Kognitionspsychologie: Session 3
Perception

Rui Mata, HS 2025

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Course structure

#	Date	Topic	Slides
1	23.09.2025	Session 1: Cognitive Psychology	
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Learning Objectives

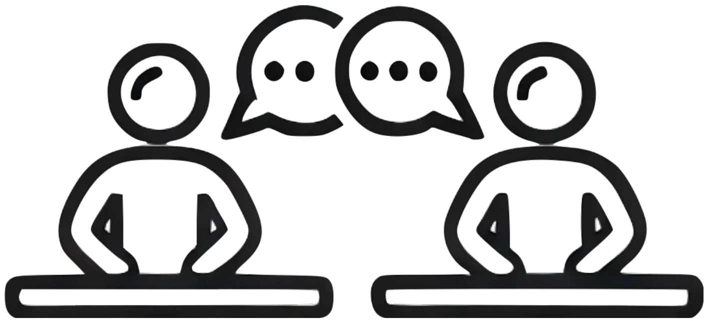
- Define sensation and perception
- Discuss the **adaptive significance** of the different senses
- Learn about **comparative approaches** to sensation and perception
- Learn about **developmental patterns** in sensation and perception, in particular the concepts of critical periods and neuroplasticity
- Learn about some of the **neural bases** of sensation and perception
- Discuss the principle of modularity in (visual) perception

Sensation and Perception

- **Sensation** refers to the raw, initial input received by sensory organs (e.g., eyes) in response to external stimuli (e.g., light). It involves the detection of physical energy (e.g., light waves) and its conversion into neural signals sent to the brain.

- **Perception**: Perception is the process by which the brain organizes, interprets, and makes sense of the sensory information (sensation) to form a structured representation of the environment.

WHAT ARE THE MAIN HUMAN SENSES AND WHAT ARE THEY GOOD FOR?



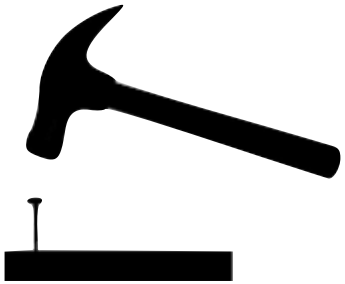
The senses and their functions

Sensation	Description	Main Adaptive Functions
Vision	Detection of light through the eyes, allowing perception of color, shape, depth, and motion.	Helps with navigation, identifying threats, and finding food.
Hearing	Perception of sound waves through the ears, enabling detection of pitch, loudness, and direction.	Helps with communication, detecting predators or prey, and environmental awareness.
Touch	Detection of pressure, vibration, and temperature changes via the skin.	Protects the body from damage and allows interaction with the environment.
Taste	Perception of chemical substances in food, detected by taste buds, resulting in flavors like sweet, sour.	Guides food choices, distinguishing between nutritious and harmful substances.
Smell	Detection of airborne chemical molecules through the olfactory system, leading to the perception of odors.	Helps identify food, potential threats (fire, toxins), and plays a role in social behavior.

DISCLAIMER: This classification is helpful but can be seen as limited. It omits other important sensory modalities such as proprioception (sense of body position), nociception (pain perception), and equilibrioception (sense of balance).

Gazzaniga, M. S., Ivry, R. B., & Mangun, G. R. (2018). Cognitive neuroscience: The biology of the mind (5th ed.). W.W. Norton & Company.

Perception

Ontogeny	Mechanism
Phylogeny	 Adaptive Significance

Gustation: Taste senses and their adaptive significance

Sensory systems, like the gustatory system, follow a pathway from sensory receptors to neural processing in the brain. In taste, taste receptor cells in taste buds on the tongue detect chemical stimuli, which are transmitted via cranial nerves to the brainstem's solitary tract nucleus. From there, signals are relayed through the thalamus to the primary gustatory cortex in the brain, where the perception of taste is further processed. This general flow—from receptors, through neural pathways, to brain representation—applies across sensory systems.

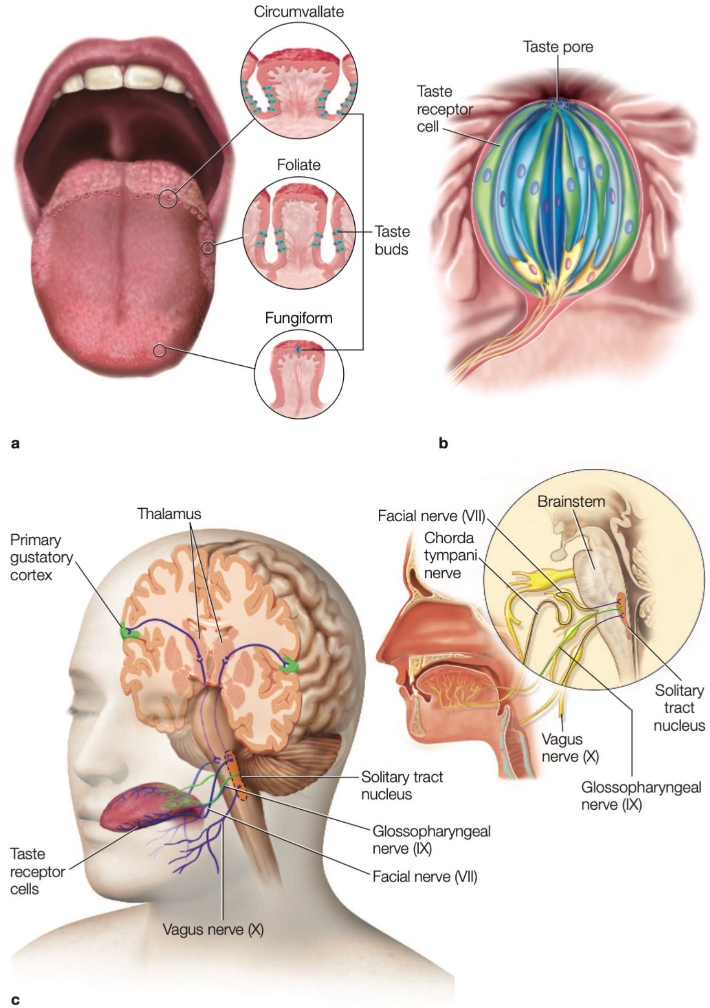


FIGURE 5.5 The gustatory transduction pathway. **(a)** Three different types of taste papillae span the surface of the tongue. Taste buds are located on the papillae. While *circumvallate papillae* can contain thousands of taste buds and *foliate papillae* can contain hundreds, *fungiform papillae* contain only one or a few. **(b)** Taste pores on the surface of the tongue open into the taste bud, which contains taste receptor cells. **(c)** The chorda tympani nerve, formed by the axons from the taste cells, joins with the facial nerve as it enters the skull and passes through the middle ear to synapse in the nucleus of the solitary tract in the brainstem, as do the sensory nerves from the GI tract via the vagus nerve. The taste pathway projects to the ventral posterior medial nucleus of the thalamus, and information is then relayed to the gustatory area in the insula cortex.

Gazzaniga, M. S., Ivry, R. B., & Mangun, G. R. (2018). Cognitive neuroscience: The biology of the mind (5th ed.). W.W. Norton & Company.

Gustation: Taste senses and their adaptive significance

Taste Sense	Description	Adaptive Function
Sweet	Detection of sugars and carbohydrates.	Indicates energy-rich foods, essential for survival and providing quick energy.
Sour	Detection of acidity, often found in citrus fruits and spoiled foods.	Helps to avoid spoiled or unripe foods that may contain harmful bacteria or are nutritionally poor.
Salty	Detection of sodium and other salts.	Essential for maintaining electrolyte balance and proper cellular function.
Bitter	Detection of a wide variety of chemical compounds, often toxins.	Warns against potentially toxic or poisonous substances. Many toxic plants taste bitter, encouraging avoidance. Bitter substances can be detected 1,000 times better than salty substances.
Umami	Detection of glutamates, which are often found in protein-rich foods.	Encourages consumption of protein, which is necessary for growth, tissue repair, and immune function.

The basic tastes give the brain information about the types of food that are being consumed, and their essential role is to activate the appropriate behavioral actions: consume or reject. Other functions include nociception (think chili peppers!).

Gazzaniga, M. S., Ivry, R. B., & Mangun, G. R. (2018). Cognitive neuroscience: The biology of the mind (5th ed.). W.W. Norton & Company.

Vision: Photoreceptors and their adaptive significance

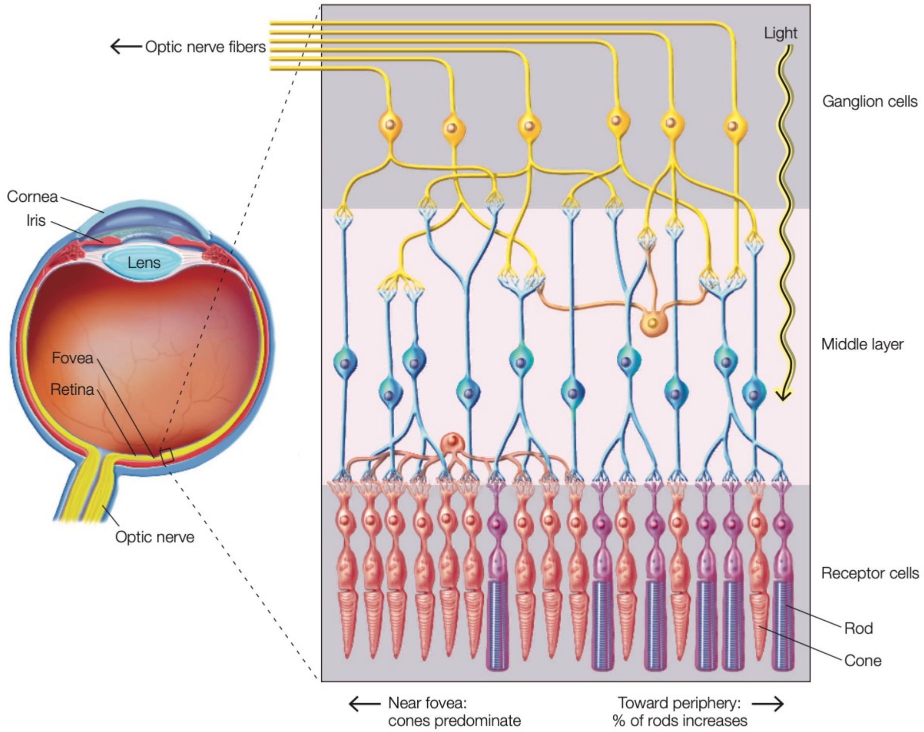


FIGURE 5.20 Anatomy of the eye and retina.
Light enters through the cornea and activates the receptor cells of the retina located along the rear surface. There are two types of receptor cells: rods and cones. The output of the receptor cells is processed in the middle layer of the retina and then relayed to the central nervous system via the optic nerve, the axons of the ganglion cells.

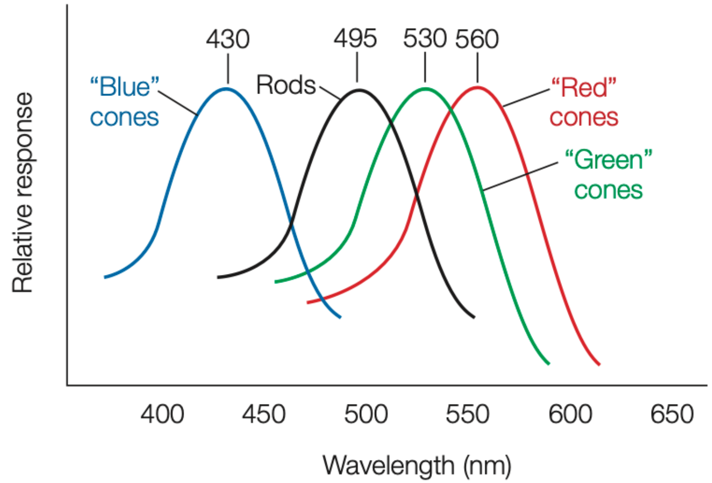


FIGURE 5.21 Spectral sensitivity functions for rods and the three types of cones.
The short-wavelength ("blue") cones are maximally responsive to light with a wavelength of 430 nm. The peak sensitivities of the medium-wavelength ("green") and long-wavelength ("red") cones are shifted to longer wavelengths. White light, such as daylight, activates all three cone receptors because it contains all wavelengths.

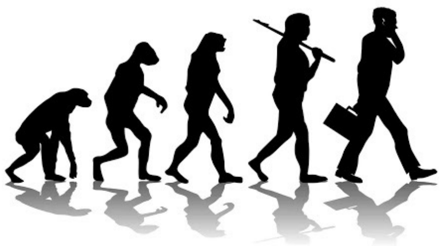
FUN FACT Some humans have a fourth type of cone cell, enabling tetrachromatic vision and the ability to perceive additional color shades, while others, also typically due to genetic mutations, have deficiencies in one or more cone types, leading to color blindness—a reduced ability to distinguish certain colors, most commonly red and green.

Gazzaniga, M. S., Ivry, R. B., & Mangun, G. R. (2018). Cognitive neuroscience: The biology of the mind (5th ed.). W.W. Norton & Company.

Vision: Photoreceptors and their adaptive significance

Feature	Cones	Rods
Location	Concentrated in the fovea (center of the retina)	Primarily in the periphery of the retina
Number	Approximately 6 million	Approximately 120 million
Sensitivity to Light	Less sensitive to light, work best in bright conditions (photopic vision)	Highly sensitive to low light levels (scotopic vision)
Color Sensitivity	Responsible for color vision; three types of cones sensitive to red, green, and blue light	Do not detect color; only perceive shades of gray
Visual Acuity	High acuity; responsible for sharp, detailed central vision	Low acuity; not good at detecting fine detail
Adaptation Speed	Fast adaptation to changes in light levels	Slow adaptation to changes in light levels
Primary Function	Best for daylight vision, color perception, and fine detail	Best for night vision and detecting motion in peripheral vision
Adaptive Significance	Enable detailed vision and color discrimination during the day, crucial for tasks requiring precision (e.g., hunting, gathering, tool use)	Allow humans to see in dim or dark conditions, important for nighttime survival and detecting motion in peripheral vision

Perception

Ontogeny	Mechanism
 Phylogeny	Adaptive Significance

General principles of sensation and perception

Because perception serves adaptive functions…

- Senses are limited in range and acuity as a function of the type of ecological niche occupied by the organism (e.g., sensitivity to different wave lengths)

- Senses are often dynamic and adaptive to deal with contex-dependent nature of natural ecologies (e.g., light adaptation)

- Perception is not an end in itself but an instrument for additional action (e.g., hand-eye coordination)

Comparative approach: Color sense across species

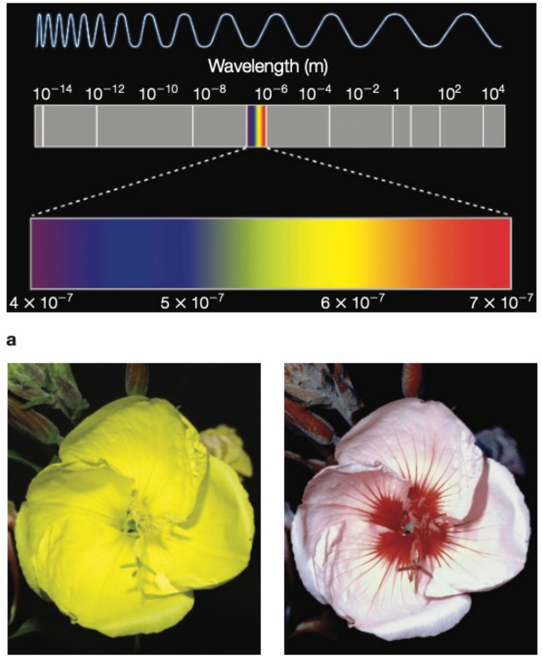
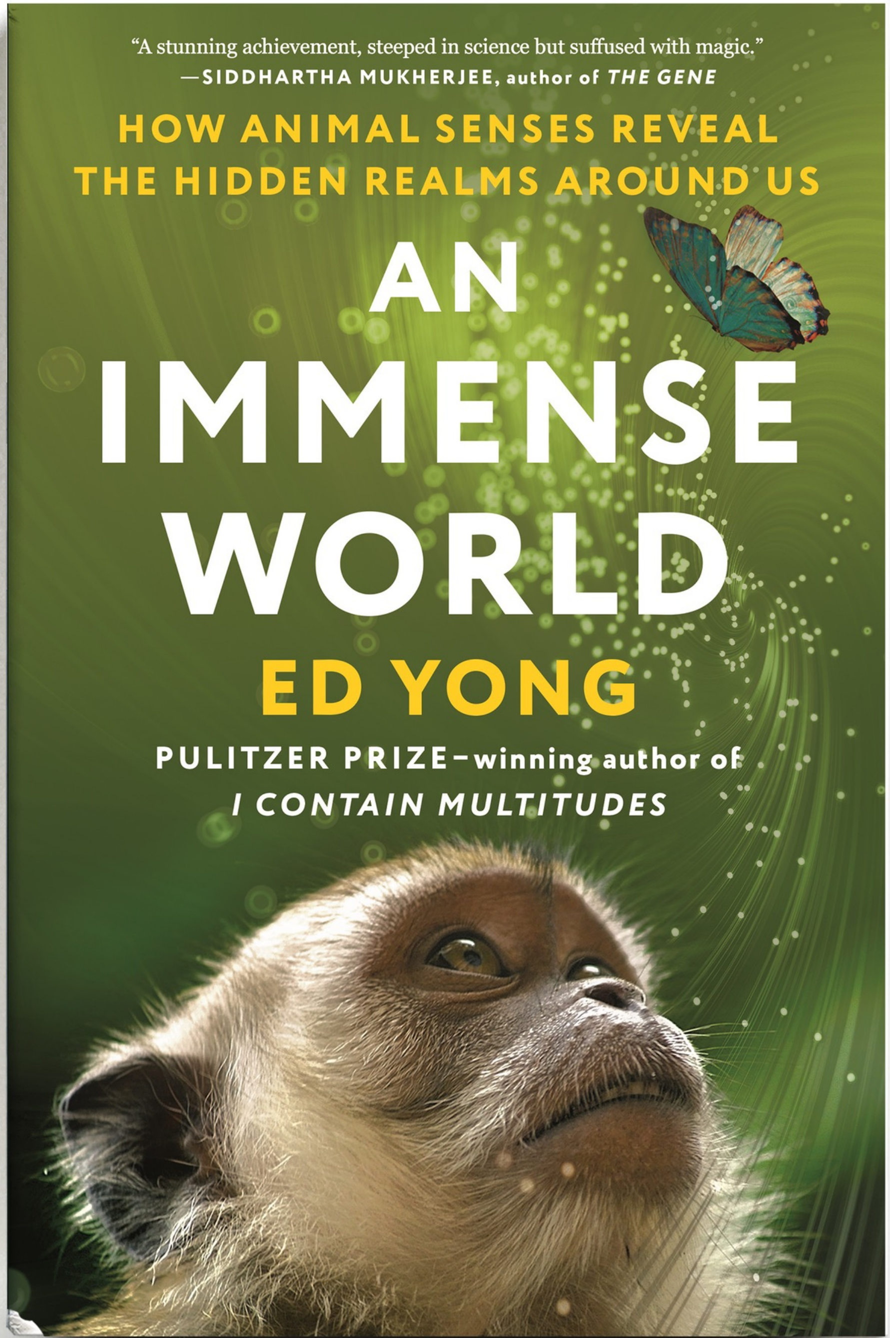


FIGURE 5.1 Vision and light.
(a) The electromagnetic spectrum. The small, colored section in the center indicates the part of the spectrum that is visible to the human eye. (b) The visible region of the electromagnetic spectrum varies across species. An evening primrose as seen by humans (left) and bees (right). Bees perceive the ultraviolet part of the spectrum.

Senses are limited in **range** and **acuity** as a function of the type of ecological niche occupied by the organism (e.g., sensitivity to different wave lengths in humans vs bees)



Provides a good demonstration of the idea that every animal has its own sensory world, shaped by the types of sensory inputs it can detect and process based on its biology and ecological niche. Helps build an idea of how perception is adaptive and specific to each species' survival needs, showing how animals are fine-tuned to their environments – a story of **diversity** rather than *superiority*!

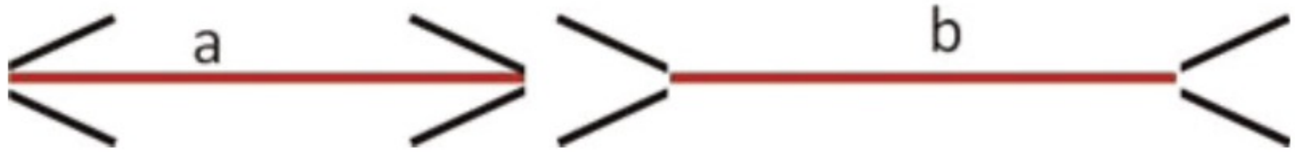
Perception

Ontogeny

Mechanism

Phylogeny

Adaptive Significance


a
b

The role of experience

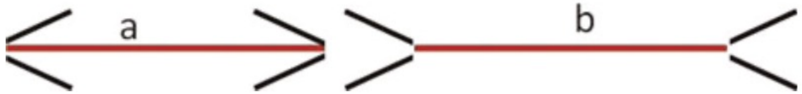


Figure 1. The Müller-Lyer illusion. The lines labeled "a" and "b" are the same length. Many subjects perceive line "b" as longer than line "a".

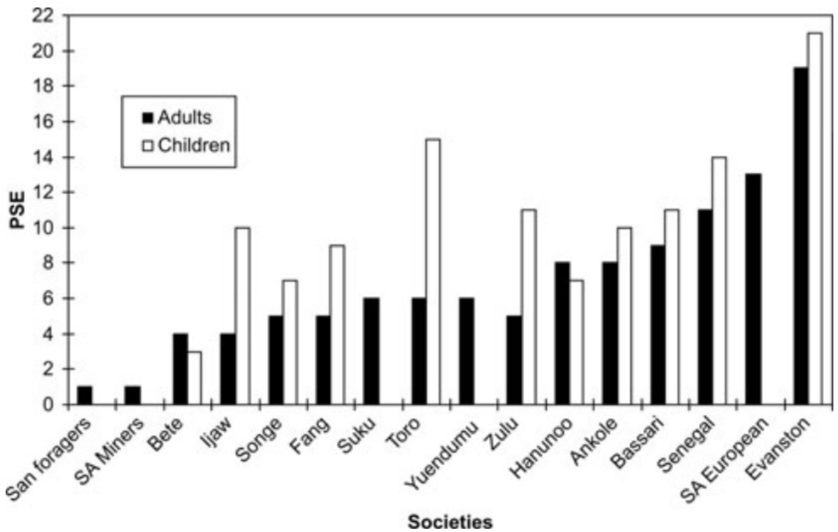
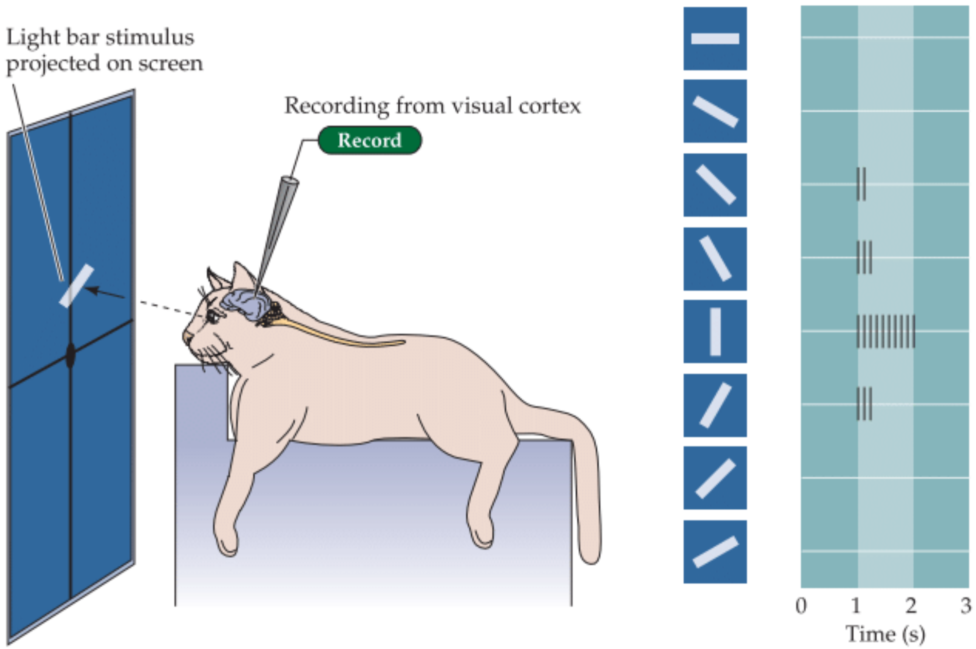


Figure 2. Müller-Lyer results for Segall et al.'s (1966) cross-cultural project. PSE (point of subjective equality) is the percentage that segment a must be longer than b before subjects perceived the segments as equal in length. Children were sampled in the 5-to-11 age range.

The data show that different cultures have varying sensitivity to the Müller-Lyer illusion, with some groups, such as those from urbanized societies (e.g., Europeans), being more susceptible to the illusion than others (e.g., San, who live in more rural or non-industrialized environments).This suggests that perceptual development is influenced by environmental factors, such as exposure to different types of visual stimuli during development. Cultures with more exposure to right angles, buildings, and carpentered environments (e.g., Western societies) may develop a heightened sensitivity to depth cues or illusions like the Müller-Lyer, which rely on geometric cues common in such environments.

Henrich, J., Heine, S. J., & Norenzayan, A. (2010). The weirdest people in the world? Behavioral and Brain Sciences, 33(2–3), 61–83. https://doi.org/10.1017/S0140525X0999152X

Critical periods and neuroplasticity



Hubel and Wiesel's starting in the late 1950s revealed how the visual cortex in cats (and later monkeys) responds to visual stimuli and how it develops over time. A main findings was the idea of **orientation selectivity** - neurons in the visual cortex (V1) are selectively responsive to specific orientations of visual stimuli, such as lines or edges at particular angles. these neurons are organized in a highly structured way, forming "orientation columns.

Critical Periods: Hubel and Wiesel found that normal visual development depends on exposure to visual stimuli during a critical period early in life. If one eye of a kitten was deprived of visual input during this critical period, the neurons in the visual cortex would become unresponsive to that eye, leading to permanent vision loss (even if the eye itself was healthy). This showed that early sensory experiences shape the brain's development. This work also demonstrated the brain's ability to reorganize and adapt based on sensory experiences. They showed that if a kitten's visual experience is altered, the brain's visual cortex can change its wiring, an early example of neuroplasticity—the brain's capacity to change in response to experience.

Neuroplasticity

Neuroplasticity is demonstrated in cases of phantom limb sensation following amputation. When a limb is lost, the brain does not simply stop functioning in the areas that once controlled that limb. Instead, adjacent regions in the brain's somatosensory cortex—represented by the sensory homunculus (i.e., **topographic map**)—can take over these areas. For example, the area representing the face is located next to the hand region on the homunculus, and in some cases, stimulation of the face can evoke sensations in the phantom hand. This reorganization illustrates how sensory input from one part of the body can be "remapped" to another, a process that occurs because the brain remains plastic, even in adulthood. Such findings have significant implications for designing prosthetic limbs that can integrate both motor control and sensory feedback, helping to restore a more natural sense of body ownership.

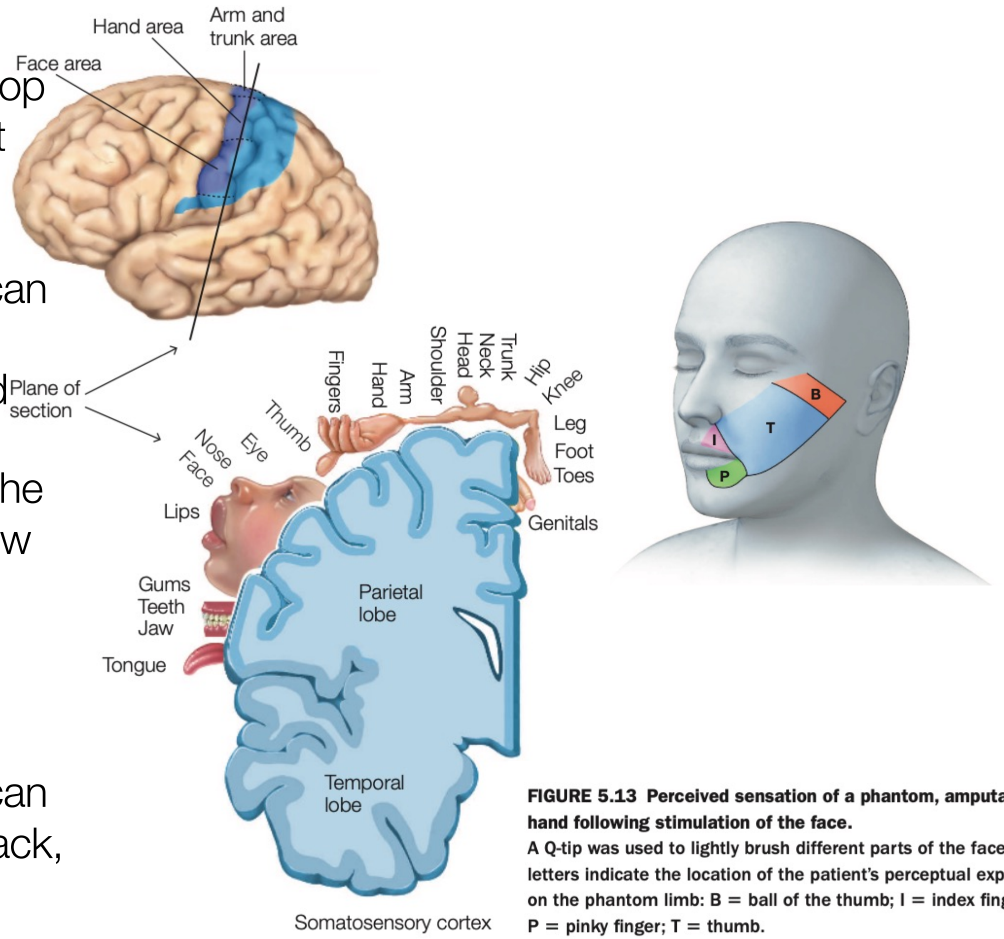


FIGURE 5.13 Perceived sensation of a phantom, amputated hand following stimulation of the face.
A Q-tip was used to lightly brush different parts of the face. The letters indicate the location of the patient's perceptual experience on the phantom limb: B = ball of the thumb; I = index finger; P = pinky finger; T = thumb.

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Neuroplasticity

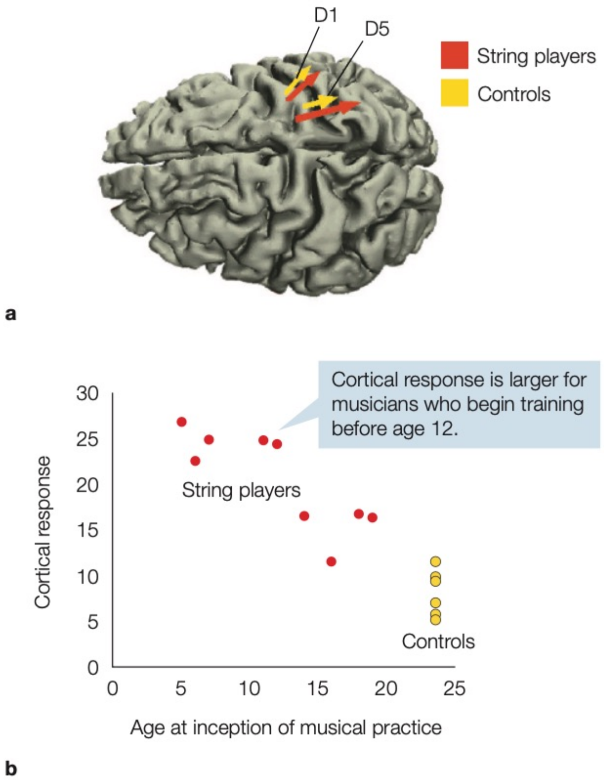


FIGURE 5.12 Increase in cortical representation of the fingers in musicians who play string instruments.
(a) Source of MEG activity for controls (yellow) and musicians (red) following stimulation of the thumb (Digit 1, D1) and fifth finger (D5). The length of each arrow indicates the extent of the responsive region. **(b)** The size of the cortical response, plotted as a function of the age at which the musicians begin training. Responses were larger for those who began training before the age of 12 years; controls are shown in the lower-right corner of the graph.

This study exemplifies the role of practice and training on neuroplasticity. The study examined how early musical training impacts the brain's cortical representation of the fingers in string players. The researchers a neuroimaging method (magnetoencephalography, MEG) to measure cortical activity in both musicians and non-musicians (controls) following stimulation of these fingers.

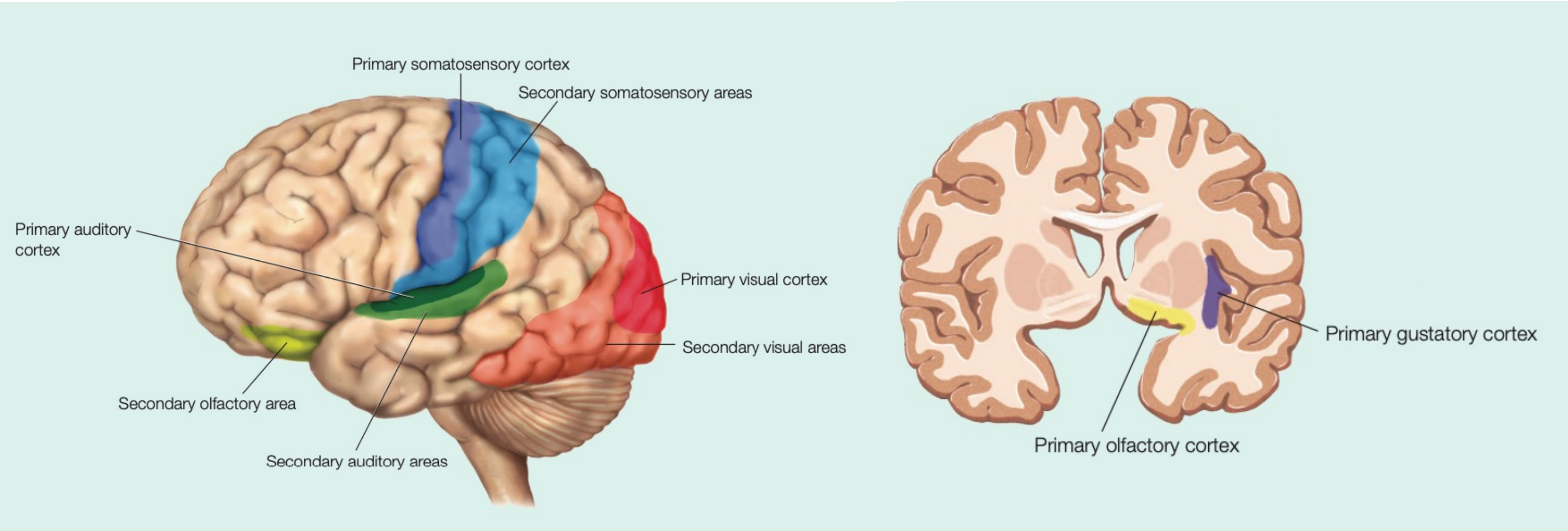
The cortical response to finger stimulation was significantly larger in musicians (depicted in red) compared to non-musicians (depicted in yellow). This suggests that the brain areas responsible for processing finger movements are more developed in string players. The size of the cortical representation was particularly enhanced in musicians who began their training before the age of 12. The study highlights neuroplasticity, demonstrating that musical training, particularly when started early in life, can enhance the cortical representation of the fingers. This increased representation is indicative of the brain's capacity to adapt and reorganize itself in response to specialized motor tasks, like playing a musical instrument.

Gazzaniga, M. S., Ivry, R. B., & Mangun, G. R. (2018). Cognitive neuroscience: The biology of the mind (5th ed.). W.W. Norton & Company.

Perception

Ontogeny	Mechanism 
Phylogeny	Adaptive Significance

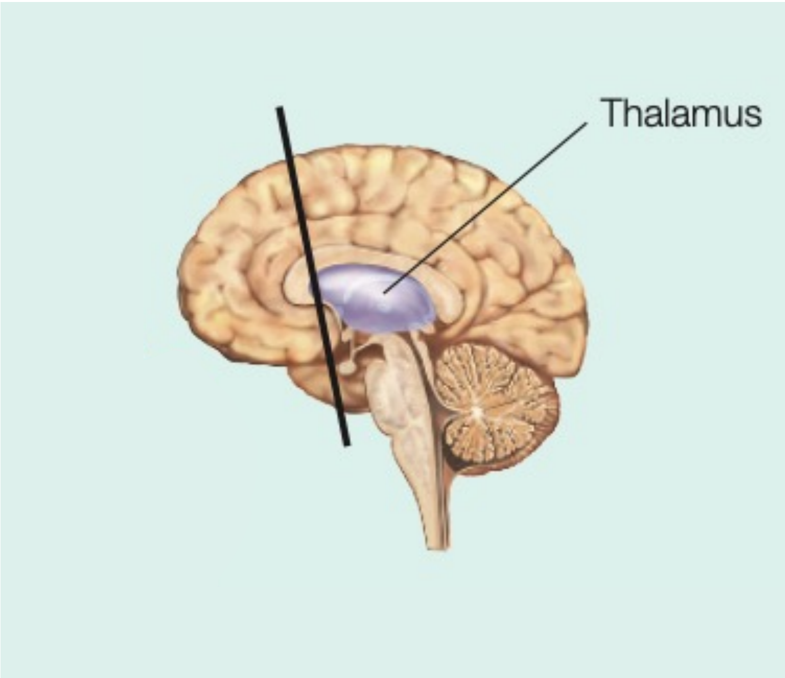
Neural bases of perception



The figure shows the **primary sensory regions** of the brain associated with each of the five major senses: vision, hearing, touch, smell, and taste. In addition, the **secondary sensory regions** refine and integrate sensory inputs, contributing to higher-level perception. The organization into primary and secondary cortices suggests a hierarchy in mental representations, reflecting how sensory information is processed from basic features to more complex, abstract representations.

Gazzaniga, M. S., Ivry, R. B., & Mangun, G. R. (2018). Cognitive neuroscience: The biology of the mind (5th ed.). W.W. Norton & Company.

Neural bases of perception: Thalamus



The visual, auditory, gustatory, and somatosensory modalities synapse in the thalamus before reaching their respective cortical areas. Olfactory signals bypass the thalamus and go directly to the primary olfactory cortex, Exactly what is going on in the thalamus is unclear, but it appears to be more than just a relay station. Not only are there projections from thalamic nuclei to the cortex, but the thalamic nuclei are interconnected, providing an opportunity for multisensory integration. The thalamus also receives descending, or feedback, connections from primary sensory regions of the cortex, as well as other areas of the cortex, such as the frontal lobe. These connections appear to provide a way for the cortex to control, to some degree, the flow of information from the sensory systems.

Gazzaniga, M. S., Ivry, R. B., & Mangun, G. R. (2018). Cognitive neuroscience: The biology of the mind (5th ed.). W.W. Norton & Company.

Neural basis of perception: Modularity in Vision?

Evidence from lesions

Lesion Type	Neural Basis	Symptoms
Achromatopsia	Damage to the occipital cortex, specifically in the V4 region.	Loss of color vision, where the world appears in shades of gray; normal visual acuity otherwise.
Akinetopsia	Damage to the middle temporal (MT) area of the brain, responsible for motion detection.	Inability to perceive motion, where moving objects appear as static images or 'snapshots'.

Evidence from imaging

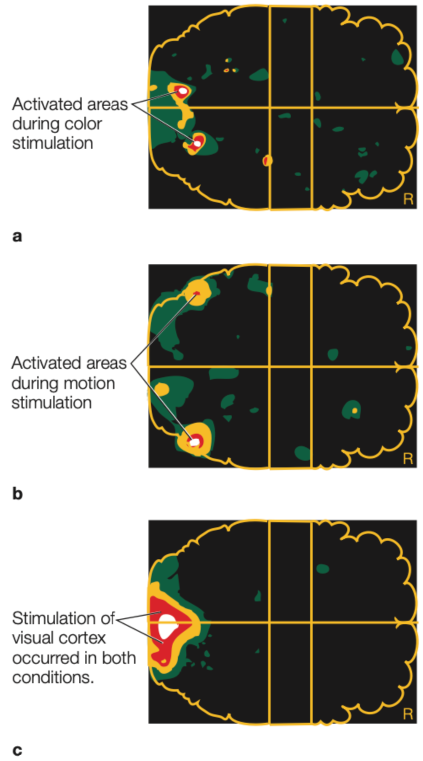
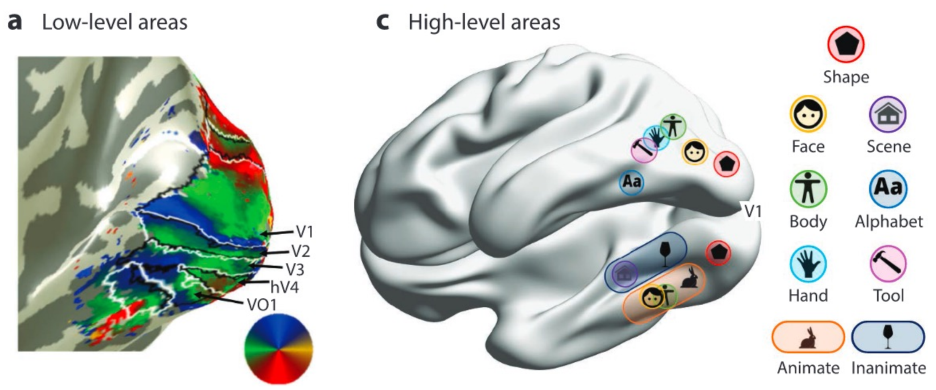


FIGURE 5.31 Regions of activation when the control conditions were subtracted from the experimental conditions in the experiment illustrated in Figure 5.30.
(a) In the color condition, the prominent activation was medial, in an area corresponding to human V4. **(b)** In the motion condition, the activation was more lateral, including human MT (also referred to as V5). The foci also differed along the dorsoventral axis: The slice showing MT is superior to that showing V4. **(c)** Both stimuli produced significant activation in the primary visual cortex, when compared to a control condition in which there was no visual stimulation.

Gazzaniga, M. S., Ivry, R. B., & Mangun, G. R. (2018). Cognitive neuroscience: The biology of the mind (5th ed.). W.W. Norton & Company.

Neural basis of perception: Modularity in Vision?



Specialization (Modularity) in the Human Visual System
This figure demonstrates the hierarchical and modular organization of the human visual system, illustrating how object recognition is processed through successive stages from basic visual dimensions to higher-level object representations. The figure highlights the division between low-level and high-level visual areas, showing the specialization of brain regions for distinct visual functions.
Panel a: Shows retinotopic organization in low-level visual areas (V1–V4), where visual information is processed based on spatial location. Early visual areas respond to simple features such as lines, orientation, and spatial frequency
Panel c: Illustrates high-level visual areas in the ventral pathway, which show strong category selectivity. Specific regions are tuned to different object categories, such as faces (FFA), bodies, tools, and scenes. This modular organization supports the idea that different regions are specialized for processing different types of objects and categories

"(…) category selectivity has been reported only for a limited number of categories, including faces (Kanwisher et al. 1997), bodies (Downing et al. 2001), scenes (Epstein & Kanwisher 1998), tools (Chao et al. 1999), hands (Bracci et al. 2010), and letter strings (Cohen et al. 2002). (…) Biederman (1987) estimated that there might be around 1,500–3,000 basic-level categories, and that most of these categories might only contain a few discriminated types or exemplars. We can compare these numbers with the recent estimate that people typically know around 5,000 faces (Jenkins et al. 2018). Given these numbers, it might be reasonable that the neural territory devoted just to the domain of faces would be comparable to the resources shared by thousands of other object categories."

Bracci, S., & Op De Beeck, H. P. (2023). Understanding human object vision: A picture is worth a thousand representations. Annual Review of Psychology, 74(1), 113–135. https://doi.org/10.1146/annurev-psych-032720-041031

https://www.youtube.com/watch?v=sxwn1w7MJvk

Multisensory integration: Rubber hand Illusion

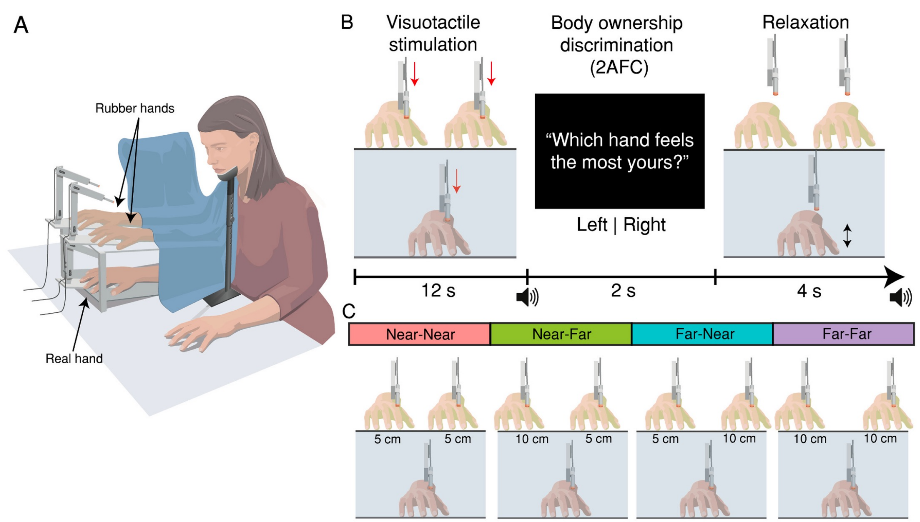


Fig. 1. (A) Experimental setting. Two robot arms apply touches to both rubber hands placed on top of the table, and one robot arm applies touches to the participant's real hand under the table. (B) Trial schematics. The robot arms tap the rubber hands and real hand with different degrees of asynchrony between the rubber hands; crucially, one rubber hand is always synchronously tapped with the real hand, which is the condition that we know produces the strongest RHI. Next, an auditory cue informs participants that they must verbally respond which rubber hand felt most like their own (left or right). An auditory cue informs them when the next trial is about to begin. (C) The relative distances between the rubber hands (skin colour) and the real hand (grey) in the horizontal plane across the four conditions. The distances are defined as the distance between each rubber hand's index finger and the real hand's index finger (hidden underneath). The white fixation dot is located halfway between the two rubber hands. Illustration by Mattias Karlén.

The Rubber Hand Illusion (RHI) demonstrates how the brain integrates visual, tactile, and proprioceptive information to create a compelling sense of ownership over an artificial limb. In this illusion, a participant's real hand is hidden from view while a lifelike rubber hand is placed in a visible and anatomically plausible position. Both the real hand and the rubber hand are synchronously stroked, and after a short period, the participant starts to feel as though the rubber hand is their own. The illusion is achieved by synchronizing the visual input of seeing the rubber hand being touched with the tactile sensation of the real hand being stroked in the same manner. As a result, participants often report feeling that the rubber hand is part of their own body. If an experimenter threatens the rubber hand (e.g., with a hammer), participants may react with fear or flinch as if their own hand is in danger.

This illusion is one of many other examples (e.g, McGurk effect, when a video of one phoneme's production is dubbed with a sound-recording of a different phoneme being spoken, leading to a third, intermediate phoneme being perceived) highlighting **multisensory integration.**

Lanfranco, R. C., Chancel, M., & Ehrsson, H. H. (2023). Quantifying body ownership information processing and perceptual bias in the rubber hand illusion. Cognition, 238, 105491. https://doi.org/10.1016/j.cognition.2023.105491

Summary

- **Adaptive Significance**: Sensory systems are tailored to support survival and behavior within an organism's ecological niche, demonstrating how perception is shaped by environmental needs.
- **Comparative Approaches**: Sensory capacities differ across species, reflecting their unique environments and evolutionary adaptations (e.g., color vision in humans vs. other animals).
- **Developmental Approaches**: Sensory development is characterized by both critical periods and neuroplasticity; early experiences fundamentally shape brain structure but a degree of plasticity remains across the life span.
- **Neural Basis of Perception**: Sensory processing follows from receptors to primary to secondary cortices, with the thalamus acting as a key relay for most senses; cortical representations seem to follow a hierarchical path from basic to more abstract representations,
- **Modularity and Integration**: The brain features specialized modules for processing different sensory inputs, and some degree of specialization/modularity within modalities (e.g., vision), but also integrates them across modalities for effective perception and action (e.g., eye-hand coordination).