Introduction to Human-Computer Interaction

3. Human Factors

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The Human Factor

- Today's goal: understand the characteristics of humans
  - As if we observe aliens

- The "H" side of HCI
- Humans differ: age, sex, expertise, handedness, education, native language, culture, …
- Approximate due to high variability

Newell's Time Scale of Human Action

- The most common dependent variable in experimental research in HCI is **time**—the time for a user to do a task.

Scale (sec)	Time Units	System	World (theory)
10^7	Months		SOCIAL BAND
10^6	Weeks		
10^5	Days		
10^4	Hours	Task	RATIONAL BAND
10^3	10 min	Task	
10^2	Minutes	Task	
10^1	10 sec	Unit task	COGNITIVE BAND
10^0	1 sec	Operations	
10^{-1}	100 ms	Deliberate act	
10^{-2}	10 ms	Neural circuit	BIOLOGICAL BAND
10^{-3}	1 ms	Neuron	
10^{-4}	100 μs	Organelle	

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Many HCI studies/models
- selection techniques
- menu design
- text entry
- gestural input

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- web navigation
- collaboration
- ...

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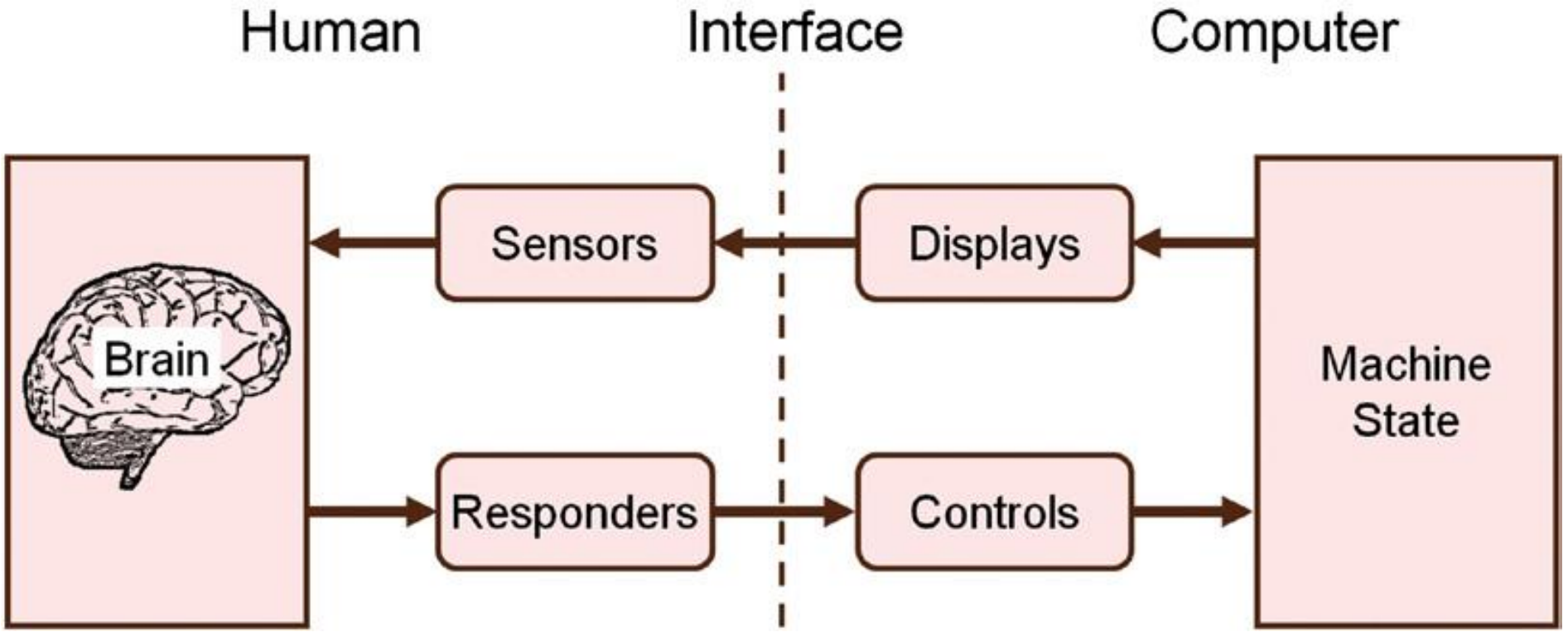
High-level research
- workplace habits
- social networking
- education
- privacy
- ...

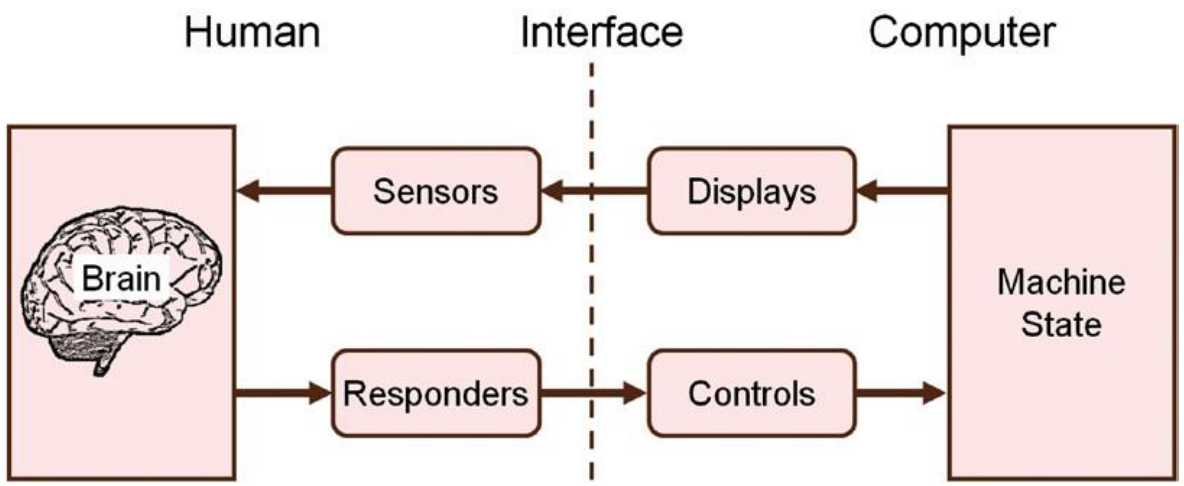
Human Factors Model



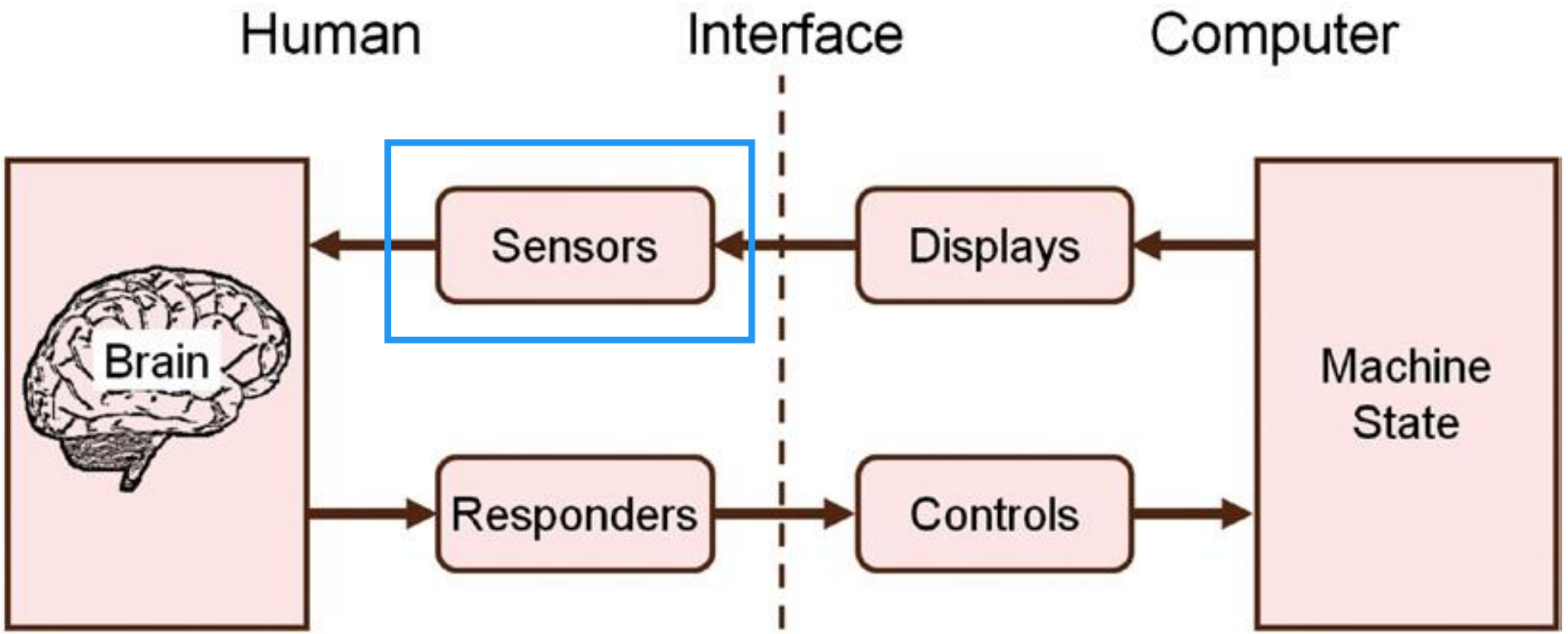
Kantowitz and Sorkin, “Human Factors: Understanding People-System Relationships”

Sensors and Responders

- Sensors:
  - Vision (sight)
  - Hearing (audition)
  - Touch (Tactition)
  - Smell and taste
- Responders:
  - Limbs
  - Voice
- Brain



Human Factors Model



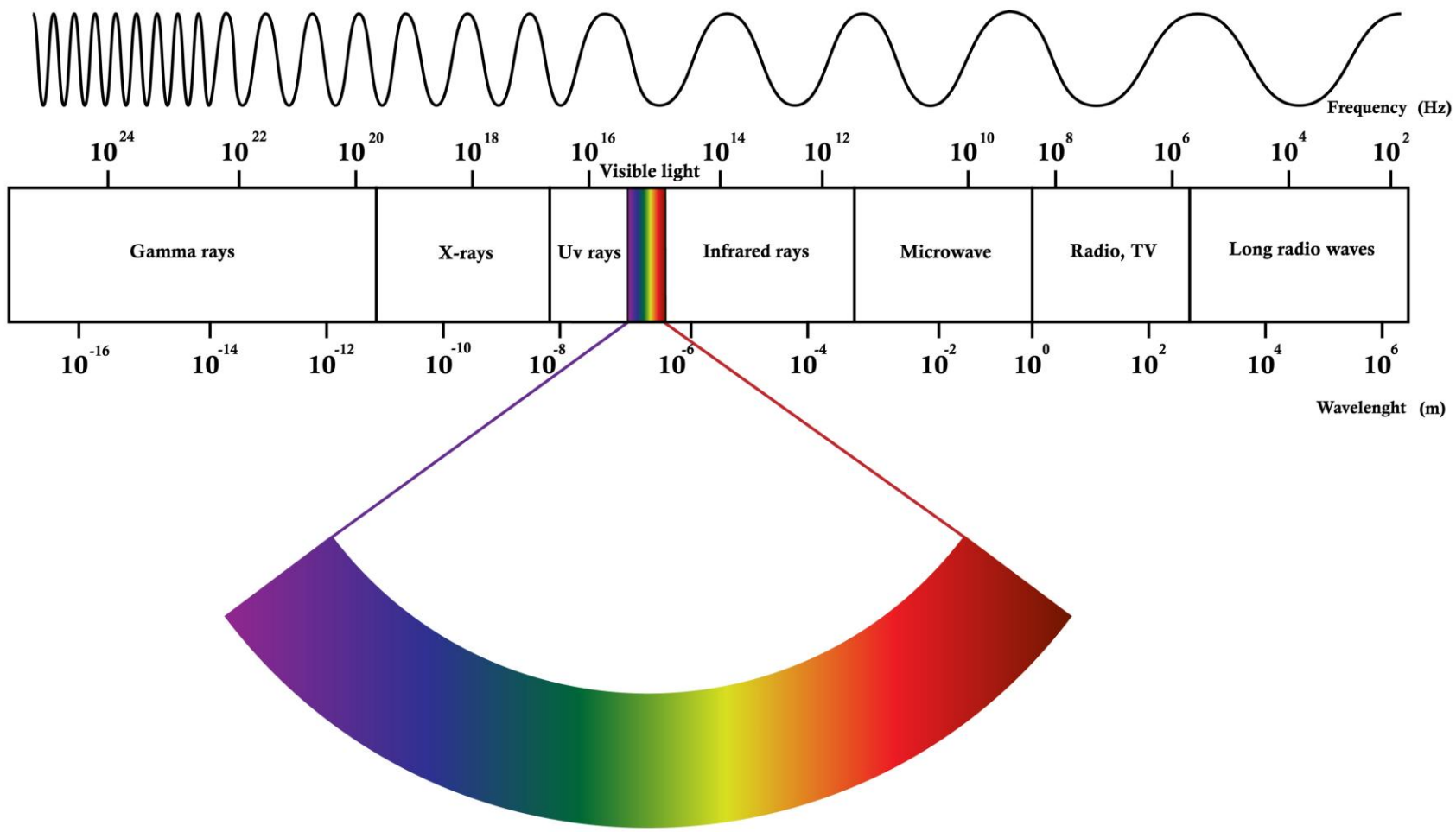
Kantowitz and Sorkin, “Human Factors: Understanding People-System Relationships”

Bandwidth of Sensors

- Sensing stimuli from outside: human sensory organs
  - Eyes (vision): **10,000,000 bps (1.25 MB/sec)**
  - Skin (touch, tactition): 1,000,000 bps
  - Ears (hearing, audition): 100,000 bps
  - Nose (smell, olfaction): 100,000 bps
  - Mouth (taste, gustation): 1,000 bps

- From The Nervous System in the Context of Information Theory

Light as Electromagnetic Wave



SOURCE Biro Emoke
Shutterstock

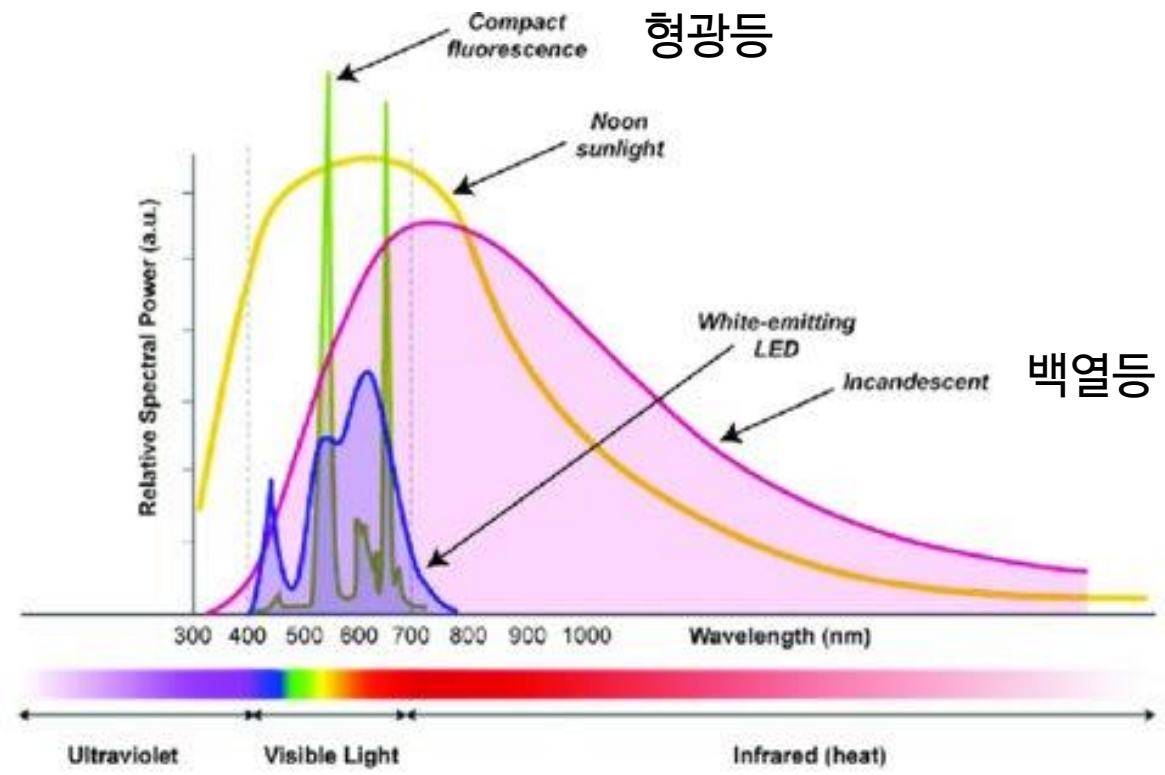
Light as Electromagnetic Wave

- Light of a single frequency is perceived as monochromatic light (단색광).

color	wavelength (nm)	frequency (10^{14} Hz)	energy (eV)
red (limit)	700	4.29	1.77
red	650	4.62	1.91
orange	600	5.00	2.06
yellow	580	5.16	2.14
green	550	5.45	2.25
cyan	500	5.99	2.48
blue	450	6.66	2.75
violet (limit)	400	7.50	3.10

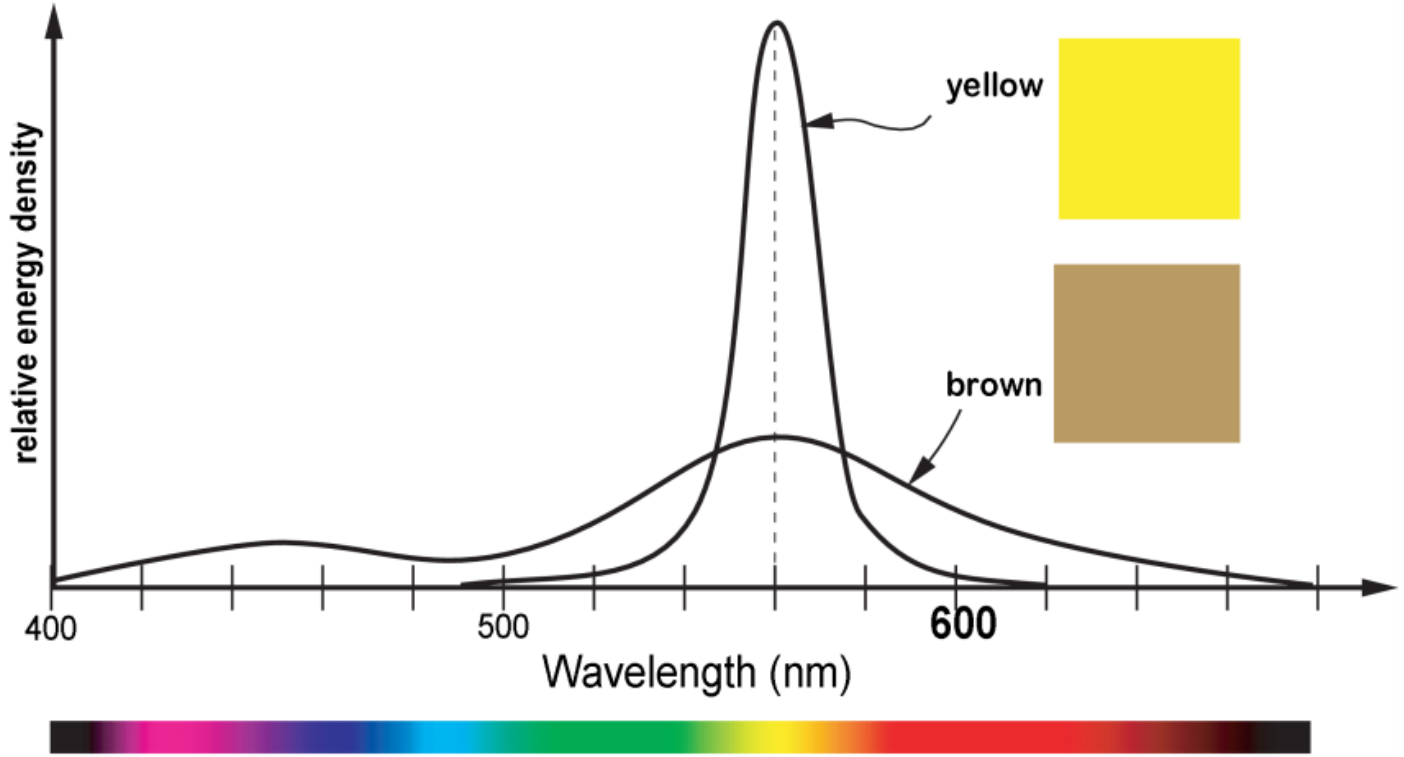
Light as Electromagnetic Wave

- Light in the real world is a mixture of lights with different frequencies!
  - Power spectrum of light



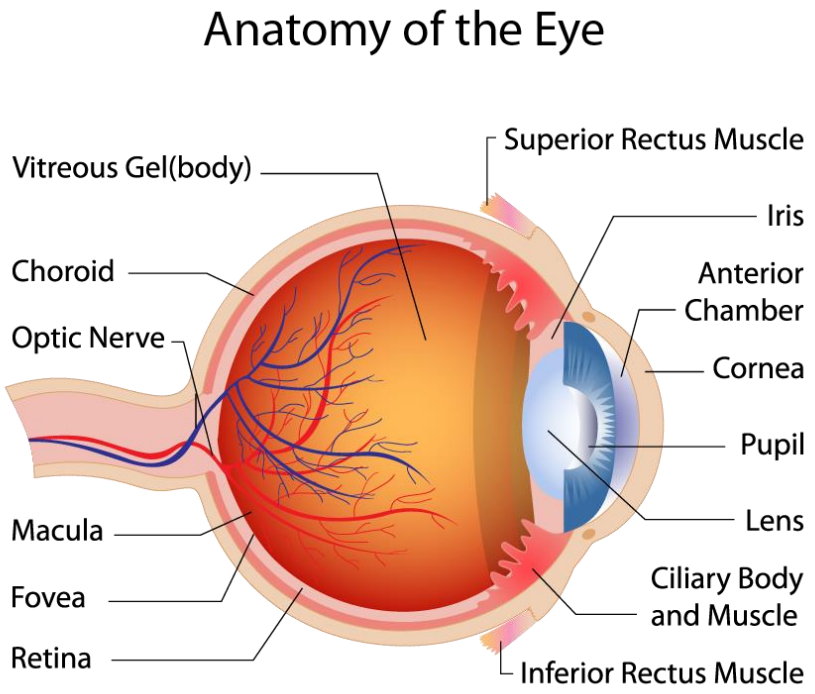
Color is not Wavelength

- There are colors that are not monochromatic.
  - Unsaturated colors such as magenta, gray, or white.



Human Eyes

- **Retina (망막)** receives light and converts the light into neural signals.
  - The signals are transmitted to the brain for visual recognition through the optic nerve.
- How to convert light to signals?
- Rod cells and cone cells!

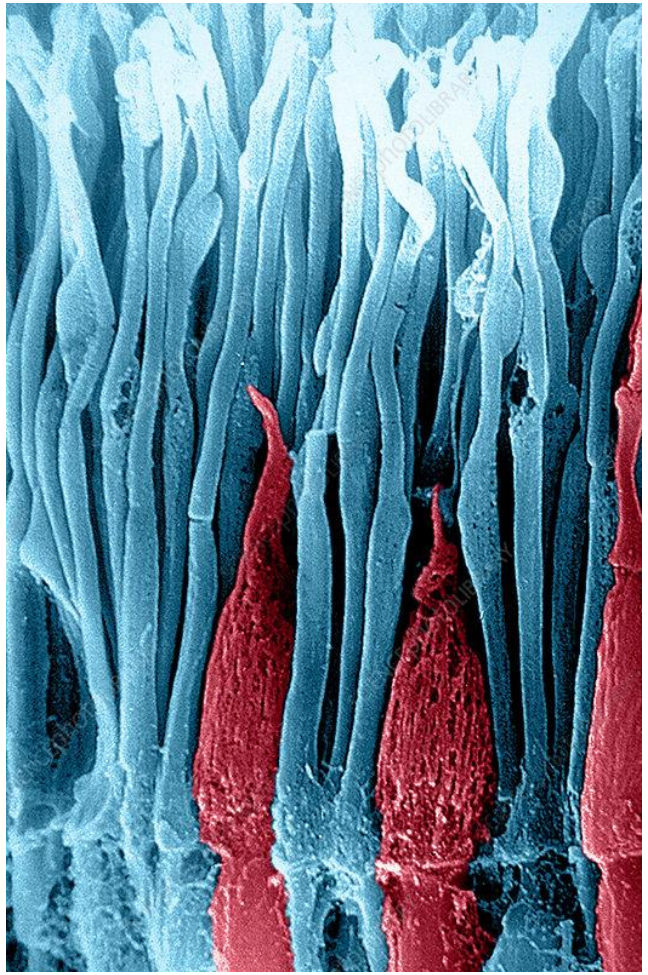


Color Vision

- Two different kinds of receptors on the retina

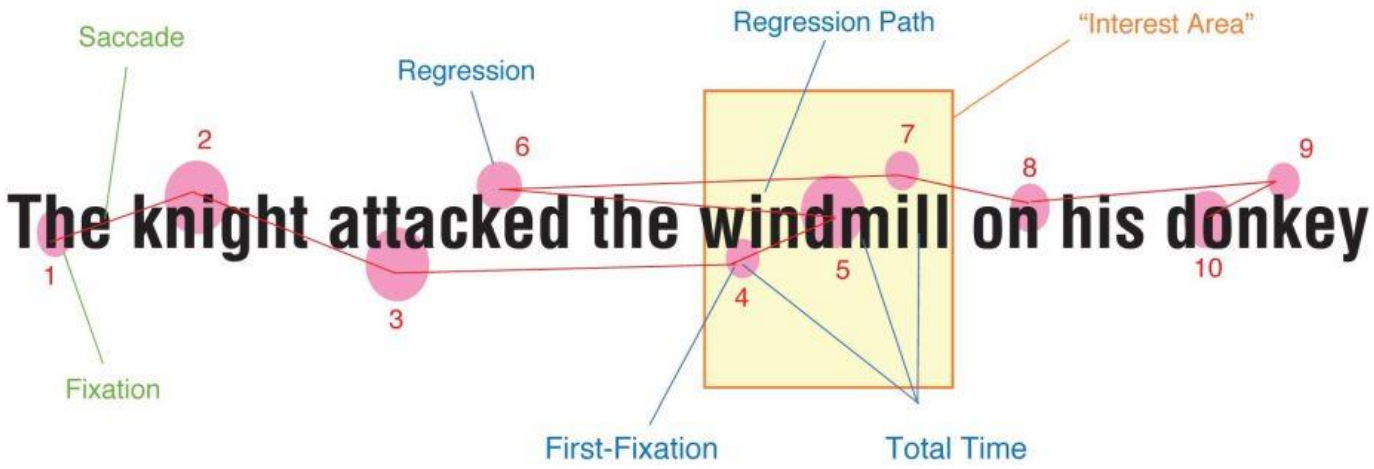
- Rods (간상세포)
  - Active at low-light settings
  - Low-resolution black and white information
  - 100 million rod receptors
  - 杆 = 몽둥이, 막대 = rod

- **Co**nes (원추세포) for **Co**lor
  - Active at normal lighting conditions
  - Three types of cones (sensitive at a different wavelength)
  - 6 million cone receptors
  - Dense in the center of vision (fovea, 중심와)



Fixations and Saccades

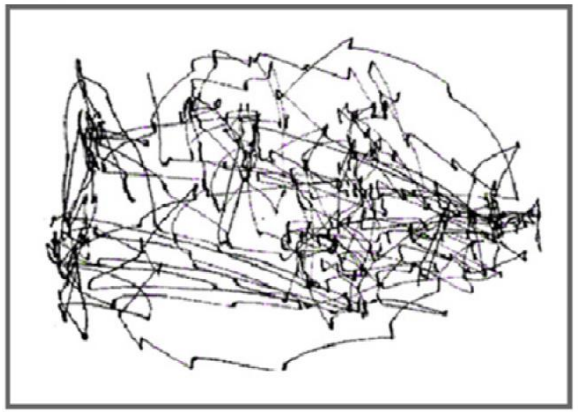
- **Fixation**: eyes are stationary, taking in visual detail from the environment.
- **Saccade**: to fixate on a different point of a scene, eyes move!
  - 20 – 200 ms



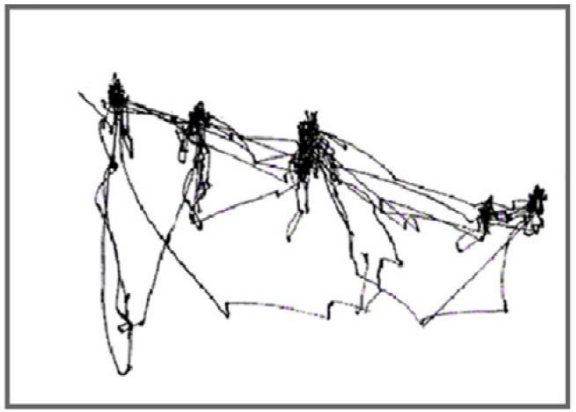
Source: https://eyewiki.aao.org/Saccade

Scanpath

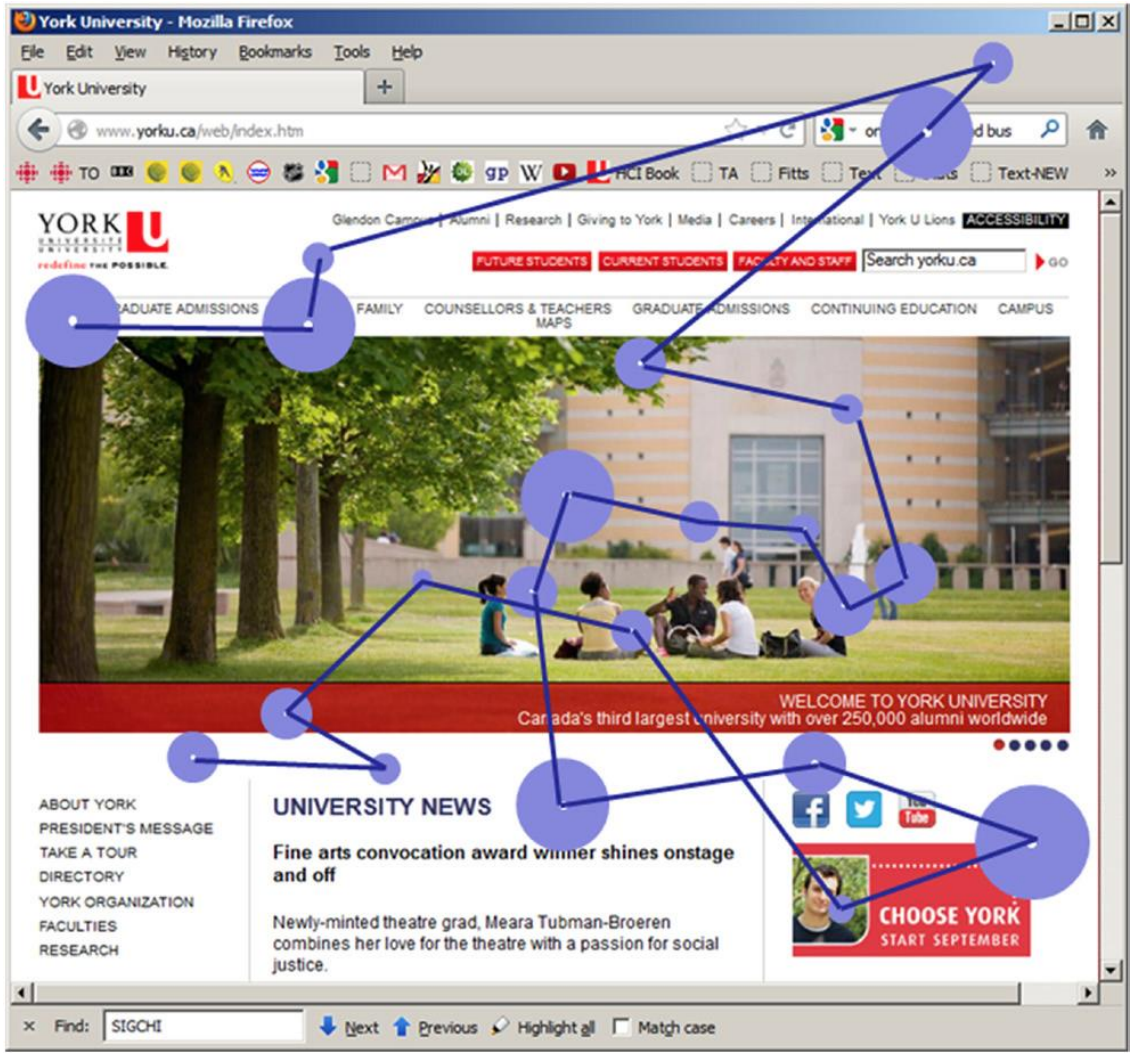
Remember the position of people/objects



Estimate # of people



Scanpath


York University - Mozilla Firefox
File Edit View History Bookmarks Tools Help
York University
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FUTURE STUDENTS
CURRENT STUDENTS
FACULTY AND STAFF
FAMILY
COUNSELLORS & TEACHERS
MAPS
CONTINUING EDUCATION
CAMPUS
WELCOME TO YORK UNIVERSITY
ABOUT YORK
PRESIDENT'S MESSAGE
TAKE A TOUR
DIRECTORY
YORK ORGANIZATION
FACULTIES
RESEARCH
UNIVERSITY NEWS
Fine arts convocation award winner shines onstage and off
Newly-minted theatre grad, Meara Tubman-Broeren combines her love for the theatre with a passion for social justice.
CHOOSE YORK
START SEPTEMBER
Find: SIGCHI
Next
Previous
Highlight all
Match case

Hearing (Audition)

- Hearing, or audition, is the detection of sound by humans.
  - Transmitted through the environment as sound waves—cyclic fluctuations of pressure in a medium such as air

- The physical properties of a sound:
  - Loudness
  - Pitch
  - Timbre
  - Envelope

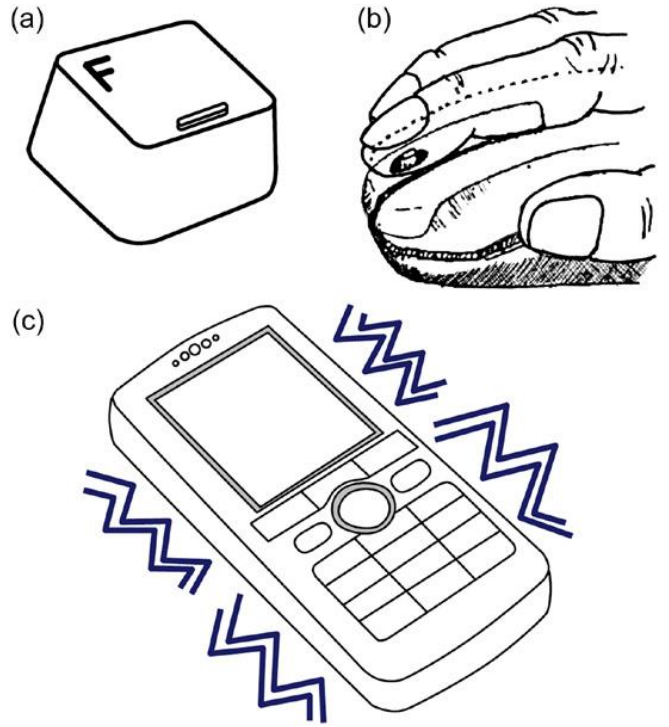
Hearing (Audition)

- **Loudness (세기)**: sound's intensity (sound pressure level)
  - Unit: dB (decibel)
- **Pitch (높낮이)**: sound's frequency (the time between peaks in a sound wave's pressure pattern)
  - Unit: Hz (hertz)
- **Timbre (음색)**: sound's brightness
  - The unique pattern of harmonics created by each instrument (purest: sine wave)
- **Envelope**: how a sound changes over time
  - attack/decay/sustain/release

Touch (Tactition)

- **Tactile feedback**, in HCI, refers to information provided through the somatosensory system from a body part.

- Temperature, shape, texture, position of the object, the amount of resistance, …



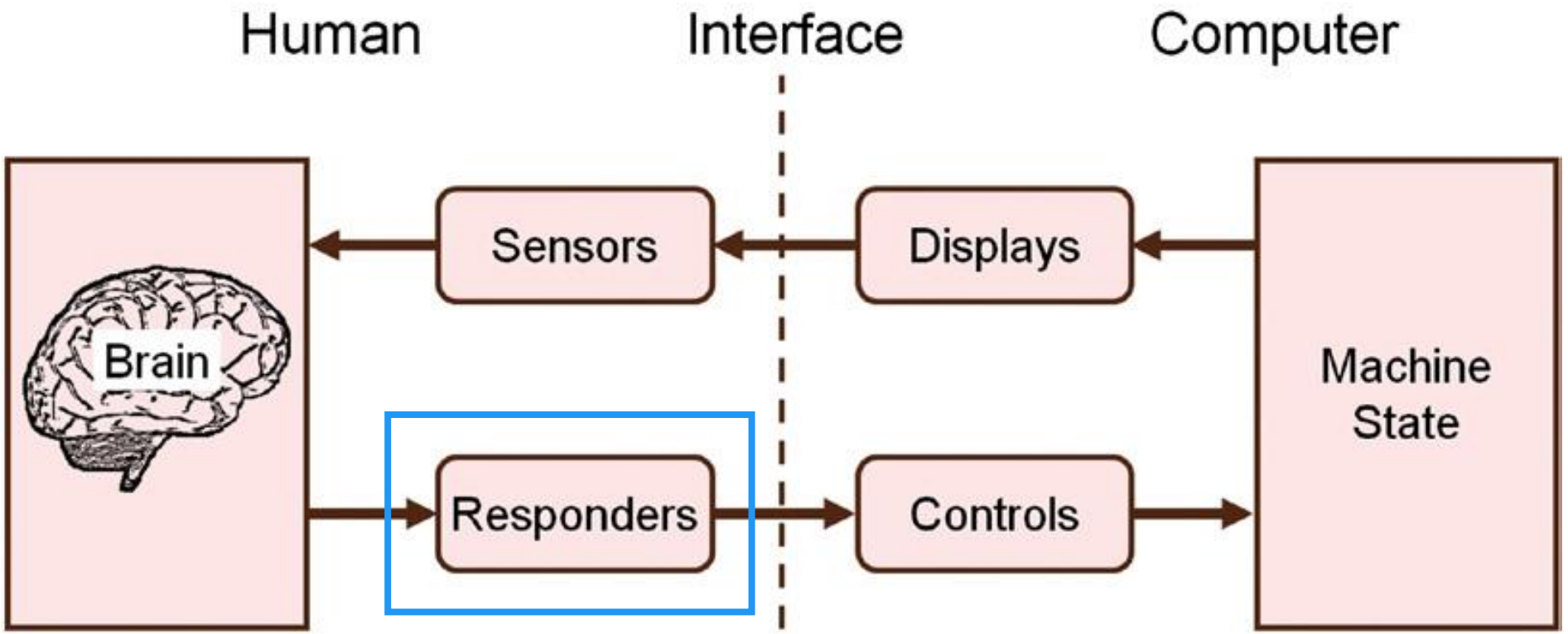
Smell and Taste

- Smell and taste are less understood than the visual and auditory senses.

- Not generally “designed in” to systems (there are a few examples, however!)

- Hard to reproduce
- Latency
- Fatigue (adaptation)

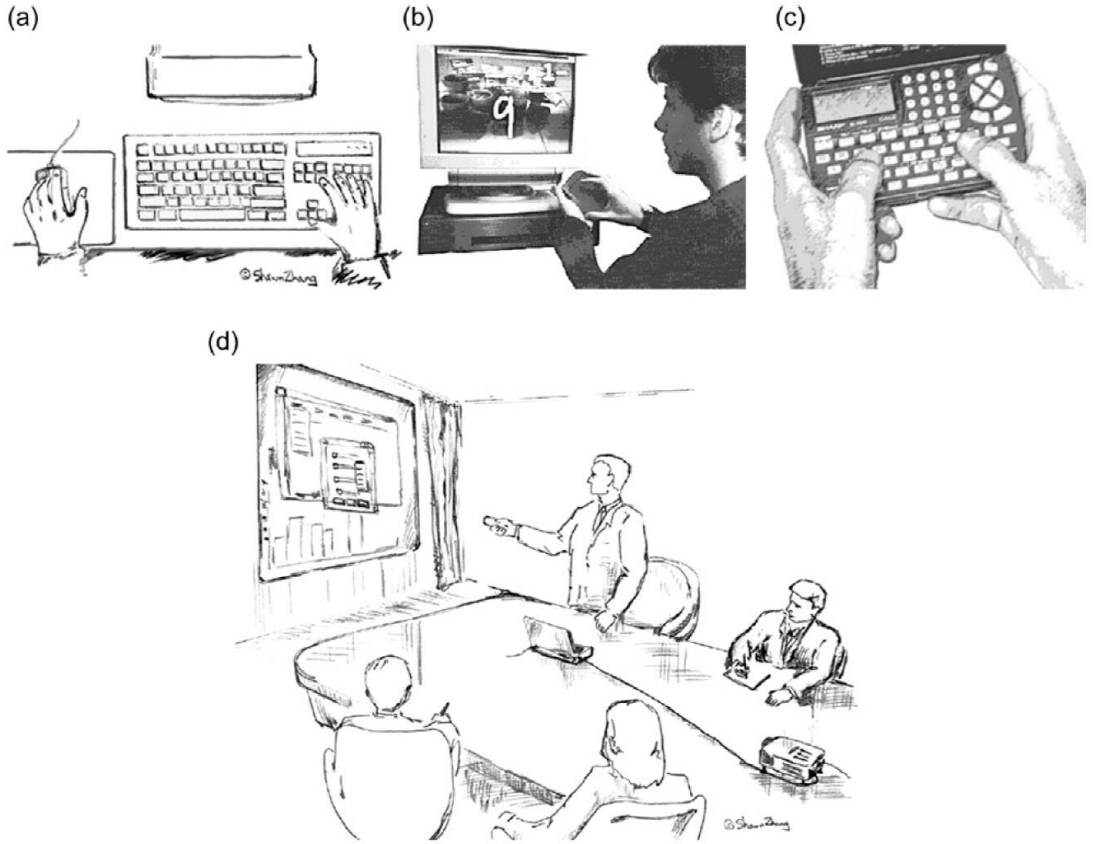
Human Factors Model



Kantowitz and Sorkin, “Human Factors: Understanding People-System Relationships”

Limbs (Responder)

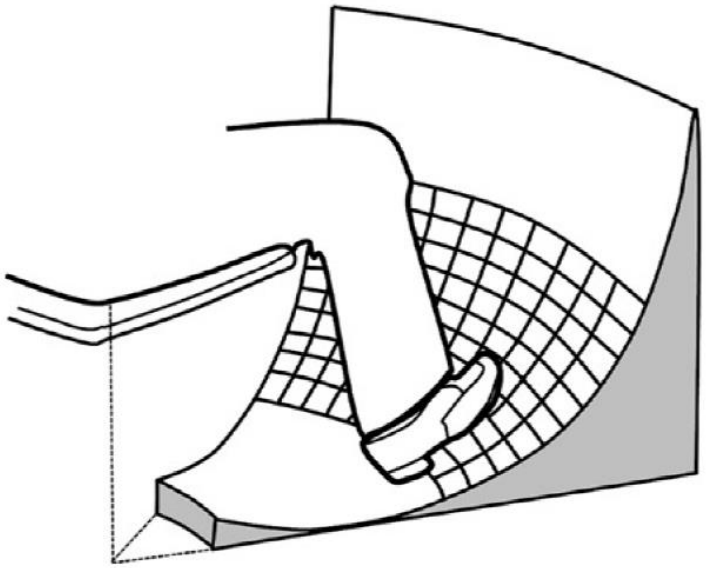
- With fingers, hands, and arms we control over machines.



Limbs

- Feet and head can also provide input to a computer, but it is rare.

(e)



(f)

Limbs

- **Handedness** (or hand dominance): the faster or more precise performance or individual preference for use of a hand
  - Dominant hand vs non-dominant hand

	Left	Right
1. Writing	☐☐	☐☐
2. Drawing	☐☐	☐☐
3. Throwing	☐☐	☐☐
4. Scissors	☐☐	☐☐
5. Toothbrush	☐☐	☐☐
6. Knife (without fork)	☐☐	☐☐
7. Spoon	☐☐	☐☐
8. Broom (upper hand)	☐☐	☐☐
9. Striking a match	☐☐	☐☐
10. Opening box (lid)	☐☐	☐☐
Total (count checks)	☐	☐

Difference	Cumulative Total	RESULT
☐	☐	☐

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

Limbs

- **Proprioception (고유감각)**: the coordination of limb movement and position through the perception of stimuli within muscles and tendons.

- When we move, our brain senses the effort, force, and heaviness of our actions and positions and responds accordingly.

- Can you clap with your eyes closed?

Voice

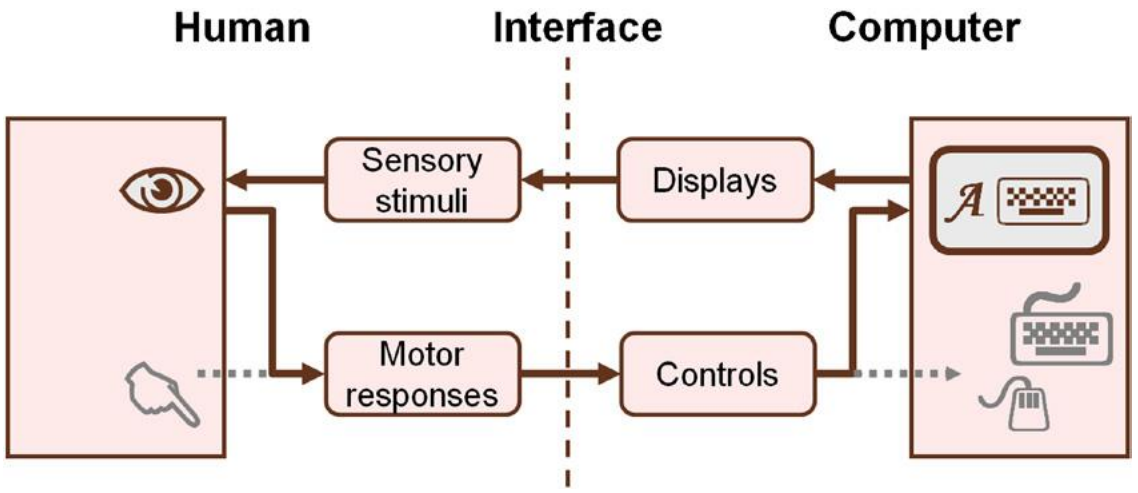
- Humans can create a great variety of sounds
  - movement in the larynx (후두), or voice box
  - pulmonary pressure in the lungs

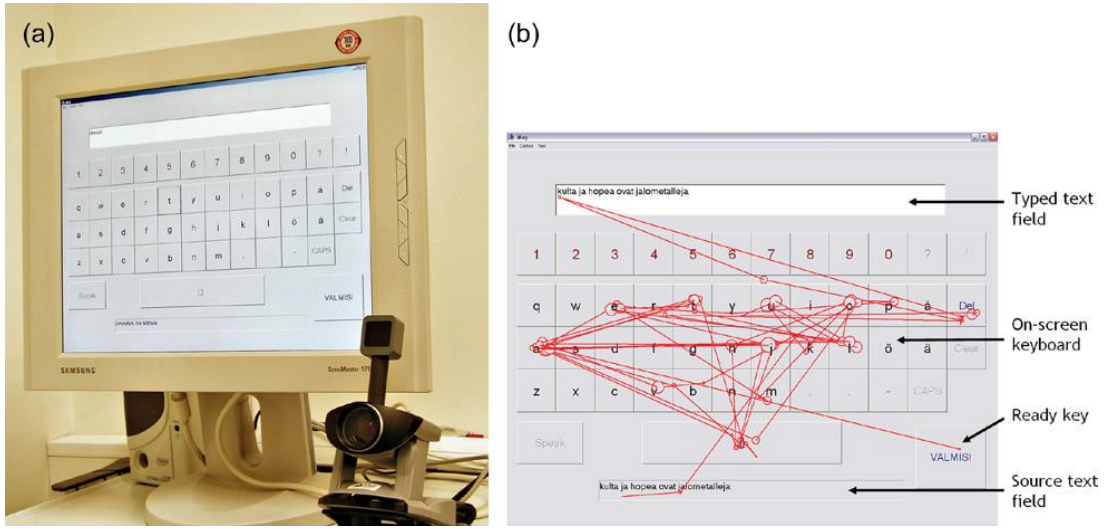
- Speech recognition
- Non-verbal voice interaction (NVVI)
- Ingressive speech

Fukumoto, SilentVoice: Unnoticeable Voice Input by Ingressive Speech

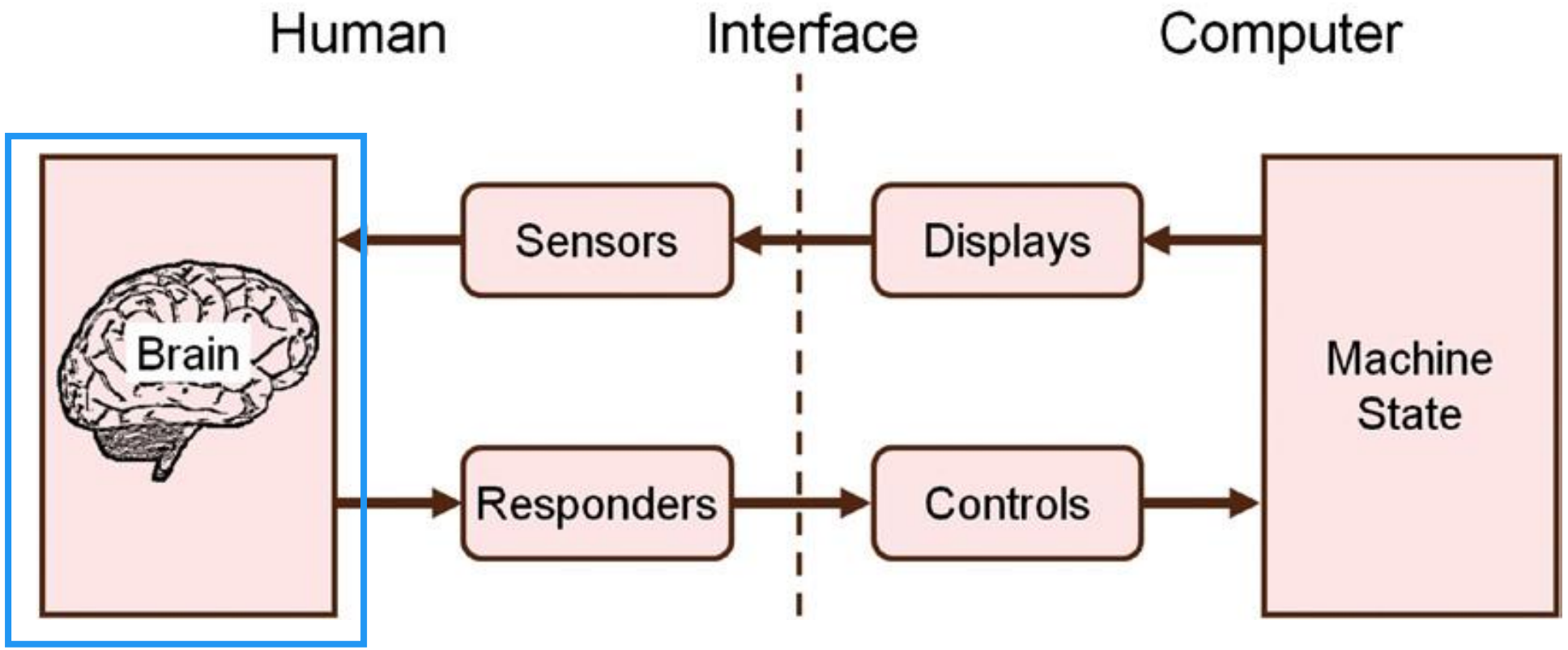
Eyes (Responder)

- Eyes can also act as reponsders to control a computer through **fixations** and **saccades**.





Human Factors Model



Kantowitz and Sorkin, “Human Factors: Understanding People-System Relationships”

The Brain

- Most complex biological structure known
- Billions of neurons
- Enables human capacity for…
  - Pondering, remembering, recalling, reasoning, deciding, communicating, etc.

- Sensors (human inputs) and responders (human outputs) are nicely mirrored, but it is the brain that connects them.

Perception

- The first stage of processing in the brain

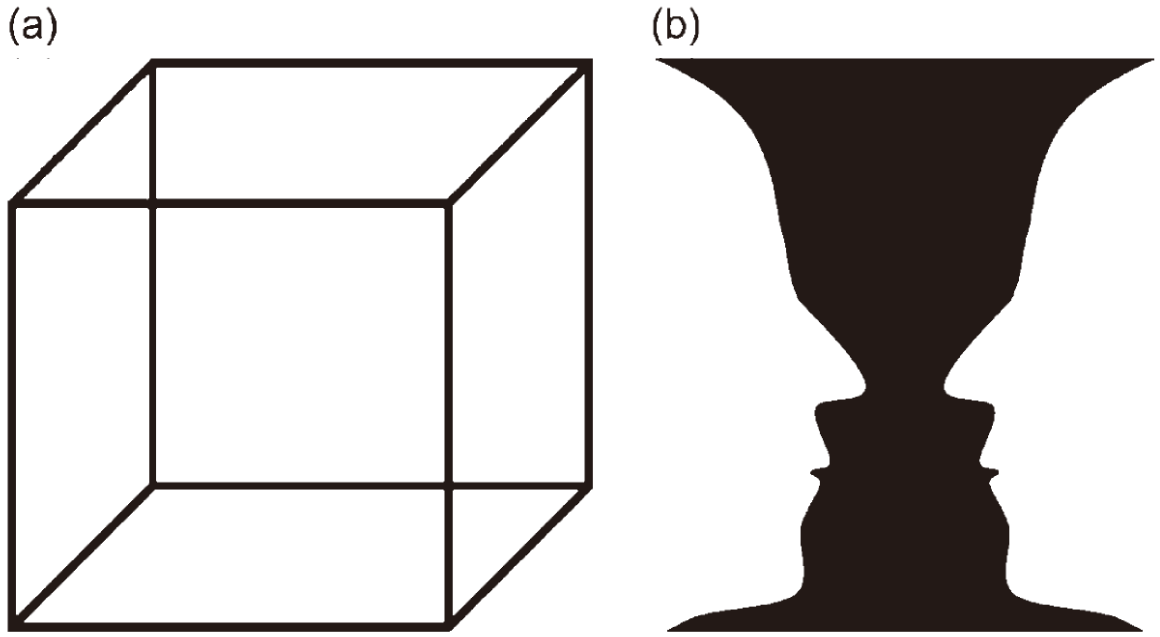
- Associations formed…
  - Auditory stimulus -> harmonious, discordant
  - Visual stimulus -> familiar, strange
  - Tactile stimulus -> warm, hot
  - Smell stimulus -> pleasurable, abhorrent
  - Taste stimulus -> sweet, sour

Perception

- Early studies in psychology: measure the **just noticeable difference (JND)** of human
- How accurate a human sensor is?
- Example (ear):
  - First sound at 200 hz
  - Second sound at 220 hz
  - Are the two sounds the same?
  - Determine threshold below which the subject deems the two stimuli “the same”.

Ambiguity

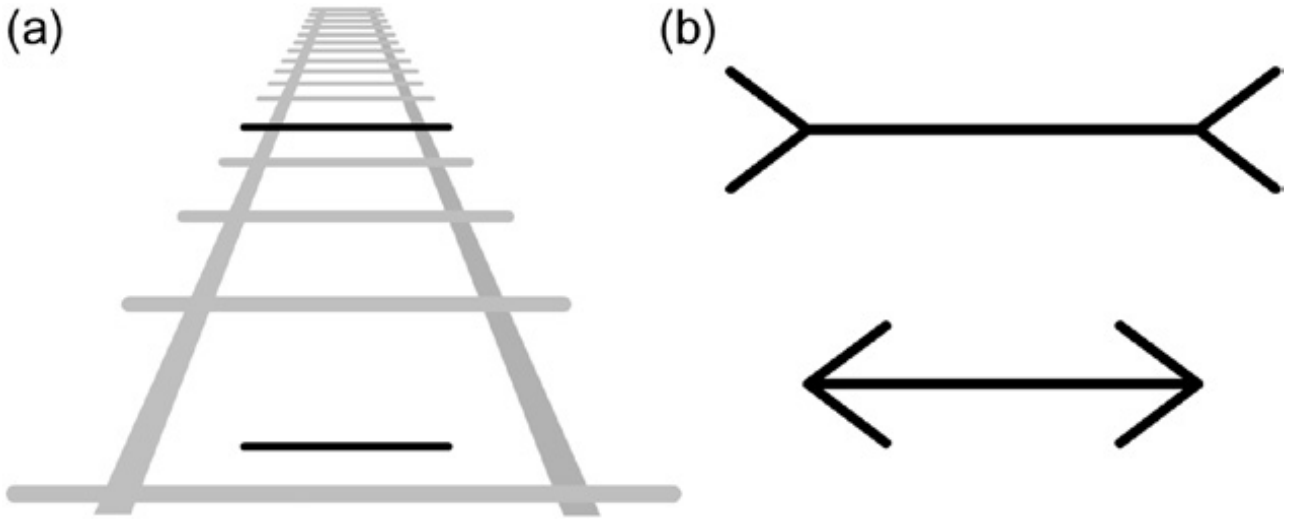
- The human ability to develop multiple interpretations of a sensory input.



Necker cube Rubin’s vase

Visual Illusion

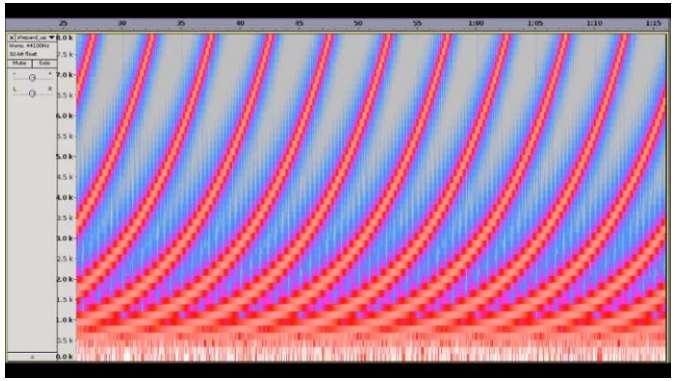
- Illusion (the deception of common sense)

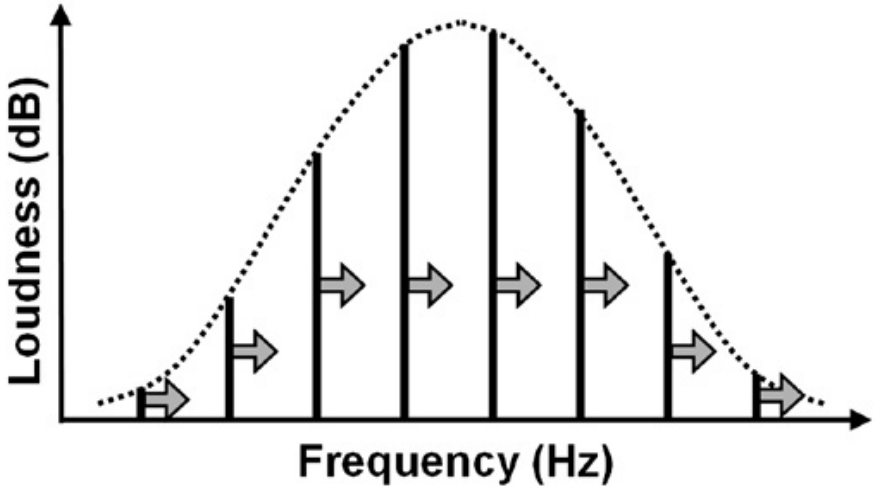


Ponzo lines Műller-Lyer arrows

Illusion

- Auditory illusion: Shepard-Risset glissando
  - https://www.youtube.com/watch?v=BzNzgsAE4F0&feature=youtu.be
- Tactile/haptic illusion: phantom limb





Cognition

- Cognition is the human process of conscious intellectual activity
  - e.g., thinking, reasoning, deciding
- Spans many fields
  - e.g., neurology, linguistics, anthropology
- Sensory phenomena: easy to study because they exist in the physical world
- Cognitive phenomena: hard to study because they exist within the human brain

Making a Decision

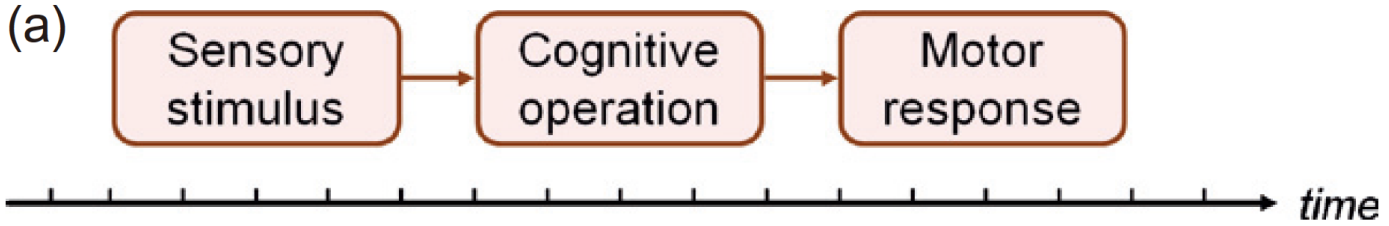
- Not possible to directly measure the time for a human to “make a decision”

- 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?

Making a Decision

- Our decision-making process is not “instantaneous.”
  - In fact, humans are slow reactors.

(a)



(b)

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

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

A More Involved Decision

Memory

- **Memory** is the human ability to store, retain, and recall information.
  - Biological SSD

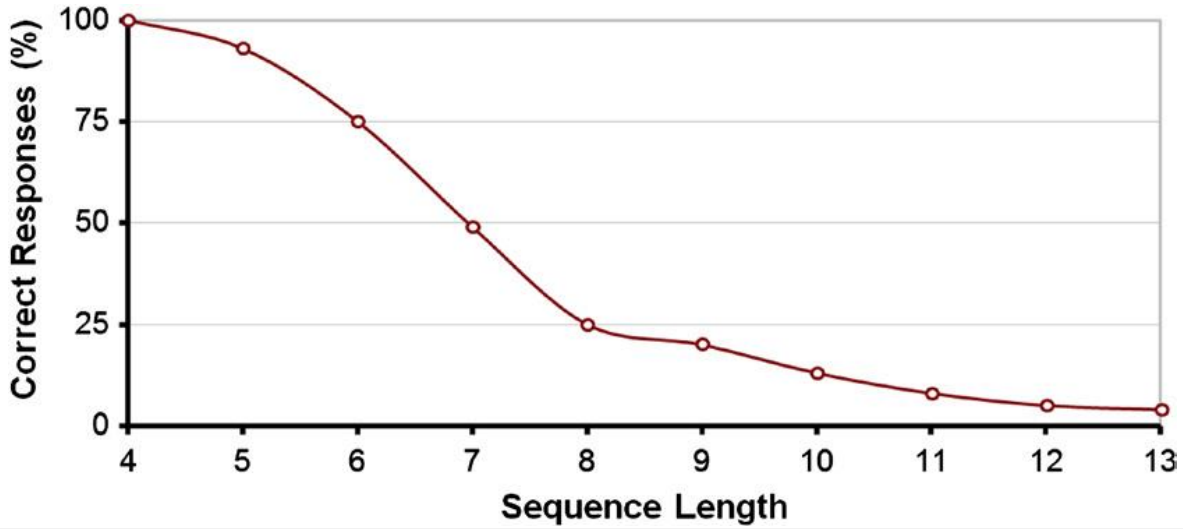
- Long-term memory
  - Declarative/explicit area: information about events in time and objects in the external world (data space in computer memory)
  - Procedural/implicit area: information about how to use objects or how to do things (code space in computer memory)

- Short-term memory (or working memory)
  - Information is active and readily available for access
  - Amount of working memory is small, about 7 (±2) units or chunks

Short-term Memory Capacity

- G. A. Miller, “The Magic Number **Seven, Plus or Minus Two**: Some Limits on our Capacity for Processing Information” (1956)

- Random sequence recall experiment
  - Recite random digits to subjects and ask them to recall the digits



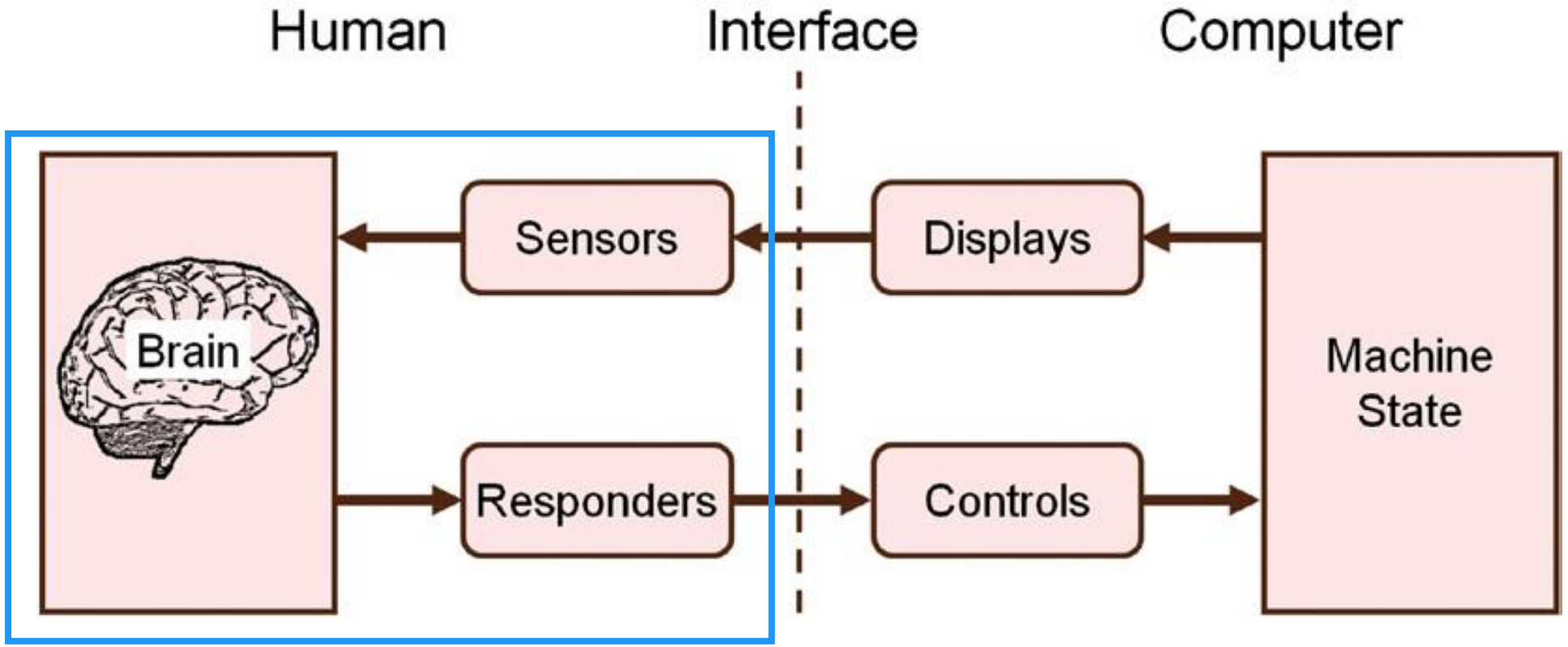
Chunking

- **Chunks**: symbols organized into larger units
  - Phone numbers
  - Credit card numbers

- 3.14 // 1592 // 6535 // 8979 // 3238
- 06252021 -> 06 // 25 // 2021

- C K N K U S S C H I
- S K K U N S C H C I -> SKKU // NSC // HCI

Human Factors Model



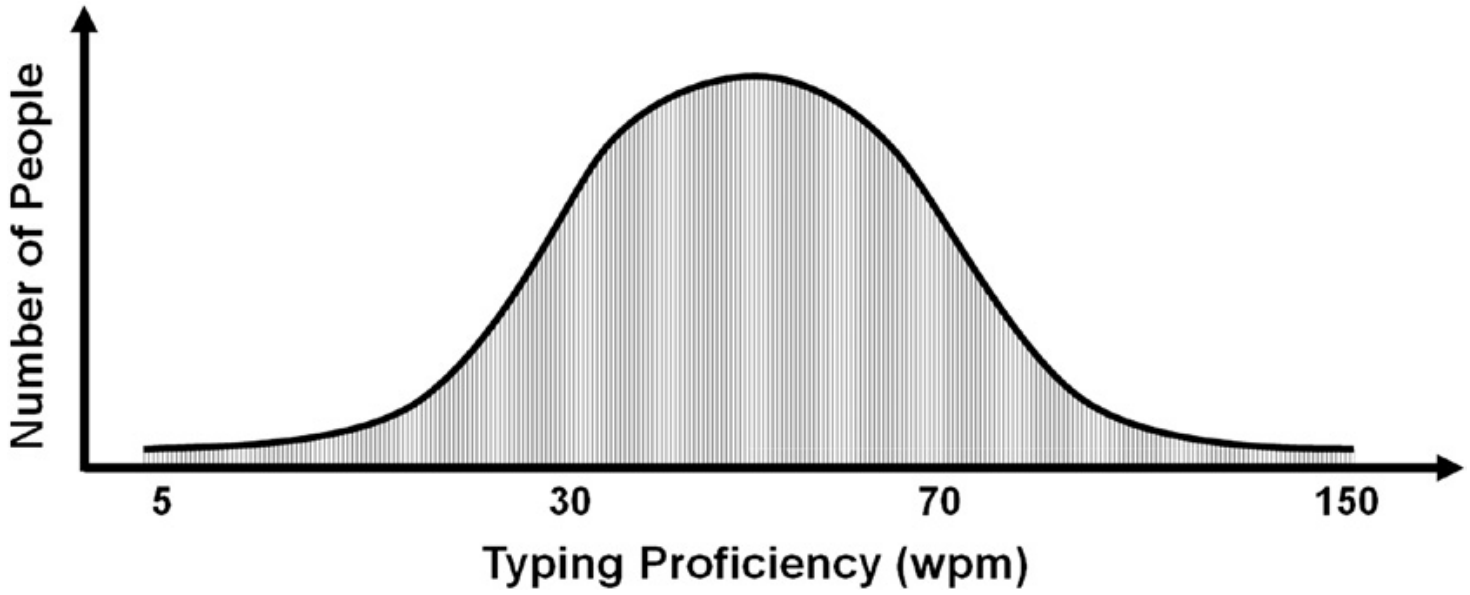
Human performance

Human Performance

- How “efficient” a human is? (like computer benchmark)
  - Example tasks: tying shoelaces, searching the Internet, entering a text message, …
- **Speed-accuracy trade-off**: go faster and errors increase; slow down and accuracy improves.

Human Performance

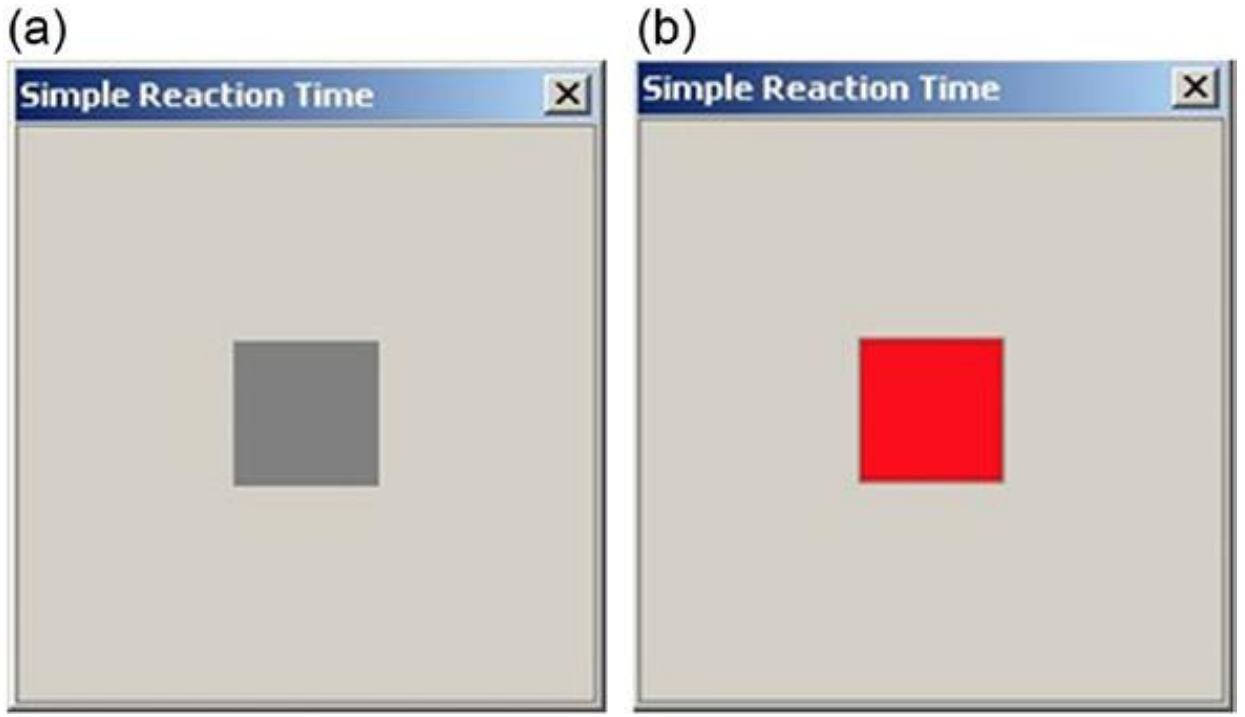
- All humans are different. So is their performance.
  - High variability (age, gender, skill, motivation, etc)
  - Understanding of the target user is needed.



Reaction Time

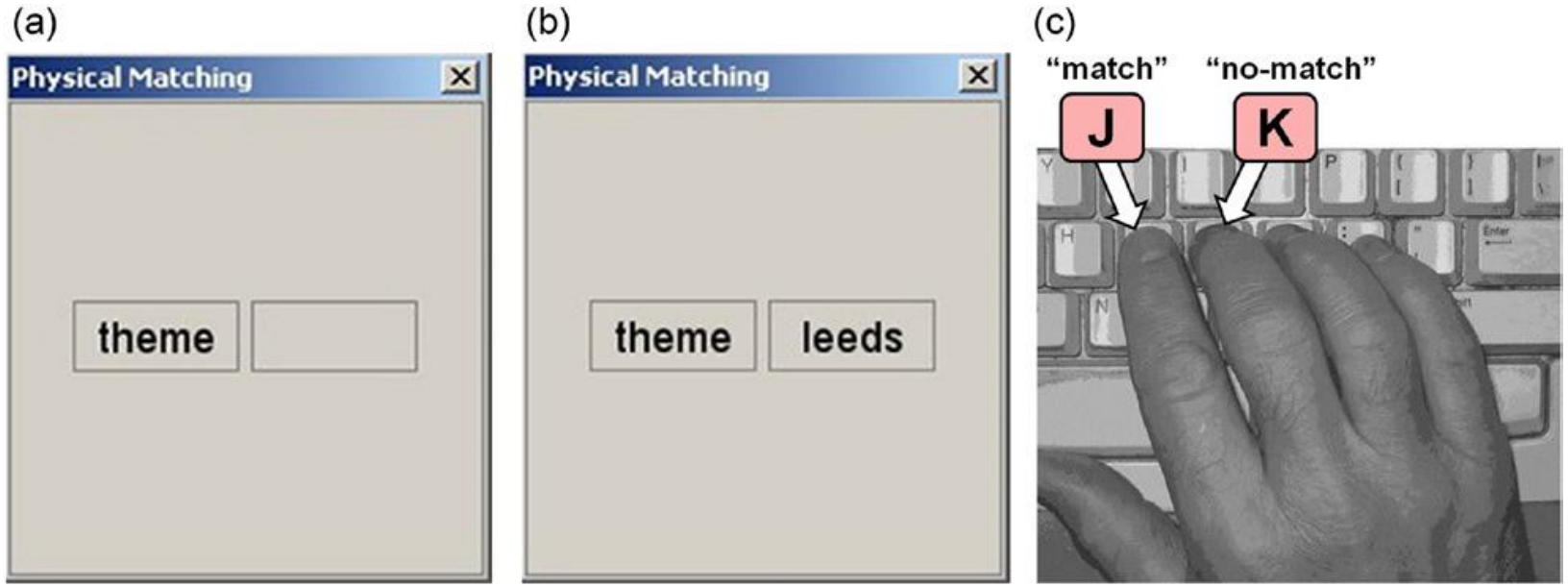
- **Reaction time**: the delay between the occurrence of a single fixed stimulus and the initiation of a response assigned to it.
  - How fast a human can react? (like how fast your server can respond?)
- Reaction time varies by type of sensory stimuli
- Approximate values
  - Auditory: 150 ms
  - Visual: 200 ms
  - Smell: 300 ms
  - Pain: 700 ms

Reaction Time Experiment

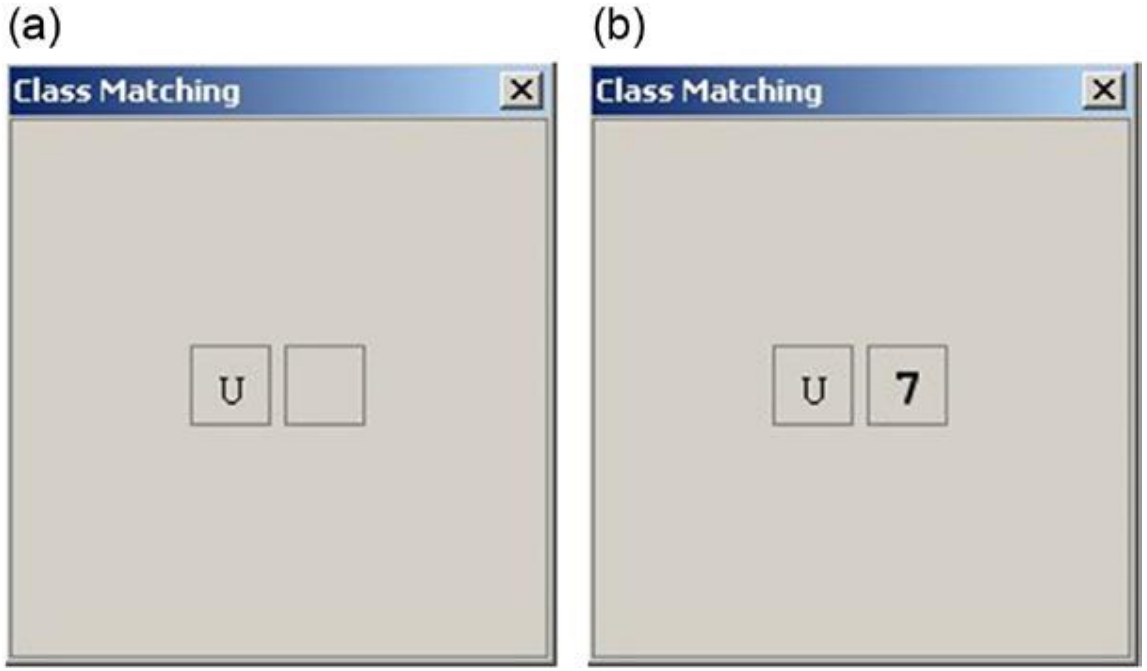


When the box becomes red, press “X”!

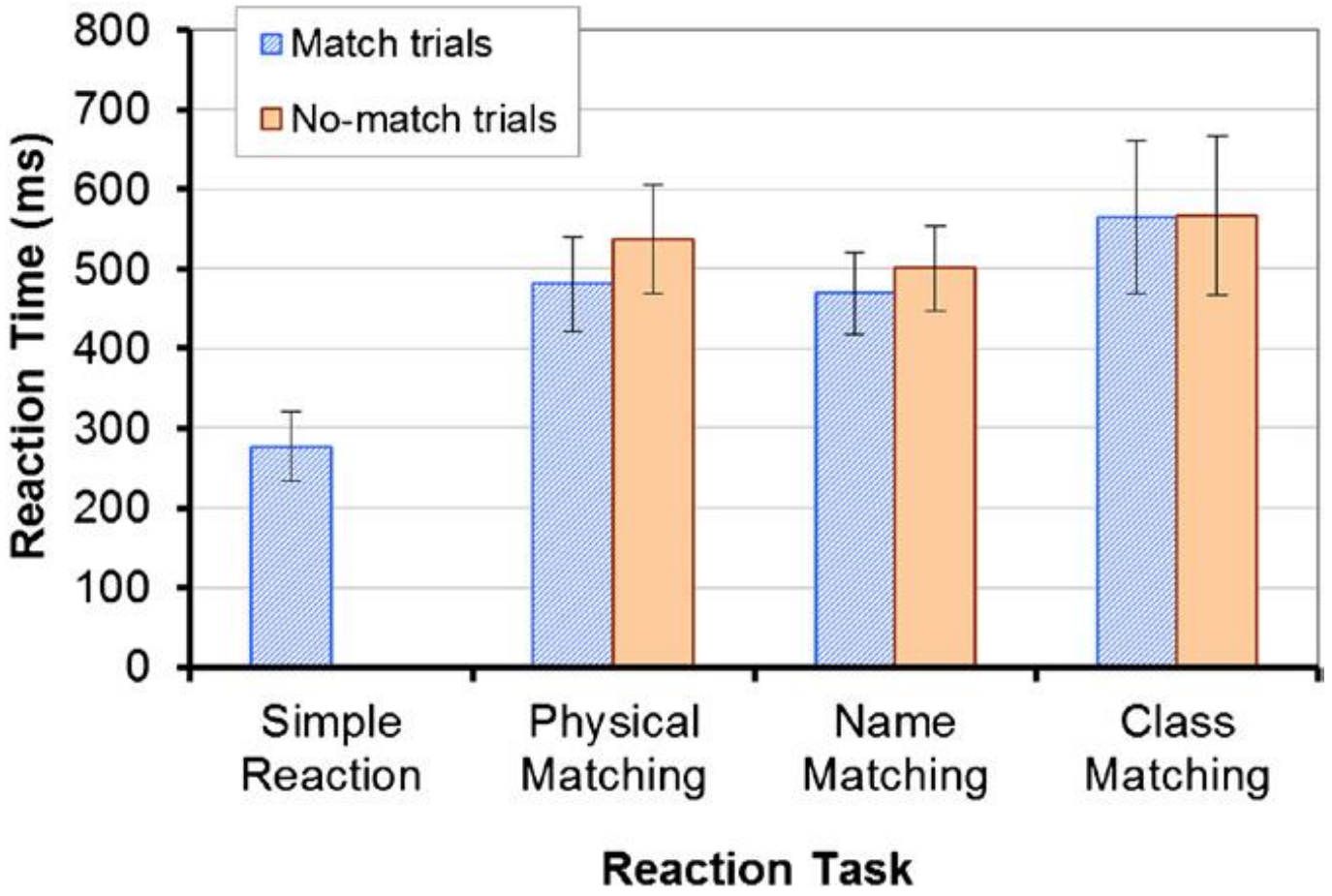
Reaction Time Experiment



Reaction Time Experiment

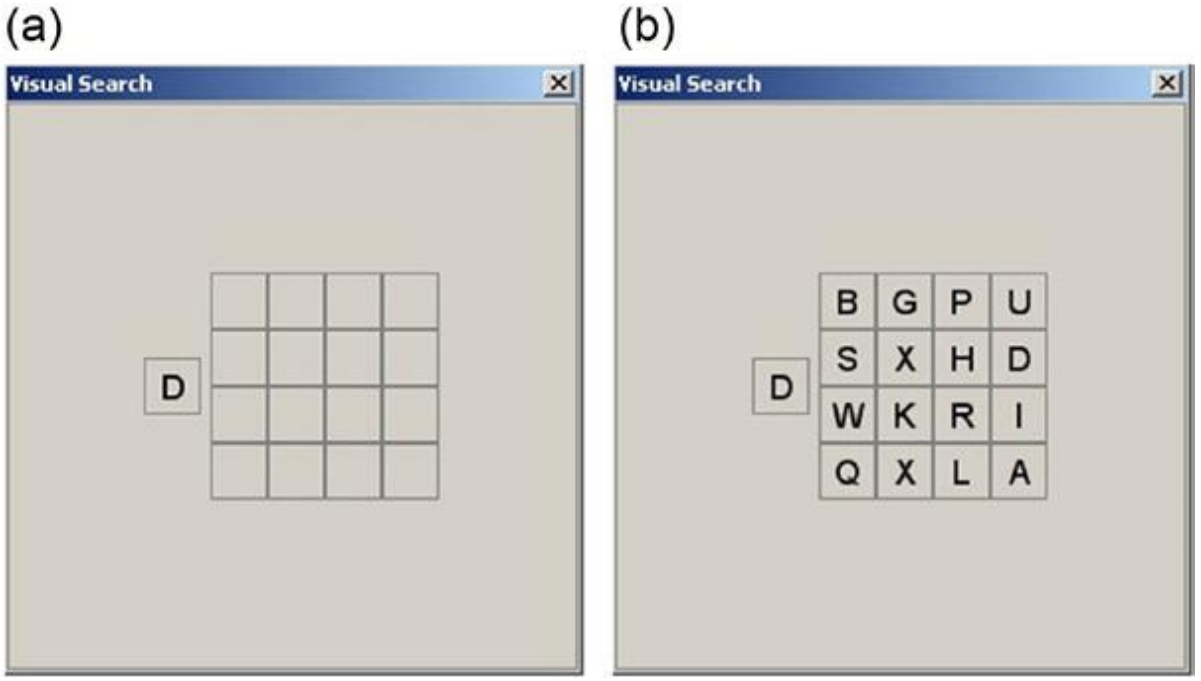


Experiment Results



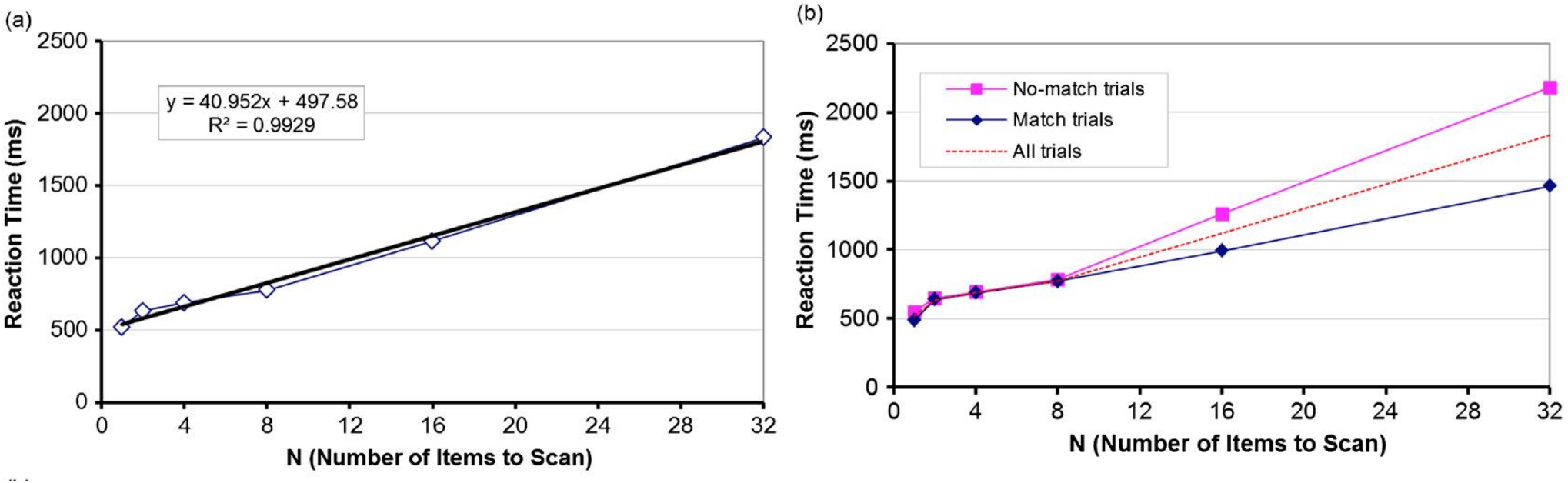
Visual Search

- **Searching** is another task that humans perform everyday.
  - Take longer than simple reaction time



Experiment Results

- Is our “biological” search algorithm *O(N)*?



Reaction Time

- Professionals have shorter reaction times.
  - Athletes, progamers, …
- It’s almost impossible for humans to react in 100 ms unless they anticipated.
  - False start in athletics (100 ms)
  - Aim hack (many FPS games)

Skilled Behavior

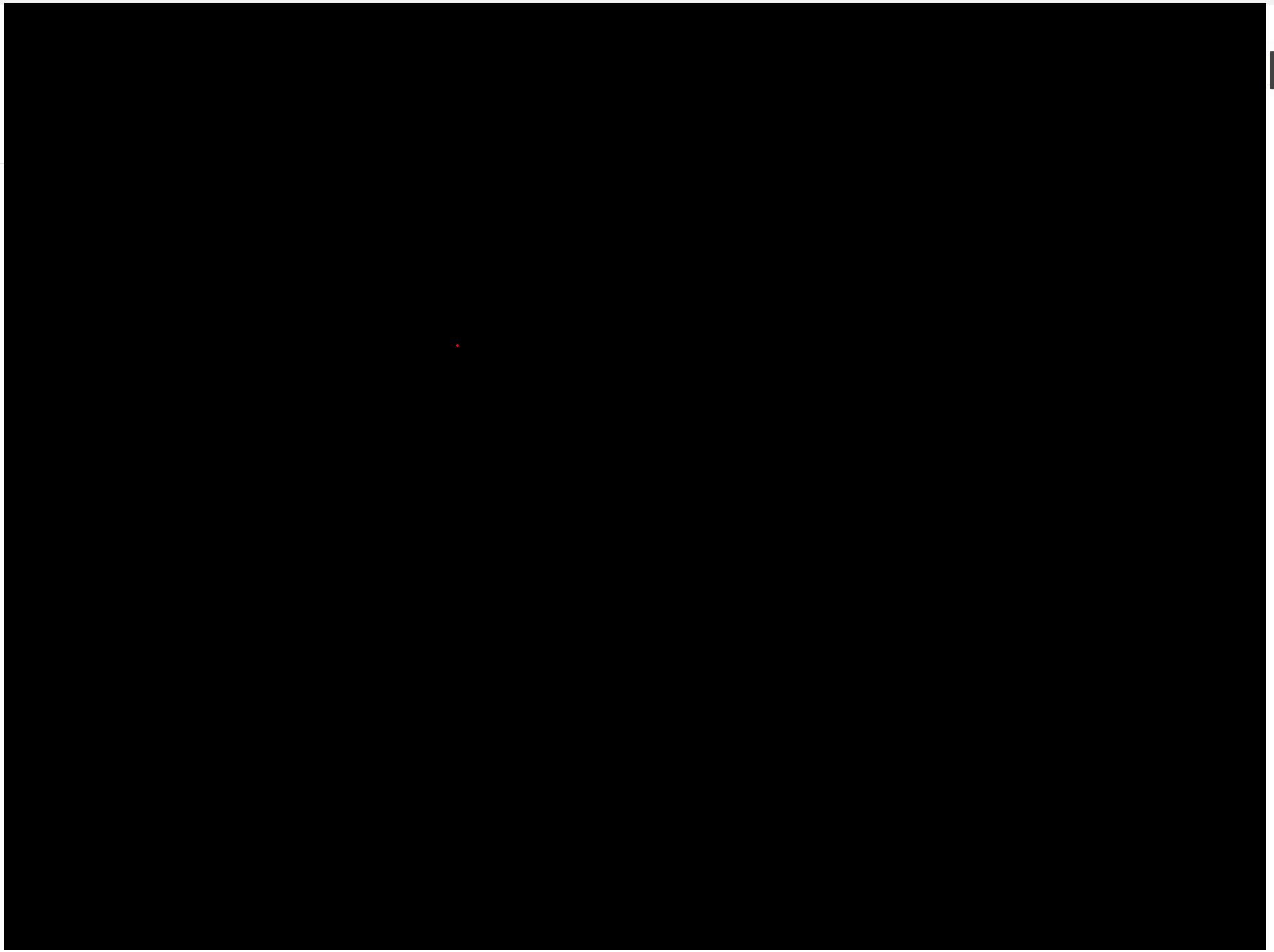
- For many tasks, human performance improves considerably and continuously with practice.
  - But not for simple reaction time tasks

- **Skilled behavior**: a property of human behavior whereby human performance necessarily improves through practice.
  - Sensor-motor skill: darts, gaming
  - Mental skill: chess, programming

- This is why we practice programming!

Attention

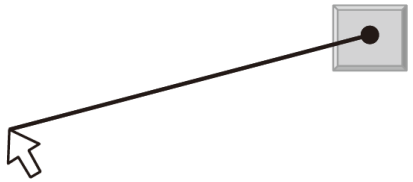
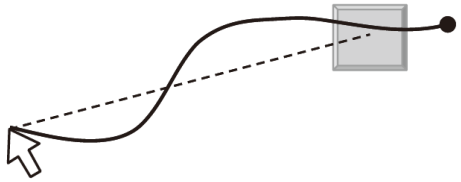
- Humans are NOT good at attending to two or more tasks simultaneously.
  - Single-core CPU?
- Like short-term memory, our attention is also limited.
- Attention is complex
  - Texting while driving -> hard
  - talk and walk -> easy
  - read and type the same text -> easy
  - read and type the different texts -> hard



https://www.youtube.com/watch?v=vJG698U2Mvo

Human Errors

- We make mistakes, and many HCI studies aimed to design a user interface that prevents human errors.
  - The ratio of incorrectly completed trials to all trials (%)

	Target Selection	Text Entry
Correct		quickly
Incorrect		qucehkly

Human Errors

- Serious accidents causing significant damage or loss of life are often attributed to human error.
- But the fault may be a *design induced error.*
- Interaction errors are not only possible, they are, in time, *likely* and must be anticipated in the design