

Development of touch

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Among the four somesthetic qualities of touch, warmth, coolness, and pain described by Mountcastle (2005), touch is the most difficult to define due to its multimodality. The sense of touch is enabled by “afferents sensitive to mechanical stimulation of the skin; they provide signals to the brain concerning the form, texture, location, intensity, movement, direction, and temporal cadence of mechanical stimuli, forms of somesthesia highly developed in the hand” (Mountcastle, 2005, p 72). The sensations included in the sense of touch are also categorized as epicritic. In the glabrous skin, the sense of touch is mediated by four types of classically described cutaneous receptors (Merkel, Ruffini, Pacini, Meissner). Tactile information from the body travels through large myelinated axons in the peripheral nerves to the dorsal root ganglia. From there, the information ascends to the medulla via the ipsilateral dorsal columns (gracilis and cuneatus tracts). In the dorsal column nuclei, the second-order neurons send projections that cross the mid-line, where they form the medial lemniscus, which further ascends in the pons and mid-brain to terminate in the ventral posterior lateral nucleus of the thalamus. From there, third-order neurons send their axons to the primary somatosensory cortex in the post-central gyrus (Kandel, 2000). The “**development of touch**” sensation is dependent upon maturational processes affecting mechanoreceptor populations, cortical neurons and myelinated fibers.

Receptors

Four types of receptors have been identified in the human glabrous skin (Vallbo and Johansson 1984).

- ✦ Merkel discs: slow adapting type I (SAI) receptors that are dynamically sensitive and exhibit a response linked to the strength of maintained skin deformation. They have small and well-defined cutaneous receptive fields.
- ✦ Meissner corpuscles: fast adapting type I (FAI) receptors that have small and well-defined cutaneous receptive fields. They only respond to changes in skin deformation.
- ✦ Ruffini receptors: slow adapting type II (SAII) receptors that are dynamically sensitive and exhibit a response linked to the strength of maintained skin deformation. They have receptive fields that are larger and less well defined than those of type I receptors. However, the role of Ruffini receptors has been put into question due to the few number of such receptors in the glabrous skin of the human hand (Paré et al., 2003).
- ✦ Pacini corpuscles: fast adapting type II (FAII) receptors that respond to changes in skin deformation. They have receptive fields that are larger and less well defined than those of type I receptors.

Additional contributions to the sense of touch are made by hair follicles in non-glabrous skin areas, as well as by muscular and joint receptors. From embryogenesis to adulthood, these receptors encounter developmental changes. Merkel receptors originate from migratory neural crest cells (Szeder et al., 2003). They appear in the epidermis of the palms of the hands and the soles of the feet between 8 and 12 weeks of gestation (Standring, 2005). By that time, cutaneous plexi are already functioning. By the fourth gestational month, the dermal plexi are very well developed, and Meissner and Pacinian receptors have emerged (Standring, 2005). The number of Merkel cells begins to decrease during the last part of gestation (Kim and Holbrook, 1995). Evidence suggests that the number of Merkel cells

continues to decrease throughout life (Besné et al., 2002). Meissner as well as Pacinian corpuscles also decrease in number throughout life (Bruce, 1980). This is consistent with the psychophysical findings for age-related PC channel decline (Cauna, 1965; Verrillo, 1979, 1982)

Cortical maturation and system myelination

The cortical areas dedicated to touch and the encoding of sensory information are the primary somatosensory cortex (SI, including Brodmann's areas 3a, 3b, 1 and 2); the secondary somatosensory cortex (SII) and the insular (retro and posterior) cortex. The insular cortex, which receives projections from SII, is thought to be important for tactile learning and tactile memory (Kandel, 2000). In addition, associative functions of the posterior parietal cortex play an important role in the sense of touch (Kandel, 2000). These cortical areas, along with the entire cortex, develop the first synapses from the 23rd week of gestation. The cortex continues to develop until birth. Afterward, changes persist; cortical thickness and size continue to increase until 4 years of age. Dendritic connections, synaptic stabilization, myelination and maturation of associative pathways are developed post-natally following a predetermined sequence. The primary areas develop early, followed by the secondary association areas and finally by the terminal zones, i.e. the long association fibers that may only become operative in the second decade of life (Connolly and Forssberg, 1997).

The myelination of both central and peripheral pathways may also play a role in the development of the sense of touch. The myelination follows a defined order: peripheral nerves are myelinated first, followed by the spinal cord, the brainstem, the cerebellum, the basal ganglia and the thalamus. Cortical myelination begins last (Yakovlev and Lecours, 1967). Whereas peripheral nerves, such as the ischiatic nerve, are already myelinated at 12 weeks of gestation, short association fibers in the cortex are not fully myelinated before the age of 16 years (Connolly and Forssberg, 1997).

Measuring the sense of touch throughout life

The description of how the sense of touch evolves throughout life is a complex challenge due to both the multimodal aspect of tactile perception and the lack of systematic investigations in the field. Tactile sensations can be roughly categorized (Jones and Lederman, 2006) into simple stimuli, such as touch detection or vibration, or complex stimuli (texture, spatial acuity/orientation, size/shape/form, manual exploration).

a. Simple stimuli

Touch detection, sensing pressure and vibration, is provided primarily by the Meissner and the Pacinian receptors, respectively. No publication has systematically investigated the changes in sensitivity to pressure and vibration throughout life; however, a decline in both has been observed in aging adults (Thornbury and Mistretta, 1981; Bruce, 1980; Kenshalo, 1986; Gescheider et al, 1994; Goble et al., 1996; Verrillo et al., 2002). The decline of the vibrotactile sensitivity has been observed by studying detection thresholds of vibrotactile signals (Gescheider et al. 1994 I and II), as well as by measuring absolute difference limens (Gescheider et al., 1996). The investigation of the subjective intensity of vibration provided also higher thresholds in older subjects (Verrillo et al., 2002). Touch detection measured with Semmes-Weinstein aesthesiometer filaments also showed increased thresholds with age (Thornbury and Mistretta 1981; Bruce 1980).

b. Complex stimuli

Texture discrimination, spatial acuity and orientation, and size/shape/form and manual exploration have been described as complex stimuli (Jones and Lederman, 2006). The Merkel-SA1 afferents are selectively sensitive to particular components of local stress-strain fields, which makes them sensitive to edges, points and curvatures

(Johnson, 2001). These receptors are believed to be determinant for size/shape/form perception, spatial acuity and orientation. Texture discrimination, or a simplified conception thereof, is also commonly attributed to the Merkel-SA1 receptors.

❖ Texture

It is estimated that from 4 to 6 months of age, infants are only able to discriminate coarse differences in surface texture (Bushnell and Boudreau, 1991; Morange-Majoux et al., 1997).

❖ Orientation and spatial acuity

The performance of children in a grating orientation task (GOT) was tested in a study showing that the spatial acuity of children from 6–10 years of age was less accurate than that of older children (Bleyenheuft et al., 2006). From 10 until 16 years of age, children performed at a level equal to that of young adults. In older adults, spatial acuity performance measured with GOT is decreased (Tremblay et al., 2003). Previous studies of tactile acuity during childhood were based on a gap detection task or on a two-point discrimination (TPD) test (Gellis and Pool, 1977; Stevens and Choo, 1996). Gellis and Pool (1977) reported that children (0 to 19 years old) had worse TPD when compared with young adults (20–29 years old), and performance peaked at 30 years of age. Stevens and Choo (1996) observed similar results when comparing 8–14 years-old children to adults.

❖ Size / shape / form

Size perception abilities have been observed in infants as young as 6–9 months (Palmer, 1989). It has been suggested that this ability may actually develop even earlier, around 2–4 months of age (Bushnell and Boudreau, 1991). Thus, infants are probably able to detect different object size before they are able to discern shape, texture or compliance variations of an object (Bushnell and Boudreau, 1991). The perception of shape begins at about 6 months. At this age, infants are able to differentiate shapes on the basis of features like sharp angles versus smooth curves (Bryant et al. 1972; Brown and Gottfried 1986). However, it is only at 15 months of age that children differentiate shapes using overall spatial configuration (Bushnell and Weinberger, 1987). The identification of geometric forms develops later, at around 4–4.5 years of age (Bushnell and Boudreau, 1991). The shape/form perception performance continues to increase with age, because children from 8–14 years of age showed improved performance in a two-dimensional form identification task (Benton et al., 1983). At 14 years of age, the performance reached that of 15–50 year-old adults, and a slight decline in accuracy was observed in 51–70 year-olds (Benton et al., 1983).

❖ Manual exploration

Manual exploration is probably dependent on the development of object shape and form perception (Jones and Lederman, 2006). It has been shown that infants as young as 4 months of age use manual exploration to recognize the boundaries and unity of an object (Steri and Spelke, 1988). However, a study in 3–8 year-olds demonstrated that older children perform object recognition with greater speed and accuracy (Morrongiello et al., 1994). The authors also showed that the older children explored common objects with more thoroughness.

Conclusion

Whereas many of the multi-modal capabilities related to tactile perception can be observed in infants aged less than one year, the refinement of touch requires at least the first decade of development to reach young adult values. These observations could have implications for children's manual abilities.

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See also

Biomechanics of touch, Dynamic touch, Encyclopedia of touch, Texture from touch, Touch-vision integration

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