ELL 788
Computational Perception & Cognition

July – November 2015

Module 3

Cuteneous perception

Which of the senses is the most important to you ?

Seeing ?

Hearing ?

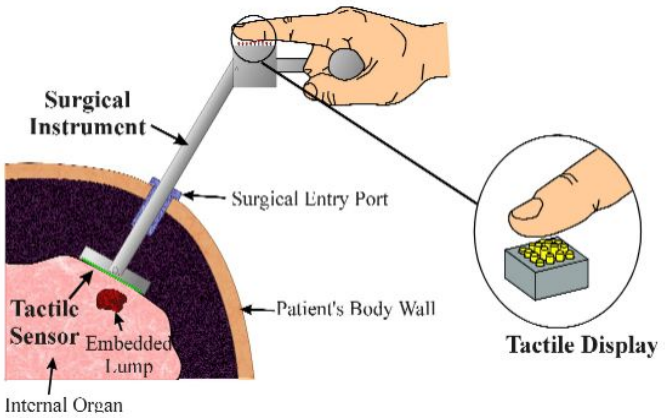
Touch ?

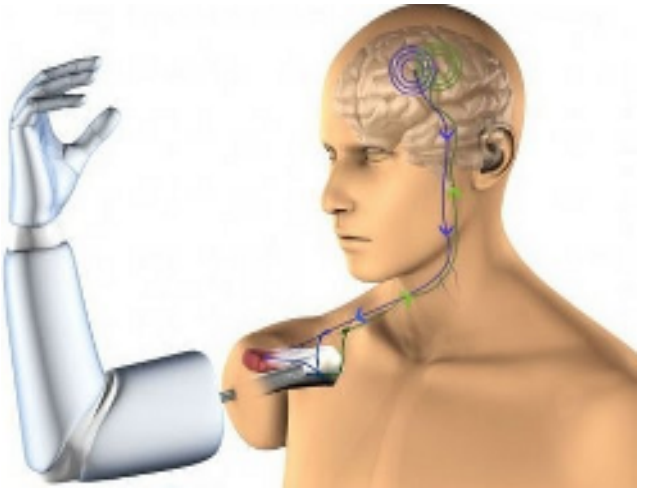
Which one is the least ?

- A blind or a deaf man can live

- Have you ever seen a living man without a sense of touch ?

Why study cutaneous perception ?

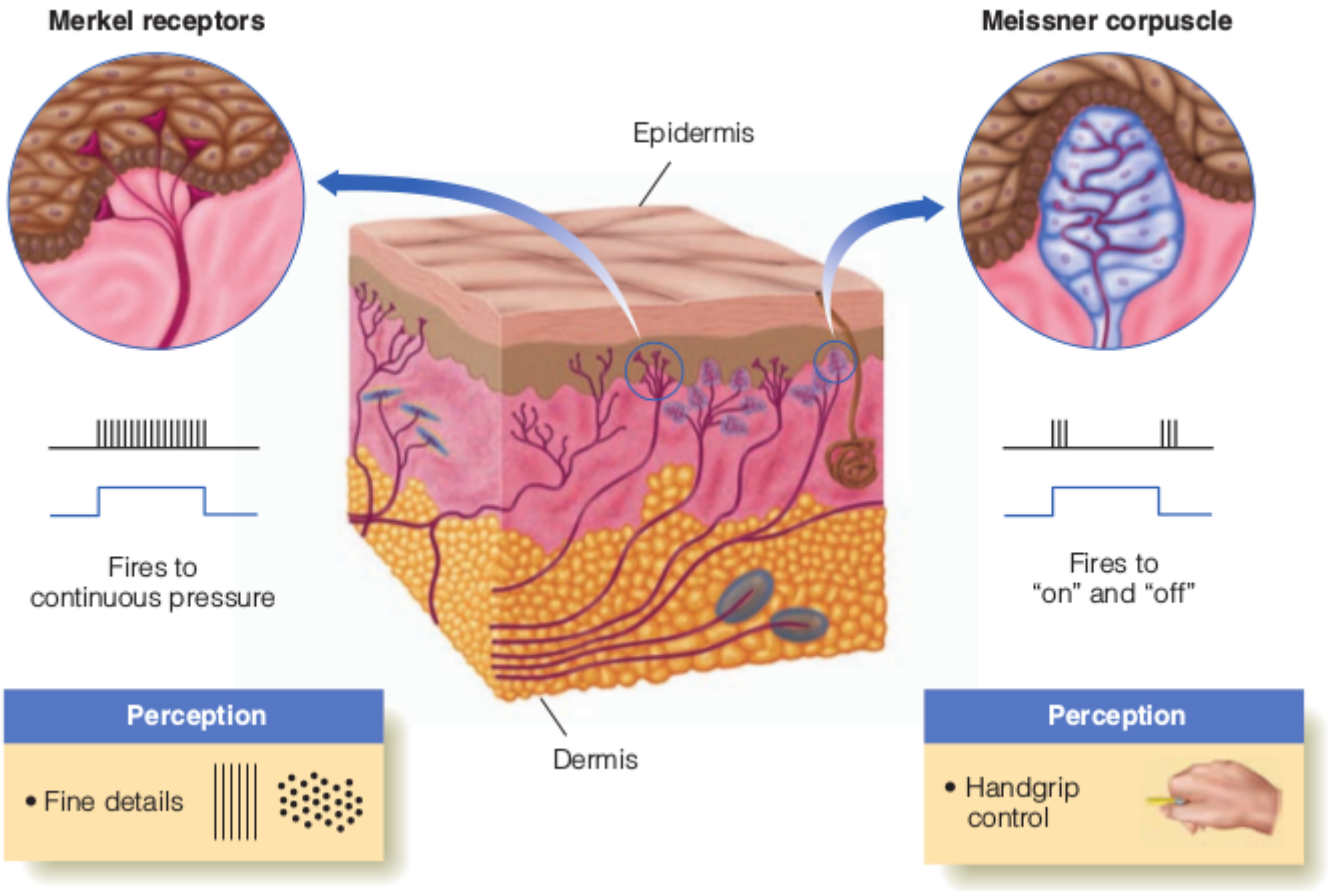




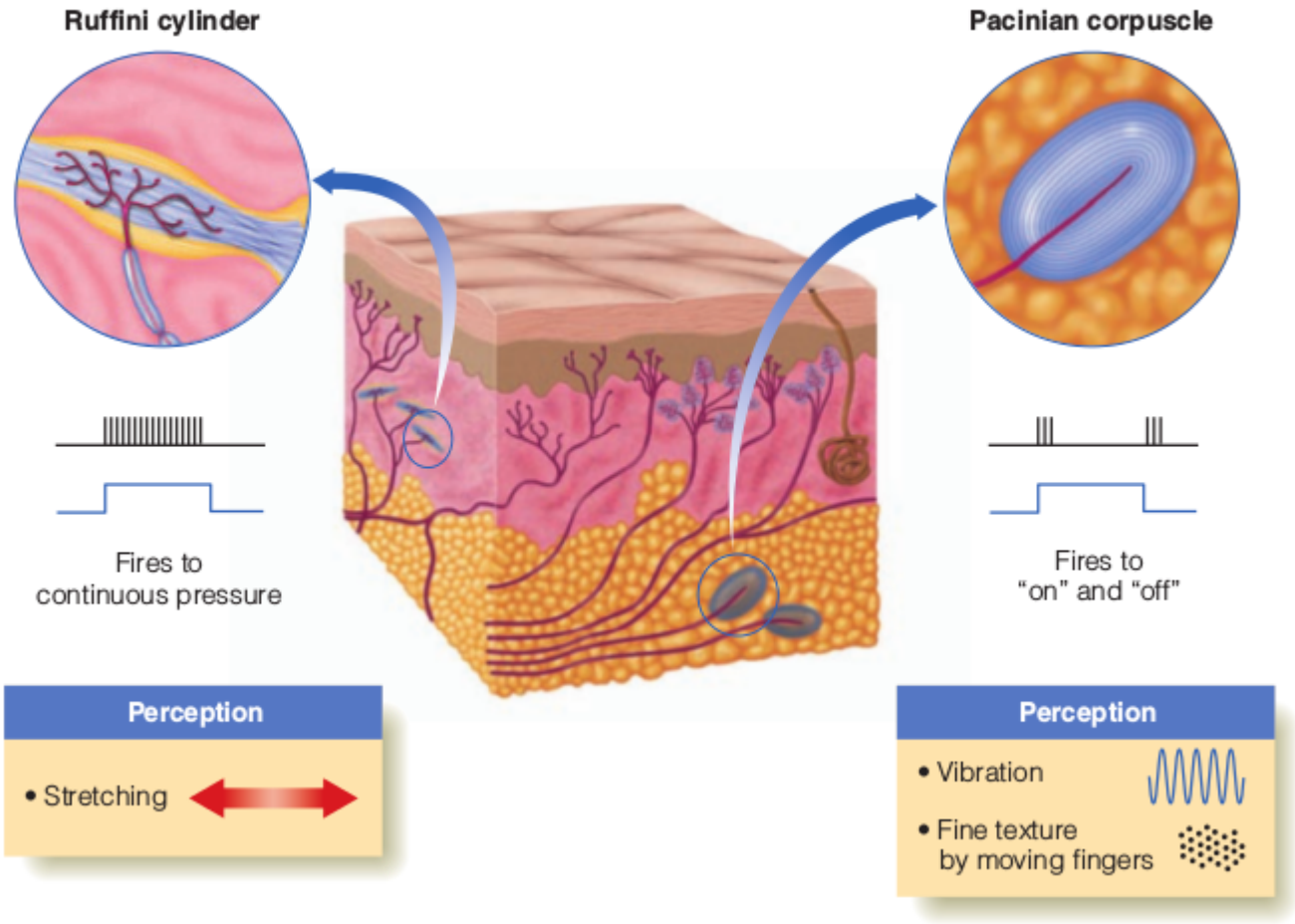
Dimensions of cutaneous perception

- **What** (signal resolution)
  - Material properties (surface texture, softness)
  - Geometric properties (shape, size)
    - Depends on object sample
- **Where** (localization)
  - Where on the body
  - Where in the space
    - Exploring a dark room with hands and reconstructing the room geometry

The human skin



The human skin ... more



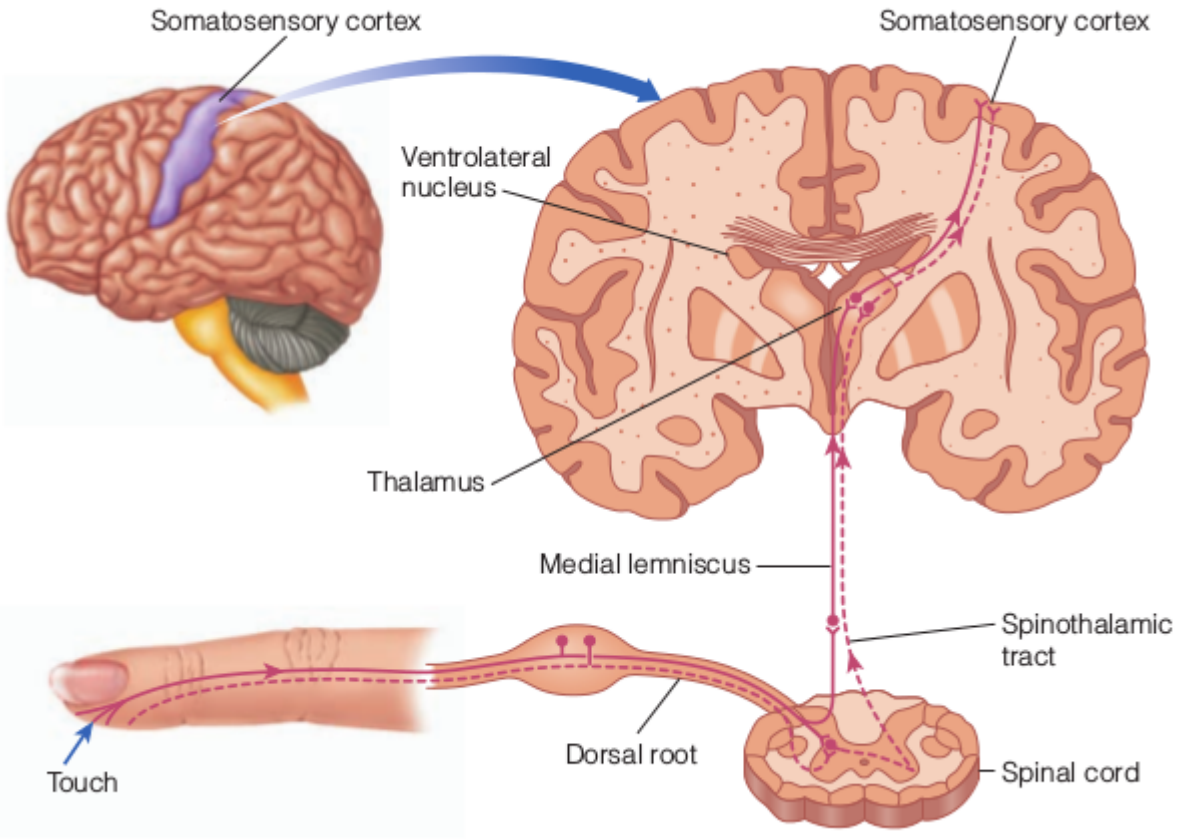
Summary

Neural Channel[a]	SA I (NP III)	RA (FA I, NP I)	SA II (NP II)	PC (FA II, P)
End Organ	Merkel Disk	Meissner Corpuscle	Ruffini Ending	Pacinian Corpuscle
Sensory Adaptation[b]	Slow	Fast	Slow	Fast
Receptive Field[c]	Small	Small	Large	Large
Frequency Range (Hz)[d]	< 5	3–100	15–400	10–500
Perceiving Property	Pressure, Fine Details	Flutter	Stretch	Vibration

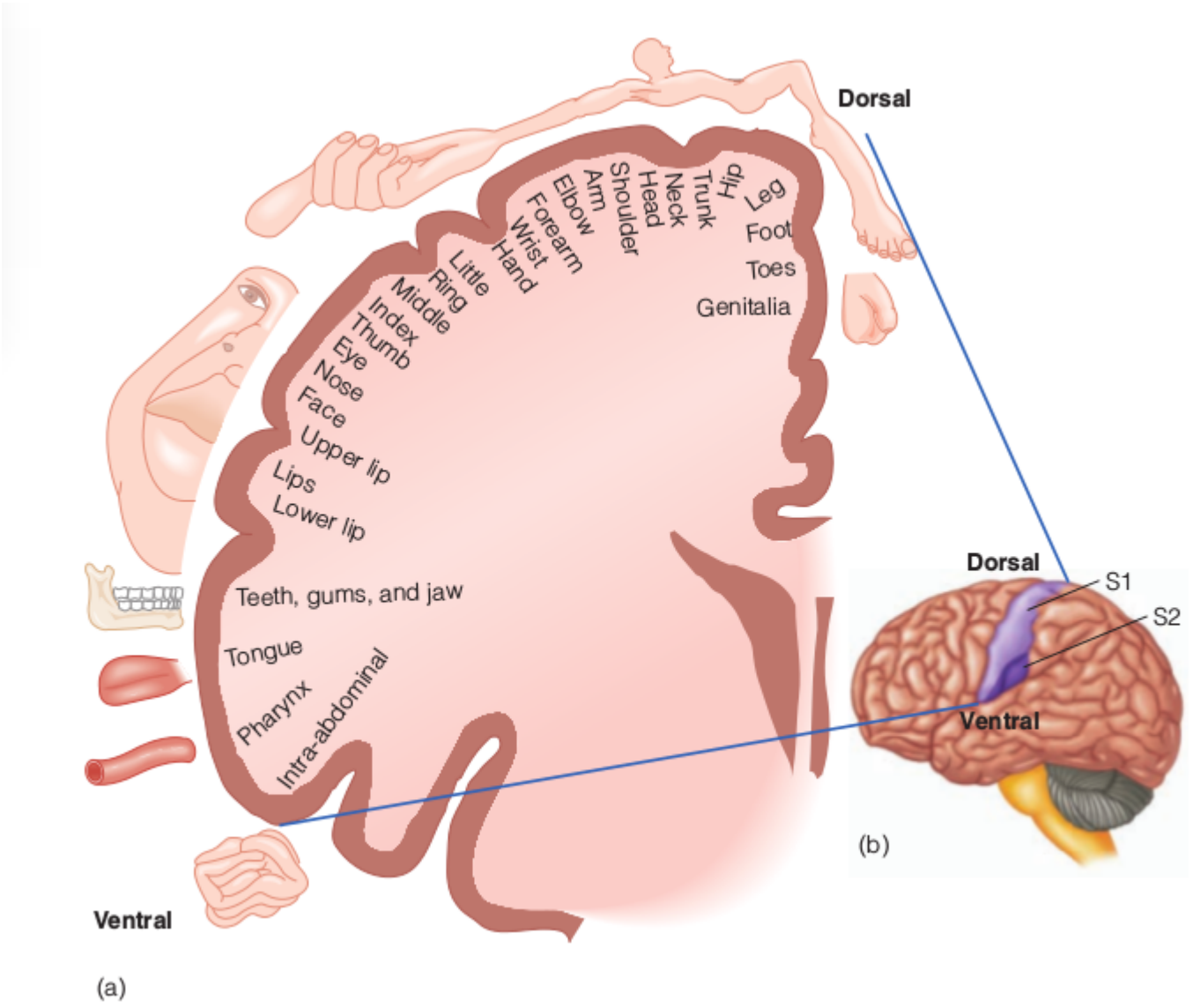
Tactile and haptic perception

- Tactile (touch based)
  - Tactile feedback is when you outfit a robot with touch/force/torque sensors, and use those sensors to provide feedback to the human operator about real forces the robot experiences as it encounters its environment.
- Haptic (pressure based)
  - Haptic feedback imparts forces on the operator, for instance by using a mechanically actuated joystick or other hand controller.

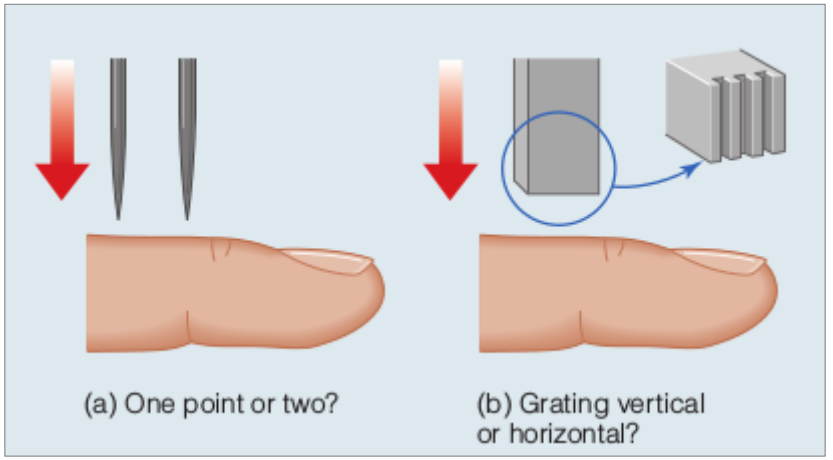
Pathway to the brain



Mapping of the body in brain

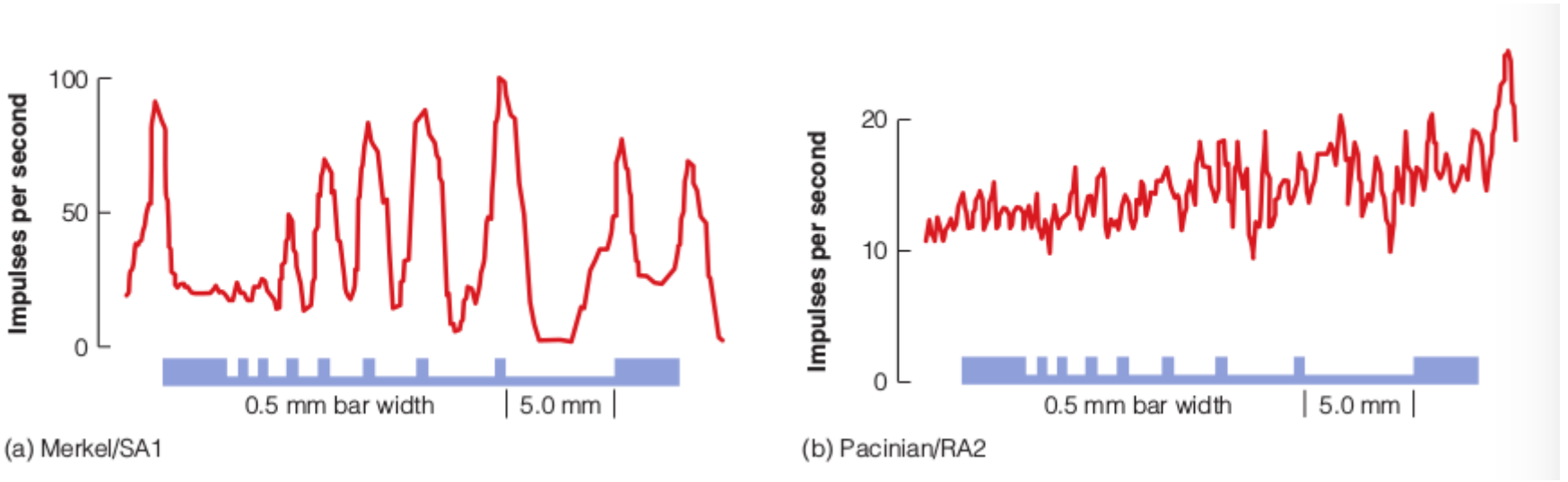


Spatial resolution

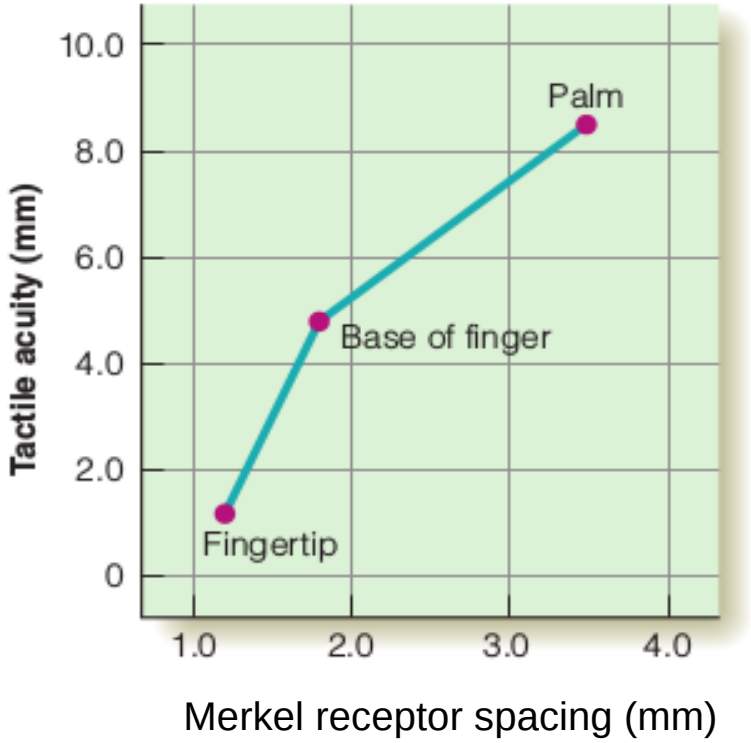


- Two point touch threshold
  - The smallest spatial separation between two stimuli applied to the skin that can be detected some arbitrary percentage of the time (e.g., 75%).
  - Whether a linear grating is applied horizontally or vertically
- Point localization threshold
  - A stimulus is presented to the skin, followed in time by a second stimulus that may or may not be applied to the same site.

Resolution by mechanoreceptors



Tactile acuity: Mechanoreceptor density

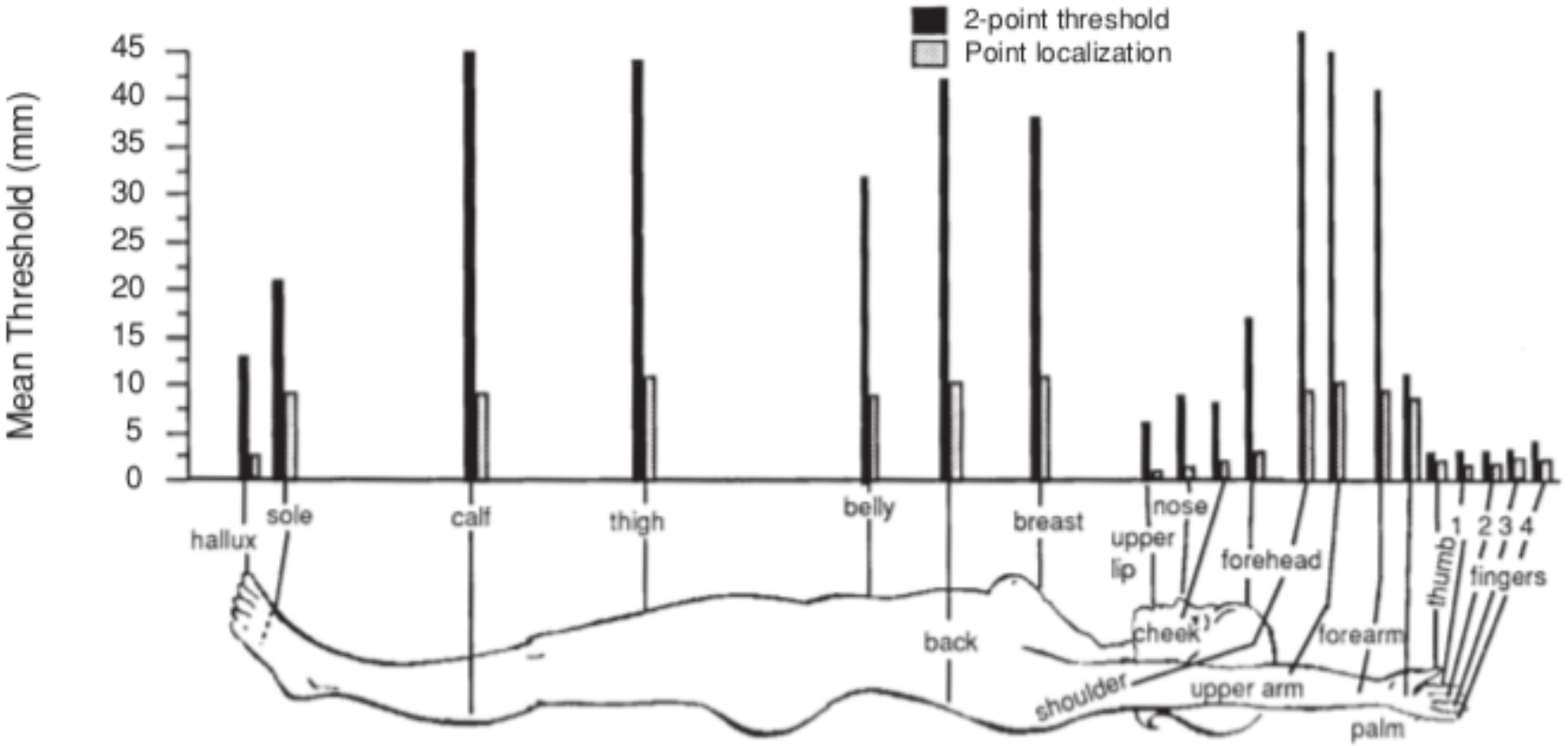


Cortical magnification also plays a role

Observations

- Two point thresholds are ~ 4 – 45 mm
  - With grating experiments, they are lower
- Localization thresholds are ~ 2 – 12 mm
  - Much smaller than two point thresholds
- Thresholds varies with part of the body
  - Lower on fingertips, nose, lips ...
  - Higher on back, chest, belly, forearm, thigh ...
  - Shows consistent pattern on male and female bodies
- The spatial resolving power of the skin is poorer than the eye's but better than the ear's.

Resolution at different parts of human body



Source: L ederman and Klatzky

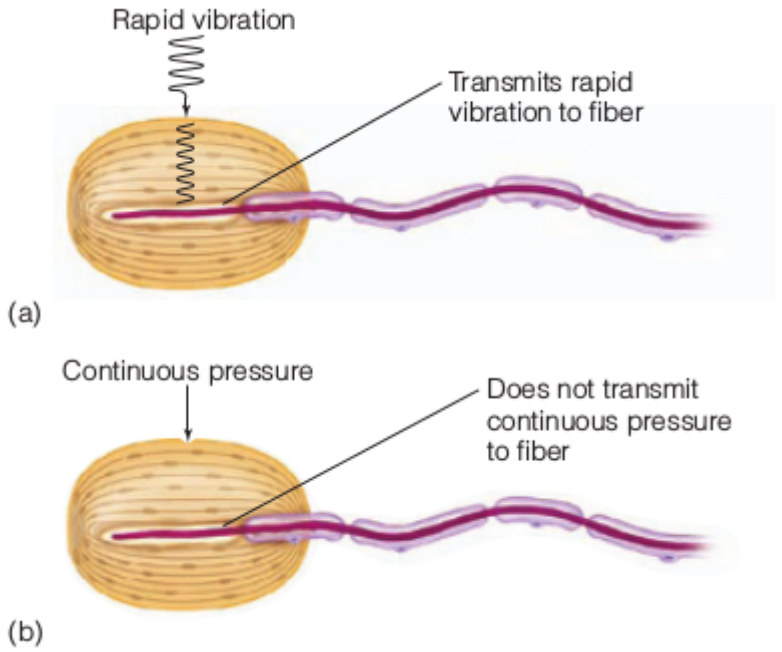
- Shows consistent pattern on male and female bodies

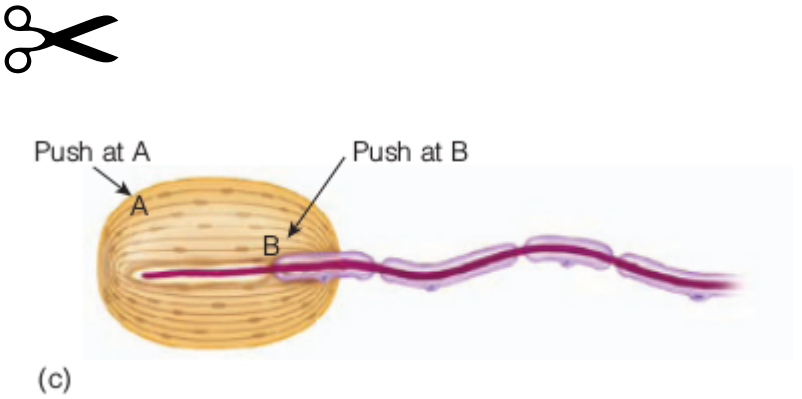
Temporal resolution

- People can resolve a temporal gap of 5 msec between successive taps on the skin

- The temporal resolving power of the skin is better than that of vision, but worse than that of audition

Perceiving vibration





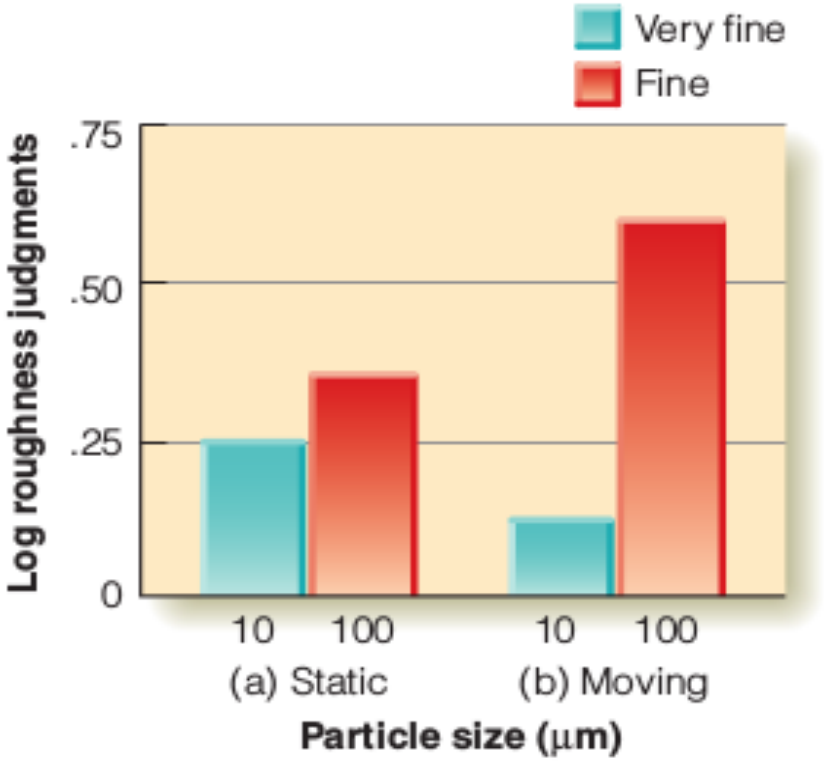
Pacinian corpuscles

Perceiving texture
coarseness of surface

- Perception of texture depends on *Katz 1925*
  - Spatial cues
    - Large surface elements, e.g. a protrusion / a groove
    - Useful for perceiving shape / size, Braille dots
    - When skin presses against the surface (pressure)
  - Temporal cues
    - Coarse surface, e.g. sandpaper, fabric
    - When skin moves over the surface (vibration)

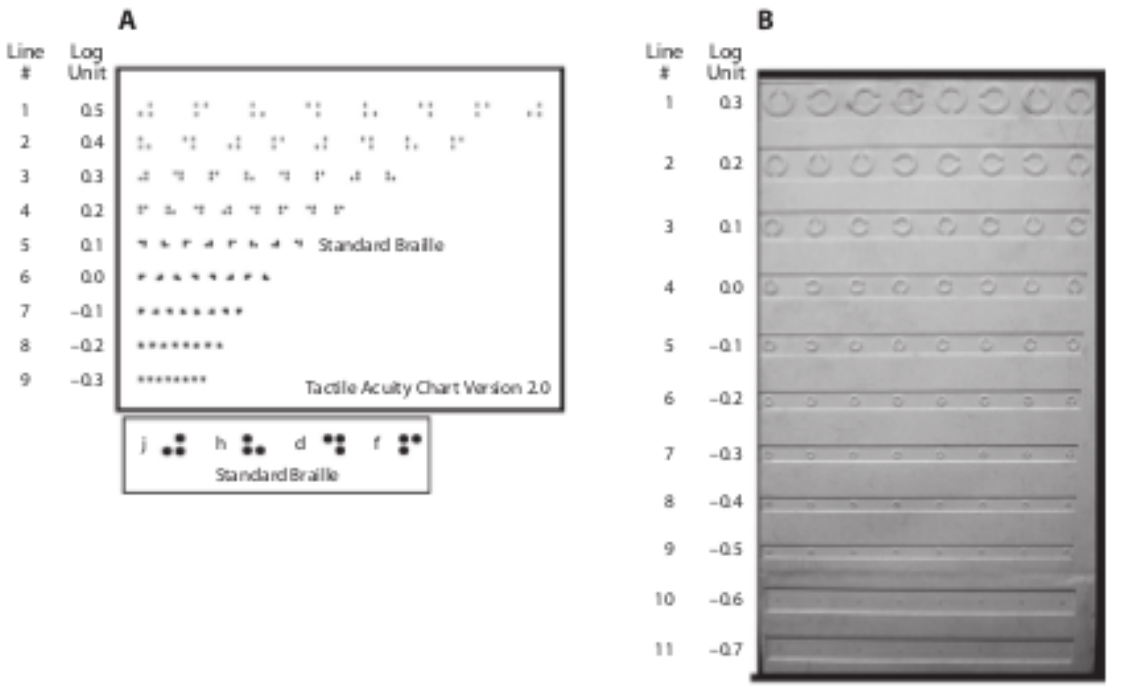
Perceiving texture ... more

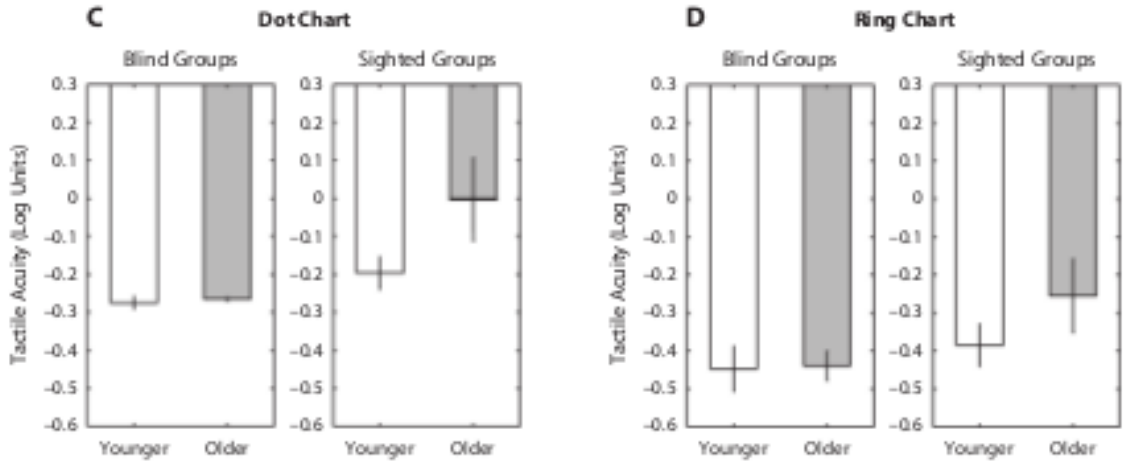
- Experimentation on temporal cues



Hollins and Reisner 2000

Surface Texture: age, disablity and perception





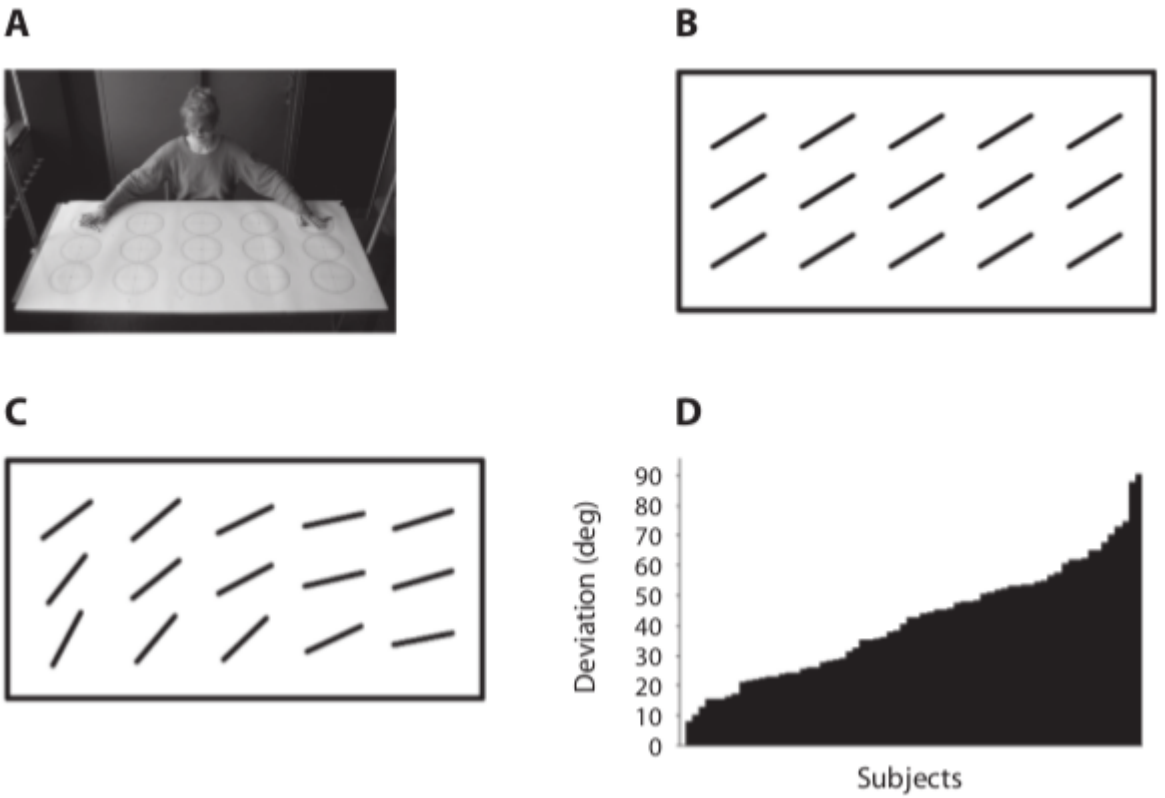
Source:
Lederman and Klatzky

Perceiving oreintation

- Horizontal / Vertical orientations are easier to compare (perceptually) than oblique ones
  - Two frames of reference (body and space) – more computation
  - Depends on position with respect to the body

Source:
Lederman and Klatzky

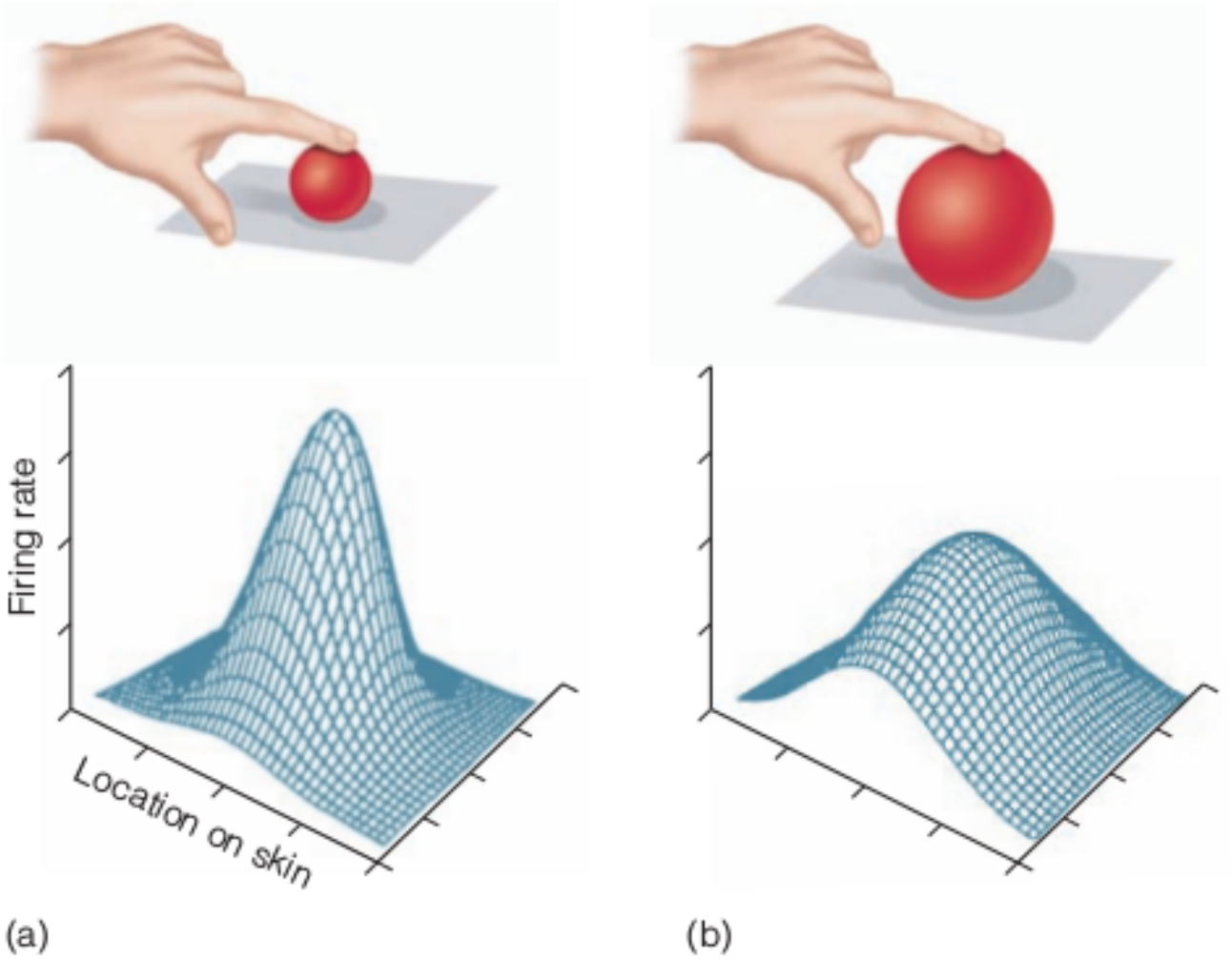
- Vertical lengths are assessed longer than vertical ones
- Distances away from the body are assessed longer than the tangential direction



Geometric properties (size and shape)

- Small objects (Fits on a finger-tip)
  - Local indentation on skin reveals shape
- Bigger objects
  - Both cutaneous and kinesthetic inputs (mechanoreceptors)
  - Varying local pressure on skin $\rightarrow$ curvature
- Perception depends on
  - Convex or concave
  - Position of stimulus on hand
  - Movement of hand over the surface ...

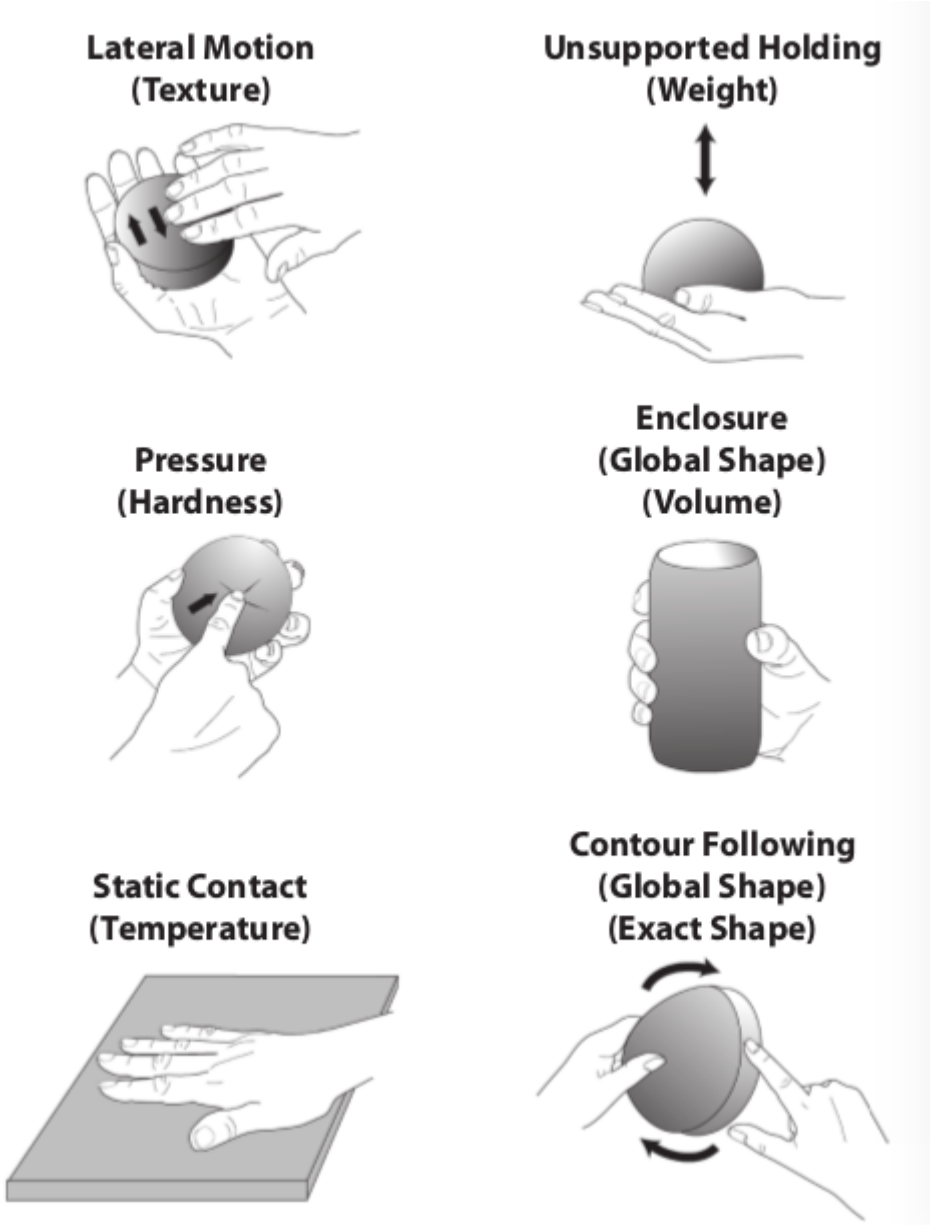
Perception of curvature



Perceiving objects

- Most of the everyday use objects can be identified with touch
  - The great grand-mother who has lost her eyesight can do a 'face recognition' with her fingers.
- Most of the research so far has centered around passive touch
  - Not active exploration

Exploratory processes

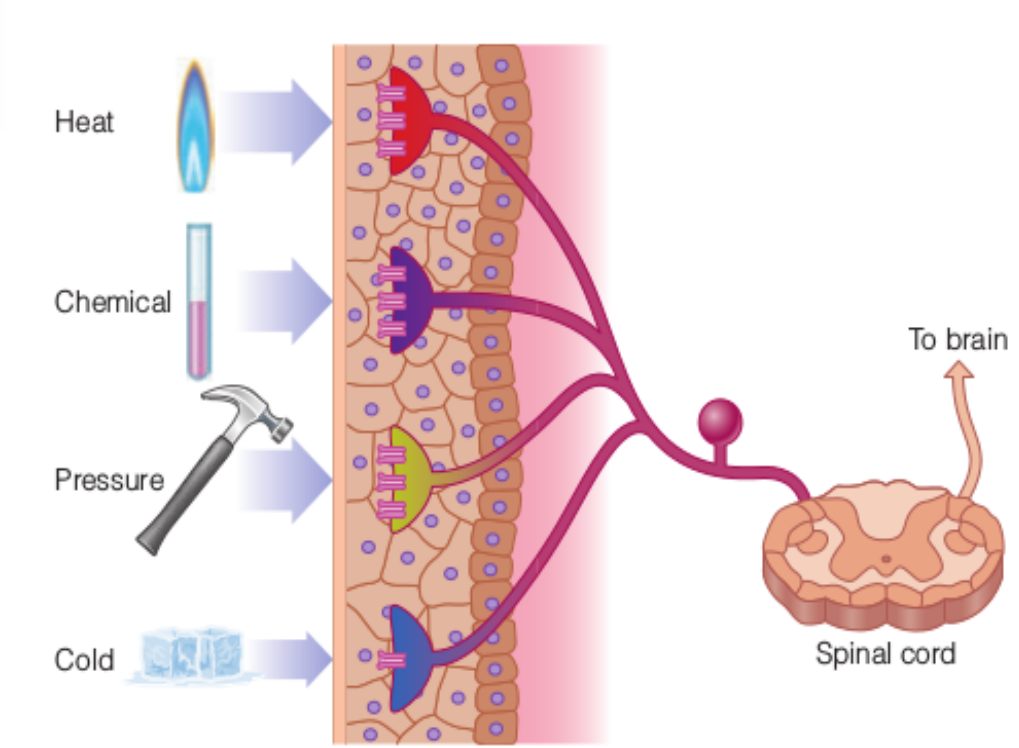


- Time to execute
- Capability
- Accuracy

Source:
Lederman and Klatzky

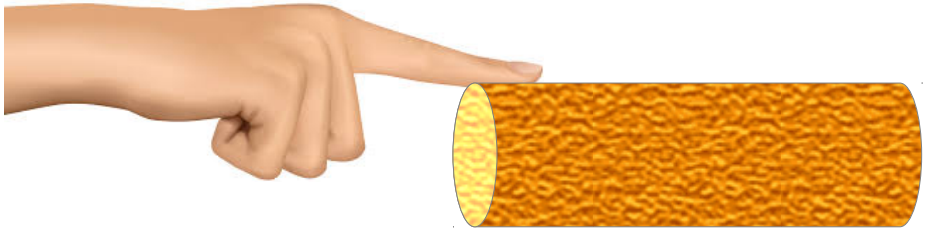
Feeling the pain

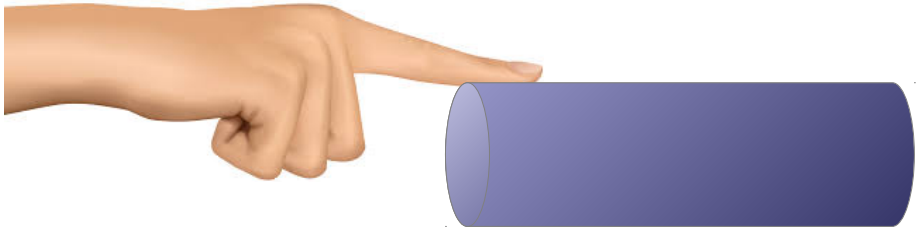
- **Nociceptive pain**
  - Caused by activation of receptors in the skin called nociceptors.
- **Inflammatory pain**
  - Caused by damage to tissues and inflammations to joints or by tumor cells.
- **Neuropathic pain**
  - Caused by lesions or other damage to the nervous system.



Perception of pain depends on mental state of a person.

Perceiving material





Thermal cue: The rate of heat dissipation

WEBER LAW / WEBER-FECHNER LAW: A Computational Model of perception

Can the user distinguish between the different vibrotactile cues being displayed?

Relationship between the physical magnitude of a stimulus and its (subjectively) perceived intensity

- The minimum change in a stimulus that can be detected is proportional to the current value of the stimulus

$$\Delta p = k\frac{\Delta S}{S} \qquad \frac{dp}{dS} = k\frac{1}{S} \qquad p = k\log S + C$$

k = Weber fraction

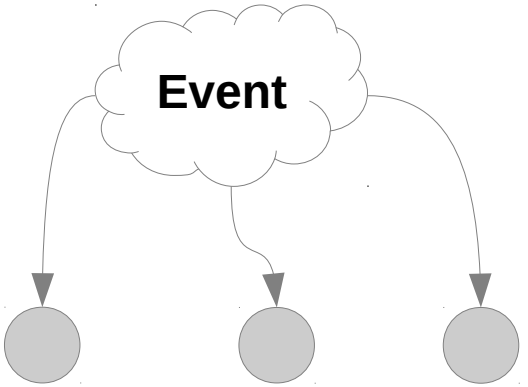
- To solve for C

$0 = k\log S_0 + C$ [Threshold stimulus] $\qquad p = k\log\frac{S}{S_0}$

- Subjective sensation is proportional to the logarithm of the stimulus intensity, measured in proportion to threshold stimulus

- **Holds for all modalities – visual, audio, haptics (approximately)**

Multimodal perception



- Supportive / contradictory signals
- Combining
  - Weighted sum
  - Expectation maximization

Higher level interactions

References

- Goldstein (e-book)
- MacLean. Haptic Interaction Design for Everyday Interfaces (chapter) http://web.stanford.edu/class/me327/readings/1-MacLean08-RHFE-Design.pdf
- Lederman and Klatzky: Haptic perception: A tutorial. http://www.queensu.ca/psychology/lederman/Publications/175.pdf