Touch Physiology

• Touch receptors:
  • mechanoreceptors
    • sensory receptors responsive to mechanical stimulation (pressure, vibration)
  • embedded in “skin”
    • 1.8m²
    • 4 kg
  • embedded on
    • outer layer (epidermis) and
    • underlying layer (dermis)

The Four Types of Mechanoreceptors

• 3 attributes of touch receptors:
  1. type of stimulation (mechano, thermo, noci)
  2. size of the receptive field (large/small)
  3. rate of adaptation (fast/slow)

Introduction

• proprioception (“self perception”):
  • perception mediated by kinesthetic and vestibular receptors
    • kinesthesia - arise from joint, muscles, tendons
    • proprioception - vestibular senses
  • somatosensation:
    • a collective term for all sensory signals from the body

Touch

• touch physiology
• tactile sensitivity and acuity
• haptic perception

1.8m²
4 kg
1.8m²
4 kg
The Four Types of Mechanoreceptors

- Tactile receptors (mechanoreceptors):
  - respond to mechanical stimulation or pressure
    - Meissner corpuscles
    - Merkel cell neurite complexes
    - Pacinian corpuscles
    - Ruffini endings

Touch Physiology (cont’d)

- Meissner corpuscles (epidemis-dermis junction)
  - Fast adapting, small receptive fields
- Merkel cell neurite complexes (epidemis-dermis junction)
  - Slow adapting, small receptive field
- Pacinian corpuscles (subcutis)
  - Fast adapting, large receptive field
- Ruffini endings (dermis)
  - Slow adapting, large receptive fields

Touch Physiology (cont’d)

- Merkel cell neurite complexes SA I
  - Fine spatial detail - texture-Braille
- Ruffini endings SA II
  - Sustained downward pressure - grasp
- Meissner corpuscles FA I
  - Low frequency vibrations
- Pacinian corpuscles (subcutis) FA II
  - High frequency vibrations - mosquitos

TABLE 12.1  Response characteristics of the four mechanoreceptor populations

<table>
<thead>
<tr>
<th>ADAPTATION RATE</th>
<th>SIZE OF RECEPTIVE FIELD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fast</td>
<td>FA I (Meissner)</td>
</tr>
<tr>
<td>Slow</td>
<td>SA I (Merkel)</td>
</tr>
<tr>
<td>FA II (Pacinian)</td>
<td>SA II (Ruffini)</td>
</tr>
</tbody>
</table>

FA I = fast-adapting type I, FA II = fast-adapting type II, SA I = slow-adapting type I, and SA II = slow-adapting type II. The receptor ending associated with each type is shown in parentheses.

Touch Physiology (cont’d)

- Each receptor:
  - different range of responsiveness
Proposed Sensitivity Ranges of Mechanoreceptors

- kinesthetic receptors:
  - limbs positions
  - limb motions

- Muscle spindles
  - embedded in main (extrafusal) muscle fibers contains inner (intrafusal fibers)
  - detect angle formed by limb at a joint

Spindles:
- rate at which the muscle fibers change in length
- receptors in tendons
  - provide signals about tension in muscles attached to tendons
- receptors in joints
  - react when joint is bent to an extreme angle

Thermoreceptors:
- receptors that signal changes in skin temperature
- two distinct populations of thermoreceptors:
  - warmth fibers
  - cold fibers
- body regulation of internal temperature
- thermoreceptors respond with contact
  - of object warmer or colder than skin
12.5 Thermal receptivity functions

• Nociceptors (pain receptors):
  – sensory receptors that detect noxious stimulation that causes damage or potential damage to skin
  – Two groups of nociceptors:
    • A-delta fibers
    • C fibers

Touch Physiology (cont’d)

• Two groups of nociceptors:
  – A-delta fibers
    • Strong pressure or heat
    • myelinated
  – C fibers
    • pressure, heat, cold, noxious chemicals
    • unmyelinated

Touch Physiology (cont’d)

• Two stages of pain (Price, 1977)
  – quick sharp burst
    • A-delta fibers
  – throbbing
    • C fibers

Touch Physiology (cont’d)

• Benefit of pain perception:
  – sensing dangerous objects

  – Case of “Miss C”:
    • born with insensitivity to pain
    • could not protect herself
    • died at 29 yrs. of age

Touch Physiology (cont’d)

• Skin to Brain
• Touch sensations travel as far as 2 meters to get from skin and muscles of feet to brain!
  – information passes through spinal cord
  – axons of various tactile receptors combine into single nerve trunks
  – nerve trunks from different areas of body
  – from spinal cord:
    • Two major pathways:
      – spinothalamic (slower);
      – dorsal-column-medial-lemniscal (faster)

– Spinothalamic pathway
  • synapses within spinal cord
  • temperature and pain
– DCML:
  • synapse in medulla, near base of brain
  • pressure, vibration, joint and position sense

• Thereafter
  • then ventral posterior nucleus of thalamus
  • then somatosensory area 1 (S1)
  • somatosensory area 2 (S2)

• Touch sensations
  – somatotopically represented
    • Adjacent areas on skin:
      • Connected to adjacent areas in brain,
        – The “homunculus”
    – brain contains several sensory maps of body,
      different sub-areas of S1
    – and secondary areas as well
• Wilder Penfield (1950’s)
  – awake brain surgery
  – stimulated somatosensory cortex
  – discovered “homonculus”
• analogy to vision
  – cortical magnification
  – somatotopic organization
  – multiple maps of the body in S1 and S2

• Phantom limb:
  – perceived sensation from amputated limb
  – parts of brain represent “missing limbs”
    • altered connections not represented
    • activity in brain areas signal “missing limb”
  • Ramachandran example
    – face-hand

12.9 Phantom limbs may appear on the face and stump

• Ramachandran
  – amputees feeling sensations in missing hands when face is touched
  – hand and arm areas in cortex “invaded” by the face area
The Sensory Homunculus (Part 2)

Touch Physiology (cont’d)

• Pain:
  – pain sensations triggered by nociceptors
  – responses to noxious stimuli moderated by:
    • anticipation, religious belief, prior experience,
      watching others respond, excitement
  – Example:
    • wounded soldier who does not feel pain
    • endogenous opiates

• Analgesia:
  – decreases pain during conscious experience
  – endogenous opiates
    • chemicals released in body to block release or
      uptake of neurotransmitters transmitting pain
      sensations to brain
    • produced in pituitary gland and hypothalamus
    – externally produced substances similar:
      • morphine, heroin, codeine

• Nociceptor types:
  – Nerve fiber (not ending) differences
    • A-delta (A-Δ)
      – mylinated - strong pressure or heat
    • C fibers
      – unmylinated
      – pressure, heat, noxious chemicals

• Gate control theory of pain:
  – pain system modulated by efferents
  – feedback circuit located in
    • substantia gelatinosa
      – dorsal horn of spinal cord
  – gate neurons block pain transmission
    • activated by extreme pressure, cold, other
      noxious stimulation applied to another site
      distant from source of pain
Touch Physiology (cont'd)

- pain sensitization:
  - "nociceptive" pain
  - impending/ongoing damage to body's tissue
  - hyperalgesia
  - increased sensitivity after damage
  - neuropathic pain
  - damage to or dysfunction of nervous system
  - allodynia - sensory fibers in skin "become" pain inducers

- Cognitive aspects of pain
  - subjective experience, two components:
    - sensation of pain
    - emotion response
  - Areas S1 and S2:
    - sensory aspects of pain
  - anterior cingulate
    - areas of brain that might correspond to more cognitive aspects of painful experiences

- Cognitive aspects of pain
  - subject experience, two components:
    - sensation of pain
    - emotion response
  - Areas S1 and S2:
    - sensory aspects of pain
  - anterior cingulate
    - areas of brain that might correspond to more cognitive aspects of painful experiences

- anterior cingulate cortex responded differentially to two hypnotic suggestions, by increasing or decreasing its activity
  - hypnosis experiment
    - lukewarm and hot water:
      - suggestion of "unpleasantness"
      - S1 not affected by hypnosis
      - anterior cingulate activated differentially

- Prefrontal cortex
  - secondary pain effect:
    - emotional response associated with long-term suffering, (e.g., cancer patients undergoing chemotherapy, associated with prefrontal cortex)
  - memory of pain....

Psychophysics of Touch
Tactile Sensitivity and Acuity

- How sensitive are we to mechanical pressure?
  - Max von Frey (Nineteenth century) developed an elegant way to measure this, using carefully calibrated stimuli:
    - horse and human hairs
  - modern researchers:
    - use nylon monofilaments of varying diameters

Sensitivity to Pressure

Tactile Sensitivity and Acuity (cont’d)

- How finely can we resolve spatial details?
  - two-point touch threshold:
    - minimum distance at which two stimuli (e.g., two simultaneous touches) are just perceptible as separate

Two-Point Threshold on the Hand

Tactile Sensitivity and Acuity (cont’d)

- Correspondence between
  - pattern of two-point thresholds across body
  - cortical magnification in sensory homunculus

- factors
  - receptor density at the skin,
  - receptive field size
Tactile Sensitivity and Acuity (cont'd)

- How finely can we resolve temporal details?
  - Sound pressure changes of
    - low-frequency sounds
      - can translate into vibratory skin pressure changes
    - higher-frequency
      - notes cannot be felt

Minimally Detectable Displacement

FA II

Haptic Perception

- Haptic perception:
  - sensory knowledge derived from sensory receptors in skin, muscles, tendons, and joints
  - usually involves active exploration
    - think Gibson!

Haptic Perception (cont'd)

- action for perception:
  - exploratory procedure:
    - stereotyped hand movement pattern used to contact objects in order to perceive their properties
  - optimal for obtaining
    - precise details about one or two specific properties,
      - (e.g., roughness -> lateral motion)

Exploratory Procedures

- the "What" system of touch:
  - geometric properties of objects:
    - most important for visual recognition
    - Klatzky, Lederman, & Mtzger (1985)
      - Recognition of common objects by touch
        - easy- fork, brush, paperclip
Objects Easy to Recognize by Vision, but not by Touch

Haptic Perception (cont’d)

• haptic “search tasks” (Luderman & Klatsky, 1997)
  – like vision…
    • preattentive pop-out properties

Feature Detection

Haptic Perception (cont’d)

• Perceiving patterns with the skin:
  – Braille alphabet:
    • raised dots
  – Loomis (1990):
    • touch acts like blurred vision when the fingertips explores a raised pattern
    • Confusion errors similar
      – in touch and blurred vision

Character Recognition Sets Used by Loomis

Haptic Perception (cont’d)

• tactile agnosia:
  – the inability to identify objects by touch
  – example:
    • patient (Reed and Caselli, 1994)
      – Tactile agnosia in right hand
      – Left parietal lesion
      – BUT - other mecho-tasks spared
        » weight comparisons, roughness detection
The "Where" system of touch:
- frame of reference:
  - coordinate system to define locations in space
- egocenter:
  - center of a reference frame used to represent locations relative to the body

Interactions between touch and other modalities:
- experiments that study competitions between sensory modalities (Spence, Nichols & Driver, 2000)
- Attention
  - visual or auditory cuing to a tactile stimulation
    - valid cues speed detection
    - invalid cues slow detection

Interactions between touch and other modalities:
- Integration (Lederman, Thorne & Jones, 1986)
  - Co-dependence between visual and tactile
    - sandpaper
      » judgments of "closely packed elements" relied more on vision
      » roughness judgments more on tactile
• Touch and vision integration
  – dependent on reliability (Ernst and Banks, 2002)
  • Informativeness of cue considered in a weighted average of the information

Haptic Perception (cont’d)

• Virtual haptic environments:
  – Video games
    • Ultimate tactile visual integration
  – Tadoma
    • method of speech perception for deaf and blind people by touching the face and lips

The Tadoma Method