explained by reduced speech audibility. Age-related differences not resulting simply from hearing loss are those for temporally distorted speech (such as rapid speech), speech presented binaurally with other sounds that are separated in space or fluctuating, or tasks requiring divided attention. Although behavioral measures of hearing and speech understanding are consistent with declines in processing timing information, it remains unclear whether these represent age-related changes in the auditory periphery, which provides impoverished signals to the CNS, or the combined effects of an ageing periphery, an ageing CNS, and cognitive factors.

Along with poorer communication abilities, untreated hearing loss in older adults can have negative effects on quality of life, contributing to social isolation, depression, and loss of self-esteem. Regrettably, no current medical treatment can prevent, delay, or reverse age-related hearing loss. The most widely used treatment is amplification provided by hearing aids and, for adults with severe-to-profound hearing loss, a cochlear implant, which is an electronic device implanted in the inner ear. Despite advances in hearing-aid technology, surveys report that more than 75% of individuals likely to benefit from a hearing aid do not own one (a gap of about 20 million people in the United States). Reasons are varied and include attitudes toward hearing loss and hearing aids, background noise and distortion, cost, adaptability, comfort, maintenance, tactile sensitivity, manual dexterity, and vision loss that may reduce benefits of speech reading.

Judy R. Dubno

See also Audition: Cognitive Influences; Audition: Disorders; Audition: Temporal Factors; Auditory System: Structure; Hearing Aids

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Ageing and Touch

Common wisdom indicates that sensory processes lose efficiency in old age. Glasses and hearing aids are a kind of standard aid for elderly people. Yet, in contrast to vision and hearing, the dramatic age-related deterioration of the sense of touch goes mostly unnoticed because there are no conditions such as reading newspapers or obtaining a driver license that would disclose an impairment of senses. As a result, the sense of touch and its vital role for coping with activities of daily living is widely underestimated. This entry discusses age effects on receptors and tactile perception, haptic perception, and treatability of age effects on touch.

Age Effects on Receptors

Touch perception is built on sensing through receptors, transmission through neurons at various stations along the sensory pathway, and central processing by the brain. As aging affects all components, multiple factors are involved in the age-related decline of the sense of touch.

Skin conformance undergoes alterations in old age. There is a loss of dermal receptors, which provide the senses of touch, pressure, and vibration. The morphology of Meissner's and Pacinian corpuscles, which detect vibrations and changes in texture change in old age, whereas Merkel-neurite touch receptors, which detect sustained touch and pressure, appear to be less affected.

Age Effects on Transmission and Central Processing

Transmission of touch information is affected by slowing of nerve conduction with increasing age and reduction of action-potential amplitude. In contrast to eyes and ears, which are close to the brain, the distances of skin receptors from the brain vary greatly across the body. Accordingly, skin receptors located on the feet are particularly vulnerable to a slowing down of conduction, which can amount to as much as 20 or 30%. It is believed that slow conduction emerging during aging results in greater temporal dispersion of incoming afferent information, which harms central processing thus contributing to perceptual impairment. At a central level, there is now agreement that neuron loss is a rare event. However, at a subcellular level, cortical sensory processing is affected through manifold age-related alterations of ion channels and receptor composition. Imaging studies in aged humans using magnetic resonance imaging indicated that gray matter density is reduced as a function of age, often starting as early as about 40 years of age; however, the time course of aging effects varies considerably over cortical areas. Thus, a major question is, what are the functional and perceptual consequences of these age-related changes, and how do these changes cause degradation of touch perception, which is discussed in the next paragraph.

Age Effects on Tactile Perception

At a perceptual level, a simple measure of tactile perceptual performance is tactile acuity, which describes the ability to resolve fine spatial details. Usually, measures of tactile acuity are obtained by testing two-point discrimination, gap detection, or grating orientation. Whatever technique is used, tactile acuity is significantly reduced during aging. For example, tactile acuity declined much more vigorously on some body regions than on others. According to one study, deterioration of acuity in the great toe averaged about 400% between young and elderly subjects (aged 65 to 87 years) compared with an average decline of 130% observed on the fingertip, meaning that acuity threshold is, depending on the body part, severalfold greater in older subjects (see also Figure 1, where spatial discrimination thresholds are plotted as a function of age).

Against intuitive thinking, the relation between receptor density and tactile acuity is far from being one-dimensional. Although the density of Meissner's corpuscles in the index and ring fingers does not differ, the acuity does. On the other hand, although males have lower density of Meissner's corpuscles compared with females, their acuity is not different. The reason for the lack of a simple relation between receptor density and perceptual outcome is that central somatosensory representations are not a mere mirror of the afferent input signals, but extract additional information through active computation based on the interaction of inhibitory and excitatory processes. In respect to the processing of touch information, there is a controversy about the role of peripheral versus central aspects that determine perception.

Haptic Perception

Providing tactile acuity information is only one among many functions the sense of touch subserves. Haptic perception, the ability to identify common objects by exploration with hands and fingers without sight, depends on accessing cutaneous information. For example, if afferent sensory information of the fingers is suppressed by wearing a glove or by local anesthesia of the fingers, motor control of the hand is severely impaired. In a study, both acuity thresholds and manual dexterity were assessed using a pegboard test that revealed a strong correlation between threshold and manual dexterity. As a result, age-related impairment of touch processing has far-reaching consequences on haptic and motor performance and may translate into great difficulties in tasks requiring fine manipulations. In addition to a reduction in tactile acuity, elderly people undergo a significant impairment in haptic perception.

In most cases, however, age-related decline of the sense of touch develops slowly and as part of a normal, that is, nonpathological, aging process over decades. As a result, elderly progressively adapt to the loss of high-level tactile performance and learn to compensate by developing behavioral strategies such as relying more on visual control to overcome the decrement in the sense of touch.

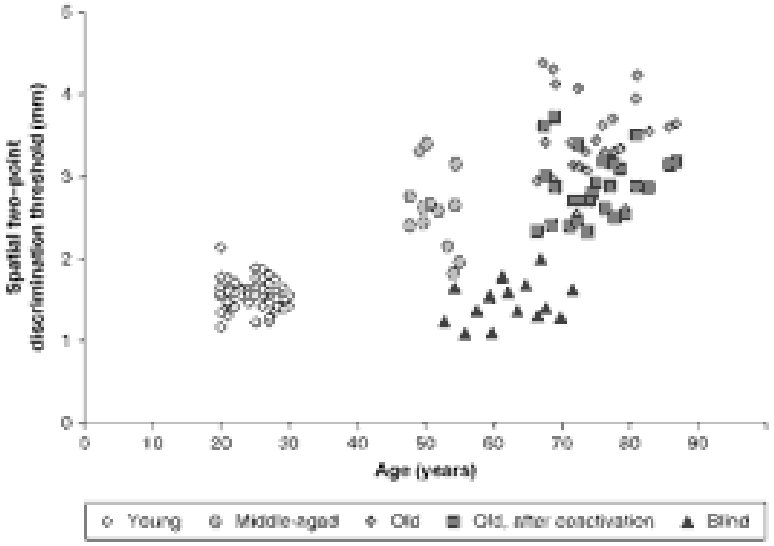

Figure 1 The Impact of Age, Training, and Sensory Stimulation on Spatial Discrimination Thresholds

Sources: Modified from Dinse, H. R., Kleibel, N., Kalisch, T., Ragert, P., Wilimzig, C., & Tegenthoff, M.(2006). Tactile coactivation resets age-related decline of human tactile discrimination. *Annals of Neurology, 60*, 88–94. Also from Heinisch, C., Kalisch, T., & Dinse, H. R. (2006). Tactile and learning abilities in early and late-blind subjects. In *Society for Neuroscience Abstracts 52.4/N2*. Washington DC: Society for Neuroscience.

Note: Each symbol represents an individual subject.

Treatability of Age Effects

Neuroplasticity is the ability of brains to adapt to new experiences and constraints of the environment during the entire life span. During the past few decades, such use-dependent plastic capacities of somatosensory systems have been intensively studied demonstrating that practice and training determine to a large extent perceptual abilities of an individual even at high age. This notion has been corroborated by recent findings demonstrating that the typical age-related decline in tactile performance is not inevitable, but that despite the accumulation of degenerative processes during aging, performance can be recovered by learning and training.

The impact of age, training, and sensory stimulation on tactile acuity is illustrated in Figure 1. Overall, discrimination performance is progressively impaired with increasing age. However, blind subjects who read Braille do not show the age-related changes, suggesting that maintained use of the fingers might play a role in preserving intact acuity. Furthermore, applying a brief period (3 hours) of tactile coactivation on the tip of the fingers, a procedure known to induce plastic changes in the somatosensory cortex, results in a significant amelioration of the age-related decline in elderly subjects, suggesting that age-related decline of tactile acuity is not irreversible. These results suggest that mechanoreceptor density may play a minor role in determining tactile acuity performance at old age but that acuity is rather controlled by cortical mechanisms. This view is also supported by recent imaging data that demonstrated a close correlation between tactile spatial resolution and the size of the area in the cortex devoted to processing of touch information. In conclusion, cortical processing, which is subject to alterations through practice and training, appears to be a crucial factor shaping the quality of touch-related performance even at high age.

Hubert R. Dinse, Martin Tegenthoff, Christine Heinisch, and Tobias Kalisch

See also Action and Vision; Ageing and Hearing; Ageing and Vision; Cutaneous Perception; Experience-Dependent Plasticity; Haptics; Neuropsychology of Perception; Perceptual Learning; Proprioception; Reaching and Grasping; Sensory Rehabilitation; Tactile Acuity

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Ageing and Vision

Age-related changes in vision can profoundly affect the quality of life for seniors, decreasing independence and mobility and increasing physical injuries, such as hip fractures. But what aspects of vision change with age? And what produces those changes? Despite the critical importance of vision for functioning in everyday life, much still remains to be learned about the effects of healthy ageing on vision. This entry provides a brief overview of some of the most important aspects of ageing and vision researchers have learned.

Age-Related Effects

As people age, their vision is affected by changes both to their eyes and their brains. The average pupil size decreases with age, so that less light enters the eye, and this reduction in light is compounded by changes in the structure of the lens. Through the normal ageing process, even in the absence of cataracts (clouding of the lens), the lens becomes less transparent, blocking additional light from entering the eye, and changing the color of the light that does get through. Changes to the lens and intraocular media also increase light scatter, reducing the contrast of the retinal image. These structural changes to the lens also make it more difficult to focus on close objects as we age; this change in accommodative ability—the ability to change the optical power of the eye to focus on objects at different distances—is known as presbyopia, and is a normal part of the ageing process. The inability to focus on close objects without wearing glasses typically occurs between about 40 and 50 years of age, and the "near point" (the closest point on which one can focus) continues to move further away throughout our lifetimes. As young adults, people typically can focus clearly on objects about 10 centimeters away; by the time they reach 60 years of age, the near point has moved away to about 1 meter. Fortunately, by wearing appropriate optical corrections (glasses), seniors can overcome many of the difficulties associated with presbyopia.

These optical changes adversely affect vision, but research has shown that the most profound age-related effects on vision stem from changes in neural, rather than optical, processing. Blurring of the optics would lead to an inability to see fine details, resulting in a decrease in visual acuity. But ageing also decreases our contrast sensitivity—defined as the inverse of the lowest contrast needed to see different sized targets—even for mid-sized objects, although the most pronounced effects are seen for objects with more fine details. For example, the general shape and features of a face would remain visible throughout our lives, but it becomes more difficult to discriminate individual eyelashes around the eye, or fine wrinkles on a face. Based on behavioral techniques that can tease optical and neural factors apart, and based on studies in which stimuli are projected directly onto the retina, bypassing the optics, the age-related reduction in contrast sensitivity is largely the result of changes in neural processing, rather than of changes in the optics of the eye. Regardless of what causes a change in our acuity and contrast sensitivity, the net result is that the world appears a bit more blurry and washed out in the elderly.