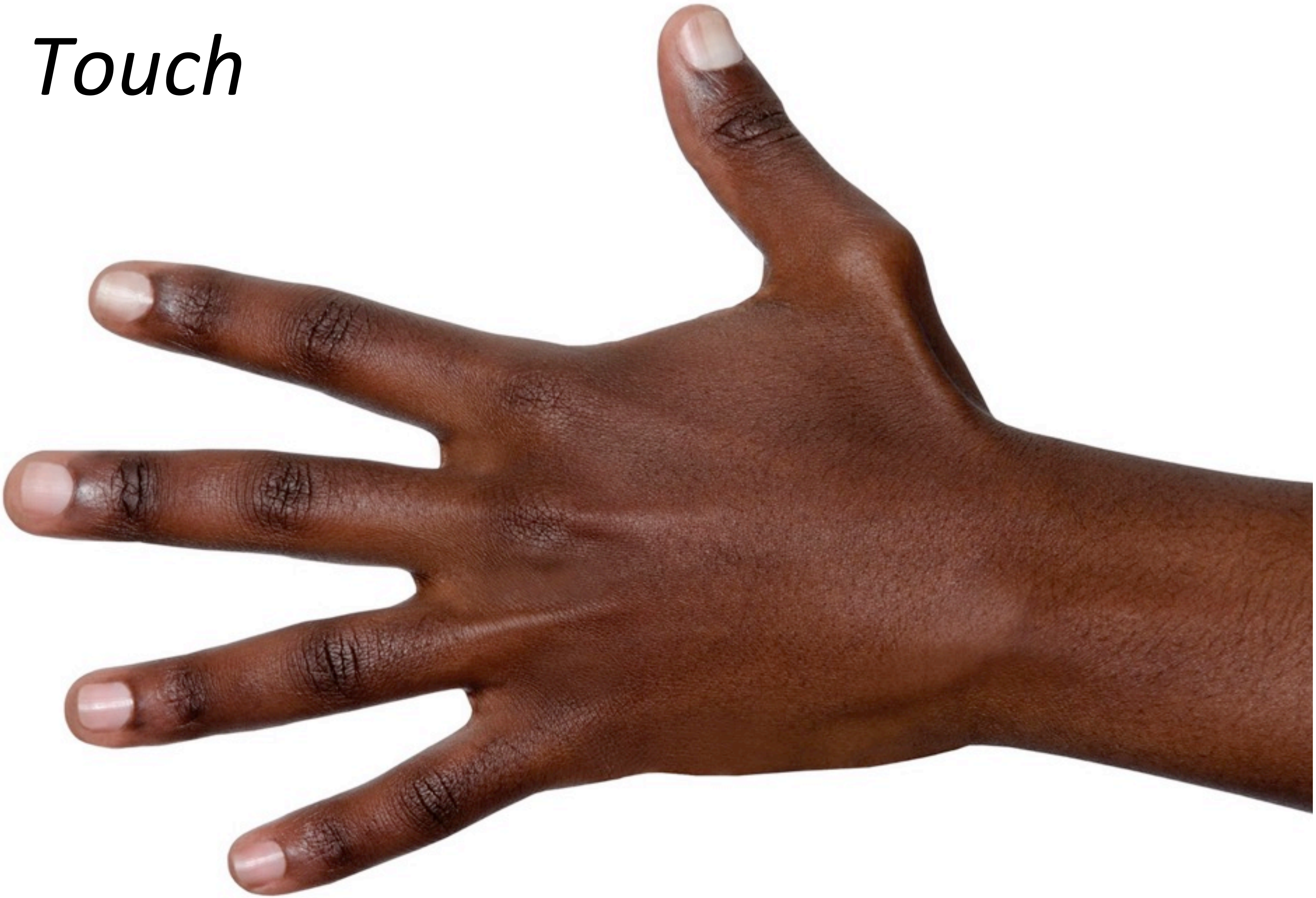
Tassu Takala 2019

Emergent User Interfaces
CS-E4200

Introduction to Multimodal Interaction 1b
–
Haptics (tactile)

these slides adapted from 2018 course materials
https://mycourses.aalto.fi/course/view.php?id=16936&section=1 (David McGookin)
https://mycourses.aalto.fi/course/view.php?id=16924&section=1 (Mark Billinghurst)

Touch



Touch

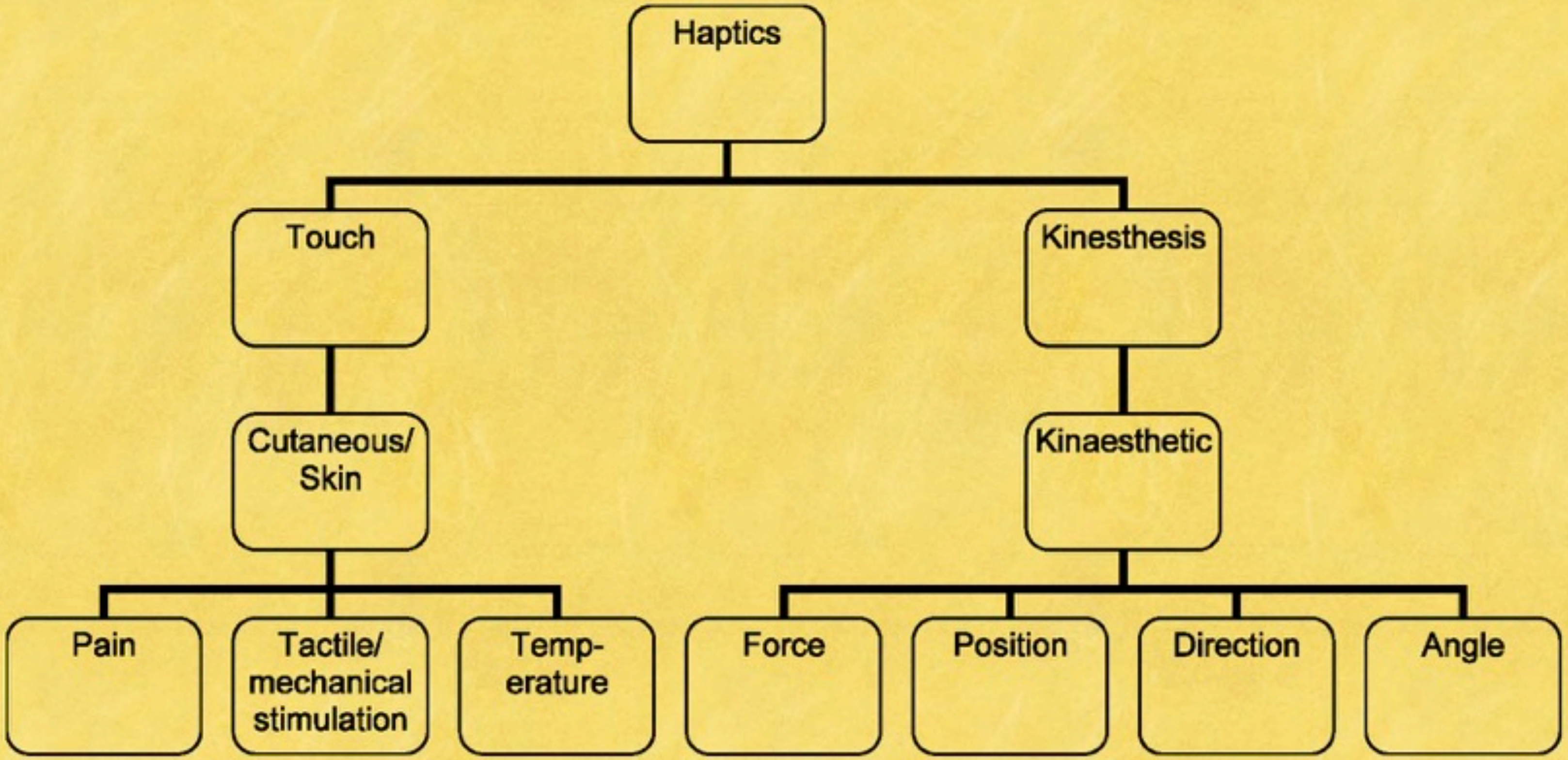
- What is haptics?
- How do we sense touch?
- How do we generate touch?
- What can we do with it?

Haptics

- Haptics: To do with the sense of touch
- Two parts:
  - Kinaesthesia: Sense and motor activity based in the muscles, joints and tendons
  - today → Cutaneous/(touch): Sense based on receptors in the skin

From new ISO Tactile/Haptic standard 9241-910

Haptic Overview



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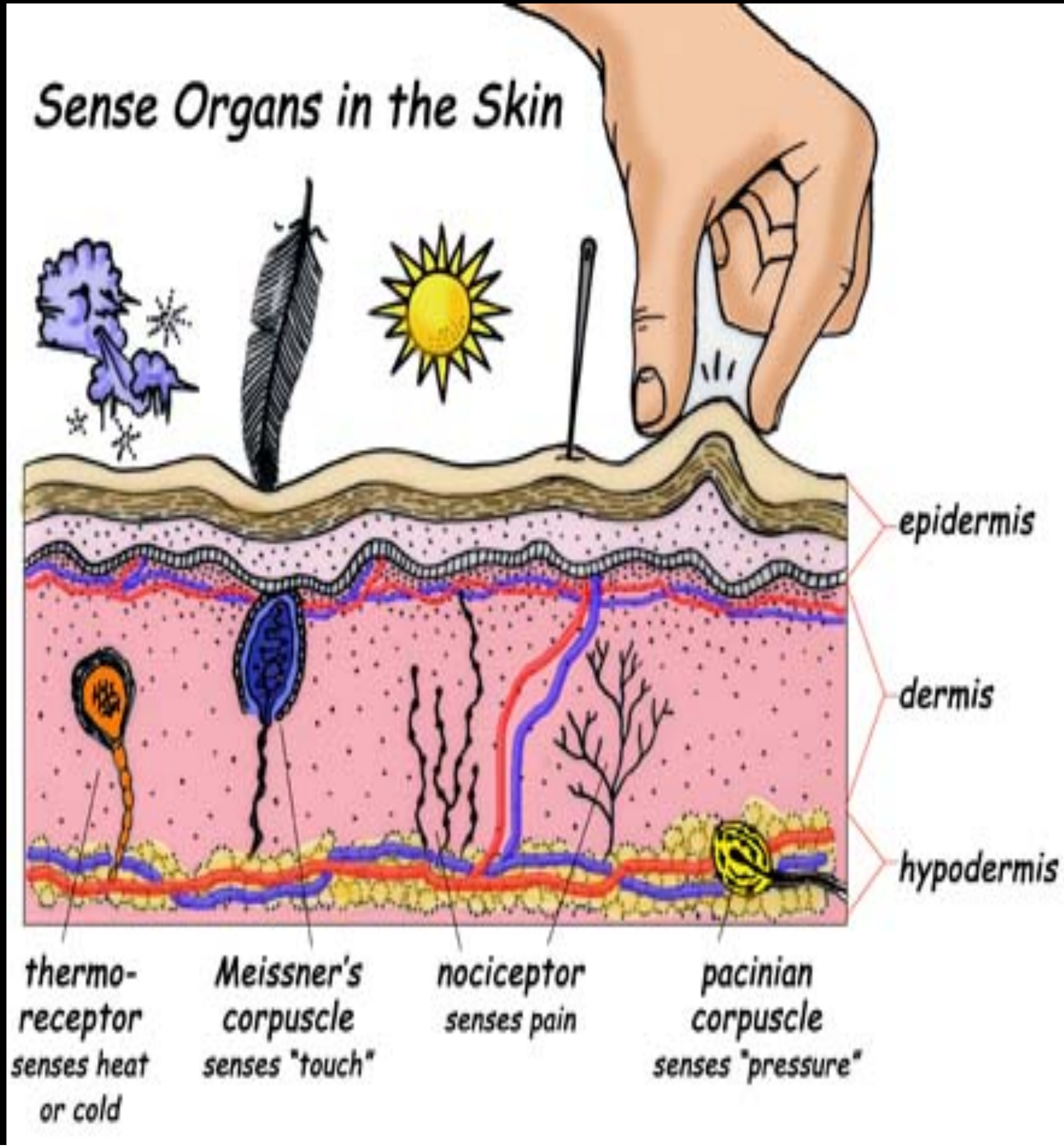
Anatomy of the Skin

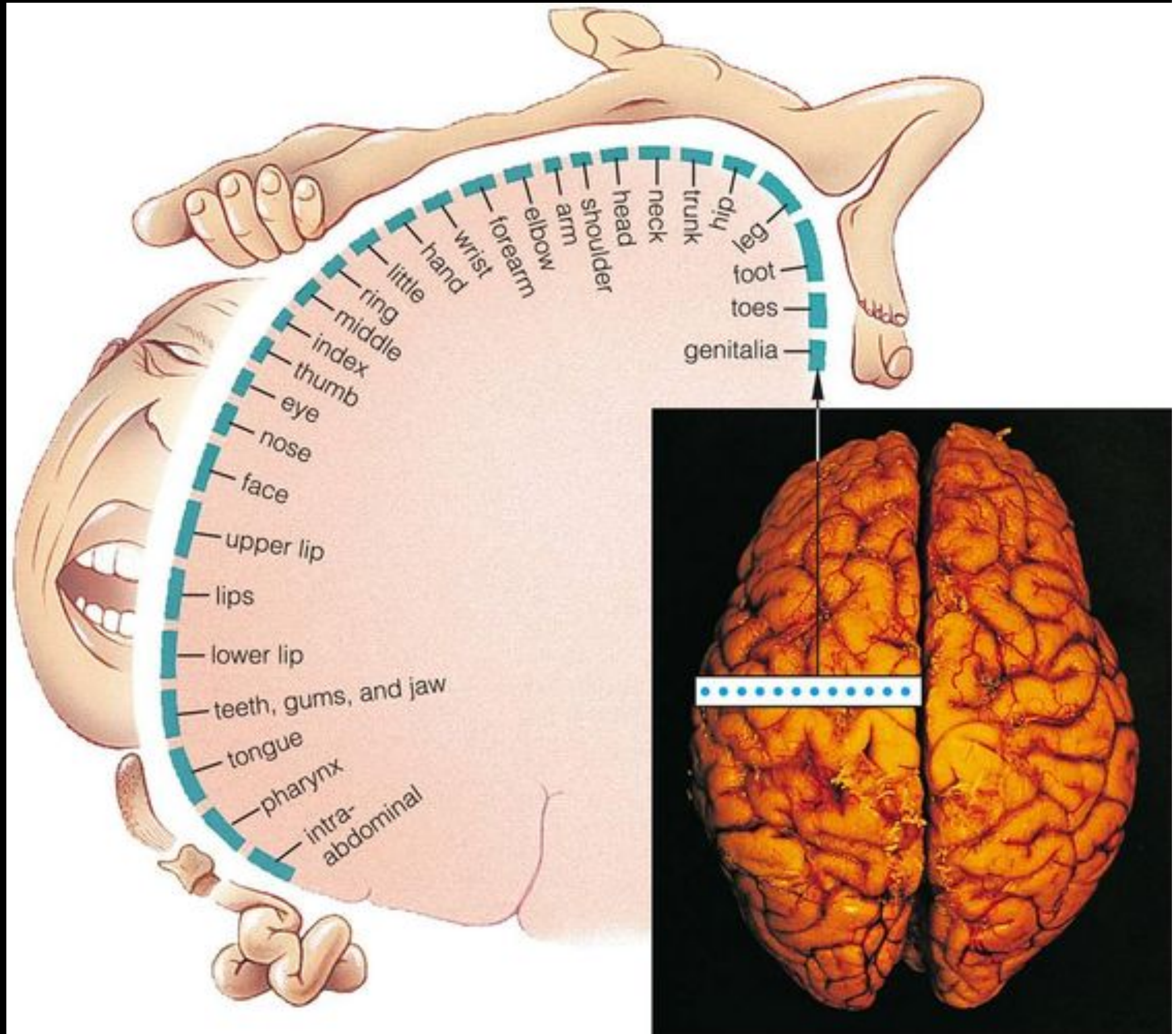


Touch

- Mechanical/Temp/Pain stimuli transduced into neural Action Potentials (AP)
- Transducing structures are specialized nerves:
  - Mechanoreceptors: Detect pressure, vibrations & texture
  - Thermoreceptors: Detect hot/cold — in skin
  - Nociceptors: Detect pain
  - Proprioreceptors: Detect spatial awareness – in muscles
- This triggers an AP which then travels to various locations in the brain via the somatosensory nerves

Somatosensory System

Map of somatosensory areas of the brain, showing more area for regions with more receptors

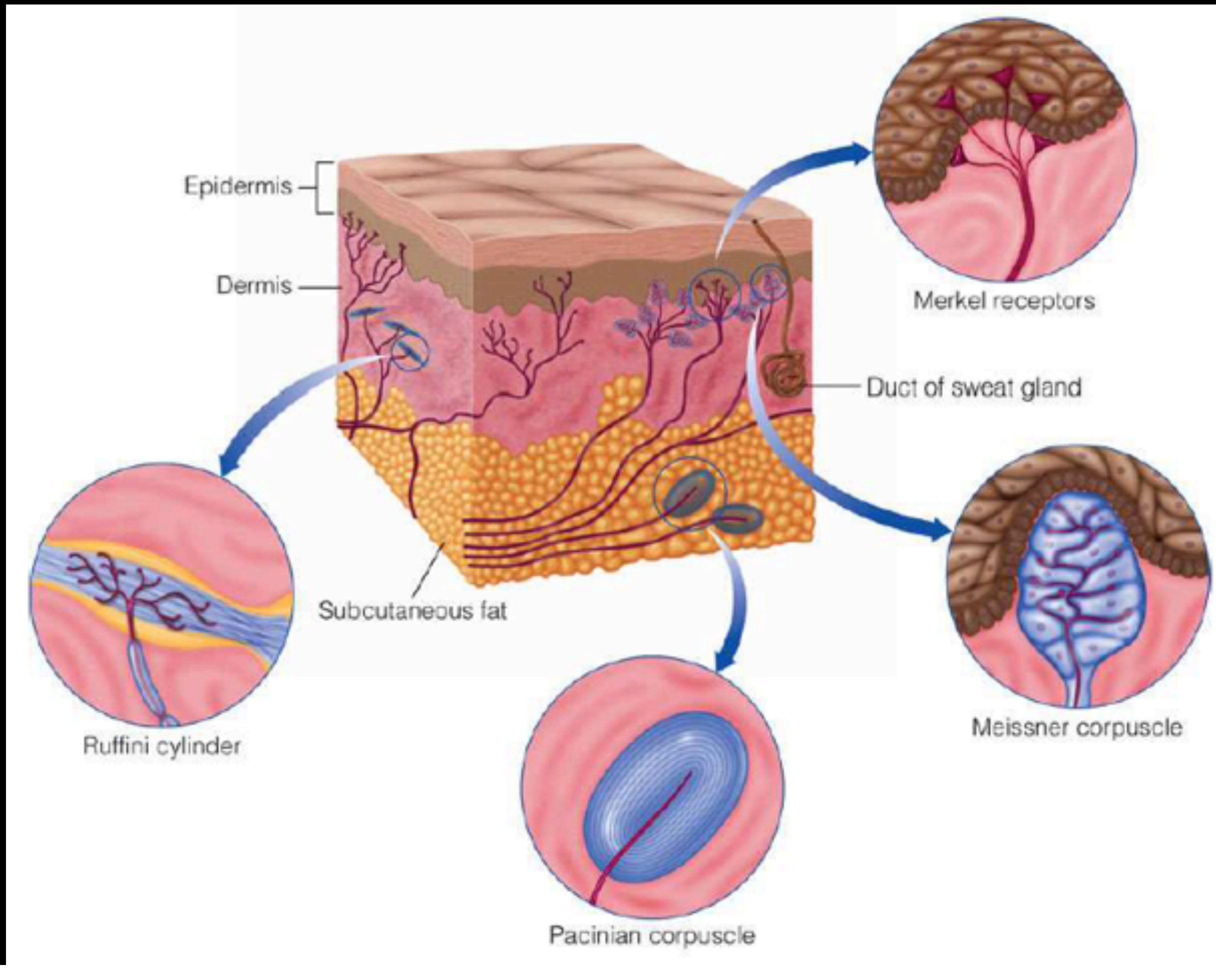


Haptic Sensation

- Somatosensory System
  - complex system of nerve cells that responds to changes to the surface or internal state of the body
- Skin is the largest organ
  - 1.3-1.7 square m in adults
- Tactile: Surface properties
  - Receptors not evenly spread
  - Most densely populated area is the tongue
- Kinesthetic: Muscles, Tendons, etc.
  - Also known as proprioception

Cutaneous System

- Skin – heaviest organ in the body
  - Epidermis outer layer, dead skin cells
  - Dermis inner layer, with four kinds of mechanoreceptors



Mechanoreceptors

- Cells that respond to pressure, stretching, and vibration
  - Slow Acting (SA), Rapidly Acting (RA)
  - Type I at surface – light discriminate touch
  - Type II deep in dermis – heavy and continuous touch

Receptor Type	Rate of Acting	Stimulus Frequency	Receptive Field	Detection Function
Merkel Discs	SA-I	0 – 10 Hz	Small, well defined	Edges, intensity
Ruffini corpuscles	SA-II	0 – 10 Hz	Large, indistinct	Static force, skin stretch
Meissner corpuscles	RA-I	20 – 50 Hz	Small, well defined	Velocity, edges
Pacinian corpuscles	RA-II	100 – 300 Hz	Large, indistinct	Acceleration, vibration

Spatial Resolution

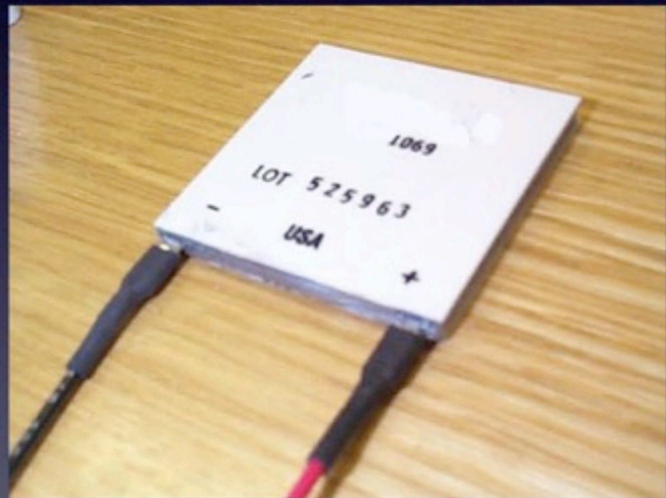
- Sensitivity varies greatly
  - Two-point discrimination

Body Site	Threshold Distance
Finger	2-3mm
Cheek	6mm
Nose	7mm
Palm	10mm
Forehead	15mm
Foot	20mm
Belly	30mm
Forearm	35mm
Upper Arm	39mm
Back	39mm
Shoulder	41mm
Thigh	42mm
Calf	45mm

http://faculty.washington.edu/chudler/chsense.html

Temperature

- Believed to be similar detected with skin based sensors
  - More cold than hot
- Complex interactions
- Temperature adapts to exposure
- Generated using a Peltier pump
  - Thermoelectric effect



- Wettach et al. (2007) found 5 levels of discriminable heat could be used in a navigation task.
  - Different temperatures as the user wandered off track

Stimulation

- Many ways to computer stimulate mechanoreceptors
- Low cost, mobile, easy to program and use.
- BUT All ways are quite low-fi in comparison to the somatosensory system.
- ~1mm spatial duration
- ~4ms temporal resolution

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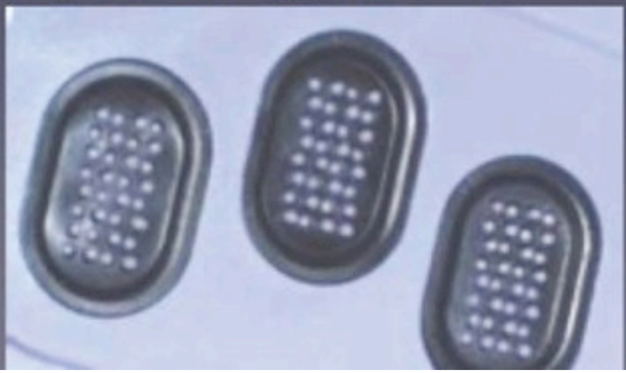
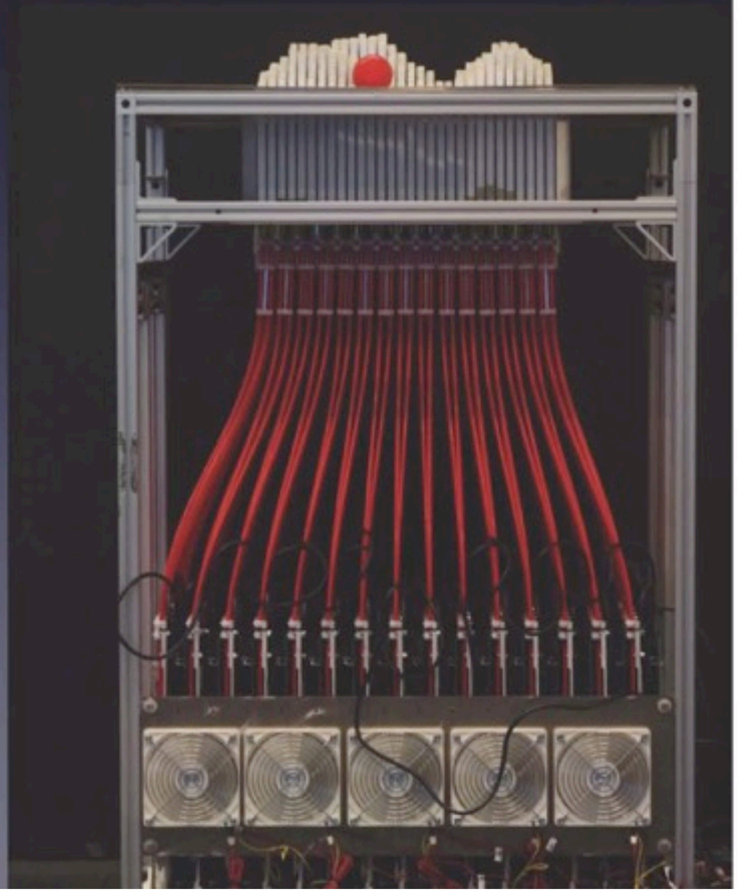
Mechanical Stimulation

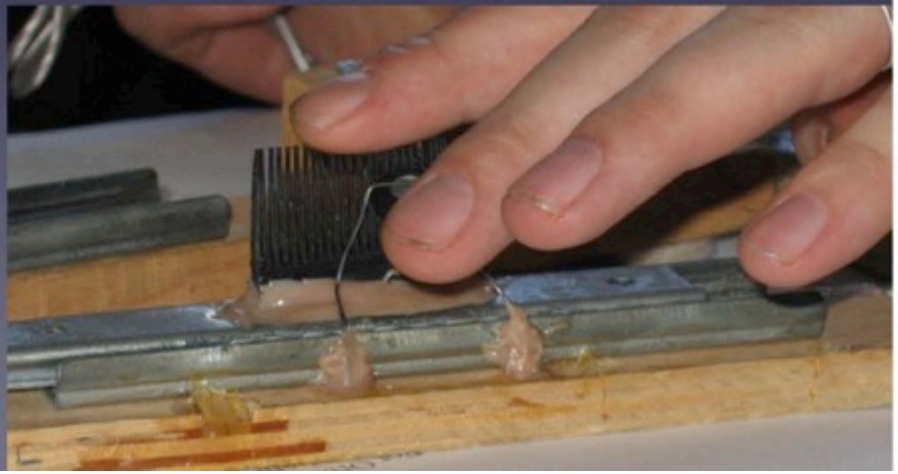
- Pin Arrays
  - Mechanical Pins move up and down
  - Can be binary or multilevel
  - Used for Braille Cells
  - Big scaling issues





Lateral Skin Stretch

- Hayward et al.
- Uses plates that are deflected based on electrical current
- Provides the same sensation of a tactile array
- BUT with less space



Vibration

- Most common way to communicate information
- Cheap
- Cruder than pin arrays
- Lower Density
  - Not localised

Vibration Motors

- An offset weight on a motor
- Most common technology to present vibration
- Cheap and Crude
- Mostly simple uses
    - e.g. games, phones etc.
    - Gives the feeling of something happening, but not what or where

Vibrotactile

- Small speaker like devices
  - Operate at frequencies lower than audible sound
  - Respond to a smaller set of frequencies than sound

Vibrotactile

C2 Tactor

$230, 200 - 300 HZ

Tactaid VBW32 actuator

$90, 100 - 800 HZ

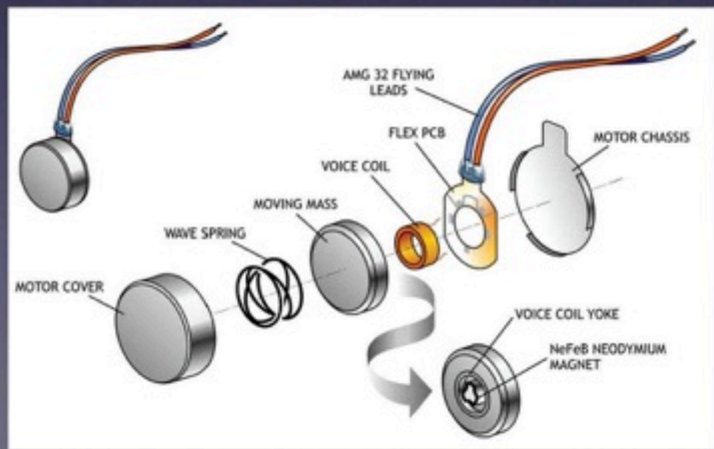
Example: CyberTouch Glove

- Immersion Corporation
  - Expensive - $15000
- Six Vibrotactile actuators
  - Back of finger
  - Palm
- Off-centered actuator motor
  - Rotation speed=frequency of vibration (0-125 Hz)
- When tracked virtual hand intersects with virtual object, send signal to glove to vibrate

http://www.cyberglovesystems.com/cybertouch/

Pietzo Electric

- A loudspeaker with a mass
- Electric charges cause the mass to move
- Pulse the charges and it vibrates
- Were included in devices for a long time without being used
- Provides a much closer to "clicking" sensation



Pietzo Electric

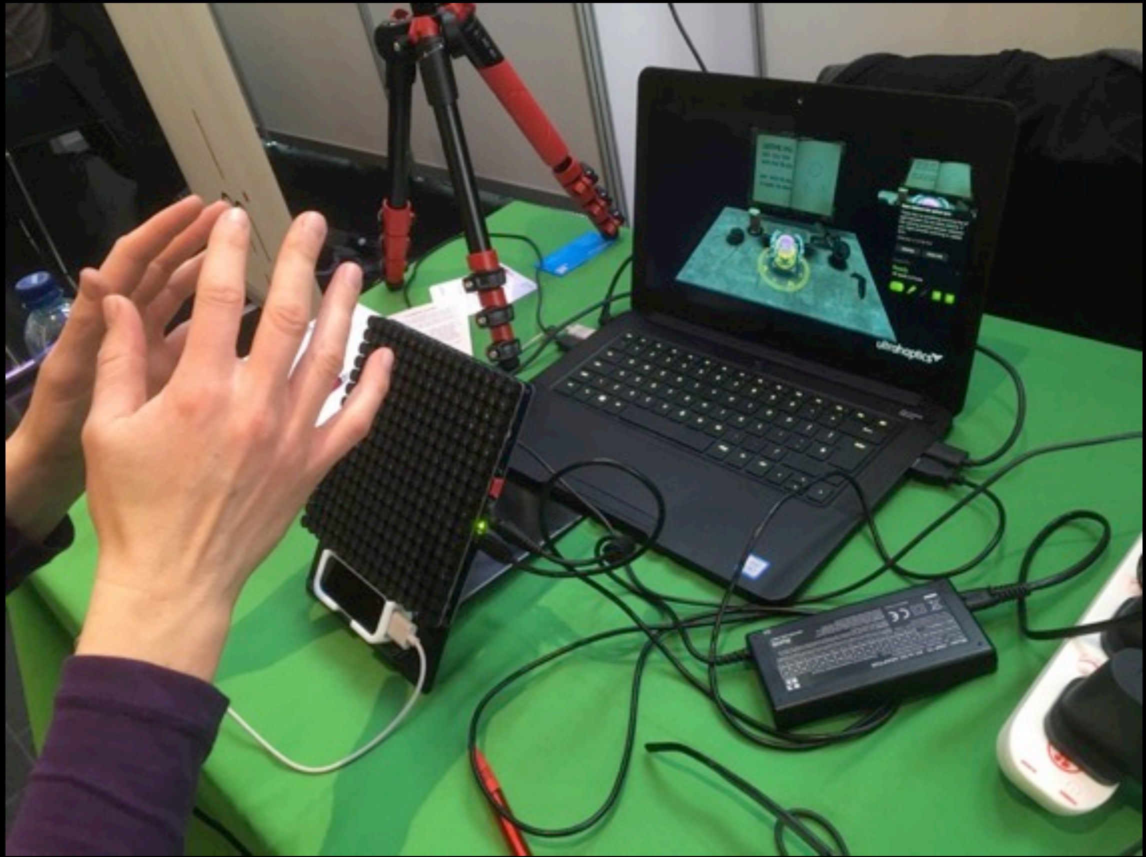
- Greater sense of "feeling" something physical
  - Fast "ramp-up"
- More precise control than vibrotactile
- Can provide virtual button feedback to touchscreens
- Used on Apple iPhones (called a 'taptic engine')

UltraHaptics

- A fairly new technology using Ultrasound
  - Higher than human hearing
- Researchers found that if they focus and integrate the waveforms of multiple ultrasonic transducers they could create physical effects
- Same as audio
- Pressure variations are created that can be physically felt, or used to levitate objects
- But low powered and physically bulky
- Not (yet) practical to be used.

UltraHaptics – tactile display without wearables

- Panel of ultrasonic transmitters makes directed wave field
- Concentrations at hands feel like light touch



Vibration Summary

Technique	Description	Pros/Cons
Vibrotactile Transducer	Similar technologies to loudspeakers	Limited Frequency Range Localised vibration
Pietzo-Electric	Vibrotactile transducer attached to a mass	Localised and controllable vibration.
Off-center motor	Off-center weight attached to a spinning	Very inexpensive Don't need direct contact
Pin Array	Mechanical Pins move up and down	Expensive for high density Doesn't scale well
Lateral Skin Stretch	Lateral stretching of the skin simulation pin array	Research prototype Usable in mobile scenarios

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What to do with this

- Probably familiar with ringtone vibration
- game vibration
- But a lot more you can do and use vibration for.
- Similar reasons for audio
  - eyes-free, visual attention elsewhere, noisy environment

Tactons

- Structured tactile messages that can be used to communicate information non-visually (Brown 2005)
- Similar to Earcons
    - Change Tempo, Rhythm, Waveform, Location

Cross-Modal Icons

- Combined Earcons and Tactons
- Can design cues so that training on one, is also training on the other
- Rythym, spatial location (around the waist) and roughness of the waveform
    - Roughness was metaphorically mapped in audio
    - Participants trained on one modality and tested on the other
- Small but not significant drop in performance
- Can dynamically change the one to present based on the circumstances.

Tacton Button Example

- Touchscreens have no tactile button feedback

- Easy to mispress keys and to have errors
- Compared performance of real buttons with tactile touchscreen
- As good as real buttons

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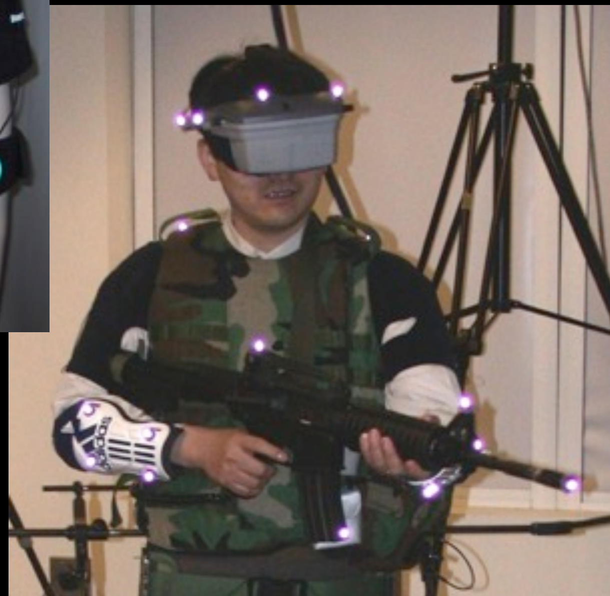
Vibrotactile Feedback Projects

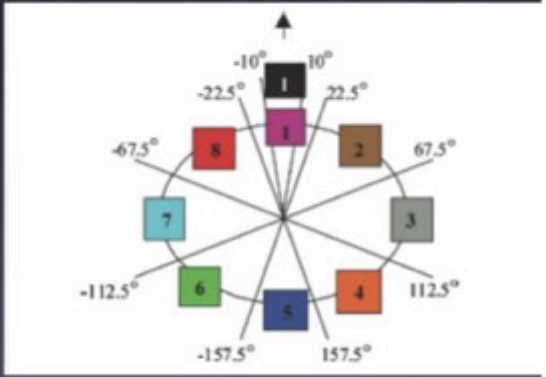
Navy TSAS Project

TactaBoard and TactaVest



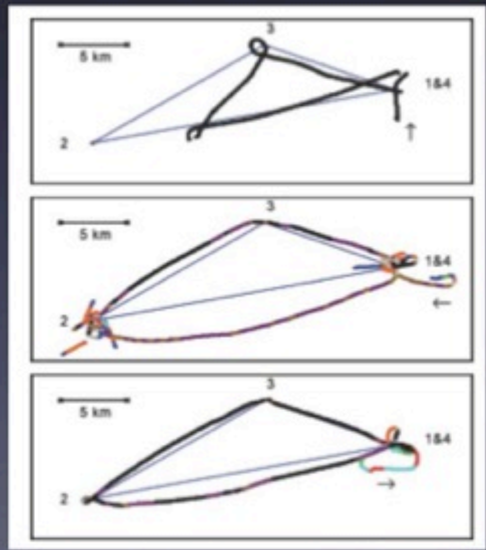
Navigation

- van Erp and van Veem
- Communication of direction & distance
  - e.g. a cockpit or helicopter pilot
- Participants wore a tactile belt
- Tried pedestrian, helicopter pilot, boat
- Found it easy and possible to steer to waypoints - assuming that there were enough granularity.



Navigation

- Harder to determine distance
  - Either difficult
  - Or not very important
- Some issues with granularity



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Pet Communication

https://www.youtube.com/watch?v=2Q9nwjWivZk

Personal Communication

- Touch is an intimate interaction
- You usually don't just touch someone!
- Shake - to - talk
- The Hug Shirt
  - Sending a wireless hug "hug" over a phone to a shirt with pager motors

Fig. 1. The interaction with Shake2Talk

Hoggan, Eve, et al. "Pressages: augmenting phone calls with non-verbal messages." *Proceedings of the 25th annual ACM symposium on User interface software and technology*. ACM, 2012

Pressages

- Hoggan et al. (2012)
- PREssure meSSAGES
- Combines force sensing on device with tactile output at the other end
  - Prior work only looked at receiving messages
- As users squeeze on the device, this is translated to a vibration
- Force used is translated to particular vibration patterns
  - Smooth (purr) for slight squeeze, to harder for rough

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Conclusions

- We've covered 1.5 modalities
- How they can be used in a Human Computer Interface
- What the benefits and drawbacks are.
- Next week we do the others