Cogs17 Neurobiology of Cognition

Lecture 6: Other Perceptual Systems

Vestibular System

Vestibular Organ, adjacent to Cochlea, consists of two complex structures that provide info for **movement, balance**

Semi-Circular Canals - Detect angular ac/deceleration – i.e. Rotation
- Three looped tubes, each in a different orthogonal (X, X, Z) plane, affected by head rotation
  - Filled with viscous fluid = **potassium-rich (K+) Endolymph**
- **Hair Cell** Receptors are embedded in gelatinous cupula (cap) = Crista ampullaris in the Ampullae at the base of each canal
  - When head begins to rotate, fluid in Ampulla lags behind movement; when head stops, fluid overshoots movement
  - This motion deforms cilia => alters NT release

Otolith ("Ear stone") Organs - Detect changes in head tilt relative to body
- **Hair Cell** receptors, embedded in gelatinous substance on which sit Calcium Carbonate crystals
  - Two chambers ("Vestibular Sacs"): Saculle, lined with Hair Cells on its walls, Utricle with Hair Cells on its floor
- Head tilts, gravity makes crystals shift against & deform cilia of Hair Cells => alters NT release

- In all of the above, deforming **Hair Cells** results in graded responses to subtle, 3D changes
  - Bend cilia toward tallest cilia, open K+ gates wide, K+ enters => hypo-polarization, **increase Spontaneous** firing rate
  - Bend cilia toward shortest cilia, close K+ gates => hyper-polarization, **decrease Spontaneous** firing rate - Both informative
  - Returns to Spontaneous rate when static or at constant velocity
    - Therefore, Vestibular System **only detects change** in velocity/orientation

PATHWAY: Hair Cells => Vestibular Ganglions, whose axons form tract within 8th Cranial Nerve (nerve shared w/Audition)
=> Vestibular Nuclei of Medulla (source of nausea); some directly to Cerebellum (as feedback for acts that require balance)
=> Spinal Cord and many Brain Stem nuclei, including Pons, & Midbrain's Red Nucleus (Tegmentum) – regulate posture
and to Superior Colliculus to coordinate with vision (help determine which movements on retina from head vs. environment)
and to Cranial Nerves (3,4,6) that control Eye Movement, to compensate for head (e.g. so can keep focus while head moves)
=> ?? Temporal Lobe – higher pathway little known

Motion Sickness = When visual and/or motor feedback inconsistent with vestibular info, Medulla connections cause nausea
e.g. In car, see environment stream by, but constant velocity so no vestibular change & no motor feedback
e.g. In outer space, move muscles & see environment change, but no gravity and rare acceleration so no vestibular change
e.g. Spin around, stop – vestibular system still detects change for a while, eyes do not (=>Nystagmus, eyes jump to compensate)

Somatosensory System

Somatosensory Receptors of are two basic types - Free Nerve Endings and Encapsulated Nerve Endings
- Deformation (or other physical impact on cell) => **Action potentials** in these Receptor cells

Free Nerve Endings respond to change in Temperature (**Thermoreceptors**) and pain & itch (**Nociceptors**)
- Plus many hair follicles have Free Nerve Endings (Follicle Receptors) coiled around them, just under the surface of the skin
  - When hair moved, receptor responds = Body hair a "reception" mechanism for increasing sensitivity to touch

Encapsulated Nerve Endings respond to 1) various types of **Touch** and 2) **Proprioception** = internal muscle & organ movement
- Have various, layered, outer coverings that determine which kind of stimulus produces a response
- **Meissner's** have small Receptive Fields & are fast adapting - so respond to rapid change (e.g slippage)
- **Merkel's** have small Receptive Fields & are slow adapting - so for detail discrimination (e.g. reading Braille)
- **Pacinians** have large Receptive Fields & are fast adapting - so respond to large scale changes (e.g. bend)
- **Ruffinni's** have large Receptive Fields & are slow adapting - so respond to sustained, large-scale events (e.g. sit)

ACROSS-FIBER CODING demonstrated via "**Selective Adaptation**"
- There are two types of Temperature Receptors (both "Free Nerve Endings")
  1) "**Warm Best**" (which respond best to stimuli warmer than the skin, and fire faster as temperature increases)
  2) "**Cool Best**" (which respond best to stimuli cooler than the skin, and fire faster as temperature decreases)

PLUS - the range of temperatures to which each type responds OVERLAPS with the range of the other.
-As a result, temperature coded by the distribution of activity across both types of receptors = "**Across fiber coding**"
- For example, about 89ºF (32ºC) is "physiological zero" (does not feel either cold or hot) = Produces equal response from Warm Best (WB) and Cool Best (CB) receptors - Thus the normal code for 89ºF is "WB = CB"
  - Exposing the skin to a warmer temperature (such as 105ºF) produces a different code: "WB > CB"
- Chilling the hand (as by putting it in ice water) will **selectively adapt** the CB receptors more than the WB receptors, producing an **aftereffect** such that tepid water (89ºF) will now feel warmer (more like 105ºF)
  - This is because the 89ºF water now produces the code normally associated with 105ºF (i.e. "WB > CB")

There are two major Pathways for Somatosensory information:

Spinal-Thalamic - **Free Nerve Endings** enter Dorsal Root of Spinal Cord and synapse there.
- "Second-order" neurons cross over in Spinal Cord, ascend on contra-lateral side to synapse in contra-lateral **VPN** (Ventral Posterior Nucleus of the Thalamus) So, pathway is named for the sites of its first two synapses.
  - Synapse in Spinal Cord plays a role in some reflexes (see upcoming Motor Processes lecture)
- Nerves are small in diameter & mostly **unmyelinated** so transmit relatively SLOWLY

Medial Lemniscal - **Encapsulated Receptors** enter Dorsal Root but, although one collateral of axon synapses there, main fiber ascends on the ipsi-lateral side of the Spinal Cord, synapsing first on ipsi-lateral side of the Medulla
  - Note: Longest nerve cells in body reach from toes to brain!
- "Second-order" cells cross -over in Brain Stem (tract called "Medial Lemniscus") to synapse in contra-lateral **VPN**
- Nerves are large and **myelinated** and thus transmit very FAST

Brown-Sequard Syndrome - Damage to only one side of spinal column (e.g. the right) will result in the reduction/loss of touch and position sense on the ipsi-lateral (right) side below the point of injury and the reduction/loss of temperature and pain detection on the contra-lateral (left) side below the point of injury.

- In Both Pathways: First major synapse occurs at place of cross-over
  - From VPN, message continues along contra-lateral side to S, and then S2, both in **Parietal Cortex**
    - After S1, **Corpus Callosum** exchanges info, so S2 reacts to both sides, altho shows dominance for contra-lateral side
- Note that above are the primary pathways, but there are a variety of other collateral paths!

Somatosensory Cortex:

- **Post-Central Gyrus** of Parietal Lobe, just posterior to Central Sulcus that separates Parietal/ Frontal Lobes
  - Topological maps of body surface: Feet, legs, body, arms, hands, face=**Penfield Map** ("homunculus","little man")
  - Multiple parallel maps for touch, proprioception, temperature, and pain

- **Magnification Factor** = Any area with small Receptive Field and a high density of high acuity (1:1) receptors takes up a disproportionately large area of the cortical map (i.e. that body area is magnified in cortex – like Fovea of retina)
  - Thus bizarre Penfield Map has large hands (object ID, manipulate, gesture) & mouth (speak, eat, kiss) vs. small torso

Gate Theory of endogenous Analgesia (pain reduction) via negative feedback from brain or body

- Nociceptors release **Substance P** in Spinal cord, stimulating "T Cells" to send message up to brain,
- But T Cell activity can be ihihbited by "closing the gate"…
- 1) **Touch Receptors** near source of pain are stimulated (e.g. scratch around mosquito bite!)
  - Collaterals synapse in Spinal Cord stimulates inhibitory inter-neurons (SG cells)
  - Inhbit T Cells from reacting to Substance P ("**Close the Gate**")
- 2) **Periaqueductal Grey Area** (**PAG** in Midbrain) releases inhibitory **Endorphins** ("endogenous morphine")
  => Inhibits Inhibitory cells in **Raphe System** in hindbrain, allowing Raphe to send Excitatory NT to Spinal Cord
  => Stimulate inhibitory inter-neurons (SG cells) in Cord, inhbit T Cells from reacting to Substance P
- 3) Within brain, some cells that release Substance P have NT receptor sites on their Terminals that respond to inhibiting Endorphins
  - So, via **Axo-Axonal** connections, Endorphins directly inhibit Presynaptic release of Substance P in brain
    - e.g. On cue from Hypothalamus when sexual activity begins (anticipatory pain prevention)
    - e.g. During strenuous exercise (producing "Runner's high")
- Acupuncture may work by stimulating PAG Endorphin release, by directly stimulating inhibitory inter-neurons in cord, or both
  - **Naloxone** – an Endorphin Antagonist – blocks effects of Acupuncture