Introduction to Physiological Psychology

Psych 260

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The cutaneous senses

- What kinds of things can we feel with our skin?
- Pressure, vibration, heat, cold, pain
Transduction!

- In the visual system, rods and cones *transduce* light to neural signals...
- In the auditory system, hair cells *transduce* sound waves to neural signals...
- In the olfactory and gustatory systems, receptors *transduce* chemicals into neural signals
- In the somatosensory system, sensory neurons in skin, joints, organs *transduce* pressure (or heat, or pain, or...) into neural signals...

Receptor cells *transduce* stimuli into neural activity
Sensing and Moving/Responding

- The two most basic nervous system functions!
  - Even single cell organisms can sense nutrients and toxins, and respond by moving towards or away

- Complex organisms have specialized cells and systems to carry out these functions
  - our simplest but most crucial behaviors involve reflexive responses to sensory stimuli
    - pain reflex to avoid damage
    - increased breathing stimulated by blood CO2

Different modalities are encoded by different receptor types

- Somatosensation
- Proprioception
- Olfaction
- Gustation
- Audition
- Vision
Sensation and Perception

Generally speaking, the brain is sensitive to change - when there is no change, no sensation

Somatosensation: Touch and Pain

Somatosensory system is three separate and interacting systems:

- Exteroceptive - external stimuli
- Proprioceptive and kinesthetic - body position and motion
- Interoceptive - body conditions (e.g., temperature and blood pressure)
Somatosensation: Touch and Pain

- Exteroceptive System - specialized receptors respond to various stimuli
  - Touch (mechanical stimuli)
  - Temperature (thermal stimuli)
  - Pain (nociceptive stimuli)

A sensory stimulus presents different kinds of information

- Modality
  - What kind?
- Intensity
  - How much?
- Duration
  - How long?
- Location
  - Where?
Your skin

- Skin is the largest, heaviest organ of the body
- Humans have both hairy and glabrous (hairless) skin.

Hairy and Glabrous

- Hairy skin
  - Free nerve endings - painful stimuli, changes in temperature
  - Ruffini corpuscles - indentation of skin
  - Pacinian corpuscles - rapid vibrations
  - (Hair Follicles)

- Glabrous skin
  - Free nerve endings, Ruffini and Pacinian corpuscles
  - Meissner’s corpuscles - stroking, fluttering, small bumps
  - Merkel’s disk - compression
Somatosensation: Touch and Pain

- **Cutaneous Receptors:**
  - Free nerve endings
    - temperature and pain
  - Merkel’s disks
    - gradual skin indentation
  - Meissner corpuscles
    - low frequency vibration
  - Pacinian corpuscles
    - sudden displacements of the skin
  - Ruffini corpuscles
    - gradual skin stretch
**Somatosensory Receptors**

- **Deep receptors:** large receptive fields (big patches of skin); low spatial resolution.

- **Superficial receptors:** small receptive fields (small patches of skin). High spatial resolution: e.g. for reading Braille.
Deep Receptors

(subcutaneous) (large RF):
- Pacinian corpuscles:
  - **Rapidly adapting**
  - responds to rapid indentation of skin; vibration; motion (of object across skin).

- Ruffini endings:
  - **Slowly adapting**
  - sense stretch of skin or bending of fingernails: this compresses the nerve endings. Perception of shape of objects.

Different receptors adapt at different rates

- Pacinian corpuscle: **Very Rapid**
- Ruffini endings: **Slow**
Shallow receptors

- (in superficial layers of skin) (small RF):
  - Meissner’s corpuscles:
    - Rapidly adapting
    - stroking, fluttering; detecting small bumps
  - Merkel disks:
    - Slowly adapting
    - give sustained responses to skin compression; pressure

Different receptors adapt at different rates
Different receptors adapt at different rates

Meissner's corpuscle
- **Rapid**

Merkel's disk
- **Slow**

Ruffini's capsule
- **Slow**

Sweat gland

Pacinian corpuscle
- **Very Rapid**

Receptive fields and adaptation of mechanoreceptors

(a) Receptors

Meissner's corpuscle

Receptive fields

Stimulus Response
The intensity of a stimulus is transmitted by the frequency of the neural response

![Sigmoidal response function/curve]

**Characteristics of sensory receptors in the skin**

<table>
<thead>
<tr>
<th>Receptor</th>
<th>Stimulus</th>
<th>Sensation</th>
<th>Adaptation</th>
<th>Location</th>
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<tr>
<td>Merkel's disk</td>
<td>Steady indentation</td>
<td>Pressure</td>
<td>Slow</td>
<td>Shallow</td>
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<tr>
<td>Meissner's corpuscle</td>
<td>Low frequency vibration</td>
<td>Gentle fluttering</td>
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<tr>
<td>Ruffini's corpuscle</td>
<td>Rapid indentation</td>
<td>Stretch</td>
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<tr>
<td>Pacinian corpuscle</td>
<td>Vibration</td>
<td>Vibration</td>
<td>Rapid</td>
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</tr>
<tr>
<td>Hair receptor</td>
<td>Hair deflection</td>
<td>Brushing</td>
<td>Rapid or Slow</td>
<td>Shallow</td>
</tr>
</tbody>
</table>
In the human hand...

- **Meissner’s** - 40% of mechanoreceptors
  - Low frequency vibrations, movement of textures across skin
- **Pacinian** - ~15% of mechanoreceptors
  - Sense of vibration, discrimination of textures
- **Ruffini’s** - ~20% of mechanoreceptors
  - Cutaneous stretching
- **Merkel’s disks** - 25% of mechanoreceptors
  - Abundant in finger tips, lips, genitalia
  - Feelings of light pressure

The Pacinian Corpuscle is a rapidly adapting receptor cell

![Diagram of the Pacinian Corpuscle]

- **Steady pressure**
  - **Action potentials**
    - **Stimulus**
      - **Rebound**
The capsule of the Pacinian corpuscle is responsible for its rapid adaptation

Ruffini corpuscles and Merkel’s disks don’t have capsules, so are continuously responsive!

The Pacinian Corpuscle responds to vibrations on the skin

A Steady pressure

Action potentials

Stimulus

B 110 Hz vibration

Action potentials

Stimulus
The receptive field of a receptor cell is determined by its morphology.

Two point discrimination
Lateral inhibition *refines the receptive field* of higher-order sensory cells

Lateral inhibition *improves precision* in higher-order sensory cells
Lateral inhibition *improves discrimination*

Neurons in the somatosensory cortex have center-on, surround-off receptive fields... of different sizes
How do the neural messages get to the brain?

Broadly Speaking...

Sensory information travels through the spinal cord and thalamus to the sensory cortex.
Cortical Areas of Somatosensation

- **Primary somatosensory cortex (SI)**
  - Postcentral gyrus
  - Somatotopic organization (somatosensory homunculus) - more sensitive, more cortex
  - Input largely contralateral
- **SII** - mainly input from SI
  - Somatotopic; input from both sides of the body
- **Much of the output from SI and SII goes to association cortex in posterior parietal lobe**
Sensory Homunculus

- Receptive fields in the somatosensory cortex comprise a somatotopic map of the body.

The “homunculus” reflects the density of receptor cells.
Neural plasticity

(a) Details of cortical map

Digit 5
Digit 4
Digit 3
Digit 2
Digit 1 (thumb)

Palm

(b) Experiment 1

Dorsal surface

Immediately after severing the nerve

Five months later

Deprived

(c) Experiment 2

D5
D4
D3
D2
D1

(d) Experiment 3

Stimulus disk

Merzenich et al.
Two Major Somatosensory Pathways

- **Dorsal-column medial-lemniscus system**
  - Mainly touch and proprioception
  - Stays ipsilateral until medulla
  - First synapse in the dorsal column nuclei of the medulla...
  - then decussate and go to ventral posterior nucleus...
  - then (generally) head to primary somatosensory cortex

- **Anterolateral system**
  - Mainly pain and temperature
  - Becomes contralateral in spinal cord.
  - First synapse upon entering the spinal cord!
  - all tracts head (generally) to primary somatosensory cortex
What could possibly go wrong?

- **Brown Sequard Syndrome**
  - Because of the two separate tracts, damage to half the spinal cord results in:
  - **Loss of movement** in the ipsilateral side of lesion (dorsal column medial lemniscus)
  - **Loss of pain and temperature** in contralateral side (anterolateral)

What can possibly go wrong?

- **Somatosensory Agnosias**
  - **Astereognosia** - inability to recognize objects by touch
    - pure cases are rare - other sensory deficits are usually present
  - **Asomatognosia** - the failure to recognize parts of one’s own body
Perception of Pain

- Pain appears to have three different perceptual and behavioral effects:
  - First is the sensory component
    - Pure perception of intensity of painful stimulus
  - Second is immediate emotional consequences
    - Unpleasantness or degree to which individual is bothered by painful stimulus
  - Third is long-term emotional consequences
    - Threat that pain represents to one’s future comfort and well-being

Phantom Limbs, Phantom Pain
The Perception of Pain

Paradoxes of Pain

- Despite its unpleasantness, pain is adaptive and needed
- No obvious cortical representation (although the anterior cingulate gyrus appears involved in the emotional component of pain)
- Descending pain control - pain can be suppressed by cognitive and emotional factors

Pain Perception

- Anterior Cingulate Cortex
  - Mediates the emotional component of pain
Next time...

- Sleep!