

# The Human Factor

**CS6501: Human-Computer Interaction**

Seongkook Heo

Fall 2020, Department of Computer Science

# The Human Factor

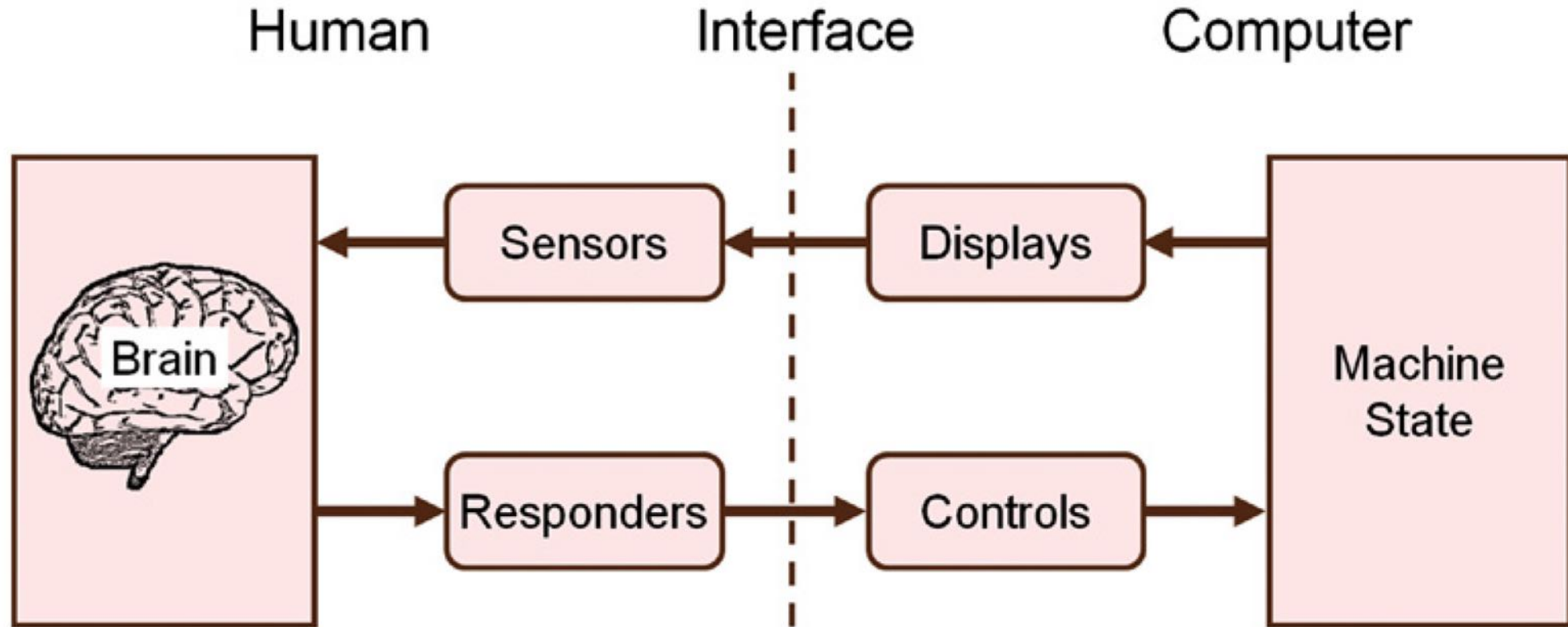
- Computers function according to their programmed capabilities.
- Humans are complicated and differ across many dimensions
  - Young, old, female, male
  - Experts, novices, strong, weak
  - Able-bodied, disabled, sighted, blind
  - Motivated, lazy, tired, alert
- No interface can work well for every user
  - “Know thy user” – Shneiderman and Plaisant, 2005, p66

# Understanding the Human

**The more we understand humans, the better are our chances of designing interactive systems that work as intended**

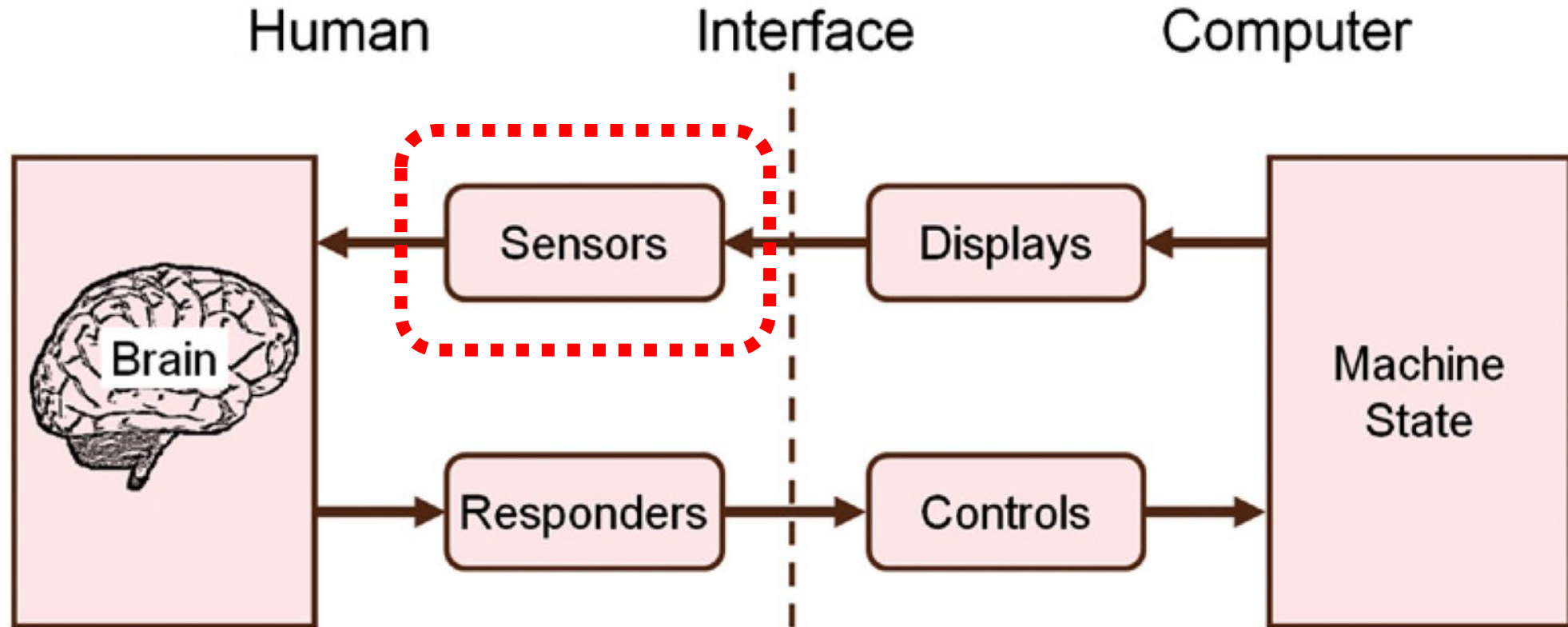
- Why do humans make mistakes?
- Why do humans forget how to do things?
- Why do humans get confused while installing apps on their computers?
- Why do humans have trouble driving while talking on a mobile phone?

# Human Factors Model



Kantowitz, B. H., & Sorkin, R. D. (1983).  
*Human factors: Understanding People-System Relationships*

# Human Factors Model

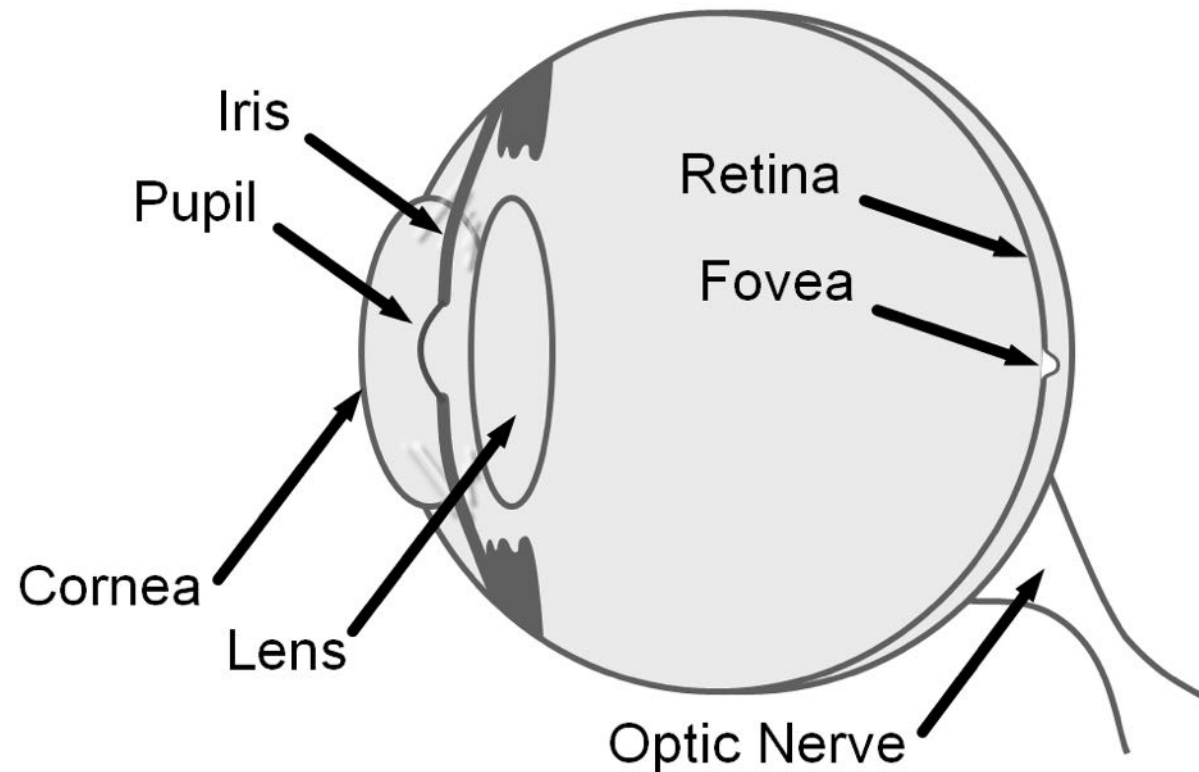


# Human Senses

- Vision (sight)
- Hearing (audition)
- Touch (tactition)
- Smell
- Taste

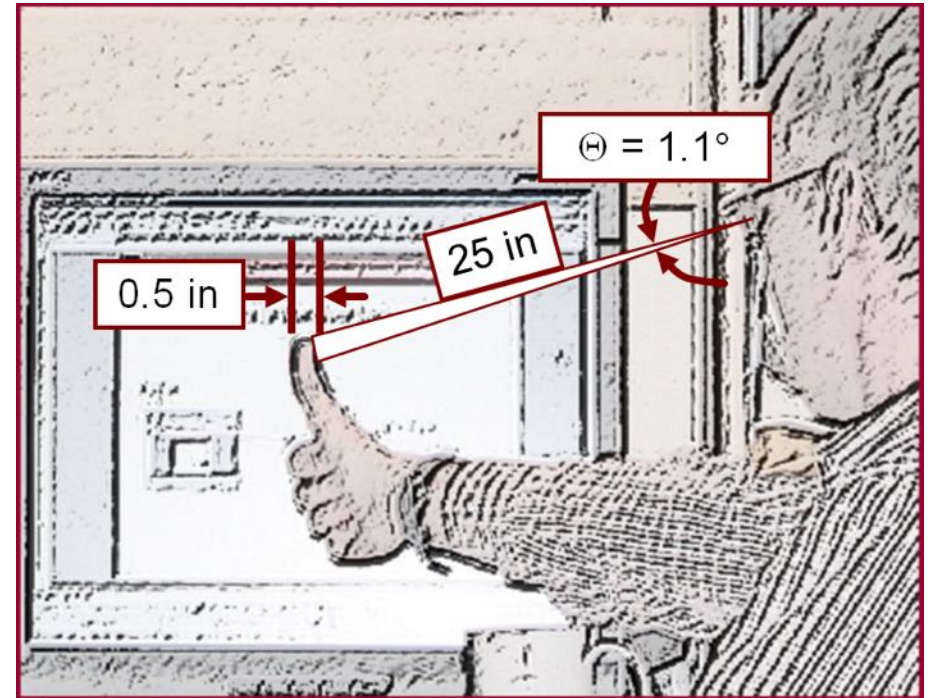
# Vision (The Eye)

- People obtain about 80% of their information through vision (the eye)



# Fovea Image

- Sharp central vision
- 1% of retina, 50% of visual cortex
- Fovea image is  $\approx 1^\circ$  of visual angle:





# Visual Stimulus

- Physical properties of light...
  - Frequency
  - Intensity (luminance)
- Create subjective properties of vision...
  - Color
  - Brightness

# Color Spectrum

Frequency  
(Hz)

$10^8$

AC  
circuits

$10^6$

Radio  
waves

$10^4$

$10^2$

$10^0$

Radar

$10^{-2}$

$10^{-4}$

Infrared

$10^{-6}$

Ultra-  
violet  
rays

$10^{-8}$

X-rays

$10^{-10}$

$10^{-12}$

Gamma  
rays

$10^{-14}$

Visible Light

Wavelength (nanometers)

400

500

600

700

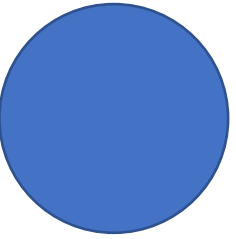
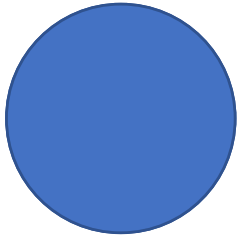


# Fixations and Saccades

- Fixation
  - Eyes are stationary (dwell)
  - Take in visual detail from the environment
  - Long or short, but typically at least 200 ms
- Saccade
  - Rapid repositioning of the eye to fixate on a new location
  - Quick:  $\approx 120$  ms

# Smooth Pursuit

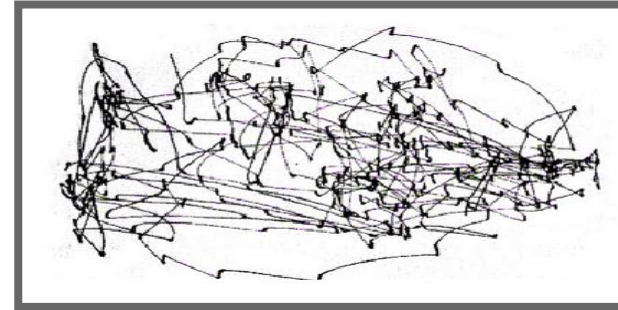
- Try to slowly shift gaze between the two objects



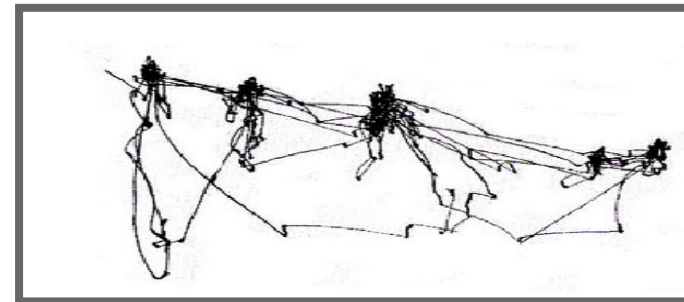
# Yarbus' Eye Tracking Research (1965)<sup>1</sup>



*The Unwanted Visitor*  
by Ilya Repin (1844-1930)



“Remember the position of people and objects in the room”



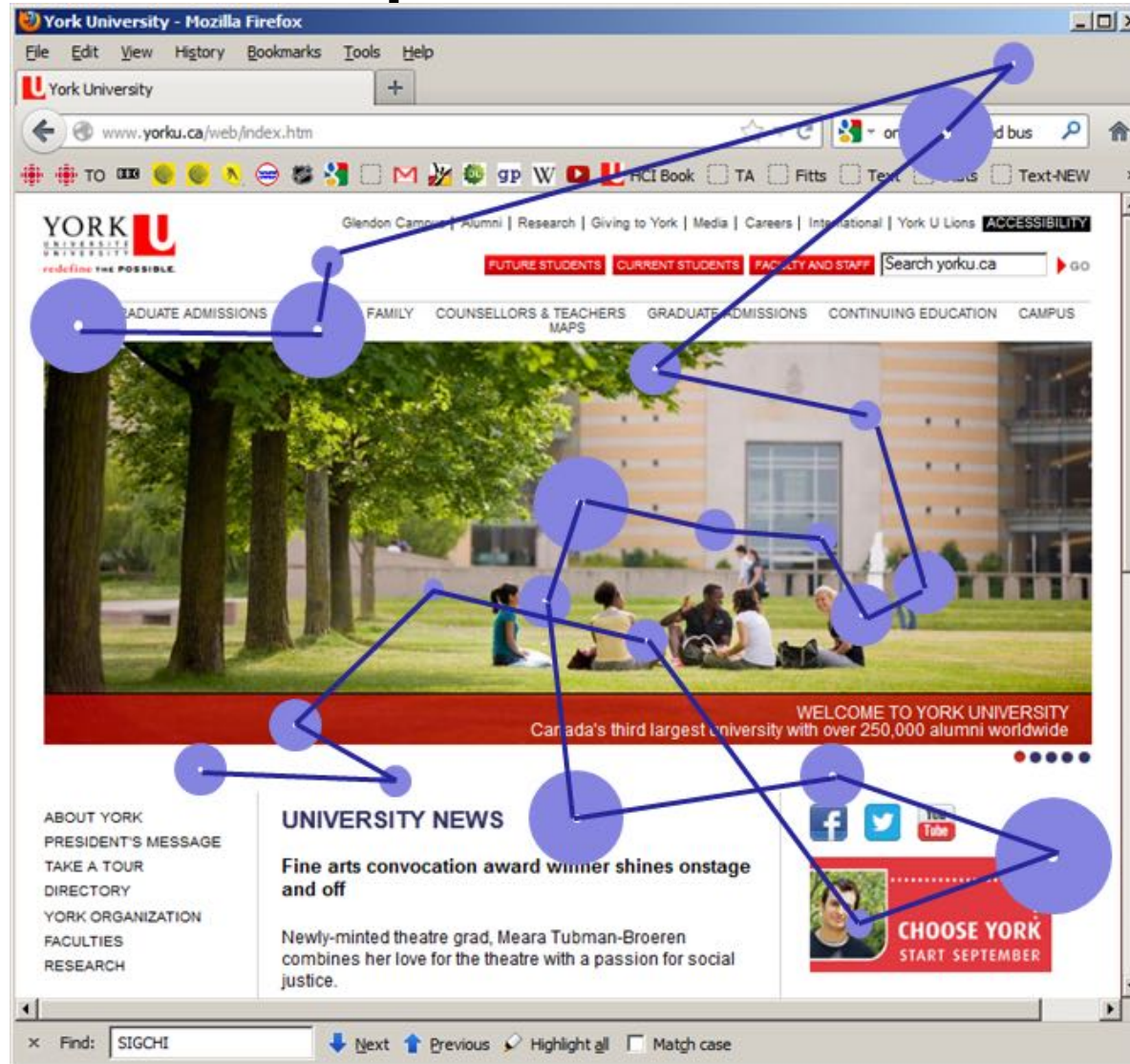
“Estimate the ages of the people”

<sup>1</sup> Tatler, B. W., Wade, N. J., Kwan, H., Findlay, J. M., & Velichkovsky, B. M. (2010). Yarbus, eye movements, and vision. *i-Perception*, 1, 7-27..

# Scan Paths

- Visual depiction of saccades and fixations
- Saccades → straight lines
- Fixations → circles
  - Diameter of circle  $\propto$  duration of fixation
- Applications
  - User behaviour research (e.g., reading patterns)
  - Marketing research (e.g., ad placement)

# Scan Path Example



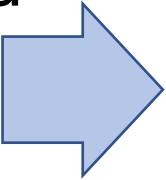
# Gaze and Touch Interaction on Tablets

Ken Pfeuffer, Hans Gellersen  
Lancaster University

k.pfeuffer@lancaster.ac.uk, hwg@comp.lancs.ac.uk



# Hearing (Audition)

- Sound → cyclic fluctuations of pressure in a medium, such as air
  - Created when physical objects are moved or vibrated
  - Examples
    - Slamming a door, plucking a guitar string, shuffling cards, speaking
  - Physical properties of sound
    - Frequency
    - Intensity
- 
- Subjective properties of hearing
    - Pitch
    - Loudness
    - Timbre
    - Attack

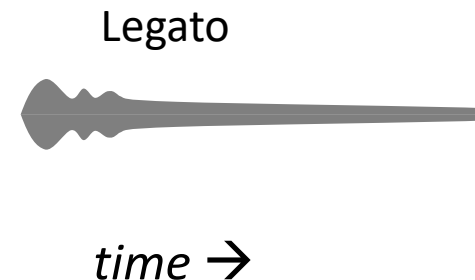
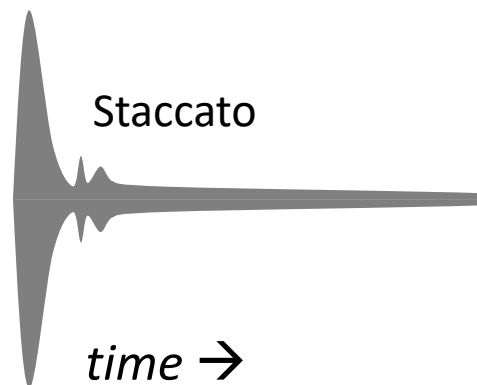
# Timbre

- Aka *richness, brightness*
- Results from harmonic structure of sound
- E.g., a musical note of 200 Hz, has harmonics at 400 Hz, 600 Hz, 800 Hz, etc.
- Notes of the same frequency from different instruments are distinguished, in part, due to timbre



# Attack

- Aka *envelope*
- Results from the way a note and its harmonics build up and transition in time – from silent, to audible, to silent
- Considerable information in the onset envelop
- Assists in distinguishing notes of the same pitch coming from different instruments
- Onset envelop created through articulation (e.g., legato, staccato)



# Hearing (Audition)

- Can be used for
  - Notification
  - Immersion
  - Feedback
  - Spatial Awareness

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# earPod

## Eyes-Free Menu Selection Using Touch Input and Audio Feedback

# HindSight

Enhancing Spatial  
Awareness by Sonifying  
Detected Objects in  
Real-Time 360-Degree  
Video

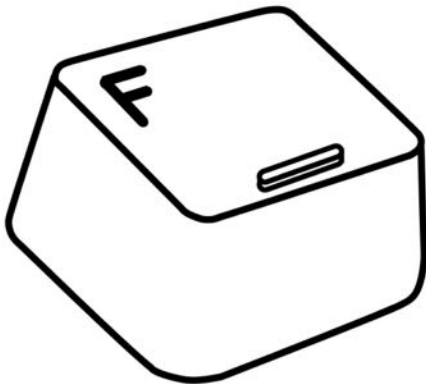
Eldon Schoop  
James Smith  
Bjoern Hartmann

CHI 2018



# Touch (Tactition)

- Part of somatosensory system, with...
- Receptors in skin, muscles, joints, bones
  - Sense of touch, pain, temperature, position, shape, texture, resistance, etc.
- Tactile feedback examples:





# Touch and Tactile Feedback



Guiding directions

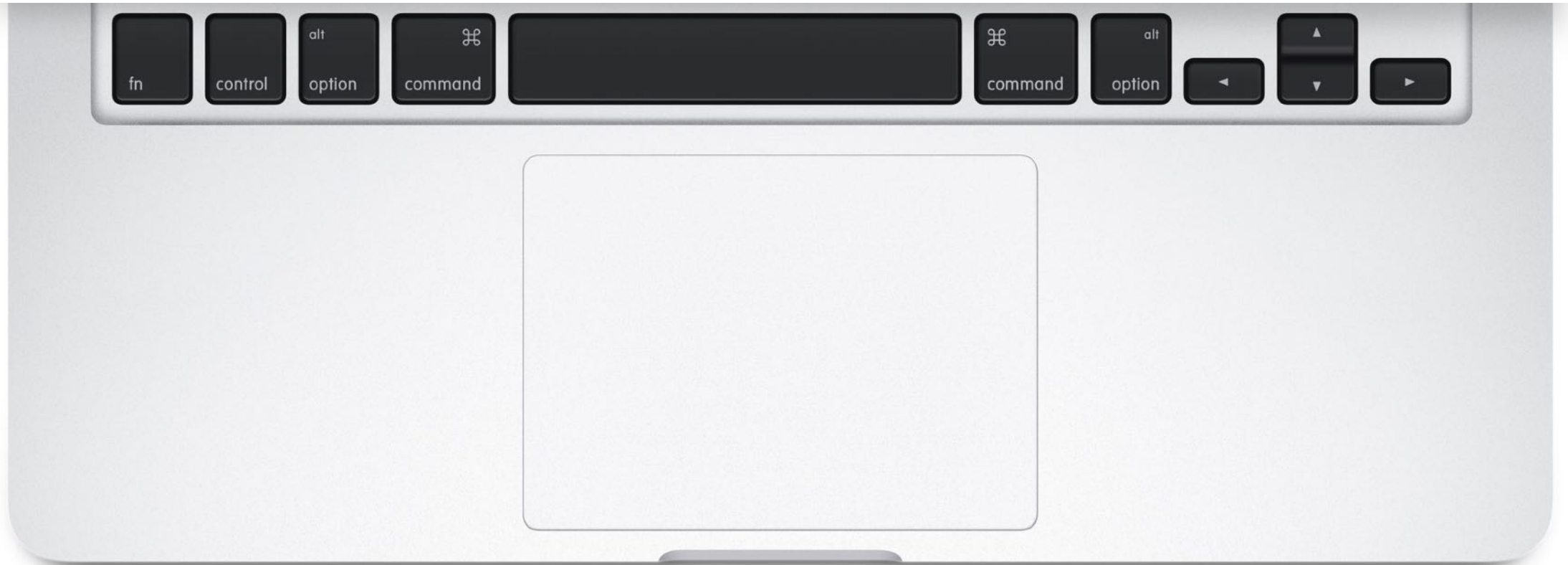
Notifications

Feedback

# Touch and Tactile Feedback



# Touch and Tactile Feedback



**Apple Trackpad**

# Smell and Taste

- Smell (olfaction)
  - Ability to perceive odours
  - Occurs through sensory cells in nasal cavity
- Taste (gustation)
  - Chemical reception of sweet, salty, bitter, and sour sensations
- Flavour
  - A perceptual process that combines smell and taste

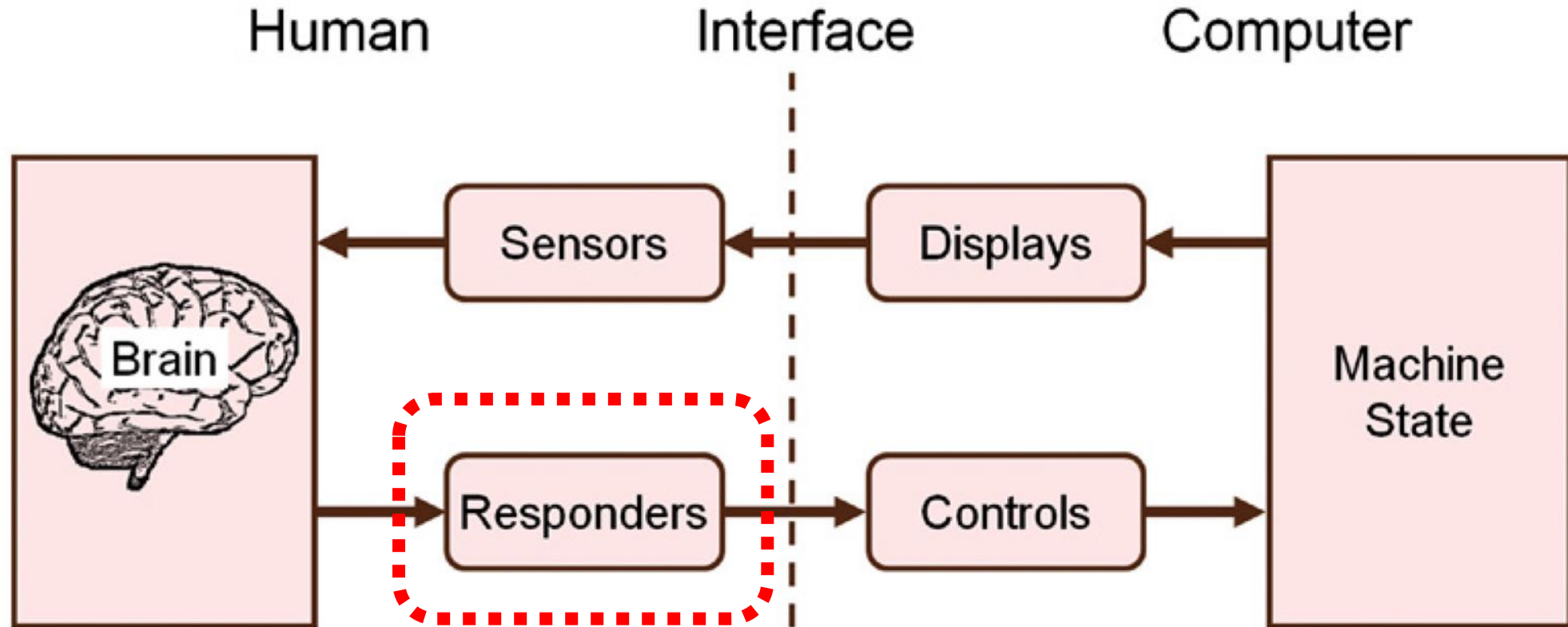
where visual information  
is short-lived



SensaBubble:

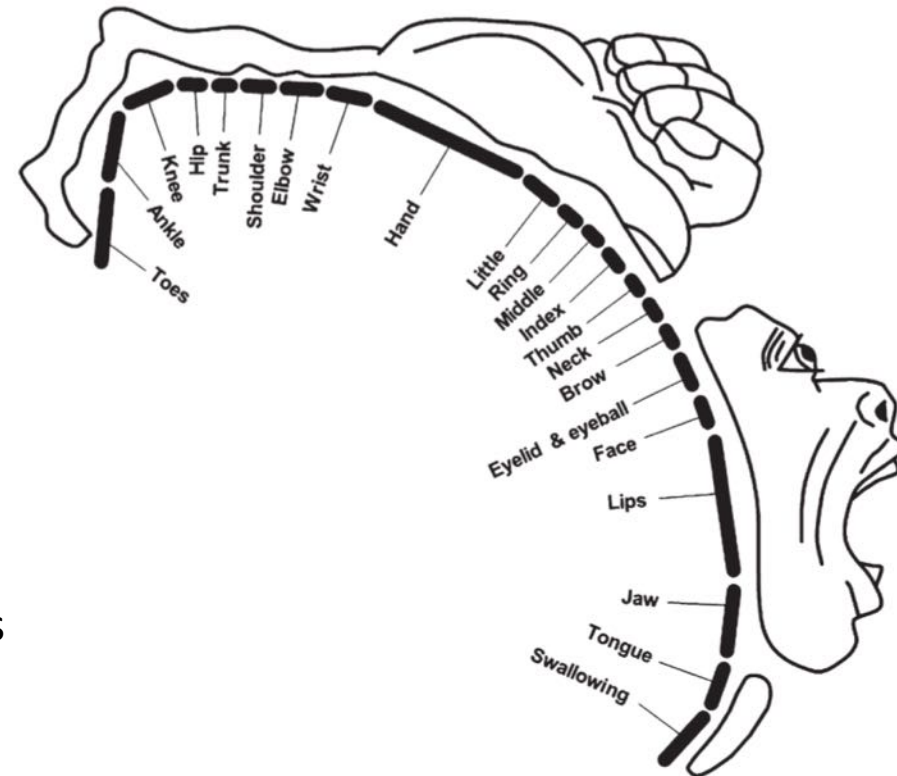
A CHRONO-SENSORY MID-AIR DISPLAY OF SIGHT AND SMELL

# Human Factors Model



# Penfield's Motor Homunculus

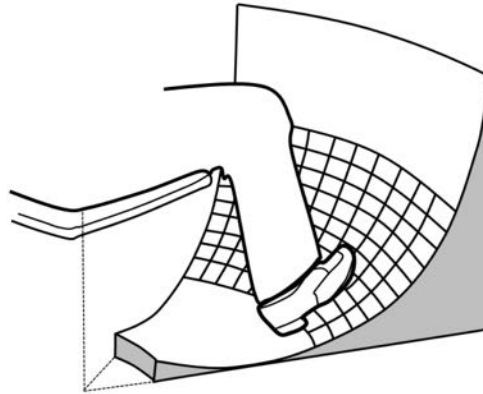
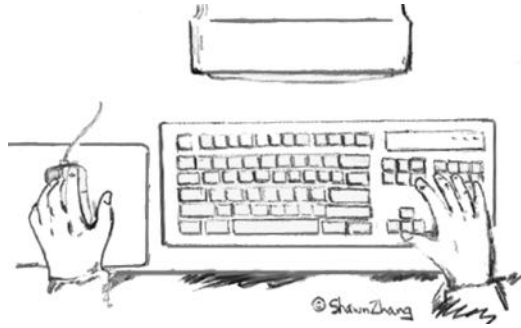
- Relative area of motor cortex dedicated to each human responder



“those groups of muscles having a large area devoted to them are heuristically promising places to connect with input device transducers if we desire high performance”

-Card et al., 1991

# Responder Examples

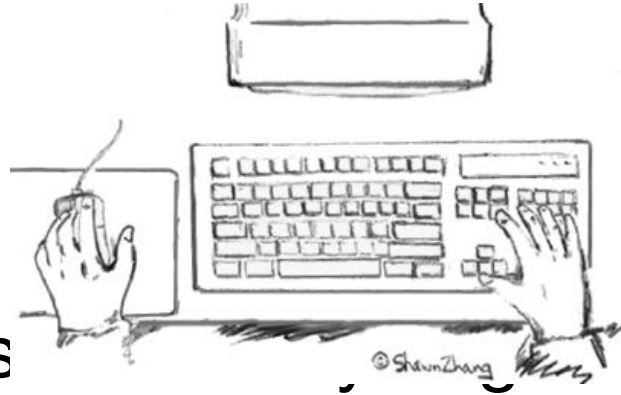




# Handedness

- Some users are left-handed, others right-handed

- Handedness



# Edinburgh Inventory for Handedness

	Left	Right
1. Writing	<input type="checkbox"/> <input type="checkbox"/>	<input type="checkbox"/> <input type="checkbox"/>
2. Drawing	<input type="checkbox"/> <input type="checkbox"/>	<input type="checkbox"/> <input type="checkbox"/>
3. Throwing	<input type="checkbox"/> <input type="checkbox"/>	<input type="checkbox"/> <input type="checkbox"/>
4. Scissors	<input type="checkbox"/> <input type="checkbox"/>	<input type="checkbox"/> <input type="checkbox"/>
5. Toothbrush	<input type="checkbox"/> <input type="checkbox"/>	<input type="checkbox"/> <input type="checkbox"/>
6. Knife (without fork)	<input type="checkbox"/> <input type="checkbox"/>	<input type="checkbox"/> <input type="checkbox"/>
7. Spoon	<input type="checkbox"/> <input type="checkbox"/>	<input type="checkbox"/> <input type="checkbox"/>
8. Broom (upper hand)	<input type="checkbox"/> <input type="checkbox"/>	<input type="checkbox"/> <input type="checkbox"/>
9. Striking a match	<input type="checkbox"/> <input type="checkbox"/>	<input type="checkbox"/> <input type="checkbox"/>
10. Opening box (lid)	<input type="checkbox"/> <input type="checkbox"/>	<input type="checkbox"/> <input type="checkbox"/>
Total (count checks)	<input type="text"/>	<input type="text"/>
	Cumulative	
Difference	Total	RESULT
<input type="text"/>	<input type="text"/>	<input type="text"/>

## Instructions

Mark boxes as follows:

x preference

xx strong preference

blank no preference

## Scoring

Add up the number of checks in the "Left" and "Right" columns and enter in the "Total" row for each column. Add the left total and the right total and enter in the "Cumulative Total" cell. Subtract the left total from the right total and enter in the "Difference" cell. Divide the "Difference" cell by the "Cumulative Total" cell (round to 2 digits if necessary) and multiply by 100. Enter the result in the "RESULT" cell.

## Interpretation of RESULT

-100 to -40 left-handed

-40 to +40 ambidextrous

+40 to 100 right-handed

Oldfield, R. C. (1971). The assessment and analysis of handedness: The Edinburgh inventory. *Neuropsychologia*, 9, 97-113.

# Human Voice

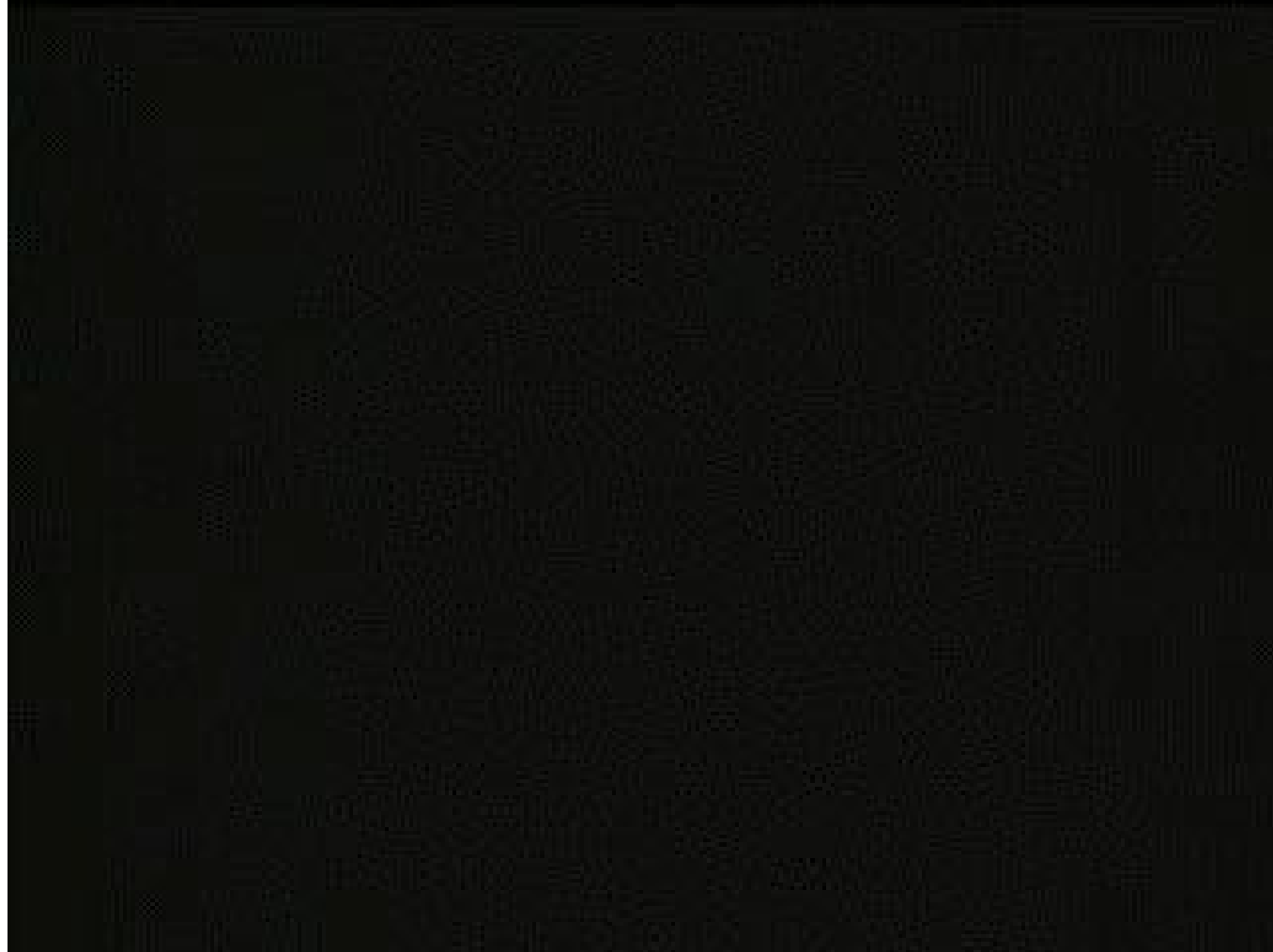
- Human vocal chords are responders
- Sounds created through combination of...
  - Movement in the larynx
  - Pulmonary pressure in the lungs
- Two kinds of vocalized sounds:
  1. Speech
  2. Non-speech
- Both with potential for computer control
  - Speech + speech recognition
  - Non-speech + signal detection (e.g., frequency, loudness, duration, change direction, etc.)

# Put That There – Verbal Input



Richard A. Bolt, "Put-that-there": Voice and gesture at the graphics interface. *Siggraph 1980*

# Non-Verbal Input



# Apple Voice Control



MacOS

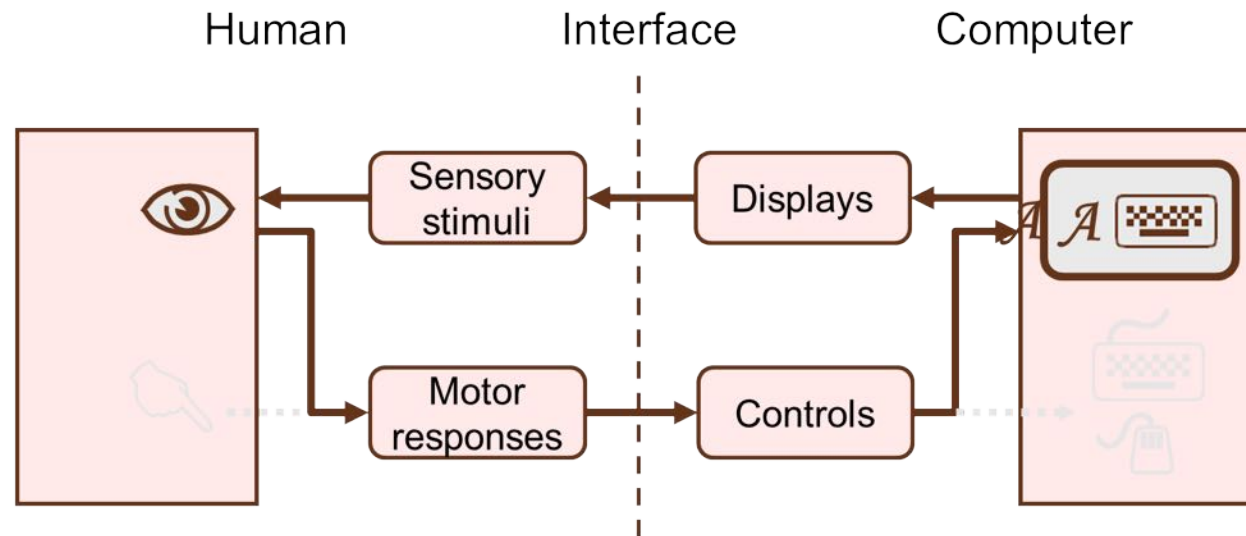
**Voice  
Control**

with Audio Descriptions

 WWDC19

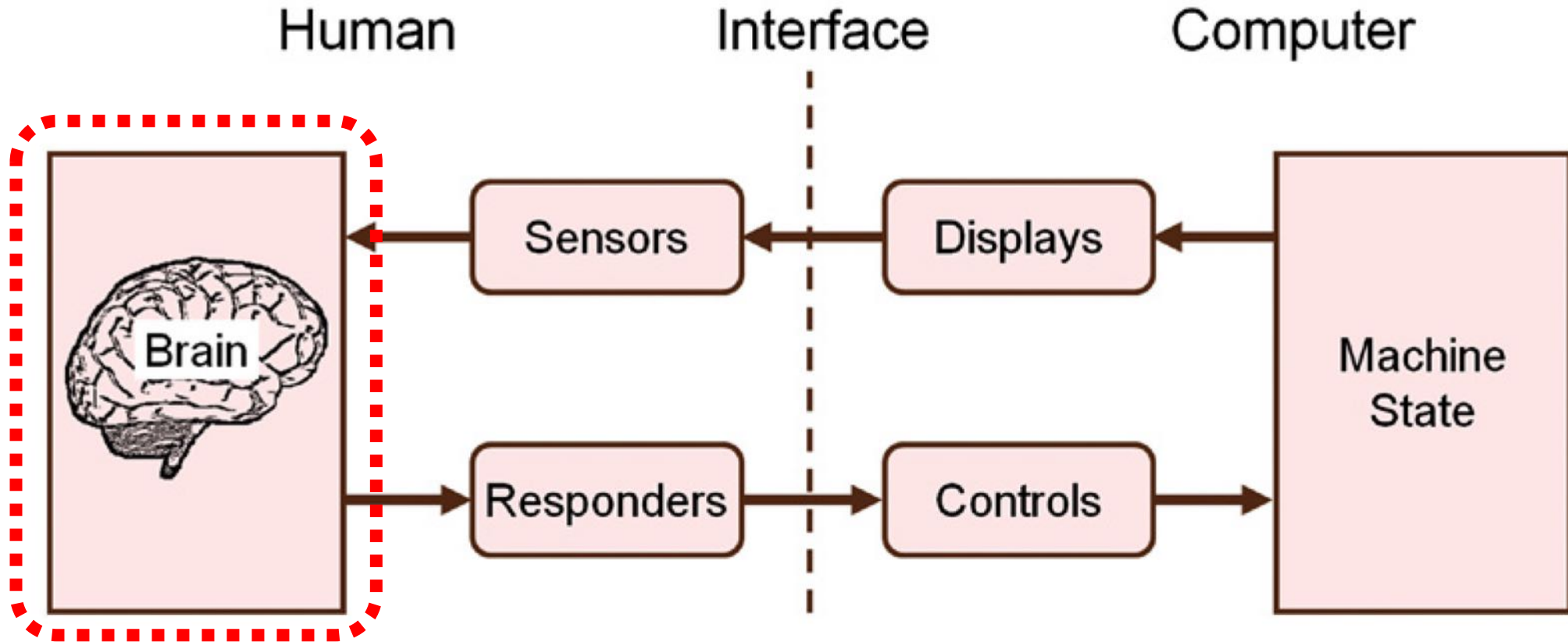
# The Eye as a Responder

- As a responder, the eye is called upon to do “double duty”
  1. Sense and perceive the environment/computer
  2. Act as a controller via saccades and fixations



<sup>1</sup> MacKenzie, I. S. (2012). Evaluating eye tracking systems for computer input. In Majaranta, P., Aoki, H., Donegan, M., Hansen, D. W., Hansen, J. P., Hyrskykari, A., & R  ih  , K.-J. (Eds.) *Gaze interaction and applications of eye tracking: Advances in assistive technologies*, pp. 205-225. Hershey, PA: IGI Global.

# Human Factors Model





# The Brain

- Most complex biological structure known
- Sensors (human inputs) and responders (human outputs) are nicely mirrored, but it is the brain that connects them
- Three core functions:
  - Perception
  - Cognition
  - Memory

# Perception

- 1<sup>st</sup> stage of processing for sensory input
- Interpretation of sensory signals
  - Auditory stimulus → harmonious, discordant
  - Visual stimulus → familiar, strange
  - Tactile stimulus → warm, hot
  - Smell stimulus → pleasurable, abhorrent
  - Taste stimulus → sweet, sour

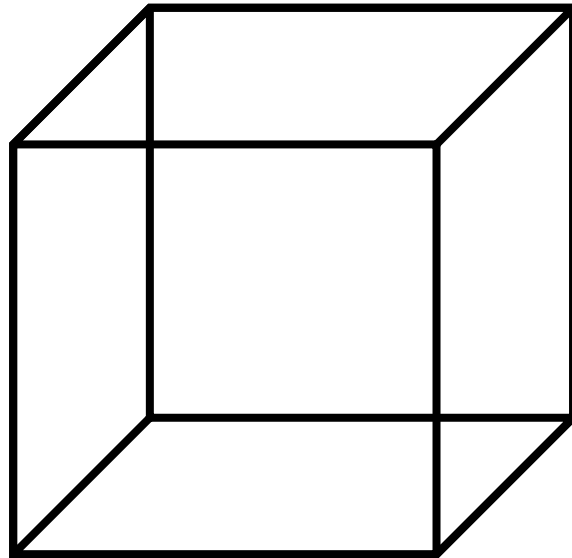
# Psychophysics

- Branch of experimental psychology
- Since 19<sup>th</sup> century
- Relationship between human perception and physical phenomena
- Experimental method:
  - Present subject with two stimuli, one after the other
  - Stimuli differ in a physical property (e.g., frequency)
  - Randomly vary the difference
  - Determine threshold below which the subject deems the two stimuli “the same”
  - This threshold is the *just noticeable different* (JND)

# Illusions

- Interpretation can be difficult and ambiguous – leading to illusions

Necker cube



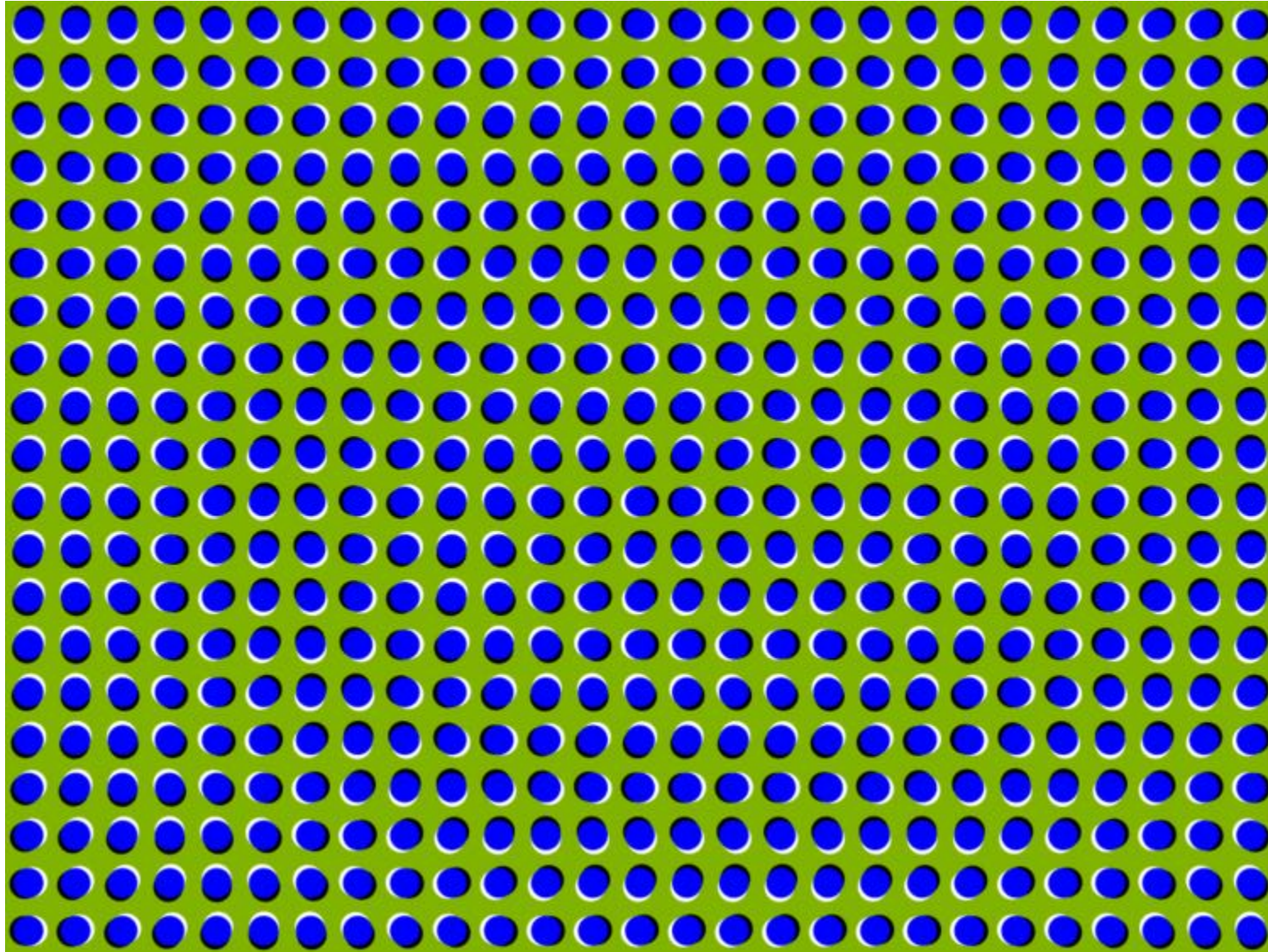
Which surface is at the front?

Ponzo lines



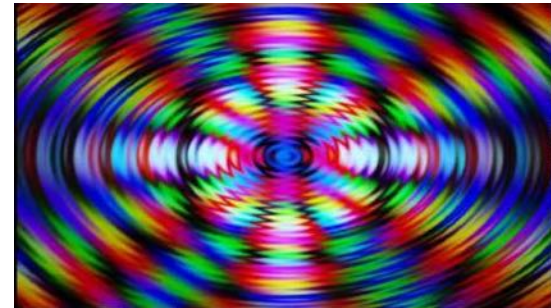
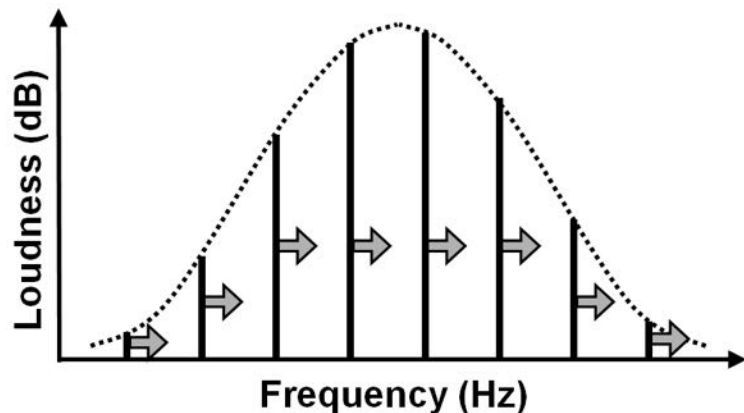
Which black line is longer?

# Illusions



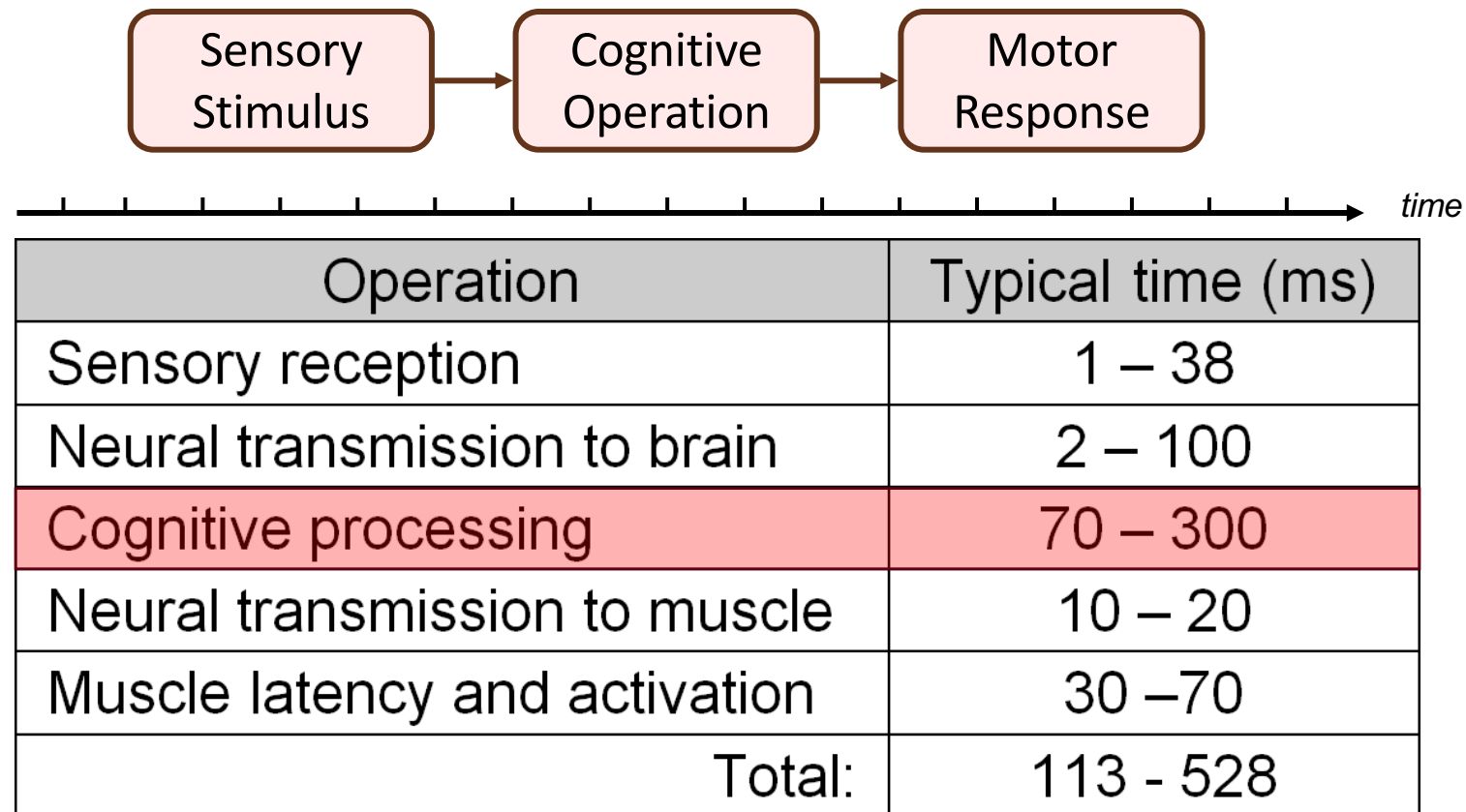
# Illusion – Other Senses

- If illusion is possible for the visual sense, the same should be true for the other senses
- Tactile illusion: Sensory Saltation
  - Also called cutaneous rabbit illusion
- Auditory illusion: Sheppard-Risset glissando



# Cognition

- Human process of conscious intellectual activity
- Thinking, reasoning, deciding, etc.

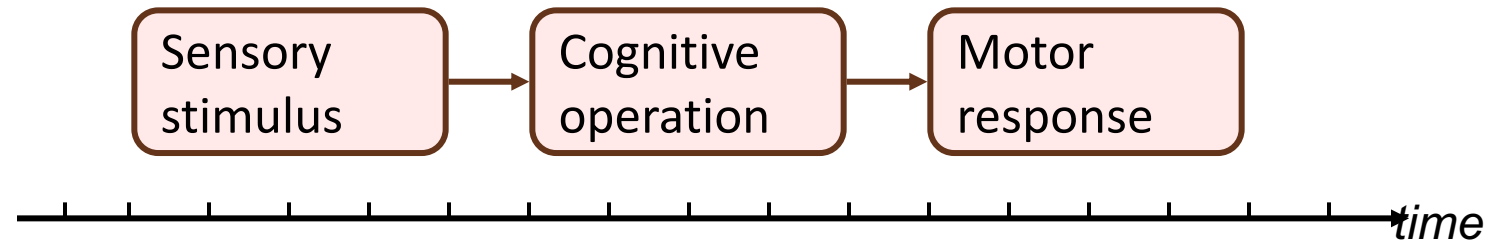


# “Making a Decision”

- Not possible to directly measure the time for a human to “make a decision”
- When does the measurement begin and end?
- Where is it measured?
- On what input is the human deciding?
- Through what output is the decision conveyed?
- There is a sensory stimulus and motor response that bracket the decision



# Making a Decision – in Parts



Operation	Typical time (ms)
Sensory reception	1 – 38
Neural transmission to brain	2 – 100
Cognitive processing	70 – 300
Neural transmission to muscle	10 – 20
Muscle latency and activation	30 – 70
Total:	113 - 528

Large variation!

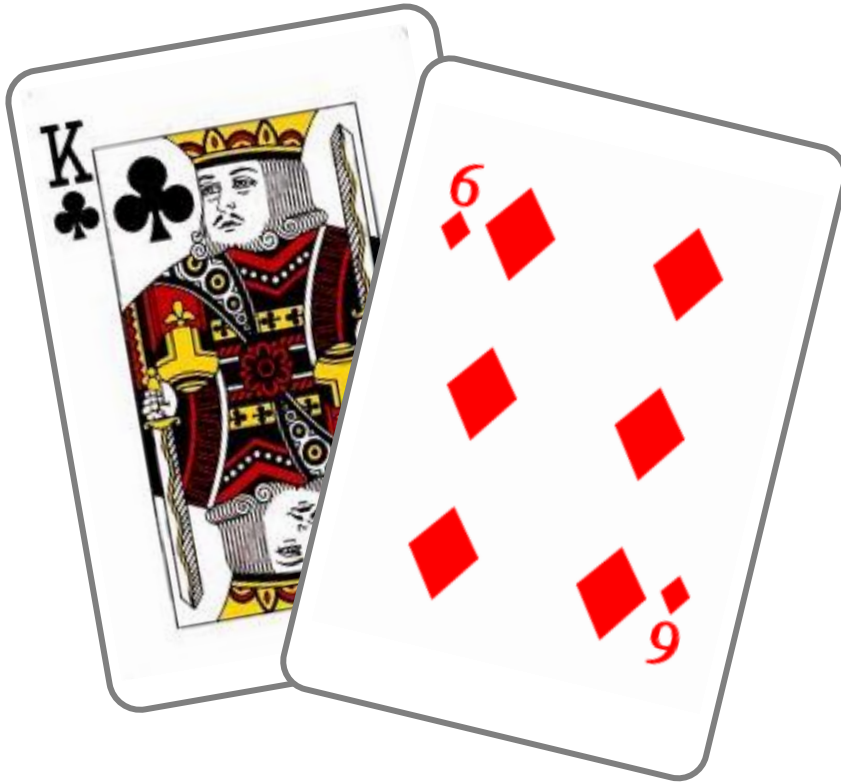


# Examples of Simple Decisions

- Driving a car → decision to depress the brake pedal in response to a changing signal light
- Using a mobile phone → decision to press REJECT-CALL in response to an incoming call
- Reading news online → decision to click the CLOSE button on a popup ad
- These are *reaction time* tasks

# A More Involved Decision

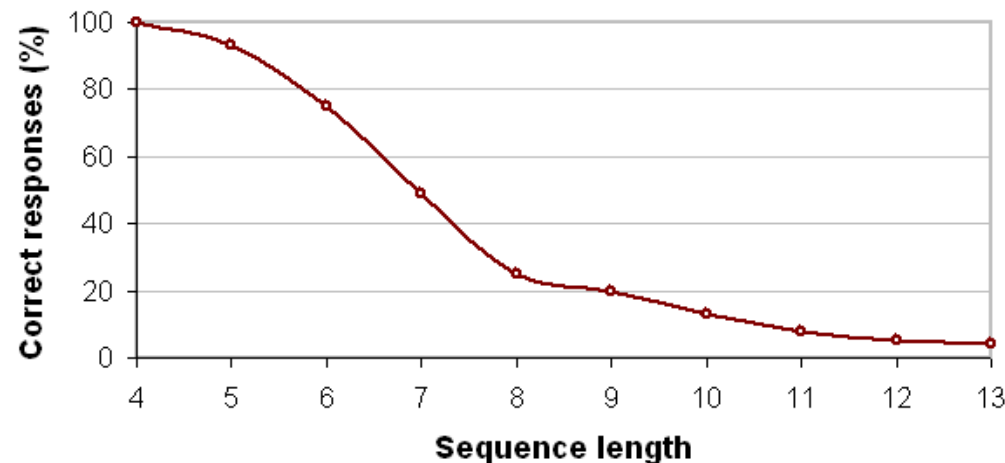
Black Jack hand:



Another card?  
(dealer has 17)

# Memory

- Human ability to store, retain, and recall information
- Long-term memory: Large storage of past events
- Short-term memory: active and readily available *working memory*
  - Miller's Law: Humans can remember about 7 ( $\pm 2$ ) items.



<sup>1</sup> Miller, G. A. (1956). The magical number seven plus or minus two: Some limits on our capacity for processing information. *Psychological Review*, 63, 81-97.

# Chunking

- Units in short term memory may be recoded as a chunk
- Expands capacity of short term memory
- E.g., Commit to memory and recall...

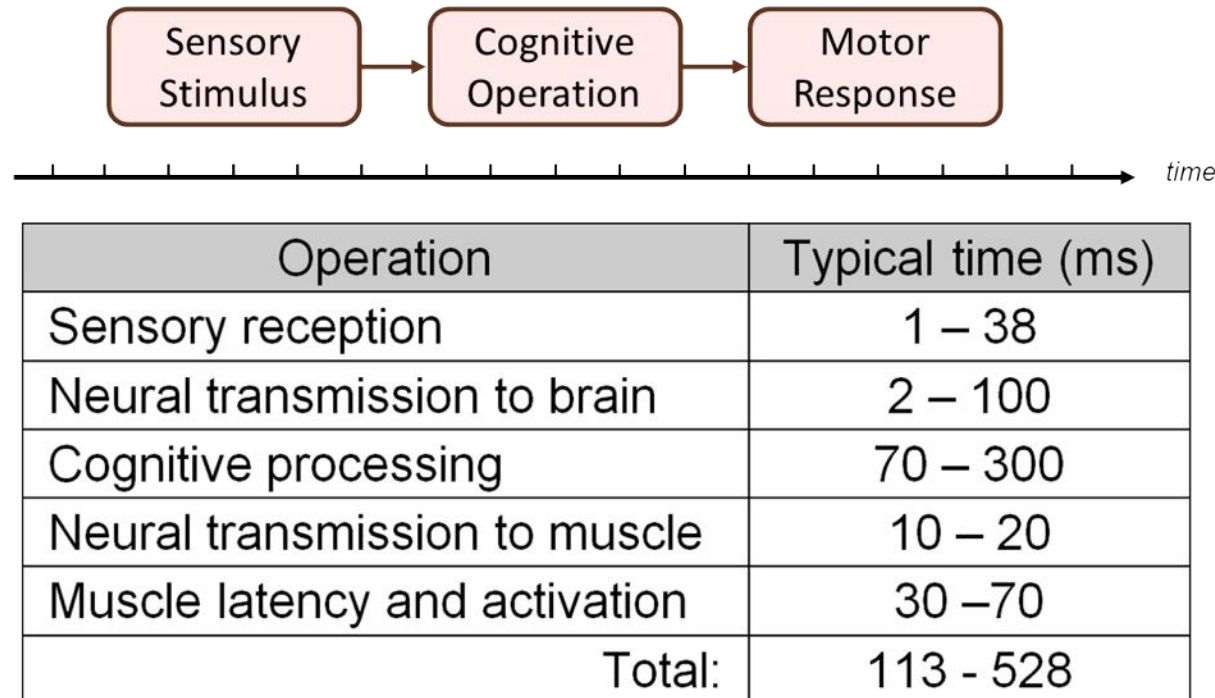
14344305382

vs

1 434 430 5382

# Information Processing Models

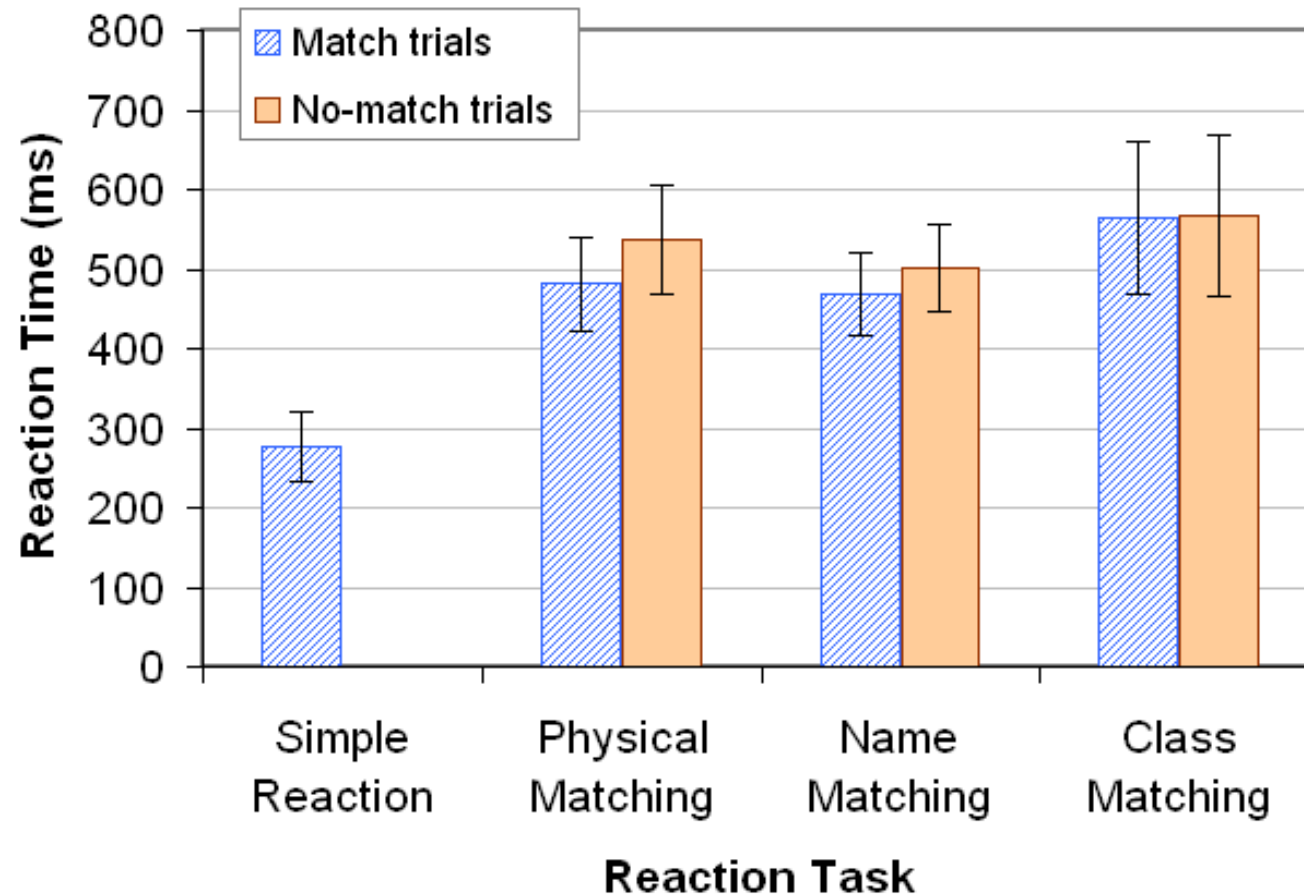
- Models the information processes of user interacting with a computer
- Predicts which cognitive processes are involved
- Enables calculations to be made of how long tasks will take



# Reaction Time

- One of the most primitive manifestations of human performance is simple reaction time
- Definition: The delay between the occurrence of a single fixed stimulus and the initiation of a response assigned to it
- Example: Pressing a button in response to a stimulus light

# Experiment Results





# Sensory Stimuli and Reaction Time

- Delay time varies by type of sensory stimuli
- Approximate values
  - Auditory → 150 ms
  - Visual → 200 ms
  - Smell → 300 ms
  - Pain → 700 ms



Video Break

# BlyncSync

Enabling Multimodal Smartwatch Gestures  
with Synchronous Touch and Blink

**Bryan Wang, Tovi Grossman**

Toronto, Ontario, Canada

DGP Lab, University of Toronto



Computer Science  
UNIVERSITY OF TORONTO

Bryan Wang, Tovi Grossman.

BlyncSync: Enabling Multimodal Smartwatch Gestures with Synchronous Touch and Blink, *CHI 2020*

# Web Programming Tutorial

- Aashik will give three web programming tutorial sessions
- Optional but **highly recommended** if you are new to web programming
- Wednesdays at 7pm on Zoom → **Starting TODAY!**
- Topics
  - Sep 2: HTML and CSS
  - Sep 9: JavaScript
  - Sep 16: Database

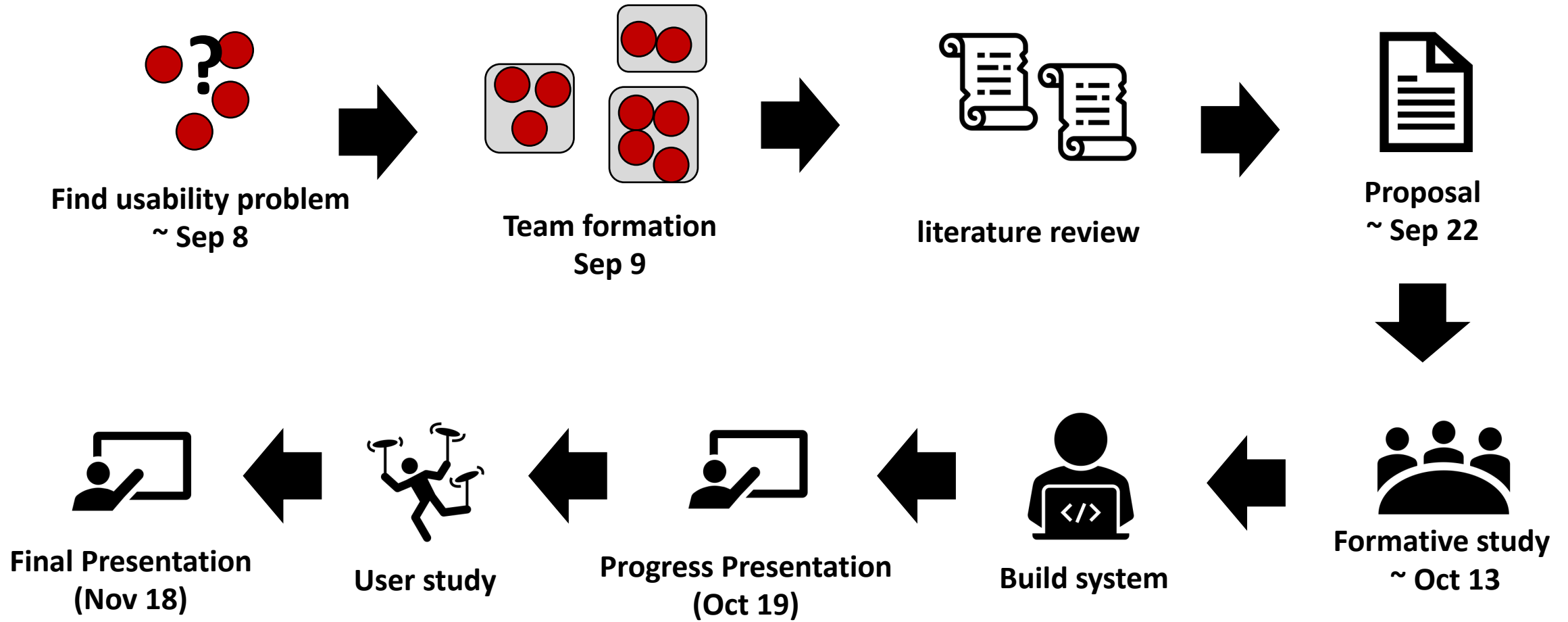
**Have Visual Studio Code installed on your computer**

# **Course Project:**

Make people's lives better in this pandemic

What do we miss, what do we struggle with, or what do we like?

# Course Project: Timeline



# Course Project: Find a problem

- Find a usability / user experience problem, or a new way to improve the use of computers, related to the COVID-19 situation
- Due Next Tuesday (Sep 8), 11:59 **am**

# Course Project: Find a problem

- After the deadline, the problems will be listed on a spreadsheet
- You will choose the ones that you want to solve or study.
- We will form project teams in Wed class



# Acknowledgements

- Some of the materials are based on materials by
  - Tovi Grossman, Univ. of Toronto
  - Juho Kim, KAIST
  - Scott MacKenzie, Human-Computer Interaction: An Empirical Research Perspective

Thank you!