eyes.[15] Many studies of infant visual behavior[16] have demonstrated that the neonate is capable of following a moving target. Kremenitzer and her associates[17] studied neonatal eye movements utilizing electro- oculograpy (EOG) and optokinetic nystagmus, in order to obtain a quantitative analysis of eye movements. Most prior studies used only a direct method of study involving the neonates turning their eyes to follow a series of moving stimuli. Smooth pursuit movements were observed in all infants who were alert during testing. Infant optokinetic nystagmus differed strikingly from adults suggesting foveal immaturity.

A recent study[18] measured the differences in visual tracking in 2- to 6-month-olds, as a function of the attractiveness of the stimulus. An attractive, face-like stimulus elicited more ocular tracking than a less attractive stimulus such as a cross. In addition, repeated exposures to the same stimuli resulted in a decrease of the total amount of tracking toward the end of the session. This study confirmed the result of other research[19,20] that demonstrated the preference of young infants for faces or face like stimuli. Babies of this age have the beginnings of sophisticated perceptual judgments. More complex perceptual abilities are available in infants as young as three months. Durand, Lecuyer and Frichtel[21] showed that babies at that young age have learned to use perspective cues to build a three dimensional representation in a two dimensional display. The results of this research are compatible with a learning hypothesis and the ages tested appear to be when this learning occurs. The results are much less compatible with the nativist theory. An interesting experiment by Wilcox[22] confirmed that infants as young as 4.5 months of age can use featural differences and similarities to reason about the number of objects involved in an occlusion (objects that appear and reappear) event.

Gestalt psychology has demonstrated that the individual parts of objects, visual features such as oriented line segments, or incomplete parts of objects, can be organized into coherent wholes. An issue of interest is how we come to perceive visual patterns as whole entities, rather than a set of independent pieces. Most theorists have suggested that this ability is a late achievement critically dependent on maturation of neural mechanisms and acquired knowledge derived from experience correlations in patterns of visual stimulation. Gestalt psychologists, on the other hand, have for some time argued that our perception of a whole entity occurs automatically in our first encounter with a visual form. This immediate accomplishment is the direct result of a perceptual system that is constrained to obey certain organizational principles that specify how small units can be grouped together to form perceptual wholes. There is some evidence that young infants can group information from individual elements into a holistic percept by utilizing Gestalt principles. Recent experiments by Quinn, Burke, and Rush[23] with 3-month-old infants not only demonstrated the presence of perceptual organization in early infancy but determined that the Gestalt principles of "grouping" and "similarity" were used to organize visual pattern information.. They speculate that some automatic processing of element information occurs. After all, how else could a perceptual system determine which elements go together? This concept suggests that there is an innate organizing principle of perception.

Kephart's stages of perceptual development

Whether we believe that early perceptual abilities are innate or learned there is no conflict that the child develops increasingly effective and efficient strategies for information processing. Lack of adequate perceptual development is associated with learning disabilities. Newell Kephart,[24] a psychologist, believed that motor development preceded perceptual development. The earliest manifestations of intelligent behavior are motor in nature, and they predate the appearance of language. There must be a sound motor development for cognitive development. Kephart worked closely with Getman and behavioral optometric influence is seen in his emphasis on eye- movements, eye-hand coordination, and visual perception. He conceptualized seven developmental stages that a normal child progresses through as the child develops increasingly effective and efficient strategies for information processing. The initial stage is at the level of proprioceptive or internal bodily awareness, and the final stage is thinking ability, which transcends motor or perceptual cues. His seven developmental stages include: motor stage, motor-perceptual stage, perceptual-motor stage, perceptual stage, perceptual-conceptual stage, conceptual stage, and conceptual- perceptual stage.

Motor stage

The child is learning how to experience his environment in the motor stage. Kinesthetic information, that is, sensory feedback from the muscles and joints, enables the infant to learn control. Although the motoric activity in the crib appears to be without purpose, the child develops increased skill and control, and coordination begins to develop. An internal system of a body schema begins to emerge, and this body schema will provide a frame of reference from which the child will explore the world.

Motor-perceptual stage

In the motor stage the child is learning about space and objects through grasp and manual exploration. This information is mainly kinesthetic, and there is a very close relationship between the kinesthic and motor response. During this activity all the other "perceptual sense" systems are detecting and transmitting information. The child uses the sense of kinesthesia as the standard by which all other perceptual data are evaluated. Eventually a body of perceptual data develops that is consistent and intersensory integration will develop. Kephart calls this establishing a perceptual-motor match. He says this is best exemplified by eye-hand coordination. In the first step, the hand leads the eye and generates most of the information. It is hand-eye with the hand leading and the visual information secondary.

Perceptual-motor stage

In the next step, vision is employed as the major source of information, and the hand is used to confirm. This is eye-hand with the eye leading and the kinesthetic information from the hand matching the visual data. Vision allows exploration of the environment much more rapidly and efficiently than the hand can, and it can process information greater quantities. The eye soon becomes the primary sense system and perception takes the lead in the perceptual-motor match in the correct order: perception matched to motor. Children who make the match in the wrong direction: motor matched to perception have perceptual distortions that create difficulties in future learning. In this stage vision is still working in concert with the established bodily coordinate system.

Perceptual stage

Upon attaining the perceptual stage the child can begin to make discriminations and comparisons between objects in the environment, independent of motoric activity. Visual perception, however, is still dependent on a prior established kinesthetic frame of reference. Without such a foundation, visual perception remains fragmentary. Copying tasks are difficult for the child who is at a lower stage even though the ability to match a model is present. Language begins to assume importance in the perceptual stage.

Perceptual-conceptual stage

A major improvement in information processing occurs when the perceptual-conceptual stage is attained. Now the child can conceive of a class of objects through perceptual constancy. All furry animals with four legs who can bark can be identified as "dog" despite the various sizes, colors, shapes, and breeds. The concept of "dog" or "shoe" or "chair" or "A" can be perceived from the common perceptual properties to these things.

Conceptual stage

The conceptual stage is a further elaboration of past and present perceptual information. The contribution of language becomes even more important and the child can abstract more information. Just as "dog" summarized the characteristics of all dogs, the still more abstract word "animal" includes more classes.

Conceptual-perceptual stage

Conceptual development now begins to dominate perception. At this level the child may shortcut the perceptual process and seemingly process only a few elements by filling in the gaps and perceptually constructing the organized whole with only a sampling of its features. The individual can now make predictions about events with little relevant information available.

Kephart believed that motor activity preceded the development of perception. This was consistent with the views of Hebb,[6] Piaget[25] and Gesell.[26] Hebb expressed the view that learning is based on repeated sequences of eye movements, and such repetition underlies the growth of the perception of form. Piaget believed that motor action becomes changed into perception and cognition through a complex series of stages in which experience at the sensorimotor stage plays a great part. Vision is presumed to be reflexive, passive, and receptive only of light intensity until the development of "vision schemas" through repetitive actions. Gesell set development norms for skill in fixating, following, and reaching for objects at successive ages, but these skills do not tell us very much about perceptual abilities. The ability to localize a dangling ring is not the same as discriminating the dangling ring from another object.

When these great researchers and theorists were active the ability to conduct perceptual research on neonates and infants was primitive at best. The sophisticated instrumentation described above was not available until the 1970's. The results of the later experimentation contradict the William James notion that the very young infant sees only an undifferentiated blur. Within minutes of birth the baby can visually track targets. At 7 to 8 weeks of life, rudimentary binocular fusion is the rule, smiling to specific simple configurations is apparent, variable accommodation to objects at varying distance begins, oculomotor anticipation of visual trajectories is present, visual acuity is improving considerably, and discrimination of form can be measured. The 2-month- old infant's visual processing capacities include many complex visual information properties including visual memory, shape and size constancy, visual organization and figure-ground perception. From birth, babies can discriminate patterns as the basis for form perception and vision perception develops before action. Early perceptual experience is essential for the growth of coordinated and visually directed behavior. The growth of sensorimotor coordination will then in turn increase the efficiency of the perceptual process. In light of this research, Kephart's developmental stages should perhaps begin with his third stage, perceptual motor. The viewpoint that perception precedes motor activity, or is coincident with it, is significant for behavioral optometrists, since it contradicts the concept that motoric training is a necessary first step for the development of perceptual abilities. In practice, of course, a combination of modalities should be utilized.

Future directions

New theories by researchers are moving in a direction that are inspired by and consistent with the tenets of ecological psychology.[8,9] They believe as the Gibsons did that the world contains information and that the goal of development is to discover relevant information in order to make a functional match between what the environment offers and what the person can and wants to do. They stress the importance of the primacy of perception and action as the basis for cognition.[27] A recent article[28] is typical of this strain of thought. The authors write about the development and learning of the visual control of movement from an ecological perspective. They propose that explicit learning would invoke vision for perception processes instead of the usual vision for action processes. Other researchers[29] have developed a unified dynamical systems theory of motor learning and development that addresses the normative order and timing of activities in the infant motor sequence. Morton and Johnson[30] promulgate a two process theory of infant face recognition that they say represents something of a return to the pioneering views of Fantz. They feel that evidence from newborns leads to the conclusion that newborns are born with some information about the structure of faces. This structural information guides the preference for facial patterns found in neonates and is contrasted with a device which is responsible for learning about the visual characteristics of the structural information. They feel that these two independent mechanisms allow a reconciliation of the conflicting data on the development of face recognition in infants. It is important that developmental optometry monitor this new thinking closely.

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