Central Representation of Touch

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Mechanosensation

- Touch and tactile exploration
- Vibration and pressure sensations; important for clinical testing
- Limb position sense
- \(\sum\) Stereognosia: identify 3-D shapes of grasped objects

Dorsal column-medial lemniscal system

- Postcentral gyrus / 1st SScx
- Ventral posterior nucleus
- Dorsal column nuclei
- Mechanoreceptors
• Somatotopic organization
• Receptive field structure: key properties for tactile acuity
• Other functions of inhibition
• Cortical columns, submodality representation, and cortical mechanisms for higher somatic sensory functions
• Elaboration of somatic sensory processing in higher-order sensory and association areas

Somatotopic Organization
• Preserves neighborhood relations
• Like a slide projector
  – Slide=peripheral receptive sheet
  – Light=peripheral and central pathways
  – Screen=central nervous system representation
• All processing stages and tracts in touch pathway are somatotopically organized
• Similar organization for vision (retinotopic) and auditory system (tonotopic)

What does the homunculus in the postcentral gyrus tell us about somatic sensory processing?…stimulus localization & discrimination
What is the basis of distortions in the cortical homunculus? ...receptive field structure

CNS neurons have receptive fields

Convergence: CNS receptive fields >> PNS receptive fields

Receptor innervation density increases from proximal to distal

CNSS receptive field size decreases from proximal to distal

and overlap increases
Receptor innervation density increases from proximal to distal.

CNS receptive field size decreases from proximal to distal and overlap increases.

Representational area inversely proportional to RF area.

Map distortions reflect genetics and experience.
• Somatotopic organization
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Receptive field

Primary sensory neuron RF
CNS neuron RF

Structural basis of RF: distribution of sensory fiber innervation

Receptive field structure

Primary sensory neuron RF
CNS neuron RF
Gradient of excitation within excitatory RF in CNS neurons

Gradient of excitation effectively reduces RF size to center

...RF area increases with stronger stimuli; not veridical

Receptive field structure

Primary sensory neuron RF
CNS neuron RF
Inhibitory RF
Inhibitory interneuron
Excitatory RF
Increase signal-to-noise ratio

Background neural activity drops

Mechanoreceptor response

CNS neuron response to stimulus
Receptive Field Structure

- Gradient of + sharpens neural response to center of RF, which is most sensitive
- Inhibitory RF turns neuron off before it is activated by stimulus, thereby increasing S/N

Other uses for inhibition in sensory systems:
- Stimulus feature extraction

Other uses for inhibition in sensory systems: Distal inhibition—usually top down

Cortical neuron excites inhibitory interneuron
Inhibitory interneuron inhibits projection neuron in nucleus
Effect: blocks or fine-tunes transmission through nucleus
How is information from different mechanoreceptors represented in primary somatic sensory cortex?

Mechanoreceptors
- Pacinian
- Meissner
- Merkel
- Ruffini

Rapid adaptation
Slow adaptation

Slowly adapting
Meissner
Pacinian

Time
Texture code:

- Different receptors respond to different components of complex stimulus
- Internal representation of a texture determined by activity in population of diverse mechanoreceptors

**How is receptor information represented in the primary somatic sensory cortex?**

- Cell-stained section (Nissl)
- Most 6 cell layers

- Neuron density varies

- Pyramidal neuron: projection neuron
- Stellate neuron: interneuron
- layer 1, layers 2 & 3, layer 4, layer 5, layer 6
Layer 1
Layer 2 & 3
Layer 4
Layer 5
Layer 6
RA-Pacinian
SA-Merkel
RA-Meissner
SA-Ruffini
RA-Meissner

Columnar organization
- same receptor
- same location
Different textures produce different column activation patterns

Pyramidal neuron: projection neuron
Stellate neuron: interneuron
from Thalamus
back to Thalamus
to other cortical areas
to Subcortical areas

Columnar organization of 1° SScx
Input from:
Thalamus
Columnar organization of 1° SScx

Projects to:
- Other cortical areas
- Brain stem, spinal cord, basal ganglia
- Thalamus

Body representation w/in each cytoarchitectonic area

Processing mechanoreceptive information within the Primary Somatic Sensory Cortex

Ventral posterior nucleus
- Area 3a
- Area 3b
- Area 1
- Area 2
- Cutaneous

Integrated representation: ?stereognosia
Summary

• Touch path has hierarchical organization
  – Not bucket brigade
  – Message transformed
• Several mechanisms for enhancing spatial acuity
  – Gradient of excitation
  – Surround inhibition
• Columnar organization of cortex
  – Same input (receptor and location)
• Intracortical processing leads to integrated representation

Conclusions

• Bottom up
  – Receptors to spinal cord to cortex
• Top down
  – Cortex to subcortical centers - Layers 5, 6
  – Other cortical areas project into somatic sensory cortex
• Result
  – Experience and expectation modulates stimulus processing, both subcortically in relay nuclei and in cortex
    • illusions
  – Pathological states can generate sensation de novo
    • hallucinations