EECS 4441 Human-Computer Interaction

Topic #2: The Human

I. Scott MacKenzie

York University, Canada

LASSONDE SCHOOL OF ENGINEERING | YORK UNIVERSITÉ UNIVERSITY | EECS ELECTRICAL ENGINEERING AND COMPUTER SCIENCE

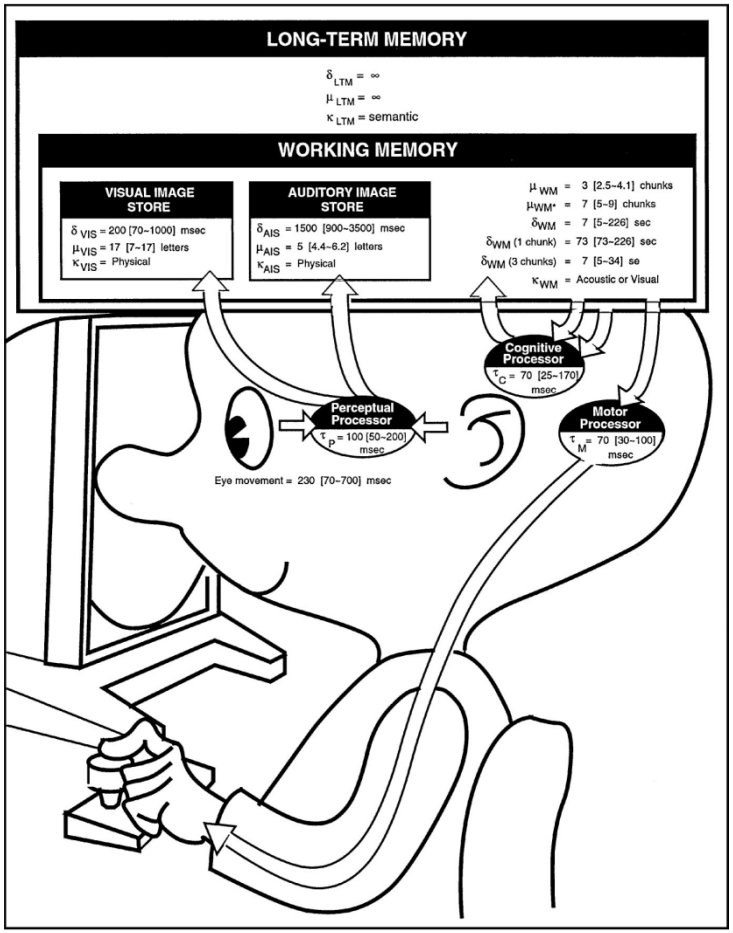
Topics

- Models of the Human
- Sensors (inputs)
- Responders (outputs)
- The Brain (memory and cognition)
- Human Performance

Topics

- Models of the Human
- Sensors (inputs)
- Responders (outputs)
- The Brain (memory and cognition)
- Human Performance

The Model Human Processor



Includes:

- Long-term memory
- Working memory
  - Visual image store
  - Auditory image store
- Cognitive processor
- Perceptual processor
- Motor processor

Card, S. K., Moran, T. P., and Newell, A., *The psychology of human-computer interaction*. Hillsdale, NJ: Erlbaum, 1983. (p. 26)

Newell's Time Scale of Human Action

Scale (sec)	Time Units	System	World (theory)
10^{7}	Months		**SOCIAL BAND**
10^{7}	Weeks		
10^{6}	Days		
10^{5}	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	

Newell, A., *Unified theories of cognition*. Cambridge, MA: Harvard University Press, 1990. (p. 122)

Descriptive Models

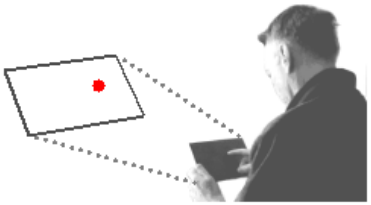
- Newell's Time Scale of Human Action is an example of a *descriptive model*
- Descriptive models are common in HCI and other fields; they…
  - Delineate or partition a problem space
  - Are "tools for thinking"
- The next slide shows another descriptive model: the Frame Model of Visual Attention[1,2]

[1] MacKenzie, I. S., & Castellucci, S. J. (2012). Reducing visual demand for gestural text input on touchscreen devices. *Proc CHI 2012*, pp. 2585-2590. New York: ACM.

[2] MacKenzie, I. S., & Castellucci, S. J. (2013). Eye on the message: Reducing attention demand for touch-based text entry. *Int J Virtual Worlds and HCI*, 1, 1-9.

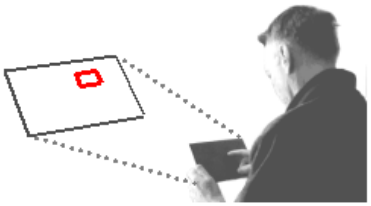
Frame Model of Visual Attention

Point Frame



Point Frame – requires the greatest demand in visual attention. Interactions in the point frame demand a high degree of accuracy and, consequently, require sharp central vision (aka foveal vision). Examples are tasks such as selecting a thin line or very small target, such as a pixel.

Target Frame

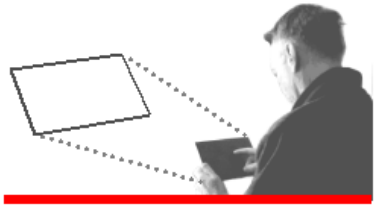


Target Frame – below the point frame. Interactions involve selecting targets such as icons, toolbar buttons, or keys on a soft keyboard. Visual attention involving foveal vision is still needed, but with less demand than in the point frame. The targets are larger and, hence, require less precision and attention.

Surface Frame

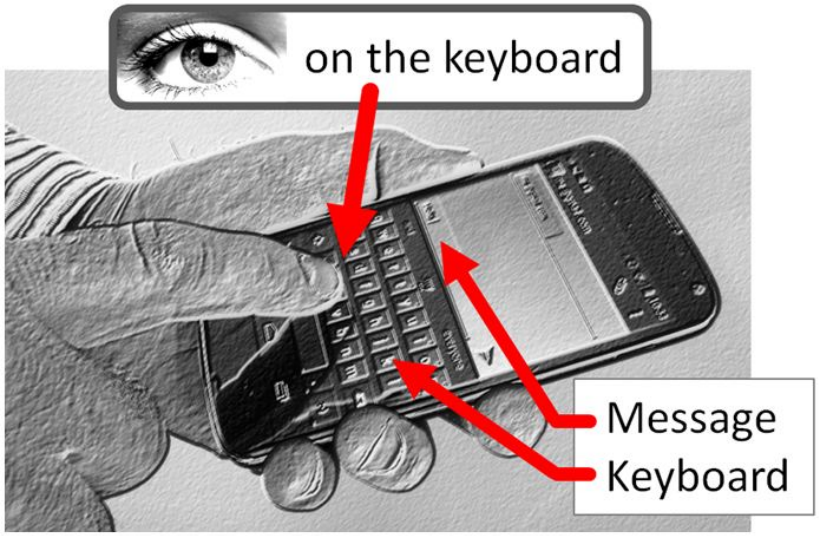
Surface Frame – applies to flicks, pinches, and most gestures on touchscreen devices. The user only needs to have a general spatial sense of the surface on which gestures are made. The visual demand is minimal; peripheral vision is sufficient.

Environment Frame



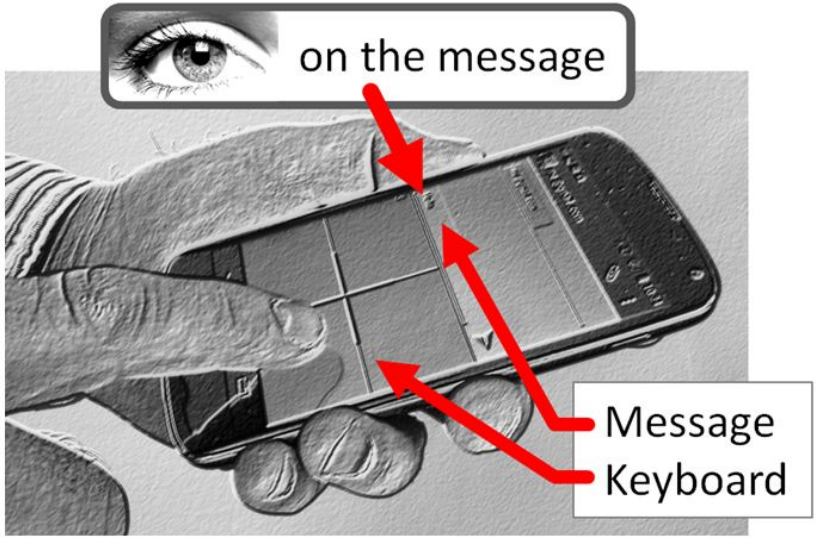
Environment Frame – requires the least demand in visual attention. The frame of reference encompasses the user, the device, and the surroundings. Visual demand is low, and requires only peripheral vision. Some accelerometer or camera interactions apply to the environment frame.

Target Frame



Qwerty Soft Keyboard

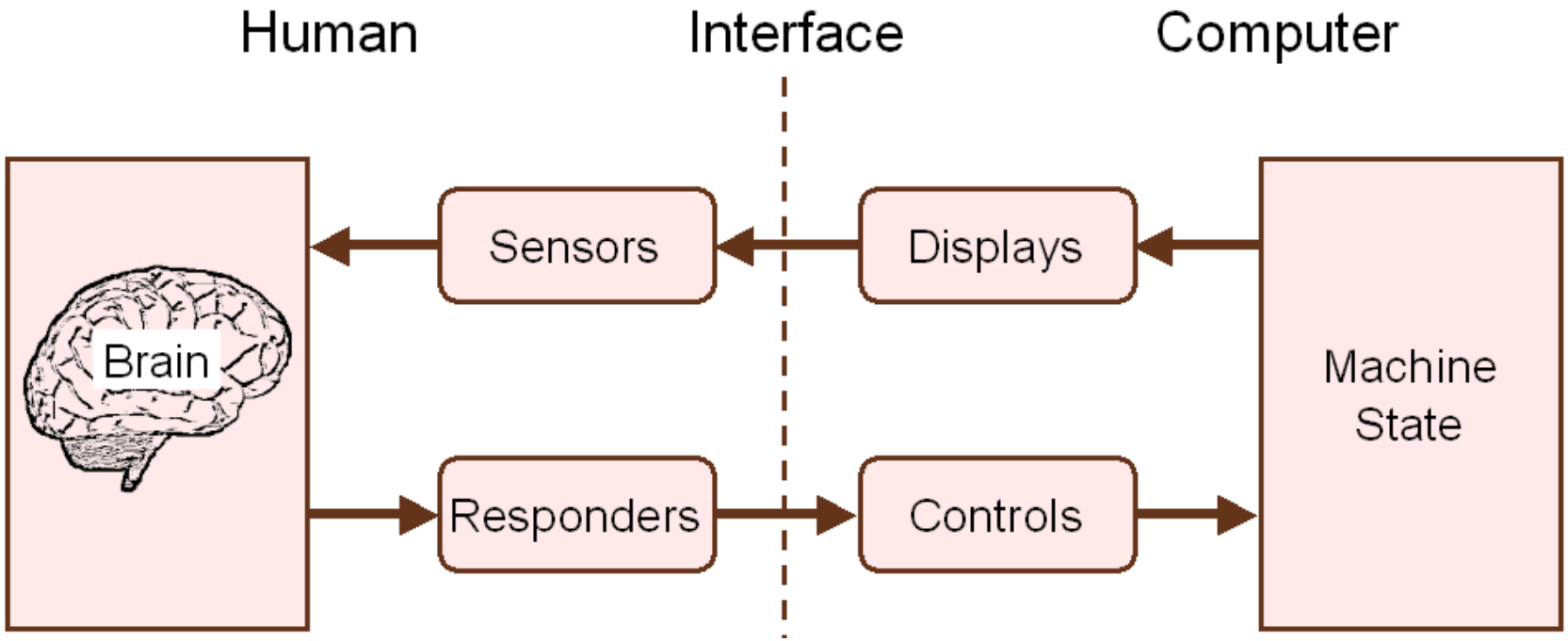
Surface Frame



H4 Writer [1]

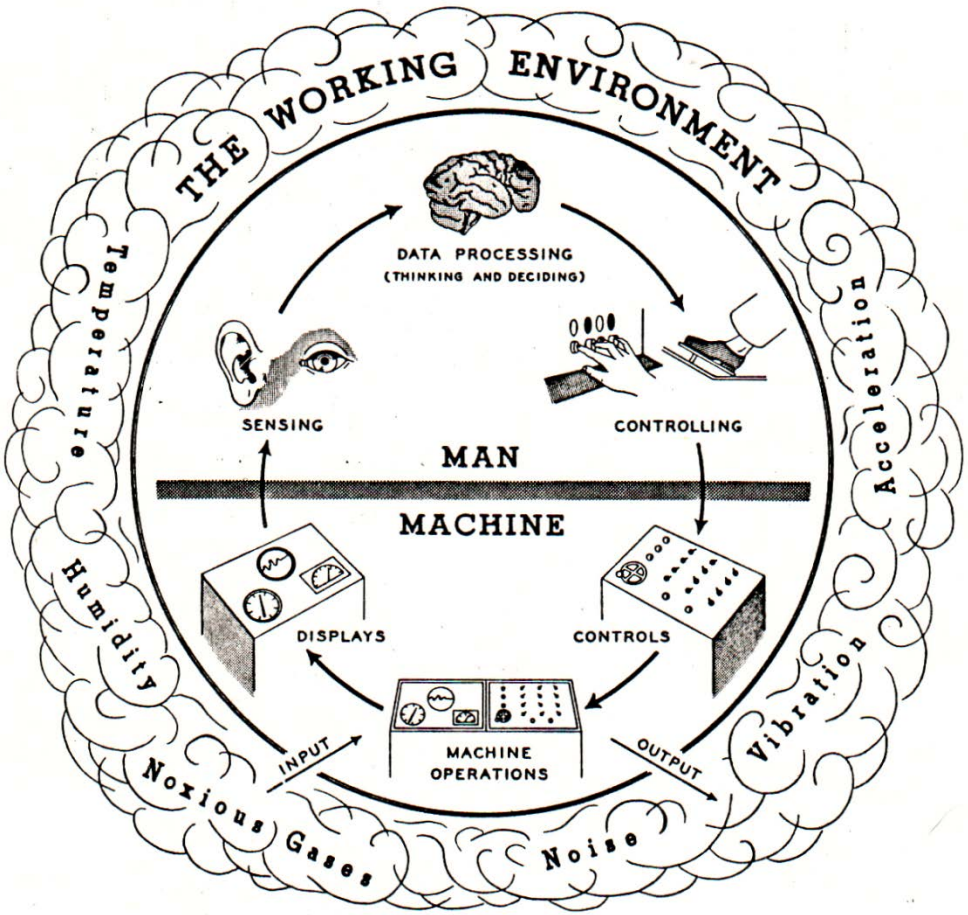
[1] MacKenzie, I. S., & Castellucci, S. J. (2013). Eye on the message: Reducing attention demand for touch-based text entry. *Int J Virtual Worlds and HCI*, 1, 1-9.

Human Factors Model (1)



Kantowitz, B. H. and Sorkin, R. D., *Human factors: Understanding people-system relationships*. New York: Wiley, 1983. (p. 4)

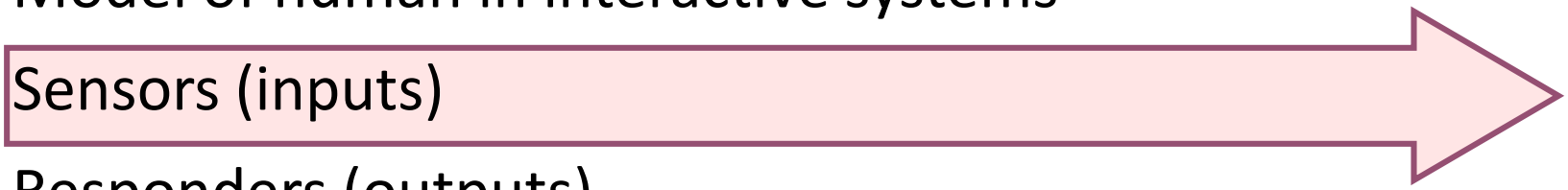
Human Factors Model (2)



Chapanis, A., *Man-machine engineering*. Belmont, CA: Wadsworth Publishing Company, 1965. (p. 20)

Topics

- Model of human in interactive systems
- Sensors (inputs)
- Responders (outputs)
- The Brain (memory and cognition)
- Human Performance



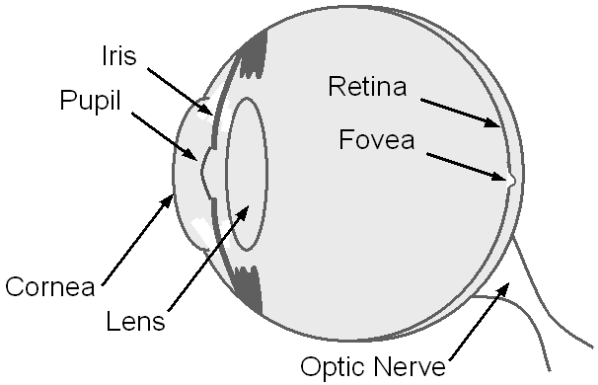
The Five Senses

- Sight (vision)
- Hearing (audition)
- Touch (tactition)
- Taste (gustation)
- Smell (olfaction)

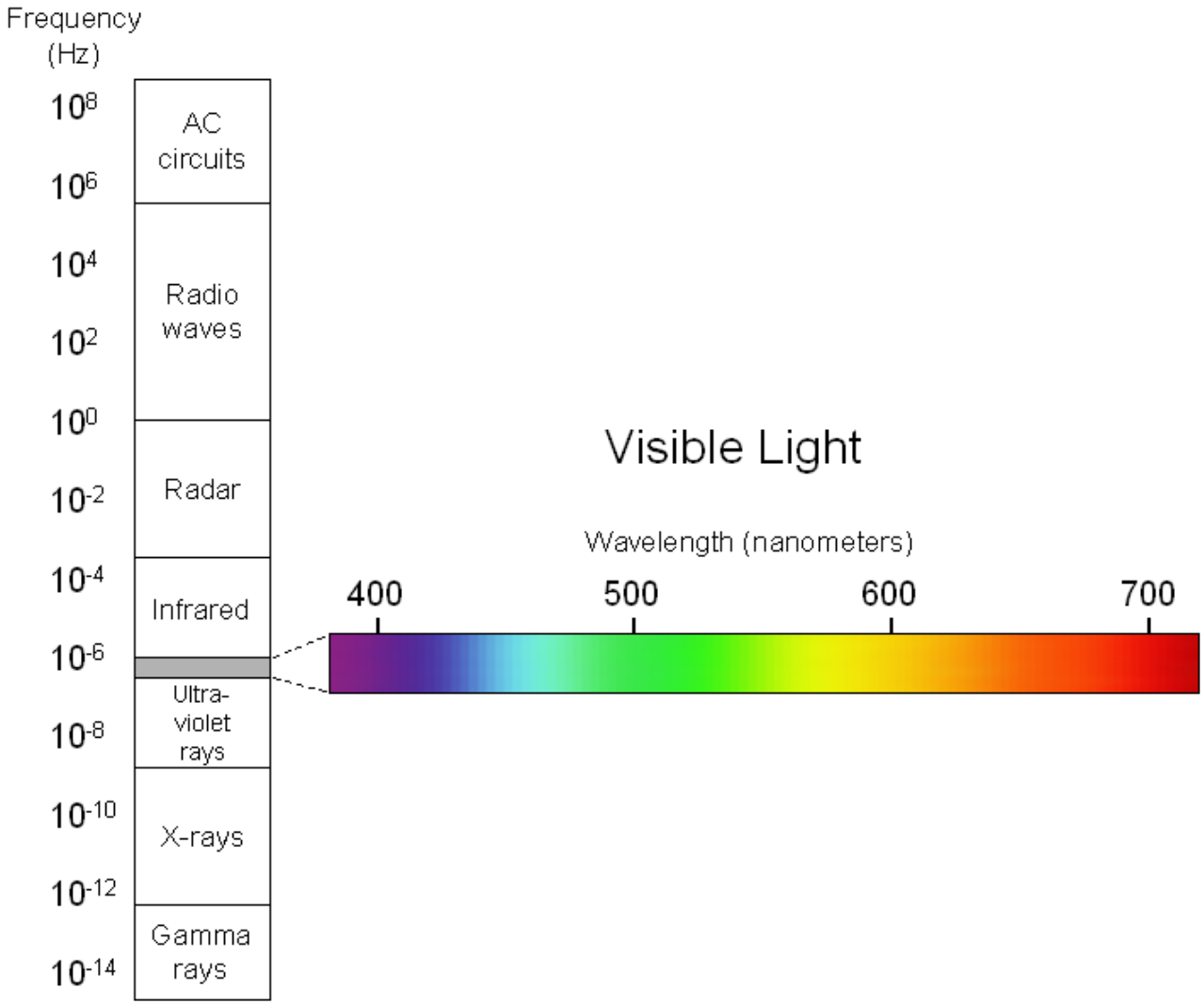
Sight (Vision)

The Eye – Physical Reception

- Mechanism for receiving light and transforming it into electrical energy
- Images are focused upside-down on the retina
- Retina contains rods for low light vision and cones for colour vision
- Fovea – area in retina for sharp central vision



Visible Light (the electromagnetic band)



Interpreting the Signal (1)

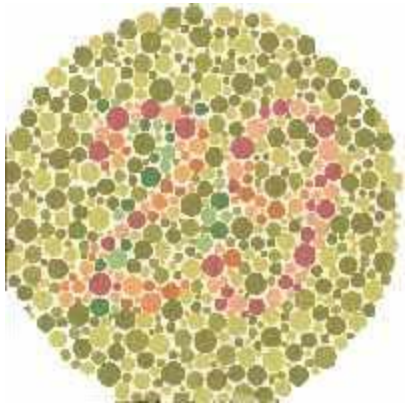
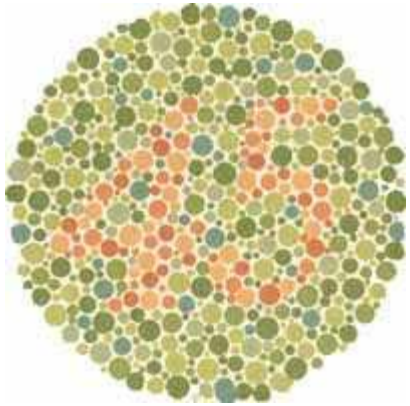
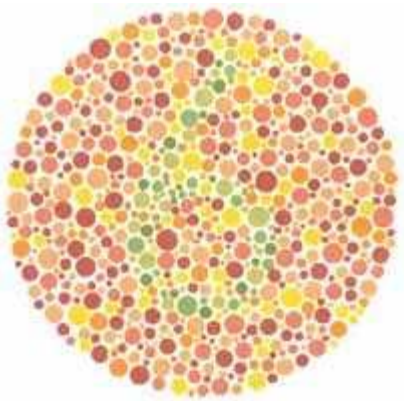
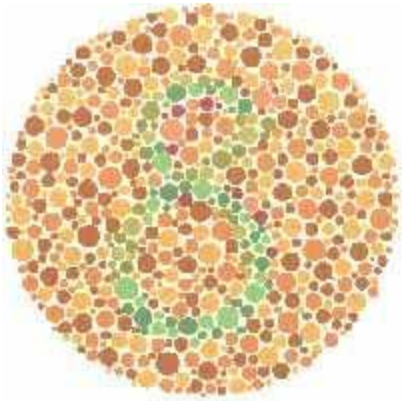
- Size and depth
  - Visual angle indicates how much of a view an object occupies (relates to size and distance from eye)
  - Visual acuity is ability to perceive detail (limited)
  - Familiar objects perceived as constant size, in spite of changes in visual angle when far away (e.g., at night, headlight spacing infers distance of car, based on “perceived size of a car”)
  - Cues like overlapping help perception of size and depth

Interpreting the Signal (2)

- Brightness
  - Subjects react to levels of light
  - Affected by luminance of object
  - Measured by just noticeable difference (jnd)
  - Visual acuity increases with luminance, as does flicker
- Colour
  - Made up of hue, intensity, and saturation
  - Cones sensitive to colour wavelengths
  - Blue acuity is lowest
  - ~8% males, ~1% females are colour blind

Test for Colour Blindness

- What do you see?

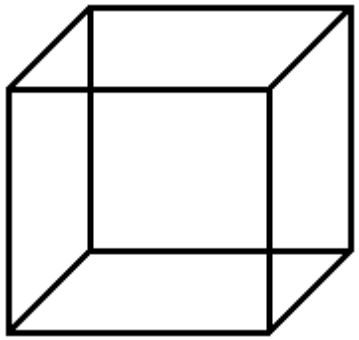





http://www.toledo-bend.com/colorblind/Ishihara.html

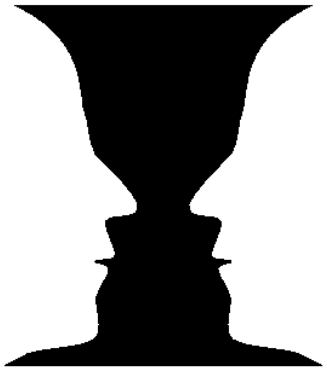
Interpreting the Signal (3)

- The visual system compensates for
  - Movement
  - Changes in luminance
- Context resolves ambiguity
  - E.g., reading road signs or reading text with parts missing

Visual Ambiguity



Necker Cube

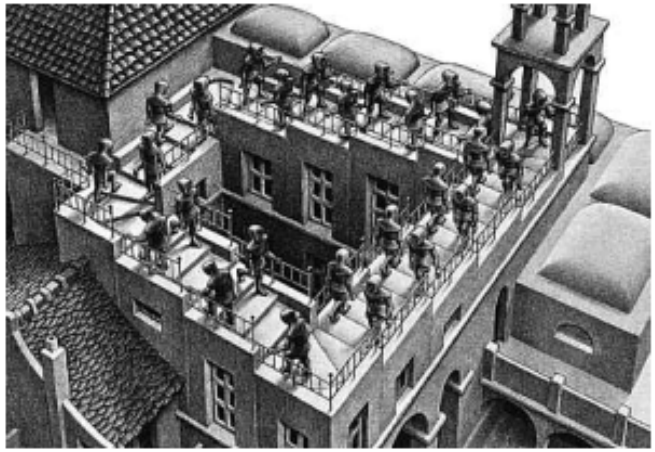


Rubin Vase

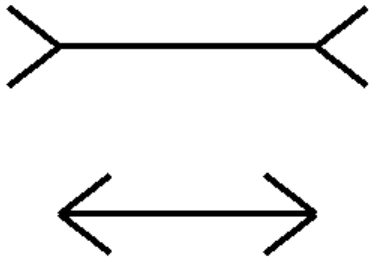
Visual Illusion

- Sometimes occurs due to over compensation

Ponzo Illusion



Escher's Staircase



Müller-Lyer Arrows

Reading

- Several stages:
  - Visual pattern perceived
  - Decoded using internal presentation
  - Interpreted using knowledge of syntax, semantics, pragmatics
- Reading involves saccades and fixations of the eye
- Perception occurs during fixations
- Word shape is important to recognition
- Negative contrast (dark characters on a light display) improves reading from computer screen

Eye Dominance

- Are you left handed or right handed?
  - (more later)
- Are you left eyed or right eyed?
  1. Find a spot on a wall opposite to you (e.g., a light switch)
  2. Get a CD and hold it at arms length
  3. Move the CD in front of the spot and fixate on the spot through the hole
  4. Now close one eye then the other to determine which eye you were using for step 3. That's your dominant eye!

References

Collins, J. F. & Blackwell, L. K. 1974. Effects of eye dominance and retinal distance on binocular rivalry, *Perceptual Motor Skills*, 39, 747-754.

Zhang, X., and MacKenzie, I. S. (2007). Evaluating eye tracking with ISO9241 – Part 9. *Proceedings of HCI International 2007*, pp. 779-788. Berlin: Springer-Verlag.

Hearing (Audition)

Hearing (Audition)

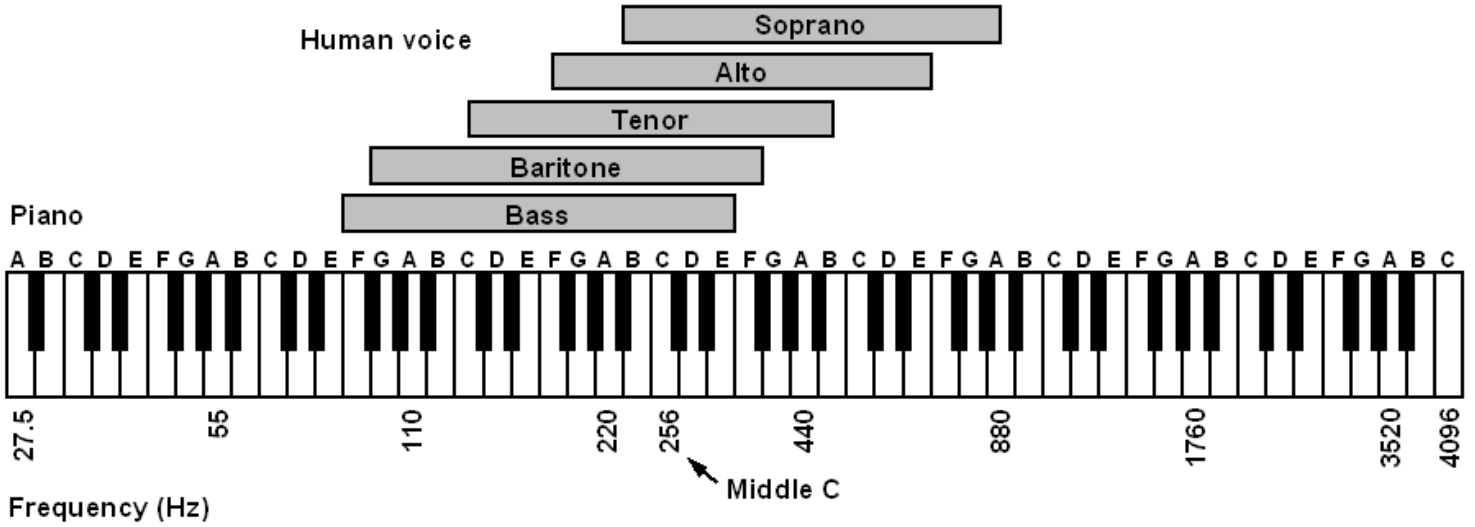
- Hearing is the detection of sound
- Sound is transmitted in the environment as waves (cyclic fluctuations of pressure in a medium, such as air)
- Sound waves are created when physical objects are moved or vibrated, thus creating fluctuations in air pressure
- Examples
  - Plucking a string on a guitar, slamming a door, shuffling cards, a human speaking, clicking a button

Sound Characteristics

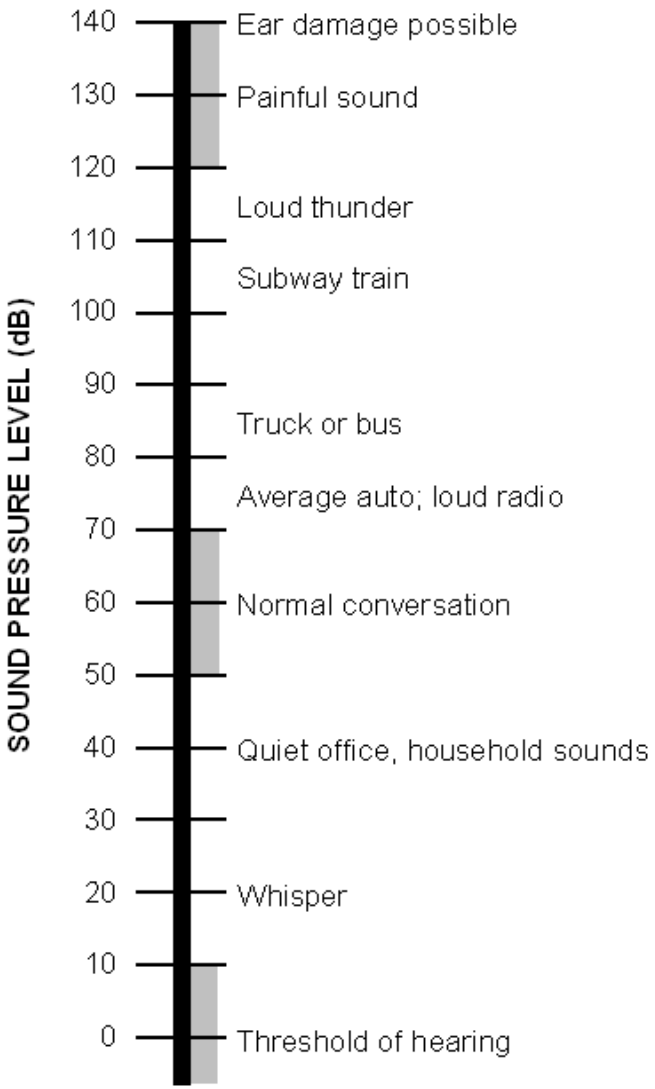
1. Pitch – sound frequency (in Hertz)
2. Loudness – amplitude or intensity (in dB or deciBells)
3. Timbre – type, quality, or harmonic structure
4. Attack (aka envelope) – the build-up over time of harmonics

Pitch

- Humans hear frequencies from ~20 Hz to ~15 kHz



Loudness


SOUND PRESSURE LEVEL (dB)
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
Ear damage possible
Painful sound
Loud thunder
Subway train
Truck or bus
Average auto; loud radio
Normal conversation
Quiet office, household sounds
Whisper
Threshold of hearing

Hearing + Perception

- Provides auditory information about environment
  - Distance, direction, type of object, quality, familiarity, etc.

Auditory Illusions (Perception)

- Sheppard scale

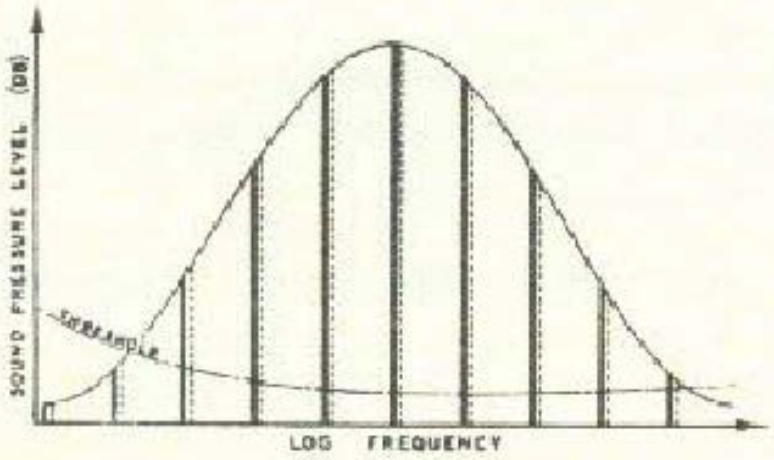


Figure 1

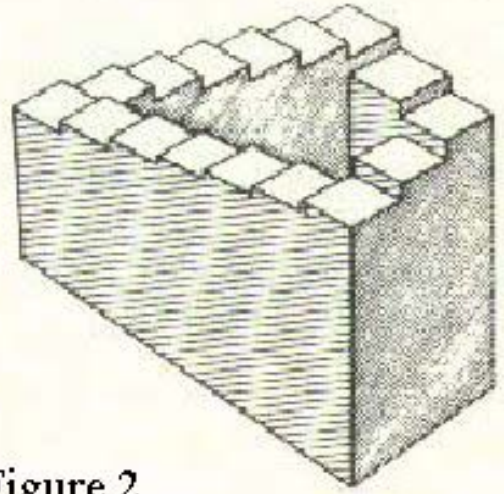
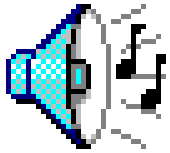


Figure 2

Demo



Touch (Tactition)

Touch (Tactition)

- Tactile = “the sense of touch”
- Provides important feedback about environment
- Particularly important for the visually impaired
- Stimulus received via receptors in the skin:
  - Thermoreceptors (heat and cold)
  - Nociceptors (pain)
  - Mechanoreceptors (pressure)
- Some areas more sensitive than others; e.g., fingers
- Kinethesis
  - Awareness of body position
  - Affects comfort and performance

Importance of Tactile Feedback

- Tend to assume (e.g., physical keys and keyboards)
- When missing, problems arise
- Alternative feedback; e.g.,

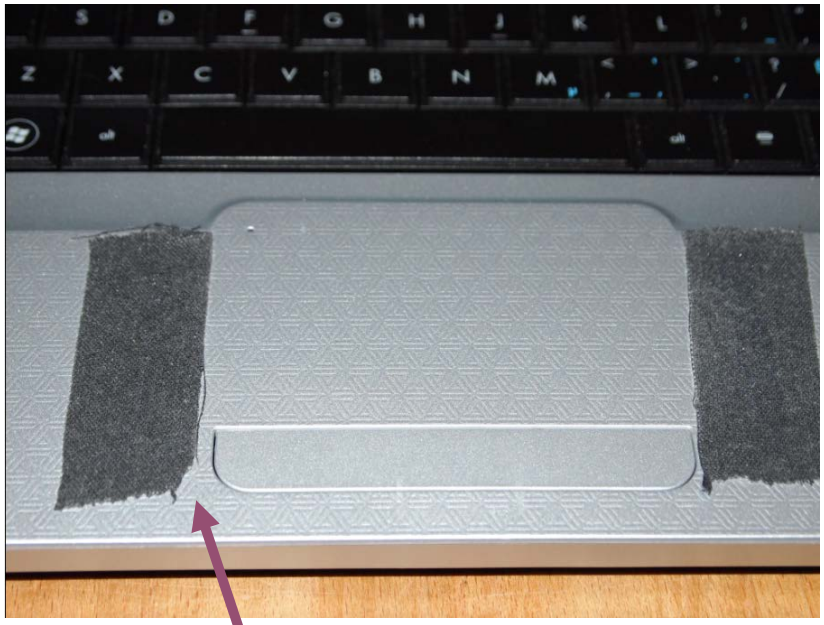
Visual feedback

Click for demo

Auditory & vibrotactile feedback

Designers Unleashed (beware)

Touchpad – sleek, but no tactile feedback for edges



Users revolt (duct tape to the rescue!)

Smell (Olfaction)
and
Taste (Gustation)

Smell and Taste

- Smell (olfaction) – the ability to perceive odors
- Taste (gustation) – the chemical reception of sweet, salty, bitter, and sour sensations

Smell in Motion Pictures (1)

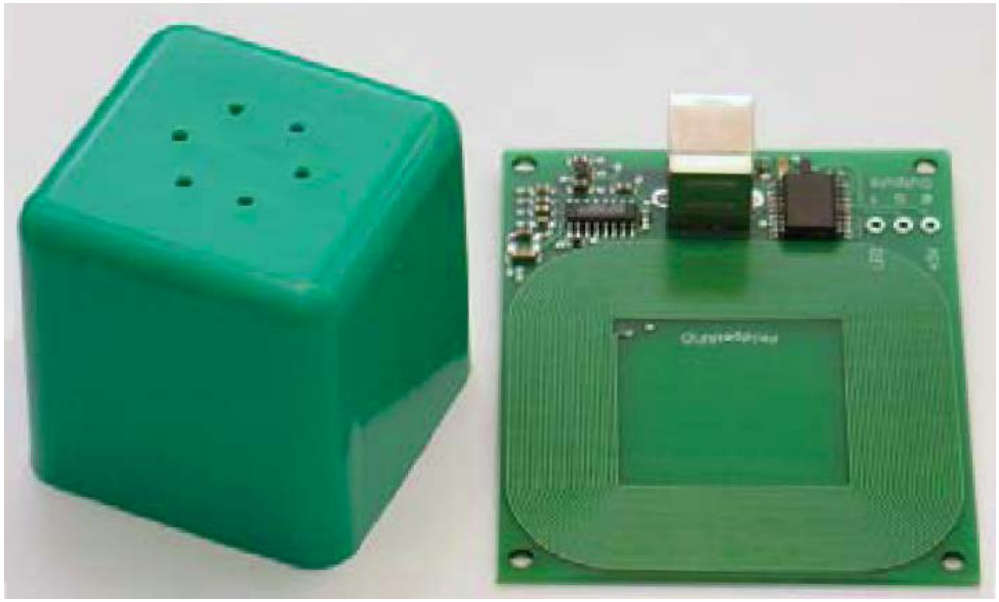
- Smell-o-vision
- Used in *Scent of Mystery* (1960)

Smell in Motion Pictures (2)

- Odorama (scratch and sniff cards)
- Used in *Polyester* (1981)

Smell in HCI

- Tagging images with smell



Brewster, S. A., McGookin, D., and Miller, C., Olfoto: Designing a smell-based interaction, *Proceedings of the ACM SIGCHI Conference on Human Factors in Computing Systems - CHI 2006*, (New York: ACM, 2006), 653-662.

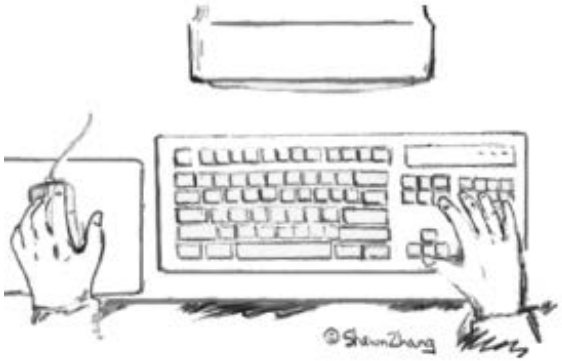
Other “Senses”

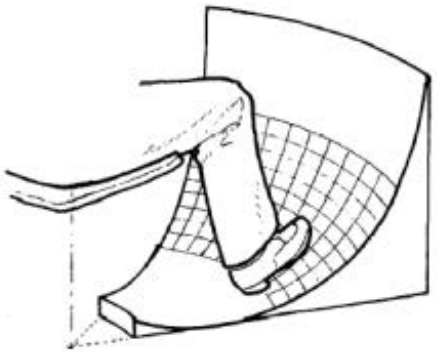
- Sense of urgency
- Sense of direction
- Sense of balance
- Sense of timing
- Musical sense
- Intuitive sense
- Moral sense
- etc.

Topics

- Model of human in interactive systems
- Sensors (inputs)
- Responders (outputs)
- The Brain (memory and cognition)
- Human Performance

Limbs





Hand Dominance

- Are you left-handed or right-handed?
- Is hand dominance an either-or condition? (no)
- Level of hand dominance assessed using the Edinburgh Handedness Inventory[1] (next slide)

[1]Oldfield, R. C., The assessment and analysis of handedness: The Edinburgh inventory, *Neuropsychololgia*, *9*, 1971, 97-113.

Edinburgh Handedness Inventory

	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

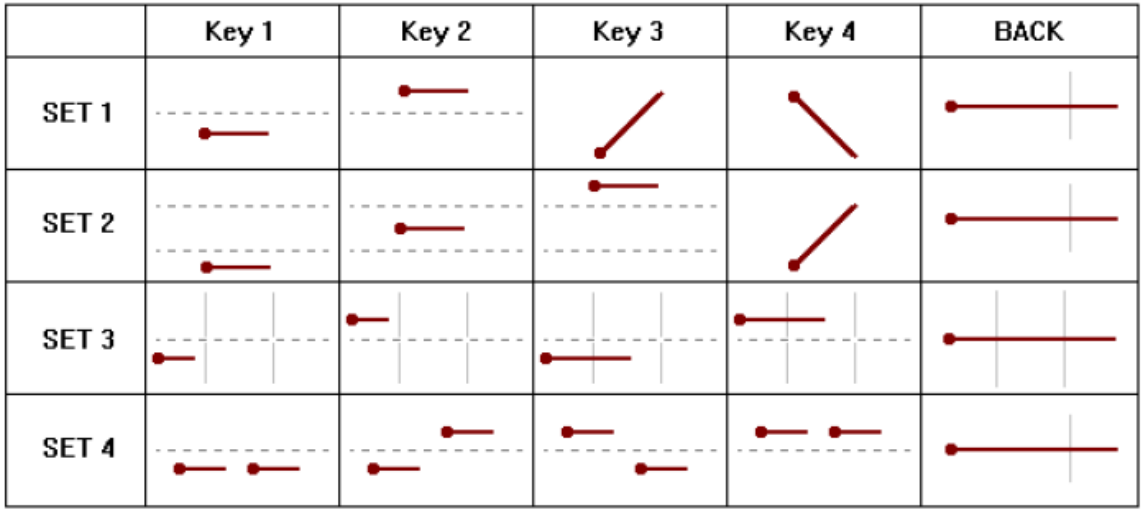
-100 to -40	left-handed
-40 to +40	ambidextrous
+40 to 100	right-handed

Voice

- Yes, the voice is a “responder”
- Vocalized sounds by exhaling air through the larynx
- Speech (with automatic recognition)
  - Works best with…
    1. Limited vocabulary
    2. Speaker dependence
    3. Discrete words
- Non-speech
  - Acoustic parameters of the sound signal (pitch, volume, timbre, etc.) measured over time
  - Data stream interpreted as an input channel
  - Particularly useful to specify analog parameters
    - “volume up, *aaah*” (volume increases while *aaah* sustained)

CHANTI[1] and NVVI

- Text input method using 5 “keys” (ambiguous keyboard)
- CHANTI = voCally enHanced Ambiguous Non-standard Text-Input
- NVVI = non-verbal voice interaction
- 5 sounds → 5 “keys” (4 sets, user selectable)



[1]Sporka, A. J., Felzer, T., Kurniawan, S. H., Ondrej, P., Haiduk, P., and MacKenzie, I. S., CHANTI: Predictive text entry using non-verbal vocal input, *Proceedings of the ACM SIGCHI Conference on Human Factors in Computing Systems - CHI 2011*, (New York: ACM, 2011), (in press).

The Eye

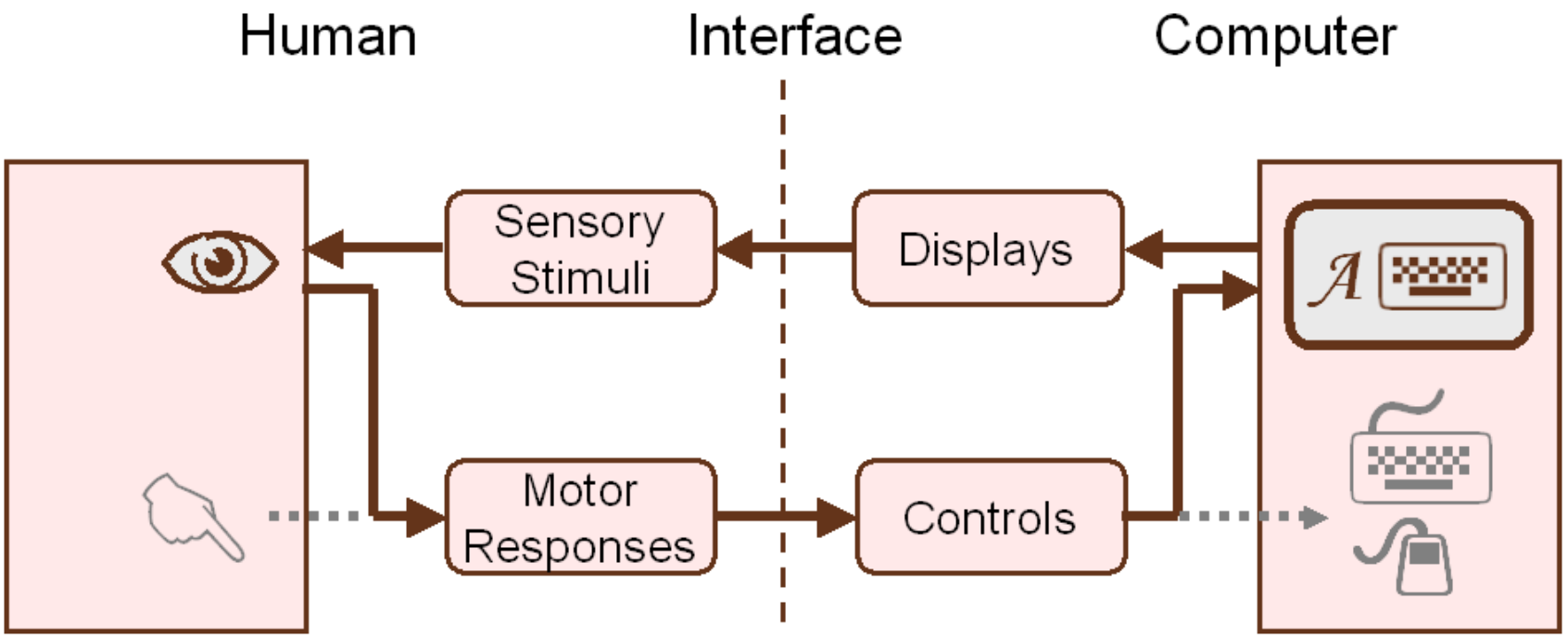
- Yes, the eyes are also “responders”
- Eye tracking (next three slides)

Eye Tracking (for computer control)

MacKenzie, I. S., & Zhang, X. (2008). Eye typing using word and letter prediction and a fixation algorithm. *Proceedings of the ACM Symposium on Eye Tracking Research and Applications – ETRA 2008*, pp. 55-58. New York: ACM.

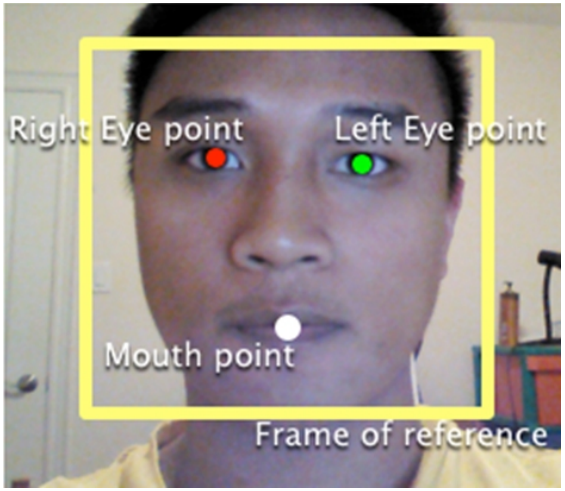
MacKenzie, I. S. (2012). Evaluating eye tracking systems for computer input. In Majaranta, P. et al. (Eds.) *Gaze interaction and applications of eye tracking: Advances in assistive technologies*, pp. 205-225. Hershey, PA: IGI Global.

Eye Tracking Model[1]

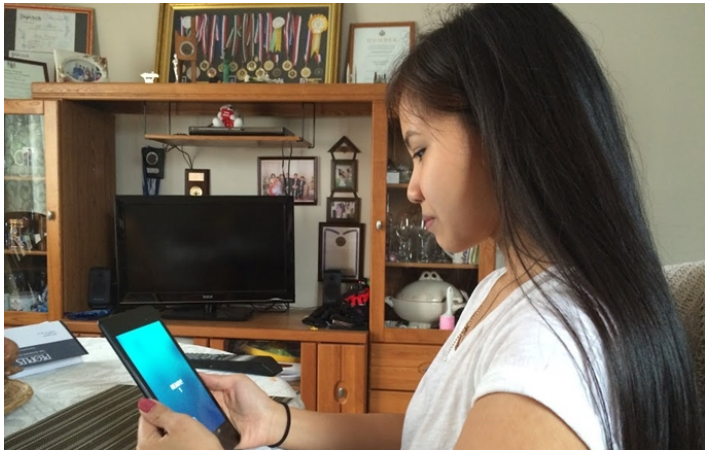


[1]MacKenzie, I. S. (in press). Evaluating eye tracking systems for computer input. In Majaranta, P. et al. (Eds.) *Gaze interaction and applications of eye tracking: Advances in assistive technologies*. Hershey, PA: IGI Global.

Face Tracking



StarJelly



Note: The Jellyfish is moved horizontally either by device tilt or by face tracking

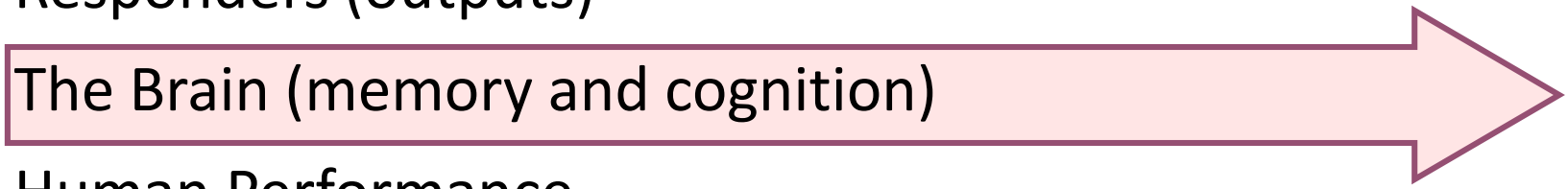
[1] Cuaresma, J., & MacKenzie, I. S. (2014). A comparison between tilt-input and facial tracking as input methods for mobile games. *Proceedings IEEE-GEM 2014*, pp. xxx-xxx, New York: IEEE.

Other Responders

- Facial expressions
- Body movement
- Tongue
- Breath
- etc.

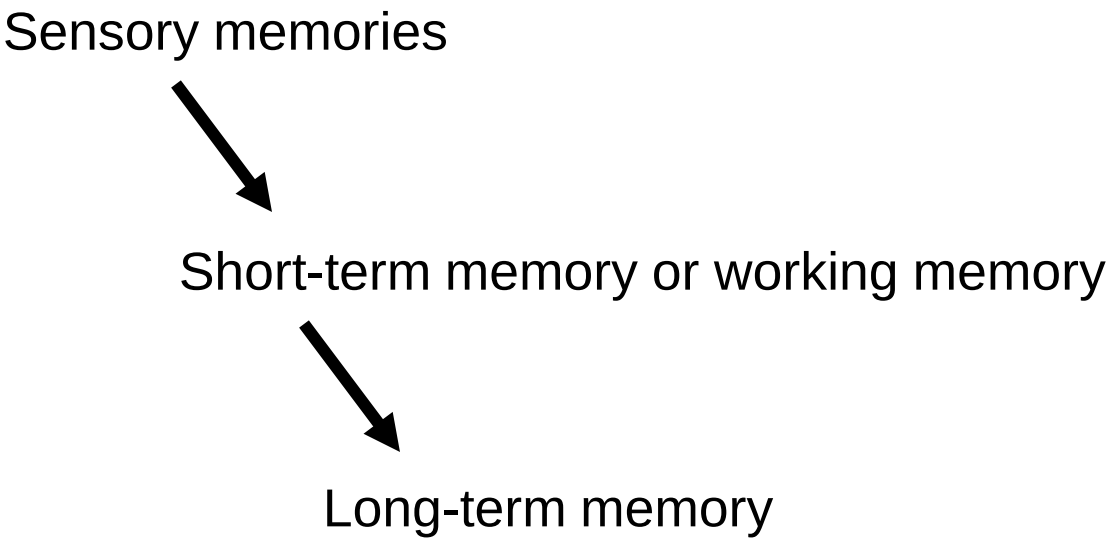
Topics

- Models of the Human
- Sensors (inputs)
- Responders (outputs)
- The Brain (memory and cognition)
- Human Performance



Memory

- There are three types of memory, by function:



Sensory Memory

- Buffers in memory for stimuli received through senses
- Buffer types
  - Iconic (for visual stimuli)
  - Echoic (for aural stimuli)
  - Haptic (for tactile stimuli)
- Examples
  - “Sparkler” trail
  - Stereo sound
- Continuously overwritten

Short-term Memory (STM)

- Scratch-pad for temporary recall
  - Rapid access ~ 70 ms
  - Rapid decay ~ 200 ms
- Limited capacity
  - Miller's 7 ± 2 chunks
  - "chunking" helps

Magical Number 7 ± 2

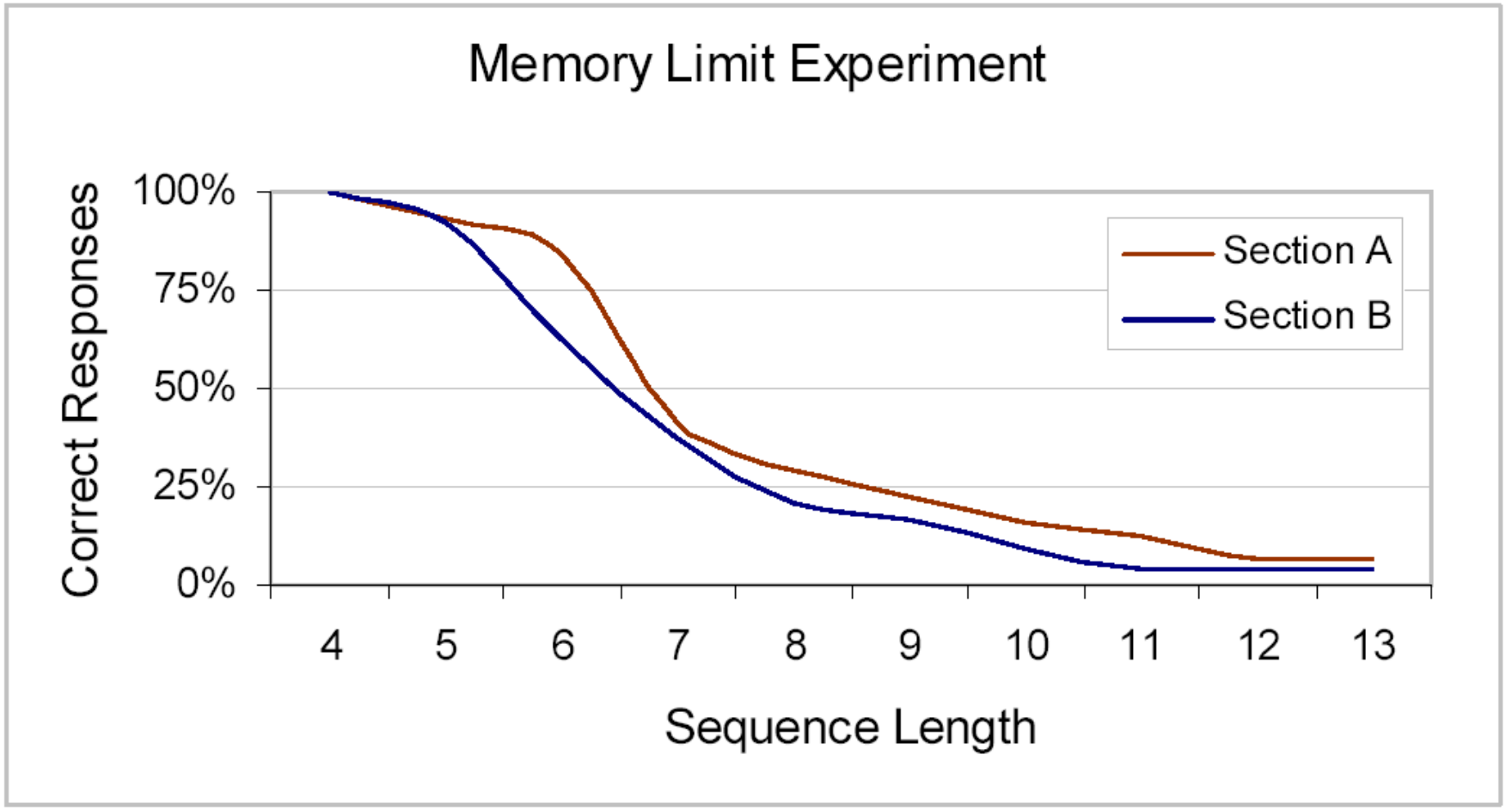
- Can you remember the following digit sequences

7 4 9 2
3 0 5 8 2
9 3 7 1 4 6
3 6 5 0 7 2 4
2 1 9 7 8 5 4 3
3 7 5 6 2 5 4 5 0
3 5 2 7 0 8 9 3 2 5
0 8 7 3 9 1 2 3 5 1 6
3 5 2 4 9 0 6 5 8 2 0 4
7 5 3 9 1 8 4 5 1 3 4 3 0

Results

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

Results

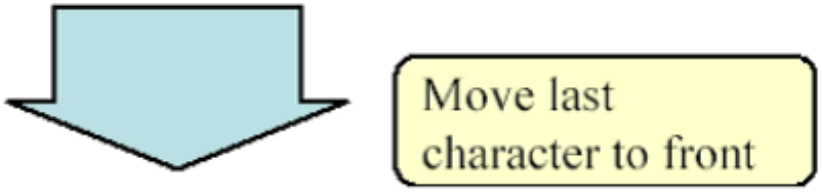

Memory Limit Experiment
Correct Responses
100%
75%
50%
25%
0%
4
5
6
7
8
9
10
11
12
13
Sequence Length
Section A
Section B

Chunking

416736210040631

416 736 2100 40631

HEC ATR ANU PTH ETR EET ?



THE CAT RAN UP THE TREE

Blackjack (aka 21)

Another card? (dealer has 18)

(What cards have already been dealt?)

Long-term Memory (LTM)

- Repository for all our knowledge
  - Slow access: ~ 1/10 second
  - Slow decay, if any
  - Huge or unlimited capacity
- Two types
  - Episodic
    - Serial memory of events
  - Semantic
    - Structured memory of facts, concepts, skills
    - Semantic LTM derived from episodic LTM

Recognition vs. Recall

- UI principle: Recognition is better than recall
- Recall example
  - *Gee! What's that command to change my password?*
- Recognition example:
  - *I'll look in this menu to see if I can find the command to change my password*

Cognition (Thinking)

- Reasoning
  - Deduction, induction, abduction
- Problem solving
  - Models, issues

Deductive Reasoning

- Definition:
  - Derive logical conclusion from premises
  - E.g., If it is Friday, then she will go to work.
    It is Friday.
    Therefore, she will go to work.

Inductive Reasoning

- Definition:
  - Generalize from cases seen to cases unseen
  - E.g., All elephants we have seen have trunks.
    Therefore all elephants have trunks.

Abductive Reasoning

- Definition:
  - Reasoning from event to cause
  - E.g., Sam drives fast when drunk.
    If I see Sam driving fast, assume drunk.

Language

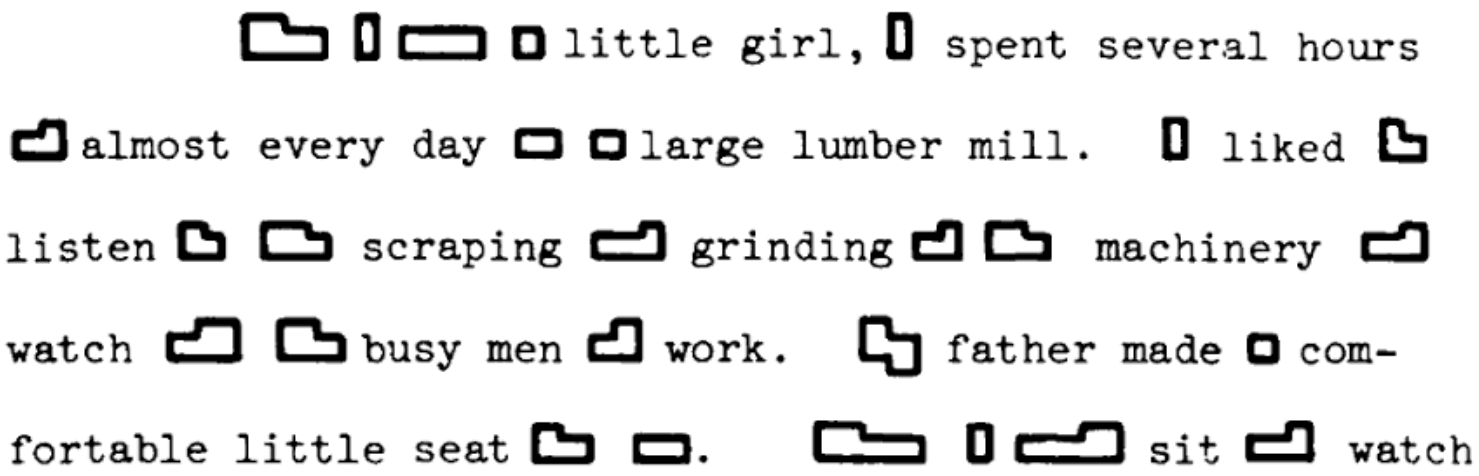
> "Humankind is defined by language; but civilization is defined by writing." [1]

- Speech → learned naturally by all humans
- Writing → learned with great difficulty
- Language includes…
  - Redundancy (what we inherently know)
  - Entropy (what we don't know)
  - (Note: entropy = information)
- HCI Context – text entry (primarily)

[1]Daniels, P. T., & Bright, W. (Eds.). (1996). *The world's writing systems*. New York: Oxford University Press. (p. 1)

Redundancy in English

When Mary was a little girl she found a newborn lamb nearly dead with hunger and cold. She tenderly nursed it back to life and became devotedly attached to her gentle charge. The lamb was her constant companion and playmate and was to her what a



Haber, L. R. and Haber, R. N, "Perceptual Processes in Reading: An Analysis-by-Synthesis Model", in *Neuropsychological and Cognitive Processes in Reading*, Pirozzolo, F. J. and Wittrock, M. C., eds., Academic Press, pp. 167-199.

Shannon's Letter-guessing Experiment[1]

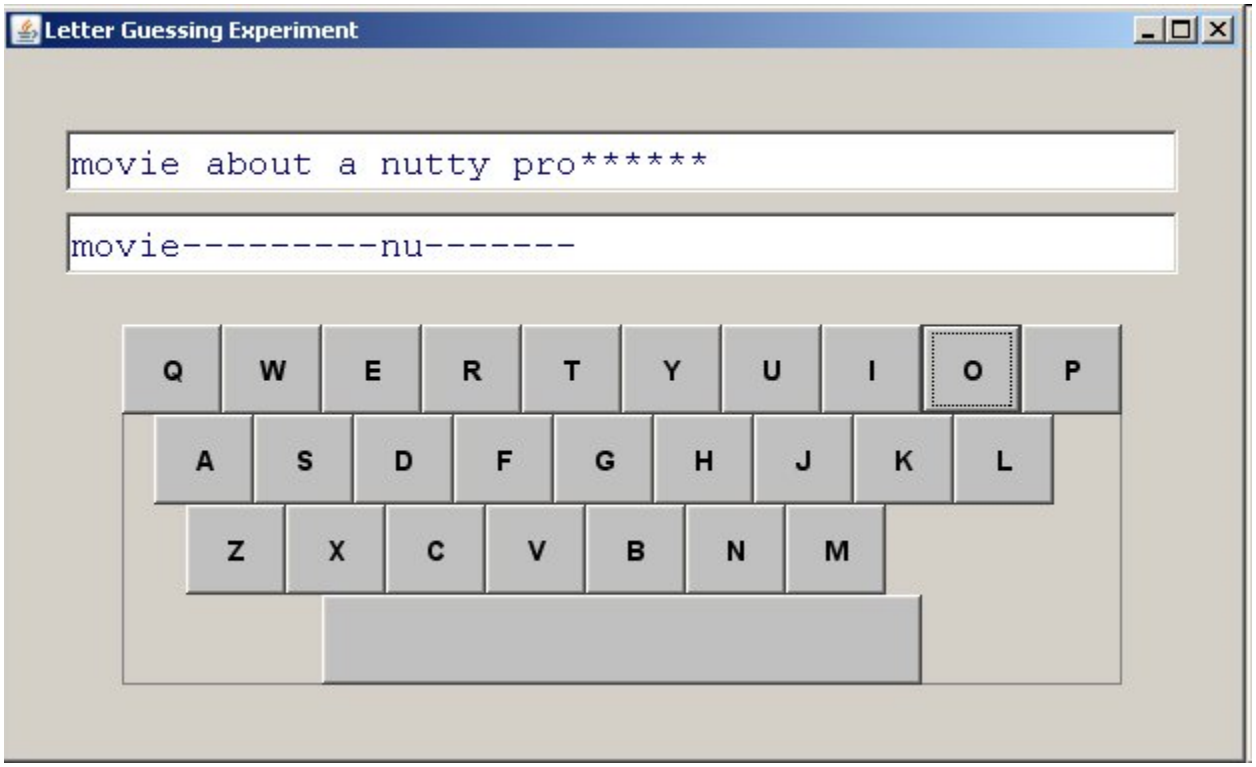
- Instructions:
  - Top line: hidden initially
  - Participant guesses letters one at a time
  - Top line revealed letter-by-letter as guessing continues
  - Bottom line: "-" = correct guess, letter = incorrect guess

```
THE ROOM WAS NOT VERY LIGHT
----ROO------NOT-V-----I---
```

```
A SMALL OBLONG READING LAMP ON THE DESK
--SM----OBL--- REA----------O------D---
```

[1]Shannon, C. E., Prediction and entropy of printed English, *Bell System Technical Journal*, 30, 1951, 51-64. (please read)

Letter-guessing Experiment Demo



Topics

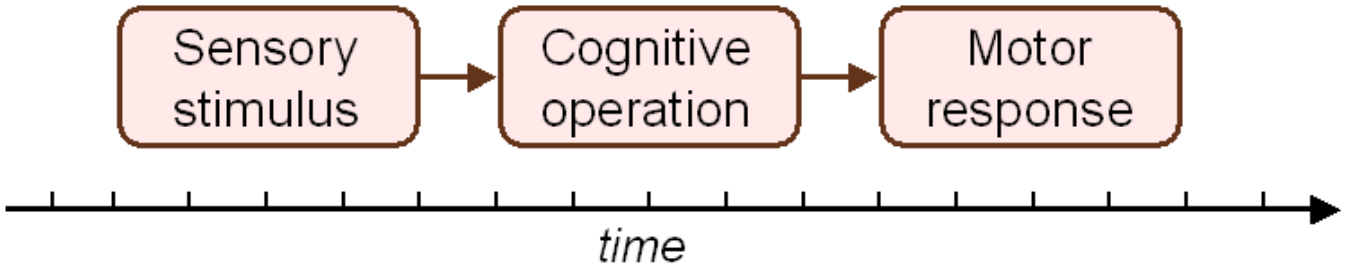
- Models of the Human
- Sensors (inputs)
- Responders (outputs)
- The Brain (memory and cognition)
- Human Performance

Human Performance

- Humans differ – we are…
  - young, old, male, female, experts, novices, left-handed, right-handed, English-speaking, Chinese-speaking, from the North, from the South, tall, short, strong, weak, fast, slow, able-bodied, disabled, sighted, blind, motivated, lazy, creative, bland, tired, alert, and on and on
- Human performance will vary…
  - From person to person
  - From trial to trial, task to task
  - With amount of practice, etc.
- Human performance is…
  - Speed in doing a task
  - Accuracy in doing a task
  - Other quantifiable properties of human interaction with computing systems

Measuring Human Performance

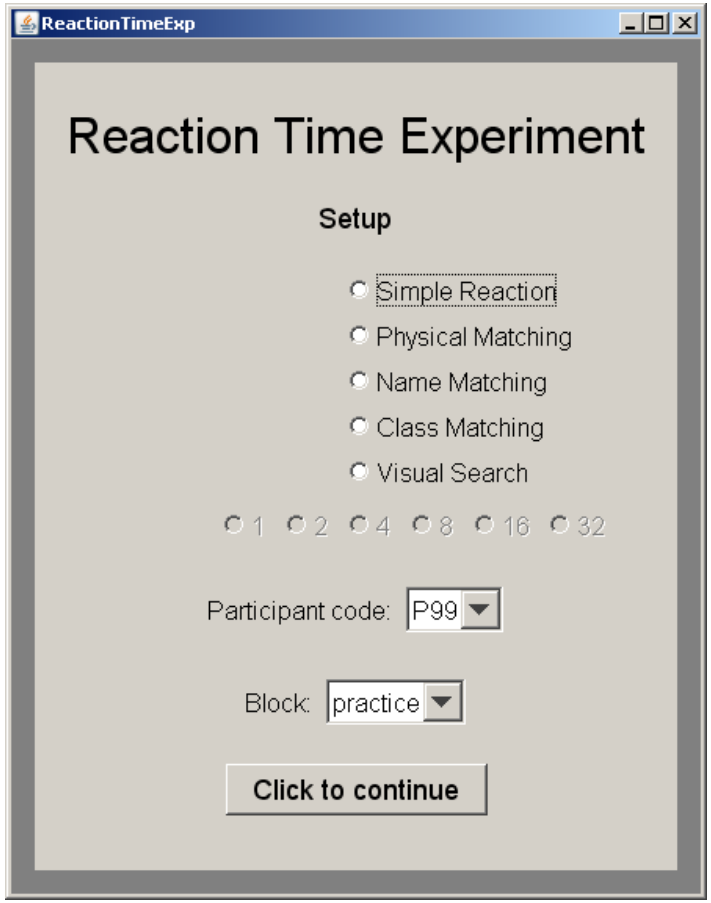
- External apparatus needed
- Observe and log events and time of events
- Difficult to observe cognitive operations separate from sensory input and response output:



Simple Reaction Time

- Simplest embodiment of human performance
- Time taken to respond to stimulus; e.g.,
  - Sensory stimulus = a light turns on
  - Motor response = a button is pushed
  - (see previous slide)
- Movement time dependent on age, fitness, etc.
- Reaction time dependent on stimulus type:
  - Auditory ~ 150 ms
  - Visual ~ 200 ms
  - Pain ~ 700 ms

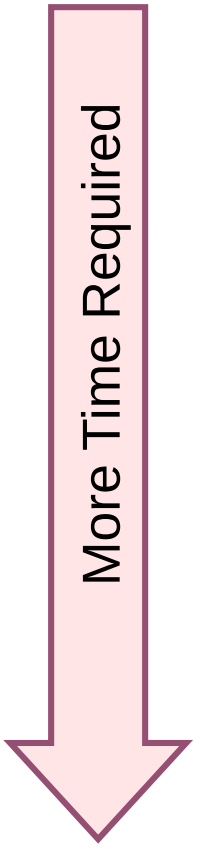
Reaction Time Demo




```
prompt>java ReactionTimeExperiment
```

Cognitive Operations in Reacting

- Simple reaction
  - Stimulus → response
- Physical matching
  - Deduce equivalence, same presentation
- Name matching
  - Deduce equivalence, presentation may vary
- Class matching
  - Deduce membership in a class
- Visual search
  - Locate code in search space



Movement - Fitts' Law

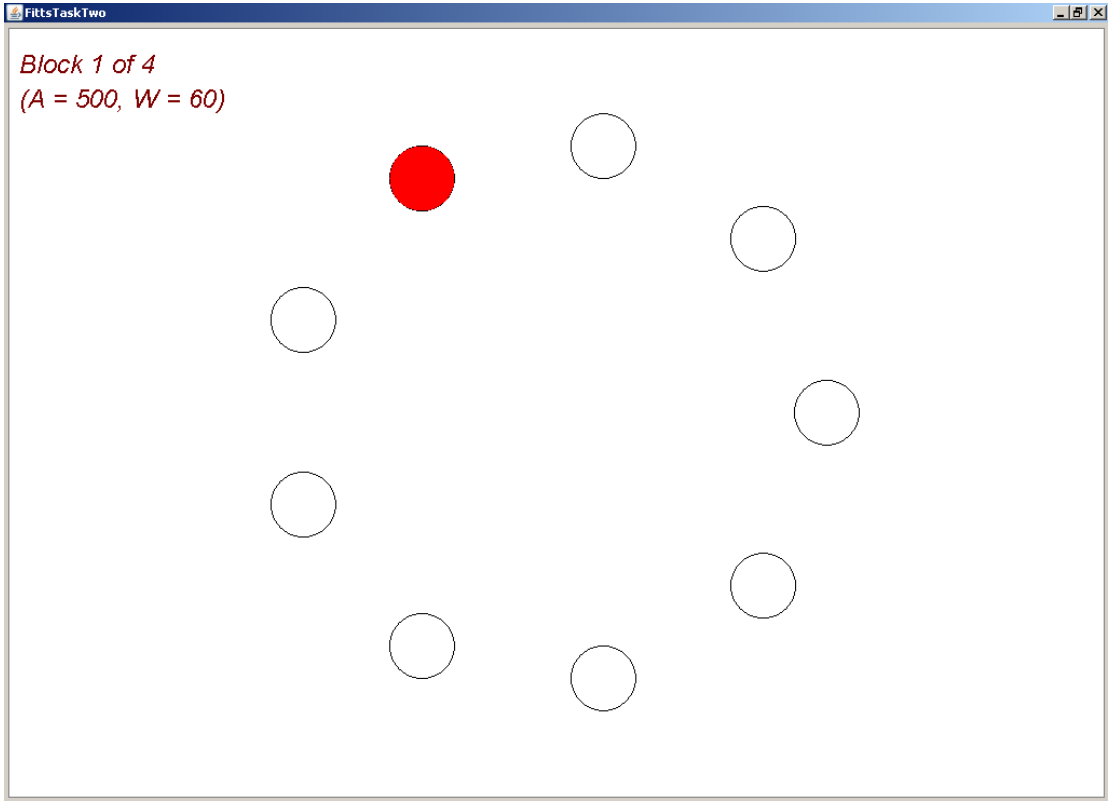
- A model for rapid-aimed movements

$$ID = \log_2(D/S + 1)$$

$$MT = a + b\ ID$$

- where:
  - *ID* is the Index of Difficulty (bits)
  - *MT* is movement time (seconds)
  - *D* is the distance to the target (cm)
  - *S* is the size of the target (cm)
  - a and b are empirically determined constants
- *MT* can be reduced using large targets or small distances

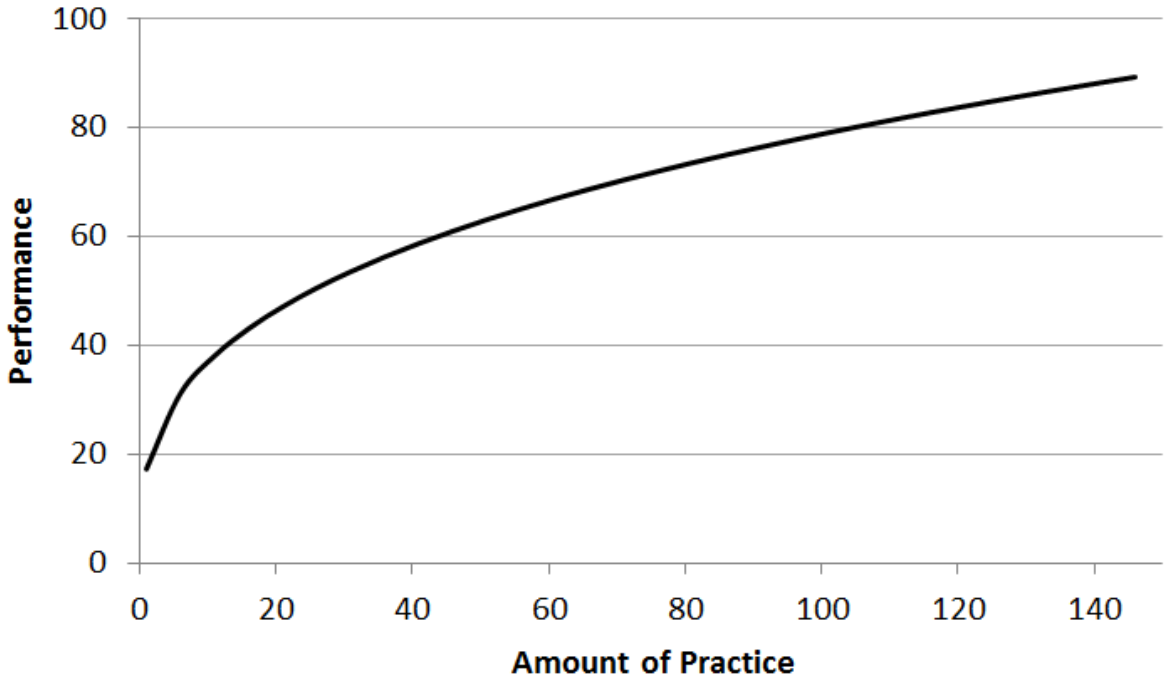
Fitts' Law Demo




```
prompt>java FittsTaskTwo
```

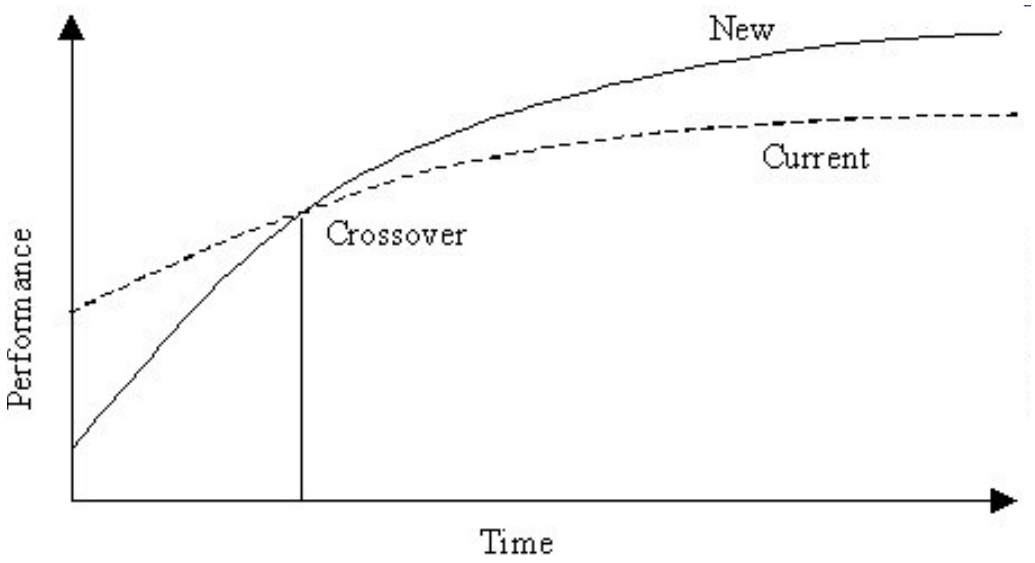
Skilled Behaviour

- With practice, performance improves according to the *Power Law of Practice*



Skilled Behaviour: New vs. Current

- A “new” interaction technique may require practice to out-perform a “current” technique



MacKenzie, I. S., & Zhang, S. Z. (1999) The design and evaluation of a high performance soft keyboard. *Proceedings of the ACM Conference on Human Factors in Computing Systems - CHI '99*, pp. 25-31. New York: ACM. (please read)

Attention, Motivation, Fatigue, etc.

- Performance suffers in the presence of a secondary task
- Performance affected by attention, motivation, fatigue.
- Attention example (click to play video)

https://youtu.be/IGQmdoK_ZfY

Thank You