neuropsychological studies of such patients after surgery by Brenda Milner and others, made it clear to Penfield that the medial temporal region, including the hippocampus, was of special importance in respect to human memory (and emotion).

Penfield’s early observations on seizures arising from deep midline portions of the brain also had an important impact on the development of ideas on the neural substrate of consciousness. In 1938 he proposed a “centrencephalic” system that stressed the role of the upper brain stem in the integration of higher functions. In arguing that consciousness is more closely related to the brainstem than the cortex, he foreshadowed Moruzzi and Magoun’s (1949) conception about the role of the midbrain reticular formation. “Consciousness,” he later wrote, “exists only in association with the passage of impulses through ever-changing circuits between the brainstem and cortex. One can not say that consciousness is here or there. But certainly without centrencephalic integration, it is nonexistent.” Penfield’s lifelong search for a better understanding of the functional organization of the brain and its disorders during epileptic seizures is symbolized by this hypothesis of the central integrating mechanism. Never localized in any specific area of gray matter, but “in wider-ranging mechanisms,” it represented a conceptual bridge he envisaged between brain and mind (cf. mind-body problem).

See also CONSCIOUSNESS, NEUROBIOLOGY OF; CORTICAL LOCALIZATION, HISTORY OF

—Richard C. Tees

References


Further Readings


Perception

See HAPTIC PERCEPTION; HIGH-LEVEL VISION; MID-LEVEL VISION; PERCEPTUAL DEVELOPMENT

Perception of Motion

See MOTION, PERCEPTION OF

Perceptrons

See COMPUTING IN SINGLE NEURONS; NEURAL NETWORKS; PATTERN RECOGNITION AND FEEDFORWARD NETWORKS; RECURRENT NETWORKS

Perceptual Development

Just a century ago it was widely believed that the world perceived by newborn infants was, in the words of William James, a “blooming, buzzing confusion.” In the decades since then, developmental research has demonstrated dramatically that James’s view was erroneous. The shift in view was prompted by research from various domains. In the 1930s, Piaget’s detailed descriptions of his infant children and Gesell’s charting of infants’ motor milestones created a climate of interest in infants as research subjects and in developmental questions. The work of ethologists studying the behavior of animals in their natural habitats (comparative psychology) paved the way for careful observations of spontaneous activity in even the youngest animals. Observation of spontaneous activity ran counter to theories of stimulus-response (S-R) chaining and the radical behaviorism fashionable in the 1930s; at the same time, it inspired the design of new methods for studying infants, including methods for asking what infants perceive.

By the 1960s, methods for studying infant perception had multiplied as psychologists exploited infants’ natural exploratory behaviors, especially looking. Preferential looking at one of two displays, habituation to one display followed by a new display, and a paired comparison test of old and new displays were highly effective methods for studying visual discrimination of simple contrasting properties and even more complex patterns. Spontaneous exploratory behavior was also the basis for research methods, particularly operant conditioning of responses such as sucking, head turning, or moving a limb. Methods which provide infants with opportunities to control their environment (e.g., operant conditioning, infant-controlled habituation) were shown to be more effective than methods without consequences for changing behavior (Horowitz et al. 1972). Psychologists found that they could also investigate what is perceived utilizing natural actions in controlled experimental situations, such as reaching for objects varying in bulk or attainability, and locomotion across surfaces varying in rigidity, pitfalls, obstacles, and slope. Methods borrowed from physiological research.
including heart rate and electrophysiological responses, have been used effectively in studying sensitivity to change in stimulus dimensions. These measures, along with psychological procedures, have revealed impressive discriminatory abilities in very young infants. (See VISION AND LEARNING; AUDITION; TASTE; and SMELL.) Researchers are now discovering the precursors of some of these competencies during the fetal period of prenatal development.

Major research topics include development of perception of events, the persistent properties of objects, and the larger layout of surfaces. Five key points that emerge are the following:

1. The perception of events is prospective or forward-looking. One example is infants' differential response to approaching obstacles and apertures, the so-called looming studies (Yonas, Petterson, and Lockman 1979). Infants respond with defensive blinking and head retraction to approaching objects, but not to approaching apertures or to withdrawing objects. Studies of neonates reaching out to catch moving objects provide another compelling demonstration of anticipatory perception as skilled reaching develops (Hofsten 1983). Infants also anticipate occurrence of environmental happenings, for example, by looking toward the locus of a predictable event (Haith 1993).

2. Motion is important for revealing the persistent properties of events, objects, and layout of the world. A striking example is the perception of biological motion when visual information is minimized. When spots of light are placed on key joints (e.g., elbows, ankles, hips), and all other illumination is eliminated, observers immediately perceive a person engaging in a uniquely specified activity, such as walking, dancing, or lifting a heavy box, but only when the actor is moving. Infants differentiate these biological motion displays from inverted displays and from spots of light moving in a random fashion (Bertenthal 1993). Motion makes possible pickup of information about social (communicative) events, such as smiling and talking, at an early age. The role of motion is also critical in visual detection of constant properties of objects, such as unity, size, shape (SHAPE PERCEPTION), and substance. At four months of age, infants perceive the unity of an object despite partial occlusion by another object, provided that the occluded object is in motion (Kellman and Spelke 1983). Constant size of an object is given in changes in distance relative to self and background, and neonates appear to detect size as invariant (Slater, Mattock, and Brown 1990). Shape constancy, invariant over changes in orientation of an object, is perceived by five months (Gibson et al. 1979). Rigidity or elasticity of substance is differentiated via mouthing in neonates (Rochat 1983), and visually by five months (Gibson and Walker 1984). Methods of visual habituation and observation of grasping skills converge on evidence for perceiving these properties. Such convergence is not surprising, since exploration of object properties is naturally multimodal. Surface properties of objects, such as color (see COLOR VISION), are not necessarily dependent on motion, but texture of an object's surface is accessed by haptic as well as visual information and is differentiated early in the first year (SURFACE PERCEPTION; see also HAPTIC PERCEPTION).

3. Perception is multimodally unified (MULTISENSORY INTEGRATION). From the earliest moments of life, infants orient to sounds, particularly human voices, and they engage in active visual exploration of faces and sounding objects (Gibson 1988). In fact, infants as young as five months can match the sounds and visible motions of faces and voices in a bimodal matching task (Kuhl and Meltzoff 1982; Walker 1982). Infants can also match the sounds and visible motions of object events (Spelke 1976), evidently perceiving a unified event. At one month, infants appear to detect and unify haptic and visual information for object substance (Gibson and Walker 1984).

4. Properties of the larger layout are made available multimodally as motor skills and new action patterns develop. Experience and practice play an important role in this development. How far away things are must be perceived in units of body scale by infants. Observation of the hands, in relation to surrounding objects, occurs spontaneously within the first month (van der Meer, van der Weel, and Lee 1995). When reaching for objects emerges as a skill, judging not only the distance of an object but its size improves rapidly. Information for the major properties of the layout is best accessed when babies begin locomotion. While recognition of obstacles, approaching objects, and surface properties is not unprepared, experience in traversing the ground surface brings new lessons. Crawling infants tend to avoid a steep drop in the surface of support (Gibson and Walk 1960). The affordance of falling is perceived early in locomotor history, but becomes more dependable with experience in locomotion. Properties of the surface of support that afford locomotion (its rigidity, smoothness, slope, etc.) are detected by experienced crawling infants. They learn to cope effectively with steep slopes by avoiding them or adopting safe methods of travel, but the same infants as novice upright walkers attempt dangerous slopes and must learn new strategies (Adolph 1997). Bipedal locomotion requires extensive adjustments of perceptual and locomotor skills, as infants learn a new balancing act, using multimodal information from ankles, joints, and visual cues provided by flow patterns created by their own movements. Novice walkers fall down in a "moving room," despite a firm and stable unmoving ground surface (Lee and Aronson 1974). Flow patterns created by the room's motion give false information that they are falling forward or backward. Perceiving the world entails coperception of the self; in this case, via visual information from perspective changes in the room's walls in relation to vestibular information about one's own upright posture.

5. Infants perceive the SELF as a unit distinct from the world (see SELF-KNOWLEDGE). By four to five months, infants watch their own legs moving currently on a television screen, contrasted with views of similarly clad legs of another infant or their own at an earlier moment.
(Bahrick and Watson 1985). They reliably prefer to gaze at the novel display rather than their own ongoing movements. However, introduction of a target that can be kicked changes the preference to monitoring the ongoing self kicking at the target (Morgan and Rochat 1995). An opportunity for making contact with an object provides motivation for controlling the encounter. Considerable other research in a contingent reinforcement situation (e.g., kicking to rotate a mobile) confirms infants’ perception of a self in control. Disruption of control results in frustration and emotional disturbance (Lewis, Sullivan, and Brooks-Gunn 1985).

Early reaction to the explosion of knowledge about the perceptual abilities of young infants was a burst of astonished admiration (“Arent babies wonderful?”), and little concern was given to how development progresses, although previously popular Piagetian views were questioned. Three current views vary in their assumptions about processes involved in perceptual development. Two are construction theories: (1) The information processing view assumes that bare sensory input is subject to cognitive processing that constructs meaningful perception. (2) The nativist view assumes that rules about order governing events in the world are inherently given and used to interpret observed events. (3) The third view combines an ecological approach to perception and a systems view. Infants actively seek information that comes to specify identities, places, and affordances in the world. Processes that influence development are the progressive growth and use of action systems, and learning through experience. Perceptual learning is viewed as a selective process, beginning with exploratory activity, leading to observation of consequences, and to selection based on two criteria, an affordance fit and reduction of uncertainty, exemplified by detection of order and unity in what is perceived.

We know much less about perceptual development after the first two years. After infancy, perceptual development takes place mainly in complex tasks such as athletic skills, tool use, way-finding, steering vehicles, using language, and reading—all tasks in which experience and learning become more and more specialized (cf. COGNITIVE DEVELOPMENT). Theoretical applications to specialized tasks involving perceptual learning can be profitable (Abernathy 1993).

See also AFFORDANCES; ECOLOGICAL PSYCHOLOGY; IMITATION; INFANT COGNITION; NATIVISM; PIAGET

—Eleanor J. Gibson, Marion Eppler, and Karen Adolph

References


Further Readings


**Phantom Limb**

Phantom limbs occur in 95 to 100 percent of amputees who lose an arm or leg. The phantom is usually described as having a tingling feeling and a definite shape that resembles the somatosensory experience of the physical limb before amputation. It is reported to move through space in much the same way as the normal limb would move when the person walks, sits down, or stretches out on a bed. At first, the phantom limb feels perfectly normal in size and shape — so much so that the amputee may reach out for objects with the phantom hand, or try to step onto the floor with the phantom leg. As time passes, however, the phantom limb begins to change shape. The arm or leg becomes less distinct and may fade away altogether, so that the phantom hand or foot seems to be hanging in midair. Sometimes, the limb is slowly “telescoped” into the stump until only the hand or foot remains at the stump tip.

Amputation is not essential to the occurrence of a phantom. After avulsion of the brachial plexus of the arm, without injury to the arm itself, most patients report a phantom arm that is usually extremely painful. Even nerve destruction is not necessary. About 95 percent of patients who receive an anesthetic block of the brachial plexus for surgery of the arm report a vivid phantom, usually at the side or over the chest, which is unrelated to the position of the real arm when the eyes are closed but “jumps” into it when the patient looks at the arm. Similarly, a spinal anesthetic block of the lower body produces reports of phantom legs in most patients, and total section of the spinal cord at thoracic levels leads to reports of a phantom body, including genitalia and many other body parts, in virtually all patients.

The most astonishing feature of the phantom limb is its “reality” to the amputee, which is enhanced by wearing an artificial arm or leg; the prosthesis feels real, “fleshed out.” Amputees in whom the phantom leg has begun to “telecope” into the stump, so that the foot is felt to be above floor level, report that the phantom fills the artificial leg when it is strapped on and the phantom foot now occupies the space of the artificial foot in its shoe. The reality of the phantom is reinforced by the experience of details of the limb before amputation. For example, the person may feel a painful bunion that had been on the foot or even a tight ring on a phantom finger.

Phantoms of other body parts feel just as real as limbs do. Heusner describes two men who underwent amputation of the penis. One of them, during a four-year period, was intermittently aware of a painless but always erect phantom penis. The other man had severe pain of the phantom penis. Phantom bladders and rectums have the same quality of reality. The bladder may feel so real that patients, after a bladder removal, sometimes complain of a full bladder and even report that they are urinating. Patients with a phantom rectum may actually feel that they are passing gas or feces. Menstrual cramps may continue to be felt after a hysterectomy. A painless phantom breast, in which the nipple is the most vivid part, is reported by about 25 percent of women after a mastectomy and 13 percent feel pain in the phantom.

The reality of the phantom body is evident in paraplegic patients who suffer a complete break of the spinal cord. Even though they have no somatic sensation or voluntary movement below the level of the break, they often report that they still feel their legs and lower body. The phantom appears to inhabit the body when the person’s eyes are open and usually moves coordinately with visually perceived movements of the body. Initially, patients may realize the dissociation between the two when they see their legs extended on the road after an accident yet feel them to be over the chest or head. Later, the phantom becomes coordinate with the body, and dissociation is rare.

Descriptions given by amputees and paraplegic patients indicate the range of qualities of experience of phantom body parts. Touch, pressure, warmth, cold, and many kinds of pain are common. They are also feelings of itch, tickle, wetness, sweatiness, and tactile texture. Even the experience of fatigue due to movement of the phantom limb is reported. Furthermore, male paraplegics with total spinal sections report feeling erections, and paraplegic women describe sexual sensations in the perineal area. Both describe feelings of pleasure, including orgasms.

A further striking feature of the phantom limb or any other body part, including half of the body in many paraplegics, is that it is perceived as an integral part of one’s SELF. Even when a phantom foot dangles “in midair” (without a connecting leg) a few inches below the stump, it still moves appropriately with the other limbs and is unmistakably felt to be part of one’s body-self. The fact that the experience of “self” is subserved by specific brain mechanisms is demonstrated by the converse of a phantom limb — the denial that a part of one’s body belongs to one’s self. Typically, the person, after a lesion of the right parietal lobe or any of several other brain areas, denies that a side of the body is part of himself.

There is convincing evidence that a substantial number of children who are born without all or part of a limb feel a vivid phantom of the missing part. The long-held belief that phantoms are experienced only when an amputation has occurred after the age of six or seven years is not true. Phantoms are experienced by about 20 percent of children who are born without all or part of a limb (congenital limb deficiency), and 20 percent of these children report pain in their...