

## Chapter 2

### The Human Factor

# Models of the Human

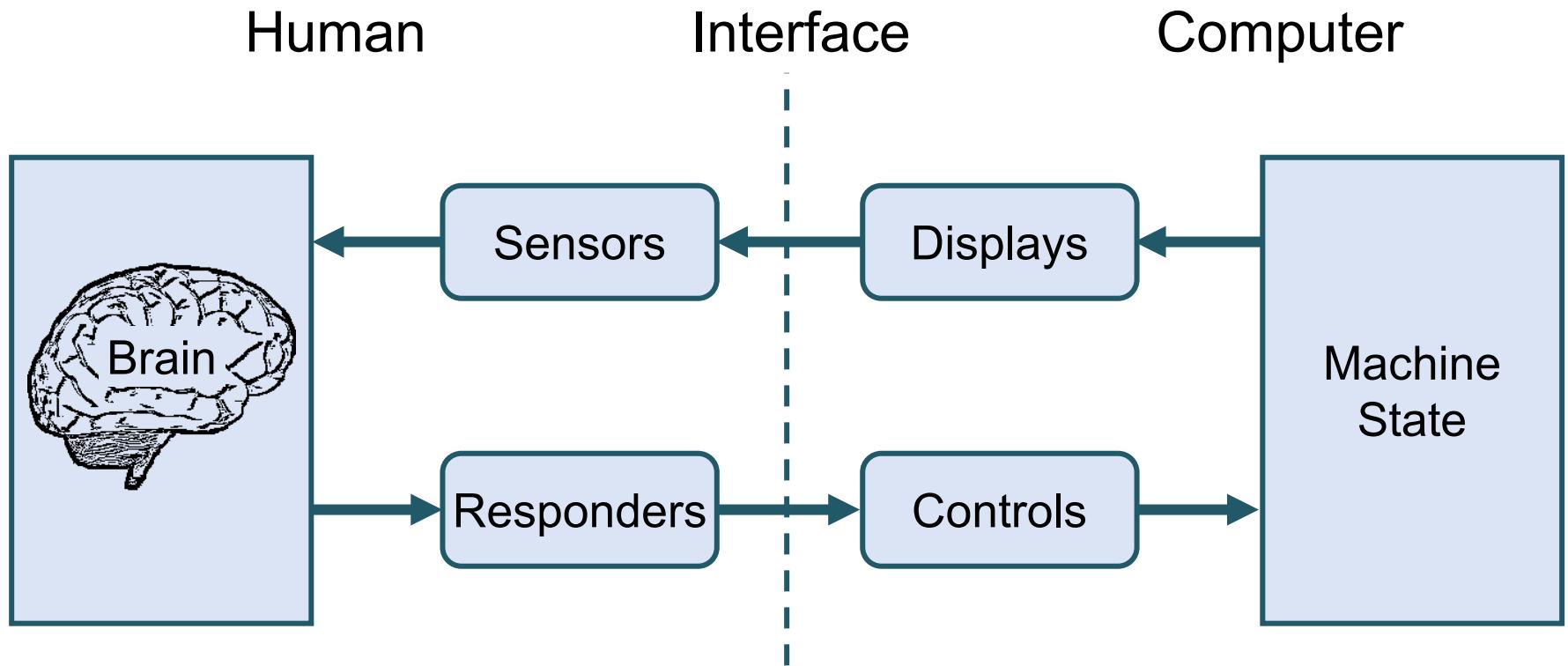
- Descriptive models are tools for thinking (see Chapter 7)
- It would be useful to have a descriptive model for the human
- In fact, there are many (e.g., Model Human Processor, Chapter 1)
- We begin with two useful models for the human...

# Newell's Time Scale of Human Action<sup>1</sup>

Scale (seconds)	Time Units	System	World (theory)
$10^7$	Months	-	<b>SOCIAL BAND</b>
$10^6$	Weeks	-	
$10^5$	Days	-	
$10^4$	Hours	Task	<b>RATIONAL BAND</b>
$10^3$	10 min	Task	
$10^2$	Minutes	Task	
$10^1$	10 s	Unit Task	<b>COGNITIVE BAND</b>
$10^0$	1 s	Operations	
$10^{-1}$	100 ms	Deliberate act	
$10^{-2}$	10 ms	Neural circuit	<b>BIOLOGICAL BAND</b>
$10^{-3}$	1 ms	Neuron	
$10^{-4}$	100 $\mu$ s	Organelle	

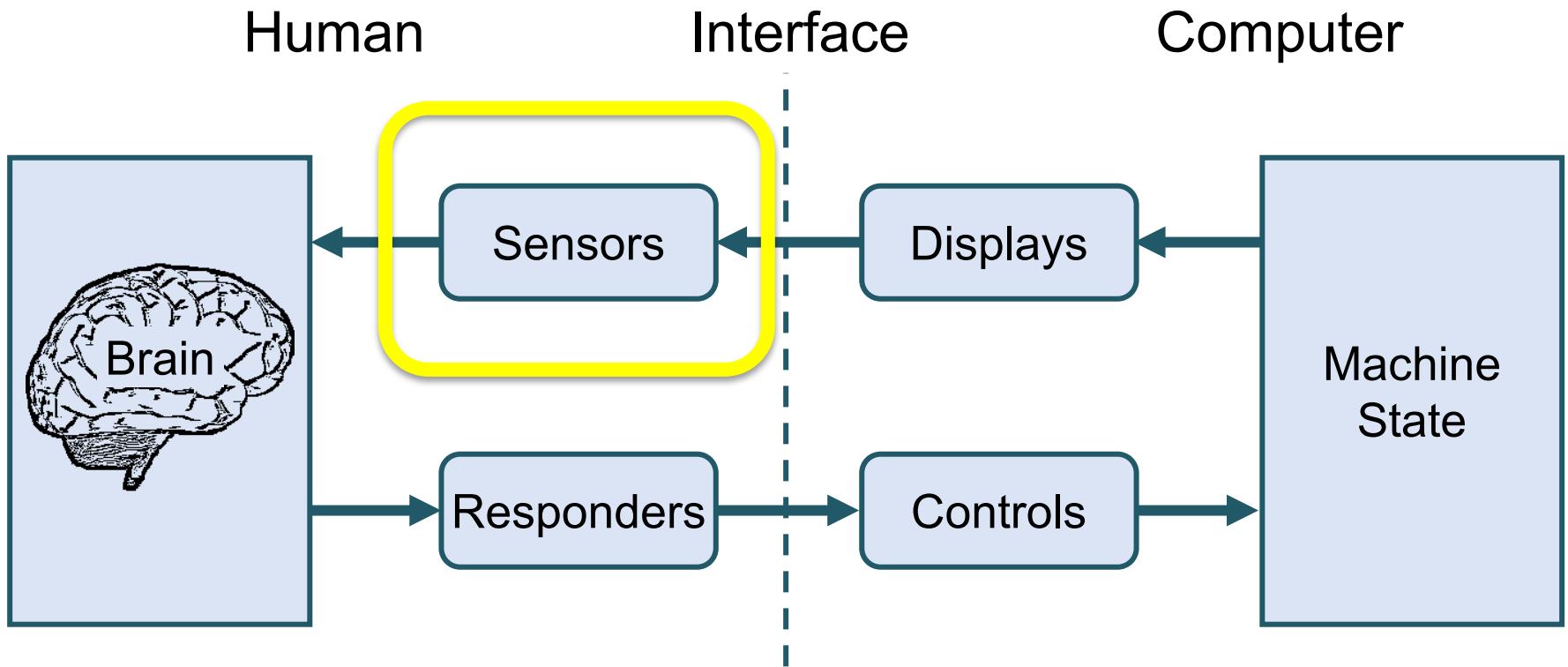
<sup>1</sup> A. Newell, Unified Theories of Cognition, Harvard University Press, Cambridge, MA, 1990.

# Human Factors Model<sup>1</sup>



<sup>1</sup> B.H. Kantowitz, R.D. Sorkin, Human Factors: Understanding People-System Relationships, Wiley, New York, 1983.

# Human Factors Model<sup>1</sup>



<sup>1</sup> B.H. Kantowitz, R.D. Sorkin, Human Factors: Understanding People-System Relationships, Wiley, New York, 1983.

# Human Senses

Rosa: You deny everything except what you want to believe. That's the sort of man you are.

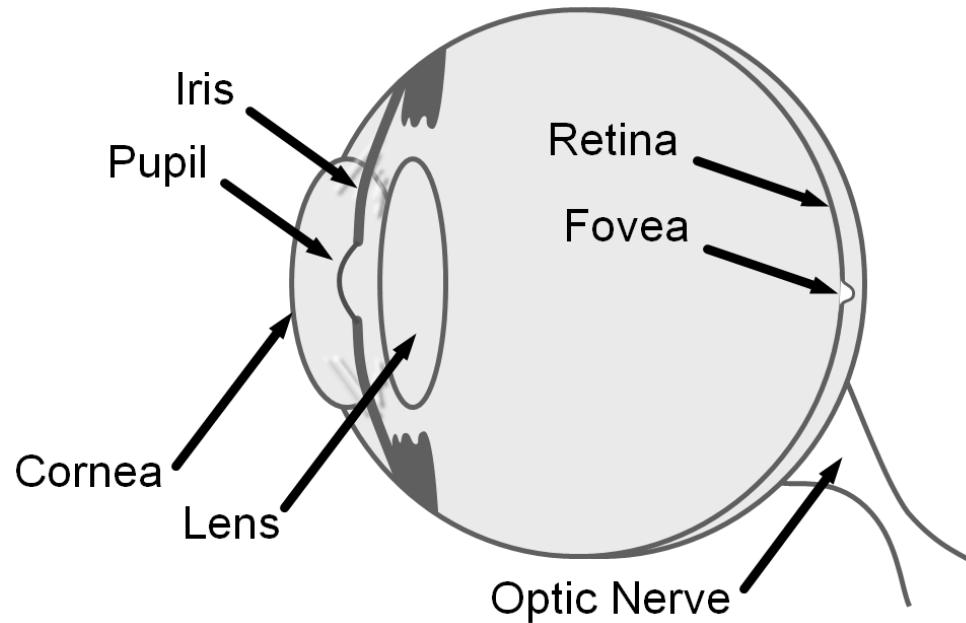
Bjartur: I have my five senses, and don't see what need there is for more.

(Halldór Laxness, *Independent People*)

- The five senses:
  - Vision (sight)
  - Hearing (audition)
  - Touch (tactition)
  - Smell
  - Taste

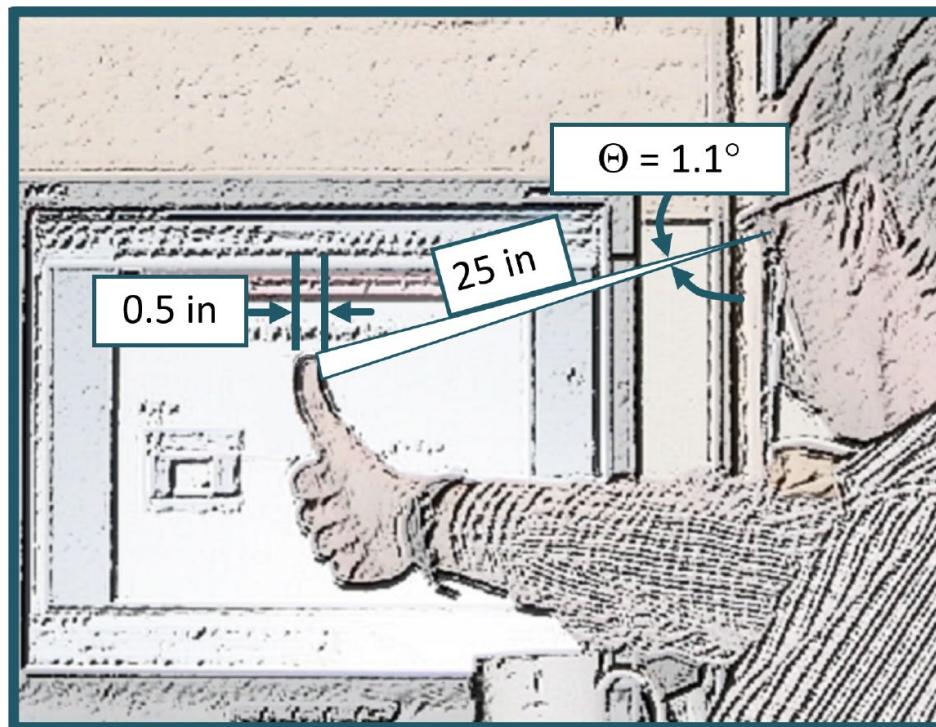
# Vision (The Eye)

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



# Fovea Image

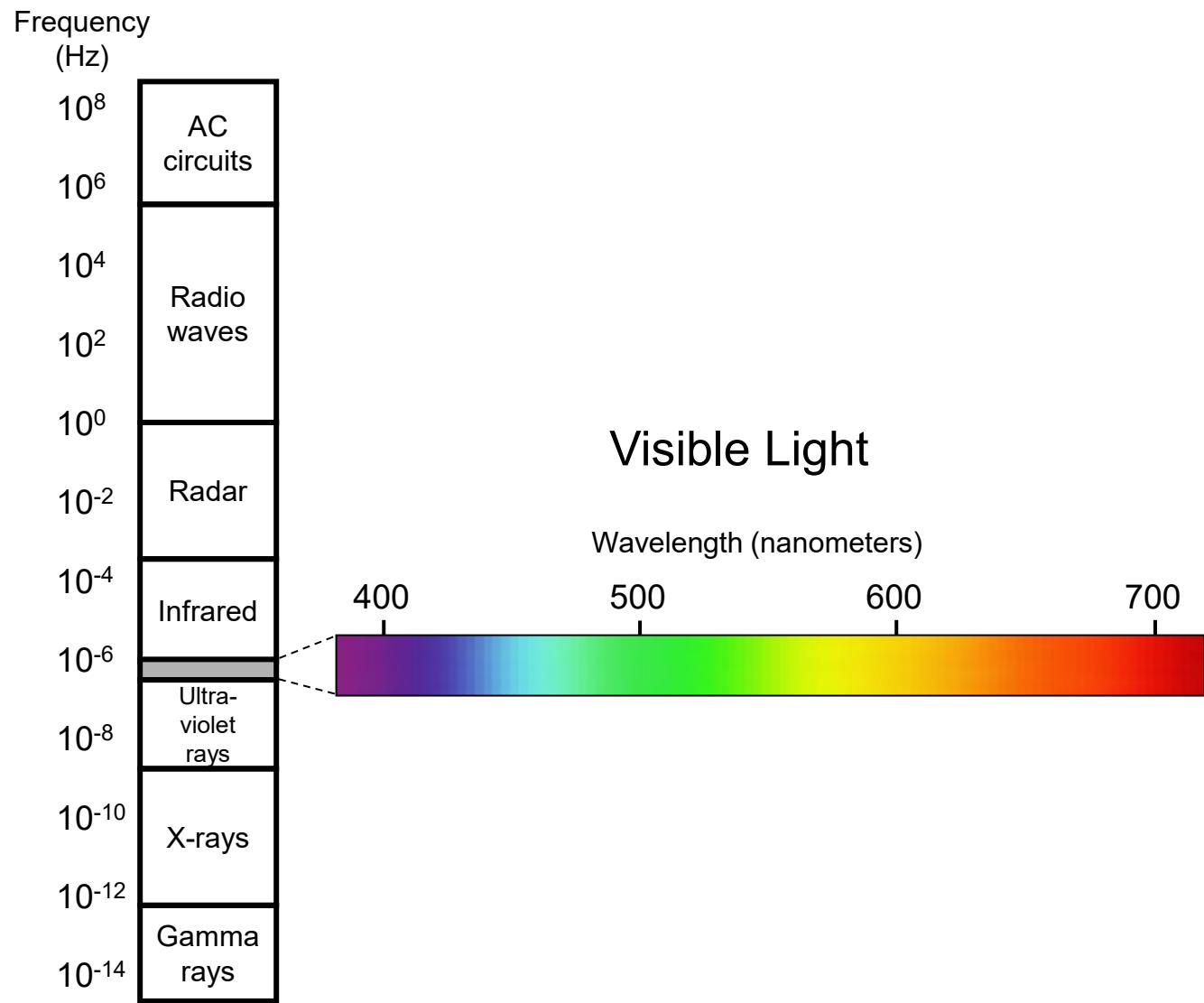
- Sharp central vision
- 1% of retina, 50% of visual cortex
- Fovea image is  $\approx 1^\circ$  of visual angle:



# Visual Stimulus

- Physical properties of light...
  - Frequency
  - Intensity (luminance)
- Create subjective properties of vision...
  - Colour (next slide)
  - Brightness

# Colour Spectrum

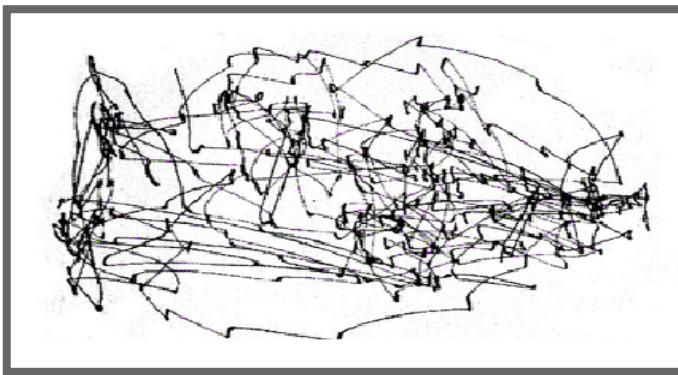


# Fixations and Saccades

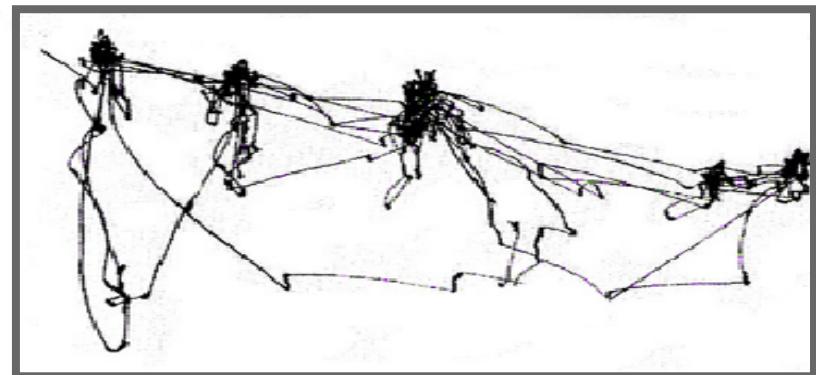
- Fixation
  - Eyes are stationary (dwell)
  - Take in visual detail from the environment
  - Long or short, but typically at least 200 ms
- Saccade
  - Rapid repositioning of the eye to fixate on a new location
  - Quick:  $\approx$ 30-120 ms

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

- Participants were given instructions and asked to view a scene; example →
- Eye movements (fixations and saccades) were recorded and plotted for a variety of tasks



Task: Remember the position of people and objects in the room



Task: Estimate the ages of the people

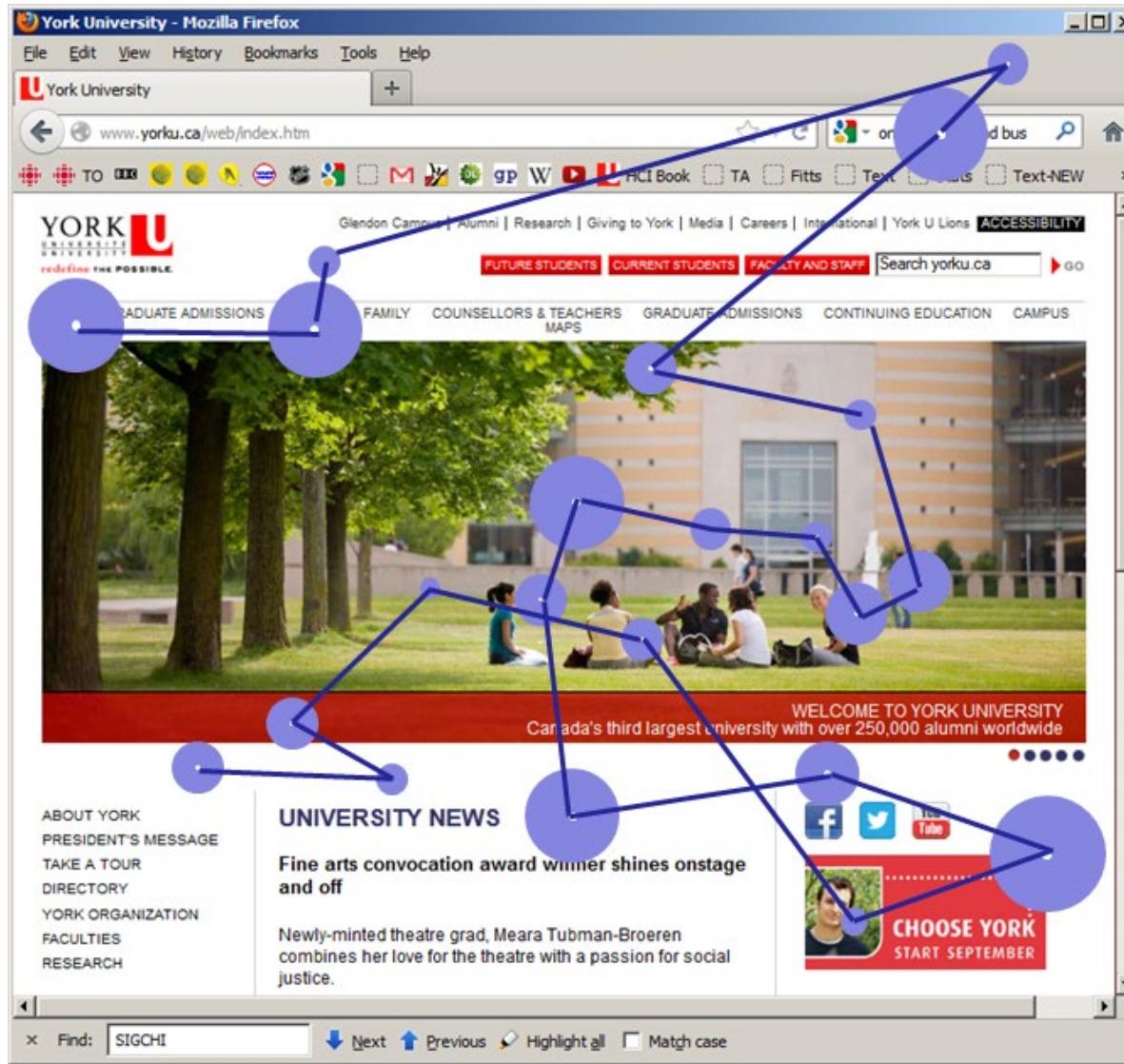
<sup>1</sup> B.W. Tatler, N.J. Wade, H. Kwan, J.M. Findlay, B.M. Velichkovsky, Yarbus, eye movements, and vision, *i-Perception* 1 (1) (2010) 7–27.

<sup>2</sup> *The Unwanted Visitor* by Ilya Repin (1844-1930)

# Scan Paths

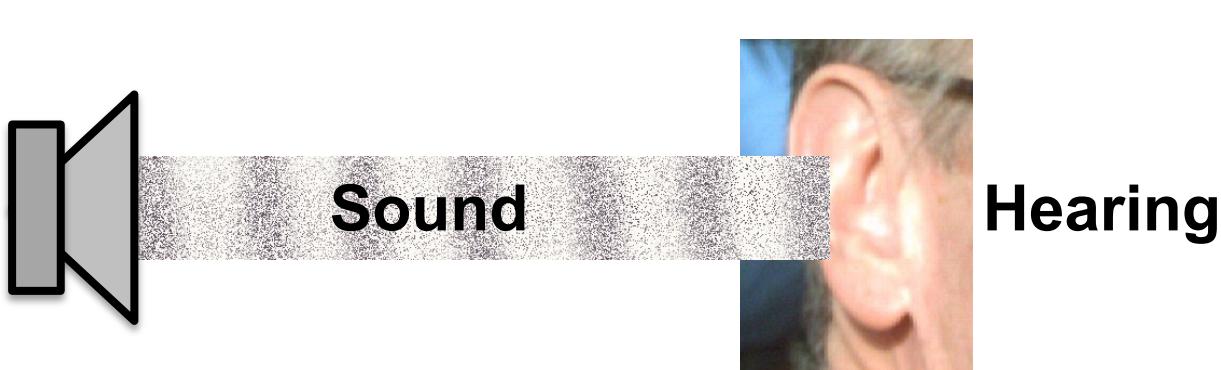
- Visual depiction of saccades and fixations
- Saccades → straight lines
- Fixations → circles
  - Diameter of circle  $\approx$  duration of fixation
- Applications
  - User behaviour research (e.g., reading patterns)
  - Marketing research (e.g., ad placement)

# Scan Path Example



# 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 (via larynx)



# Auditory Stimulus

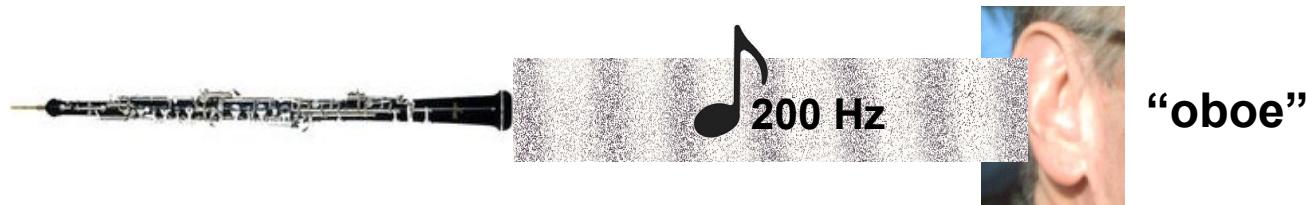
- Physical properties of sound...
  - Frequency
  - Intensity
- Subjective properties of hearing...
  - Pitch
  - Loudness

# Properties of Sounds

- Loudness
- Pitch
- Timbre (next slide)
- Attack (after next slide)

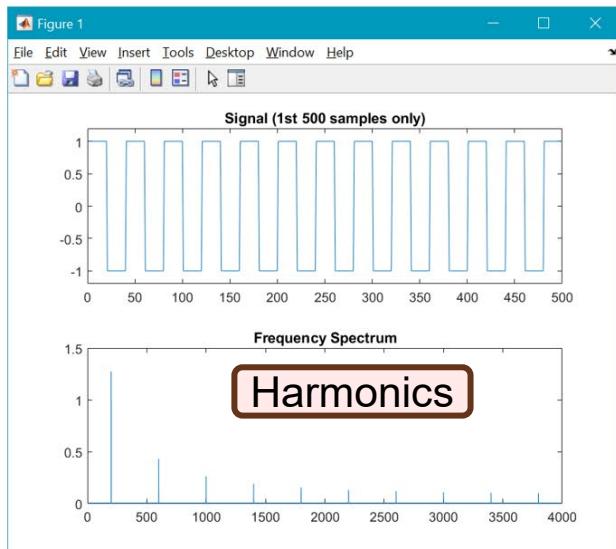
# Timbre

- 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



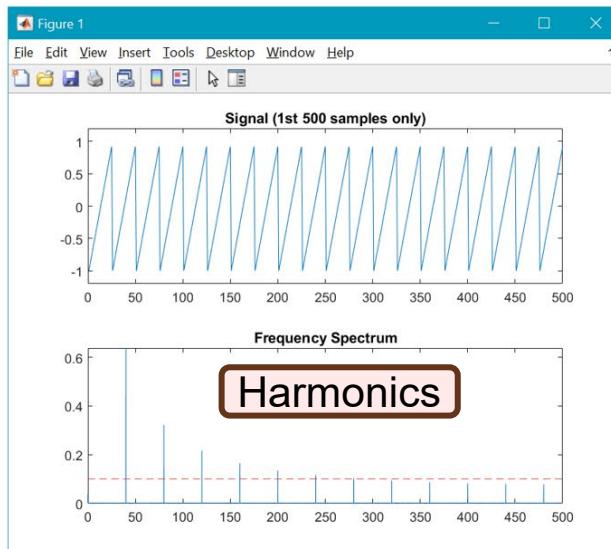
# Examples

## Square Wave



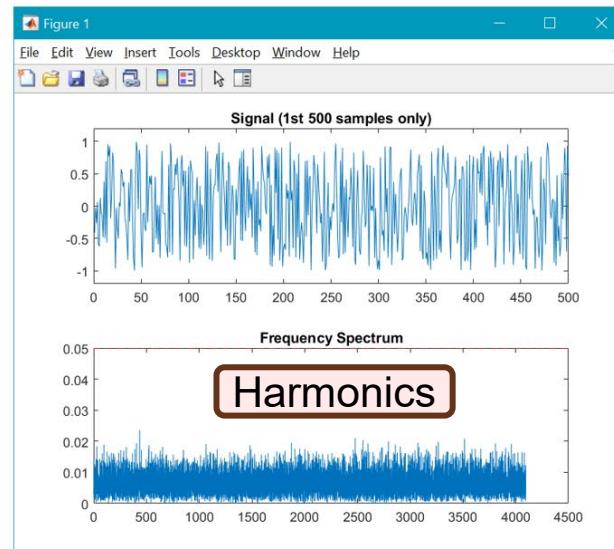
practice070\_fft\_square\_wave.m

## Sawtooth Wave



practice070\_fft\_sawtooth.m

## Noise

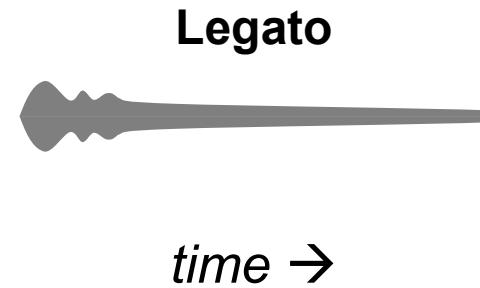
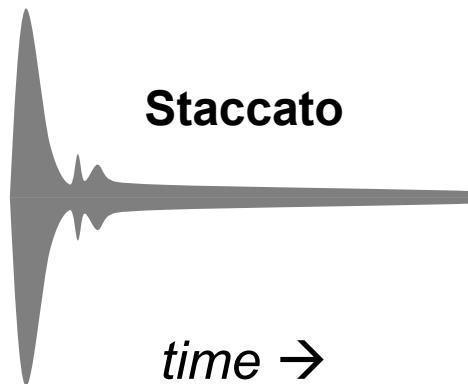


practice070\_fft\_noise.m

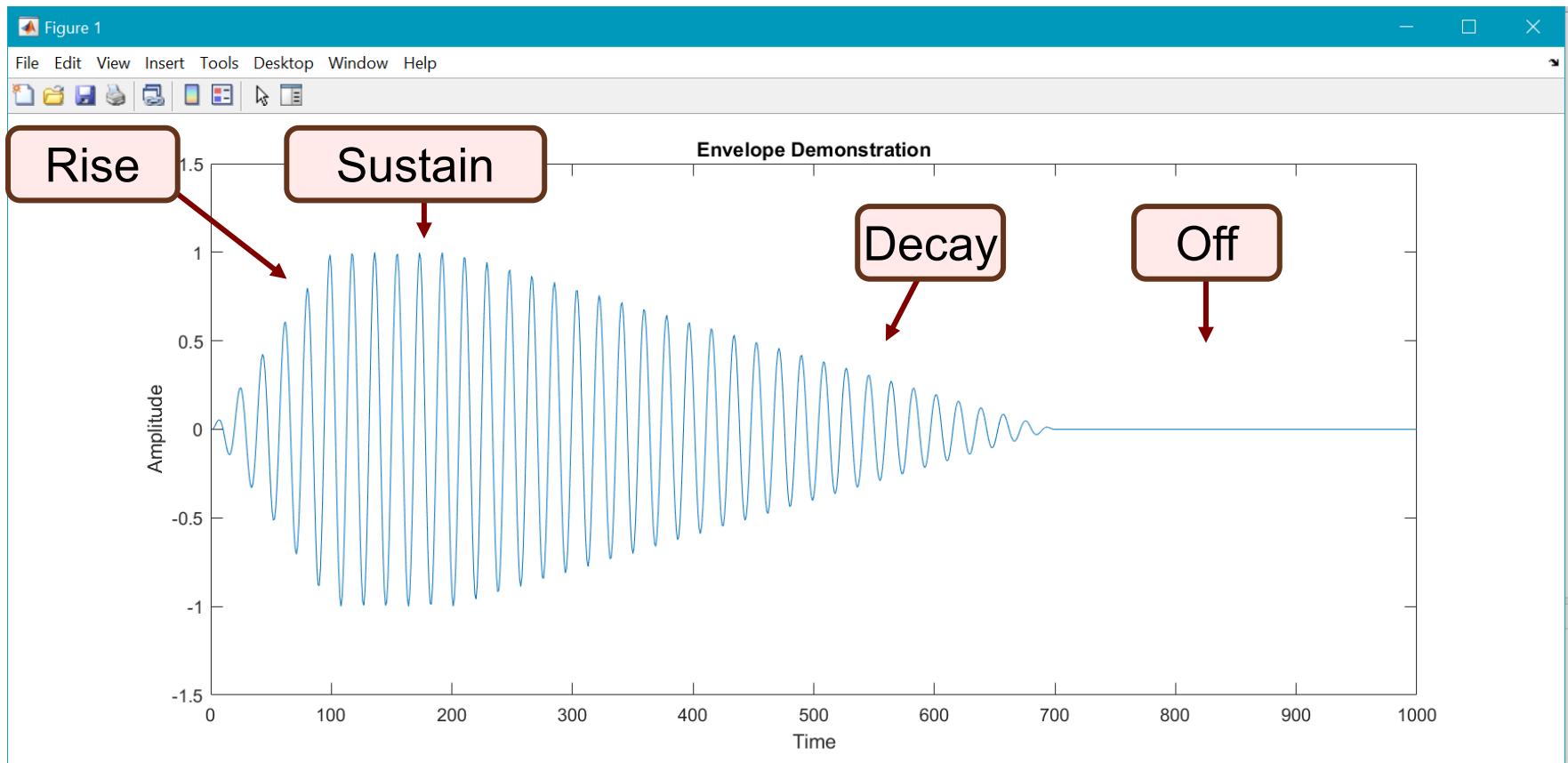


# Attack

- 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 envelope
- Assists in distinguishing notes of the same pitch coming from different instruments
- Onset envelope created through articulation (e.g., legato, staccato)



# Example



Note: Created in MATLAB



# Eyes (seeing) vs. Ears (hearing)

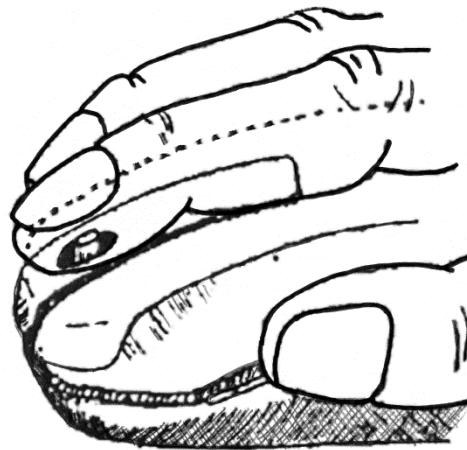
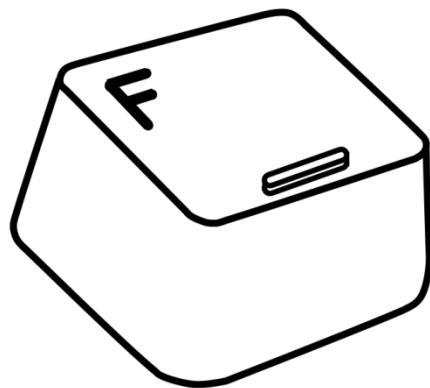
1

Quality/Ability	Eyes	Ears
Frequency sensitivity	$(4 \text{ to } 7.2) \times 10^{14} \text{ Hz}$	20 to 20,000 Hz
Wavelength sensitivity	$(4 \text{ to } 7.6) \times 10^{-7} \text{ meters}$	16.5 mm to 16.5 meters
Speed of light/sound	300,000,000 m/s	343 m/s
Can distinguish ratios	No	Yes
Primary brain processing	Intellectual, reason	Emotional, intuition
Focus	Narrow, pointed	Broad, omnidirectional
Open or closed	Either	Only open
Habitat	Space	Time
Transmission	Time	Space

<sup>1</sup> D. Sonnenschein, Sound design: The expressive power of music, voice, and sound effects in cinema, Michael Weiser Productions, Studio City, CA, ISBN 0-941188-26-4, 2001.

# Touch (Tactition)

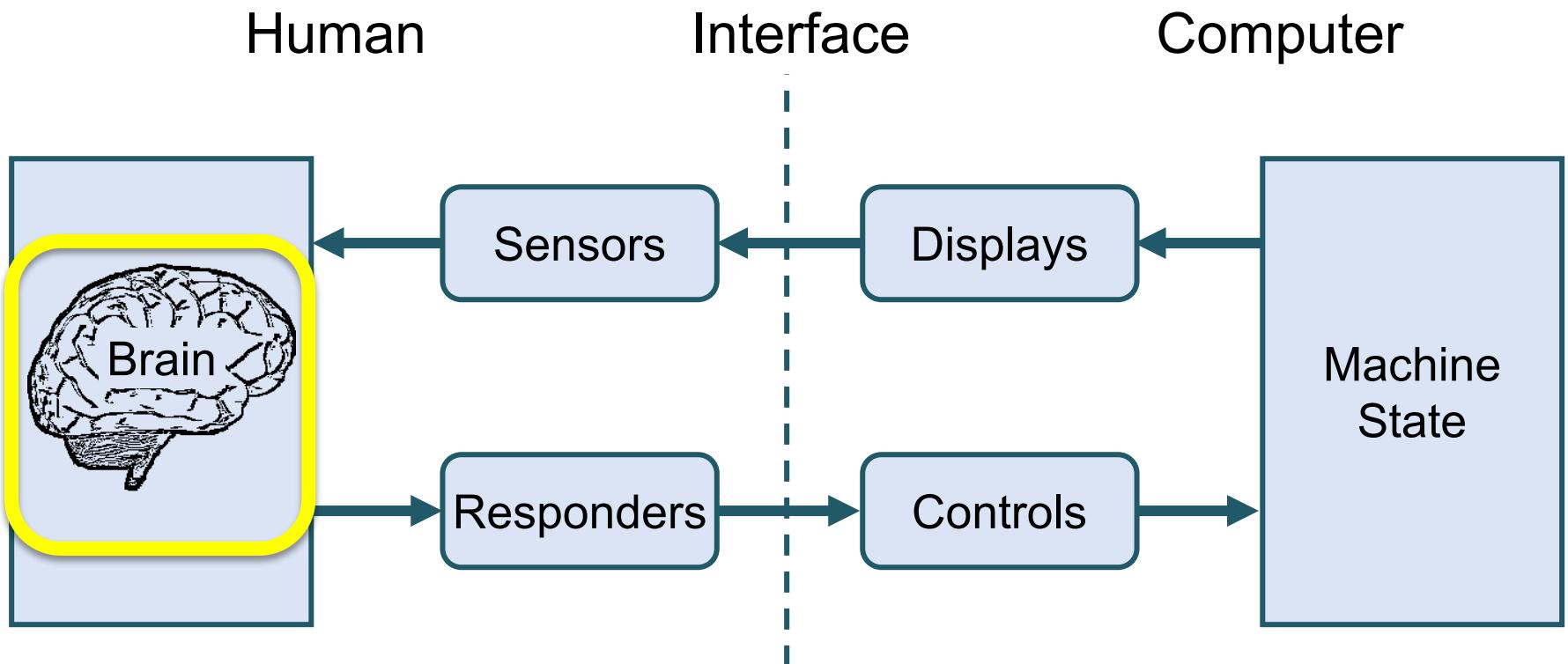
- Part of somatosensory system, with...
- Receptors in skin, muscles, joints, bones
  - Sense of touch, pain, temperature, position, shape, texture, resistance, etc.
- Tactile feedback examples:



# 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
- Only a few examples in HCI (e.g., Brewster et al., 2006; Bodnar et al., 2004)

# Human Factors Model



# 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

# Human Uniqueness

- With associations and meaning attached to sensory input, humans are vastly superior to the machines they interact with:

*People excel at perception, at creativity, at the ability to go beyond the information given, making sense of otherwise chaotic events. We often have to interpret events far beyond the information available, and our ability to do this efficiently and effortlessly, usually without even being aware that we are doing so, greatly adds to our ability to function.<sup>1</sup>*

<sup>1</sup> D.A. Norman, *The Design of Everyday Things*, Basic Books, New York, 1988.

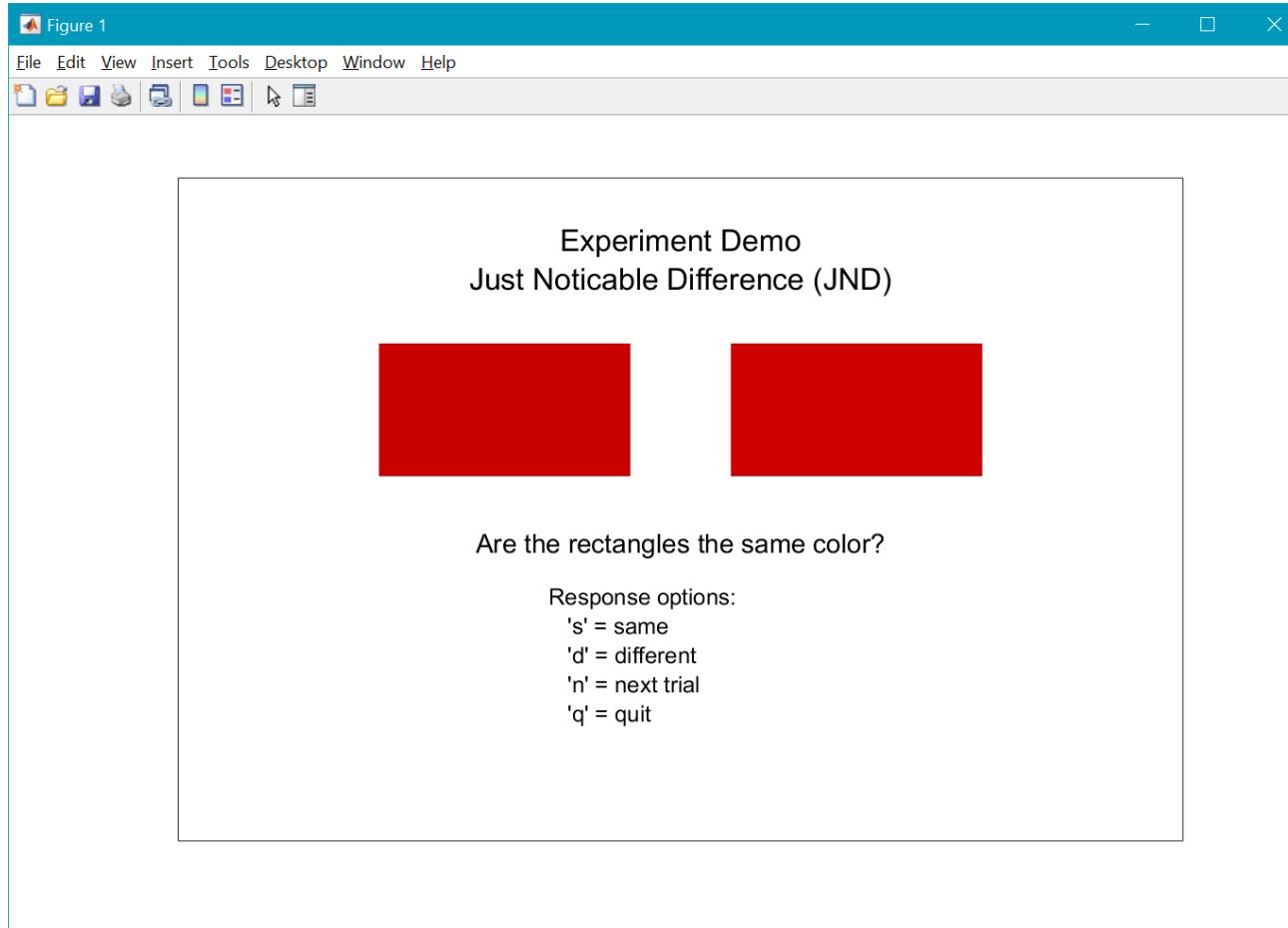
# Perception

- 1<sup>st</sup> stage of processing for sensory input
- Associations formed...
  - Auditory stimulus → harmonious, discordant
  - Visual stimulus → familiar, strange
  - Tactile stimulus → warm, hot; rough, smooth
  - 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)

# Example

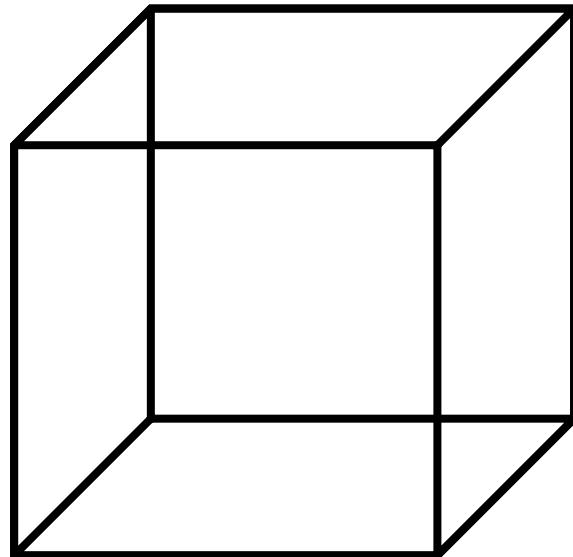


practice042d\_jnd\_experiment.m



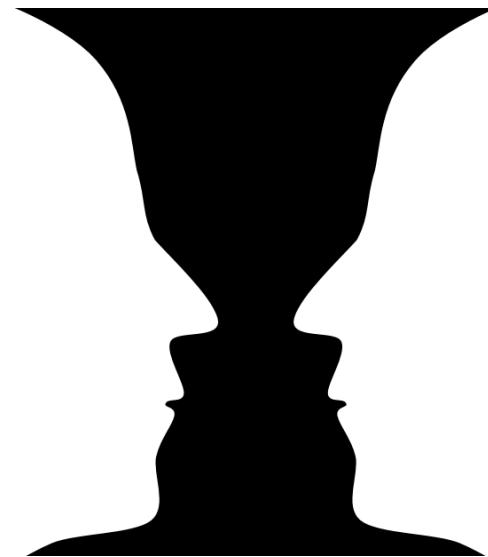
# Ambiguity

**Necker cube**



Which surface is at the front?

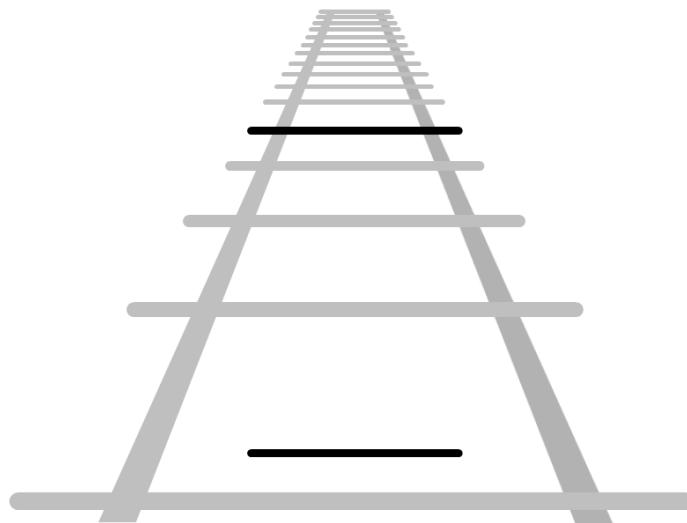
**Rubin vase**



Wine goblet or two faces?

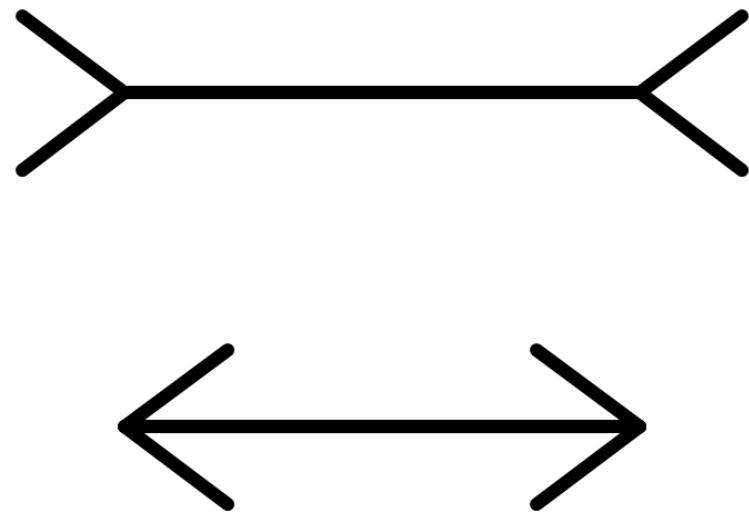
# Illusion (length)

**Ponzo lines**



Which black line is longer?

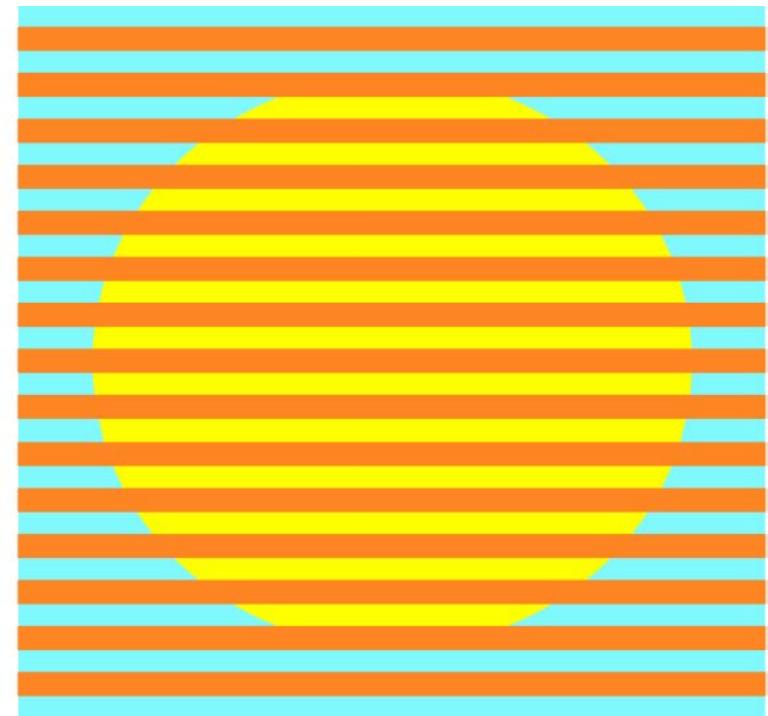
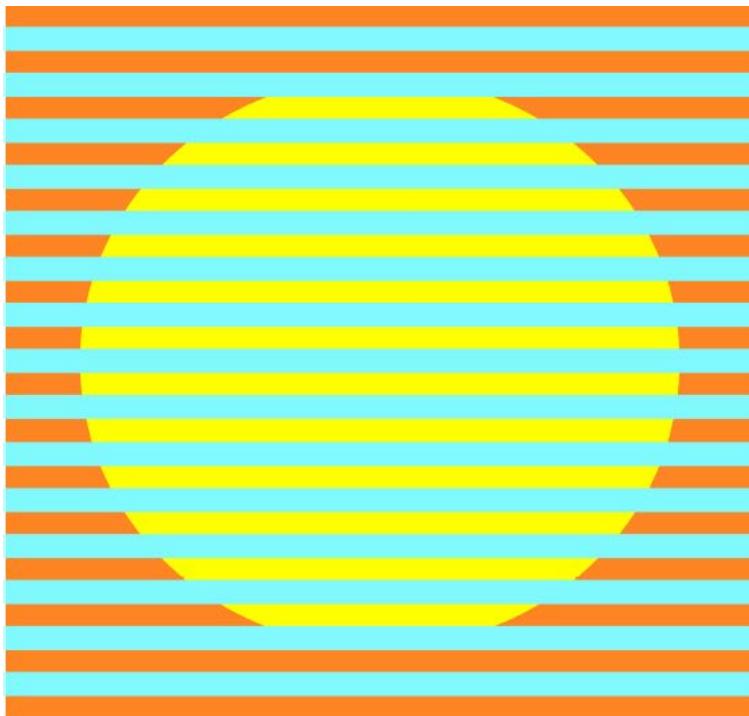
**Müller-Lyer arrows**



Which horizontal line is longer?

# Illusion (color)

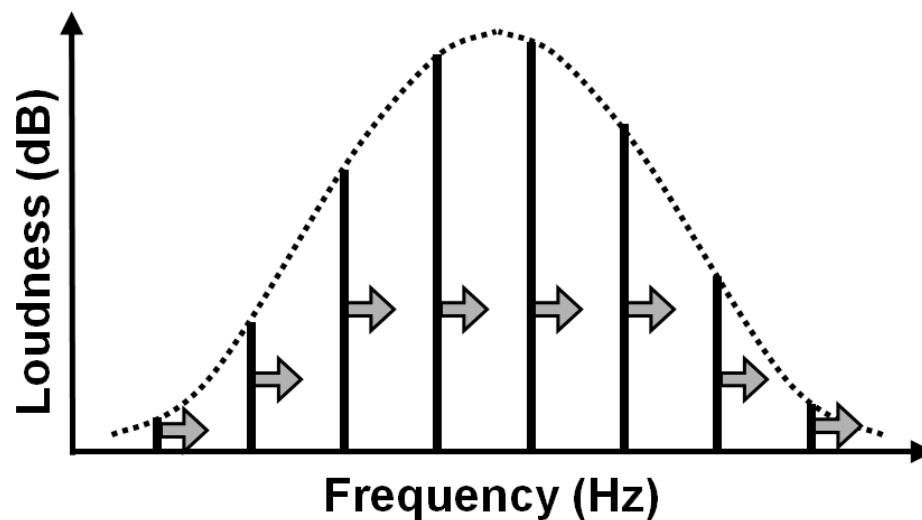
Munker illusion



The two circles are the same color.

# Illusion – Other Senses

- If illusion is possible for the visual sense, the same should be true for the other senses
- Tactile/haptic illusion: phantom limb
- Auditory illusion: Sheppard-Risset glissando
  - Visit *YouTube* for examples



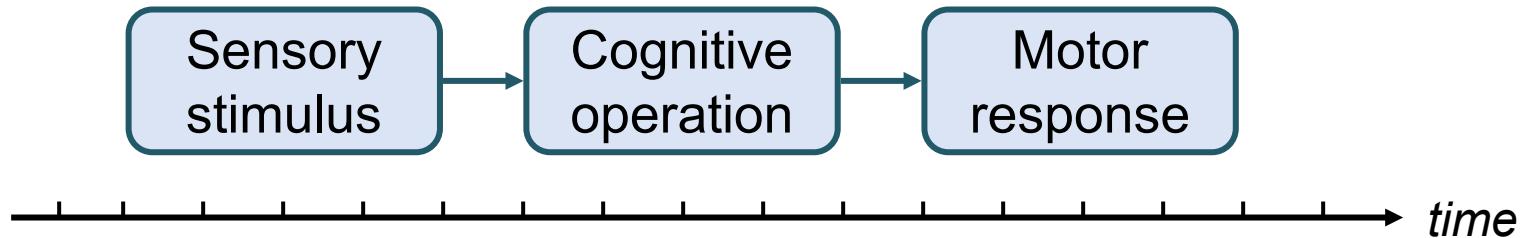
# Cognition

- Cognition is the human process of conscious intellectual activity
  - Thinking, reasoning, deciding, etc.
- Spans many fields
  - Neurology, linguistics, anthropology, etc.
- 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?
- There is a sensory stimulus and motor response that bracket the decision (next slide)

# 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!

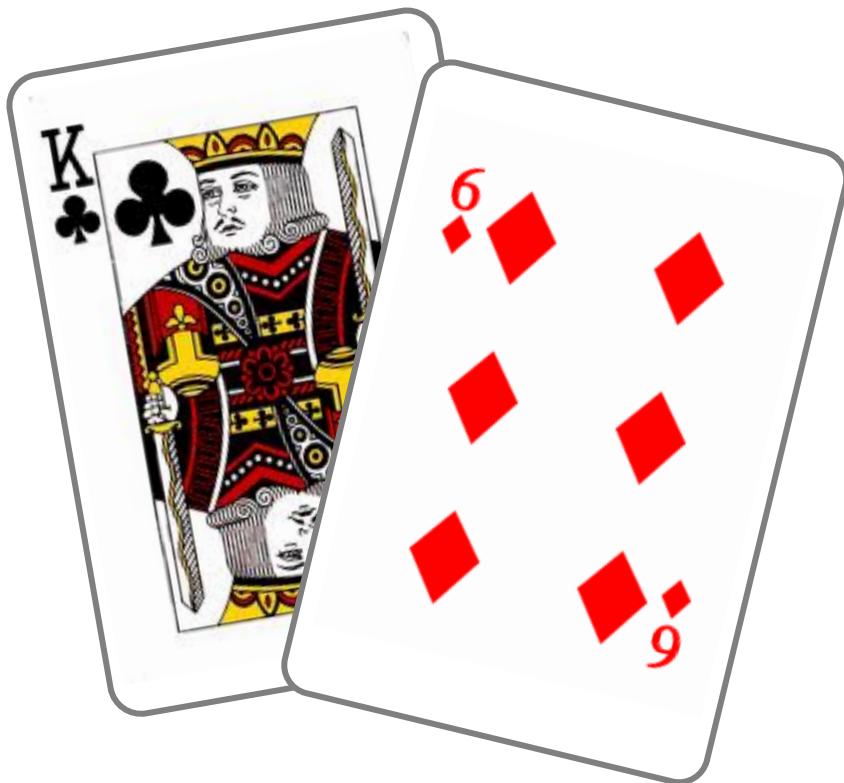


# Examples of Simple Decisions

- 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 (discussed shortly)

# A More Involved Decision

Black Jack hand:



Another card?  
(dealer has 17)

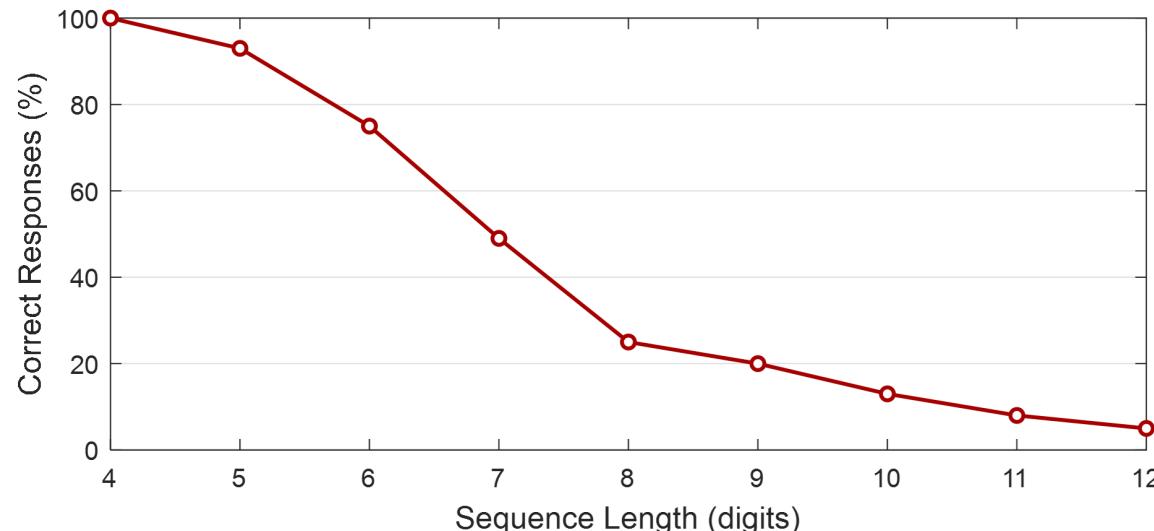
# Memory

- Vast repository
- Long-term memory
  - Declarative/explicit area → information about events in time and objects in the external world
  - Implicit/procedural area → information about how to use objects and how to do things
- Short-term memory
  - Aka *working memory*
  - Information is active and readily available for access
  - Amount of working memory is small, about 7 ( $\pm 2$ ) units or chunks<sup>1</sup>

<sup>1</sup> G.A. Miller, The magical number seven plus or minus two: some limits on our capacity for processing information, 40 Psychological Review 63 (2) (1956) 81–97.

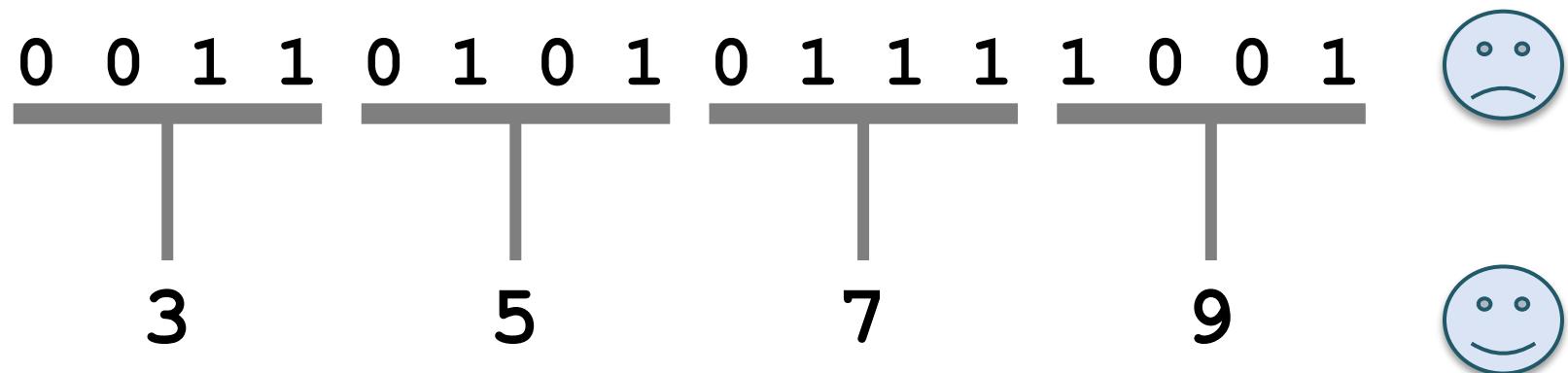
# Short Term Memory Experiment

- Random sequences of digits recited to subjects
- Sequences varied from 4 to 13 digits
- After recitation, subjects copied the sequence from memory to a sheet of paper
- Transcriptions on sheets were scored (correct/incorrect)
- Result ( $n \approx 60$ ):

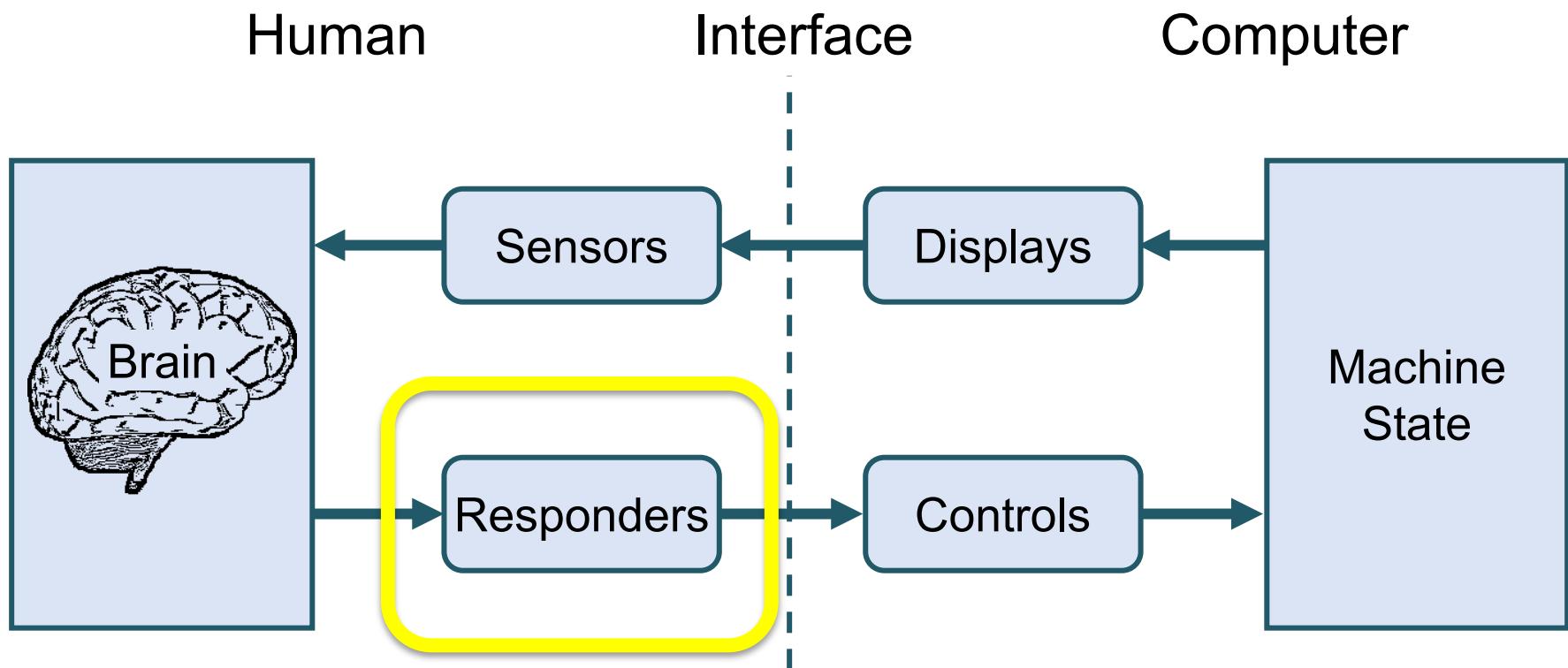


# Chunking

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

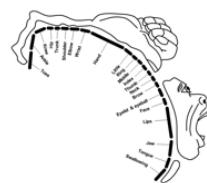


# Human Factors Model

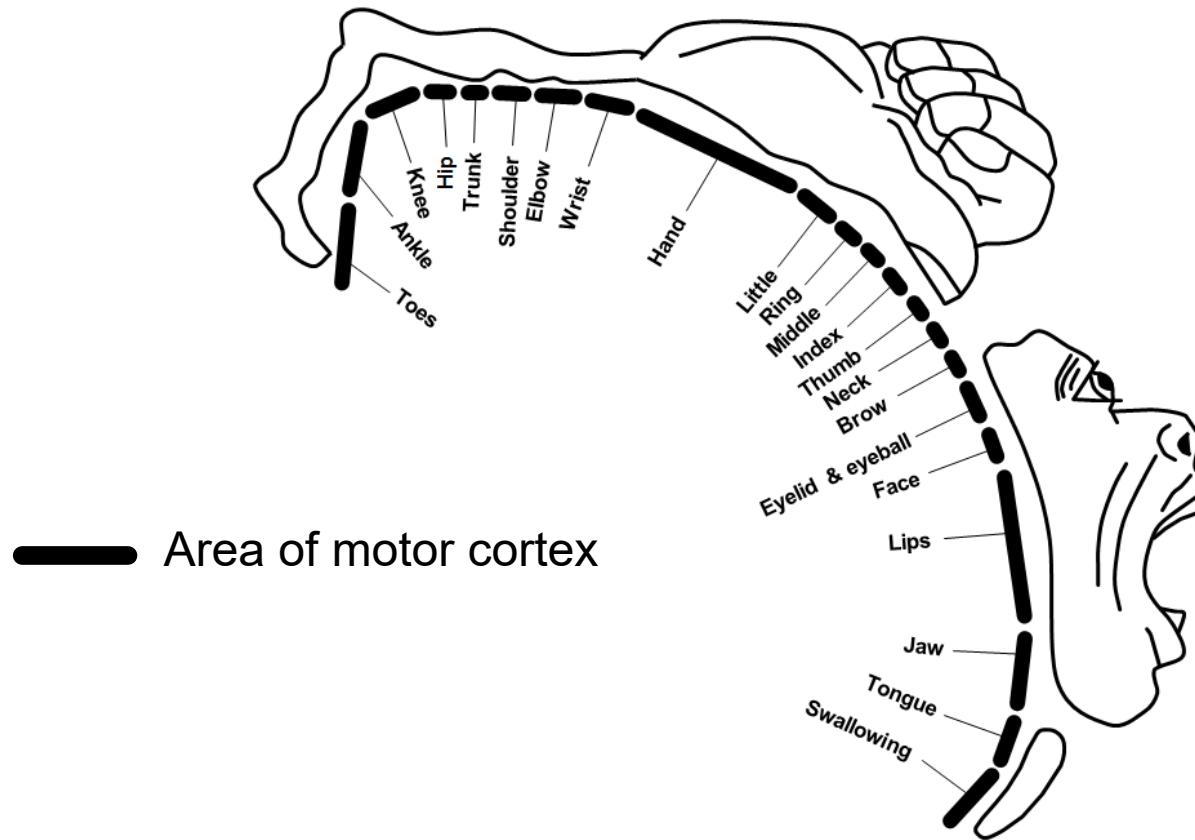


# Responders

- Humans control their environment through responders, for example...
  - A finger to point
  - Feet to walk or run
  - Eyebrow to frown
  - Vocal chords to speak
  - Torso to lean
- Penfield's (1990) motor homunculus
  - Shows human responders and the relative area of motor cortex dedicated to each:

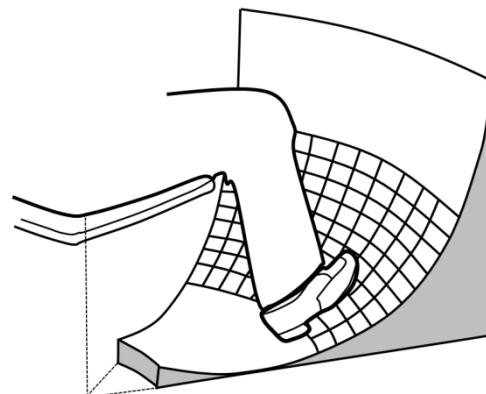
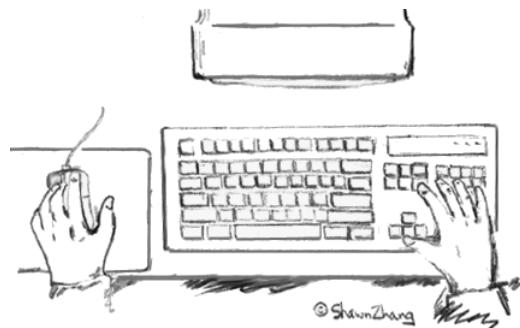


# Motor Homunculus<sup>1</sup>



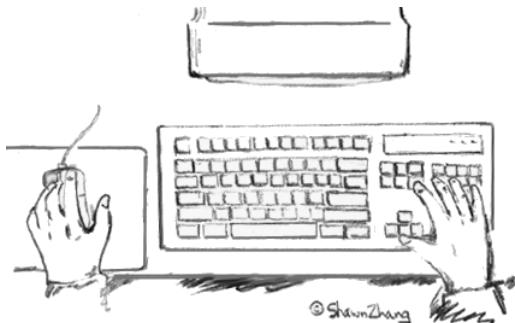
<sup>1</sup> W. Penfield, T. Rasmussen, *The Cerebral Cortex of Man: A Clinical Study of Localization of Function*, Macmillan, New York, 1990.

# Responder Examples



# Handedness

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



- Handedness exists by degree
- Edinburgh Handedness Inventory used to measure handedness (next slide)

# Edinburgh Inventory for Handedness<sup>1</sup>

	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"/>
Difference	<input type="text"/>	<input type="text"/>
Cumulative Total	<input type="text"/>	<input type="text"/>
<b>RESULT</b>	<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

<sup>1</sup> R.C. Oldfield, The assessment and analysis of handedness: the Edinburgh inventory, *Neuropsychologia* 9 (1) (1971) 97–113.

# Hand/Finger Size – Measuring

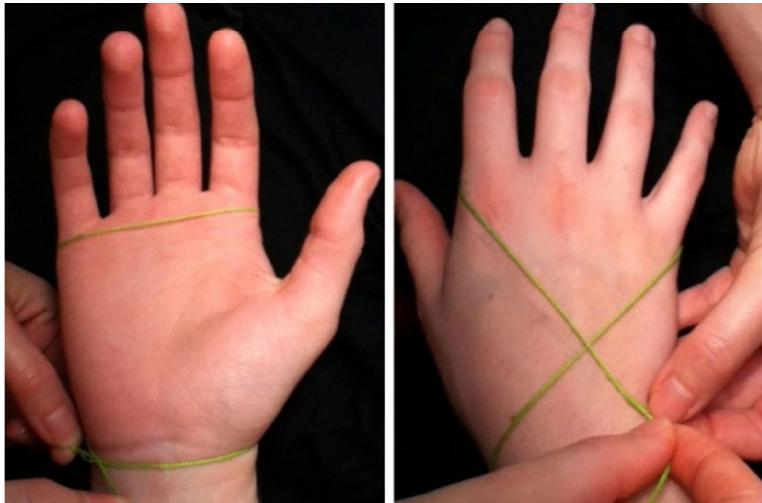
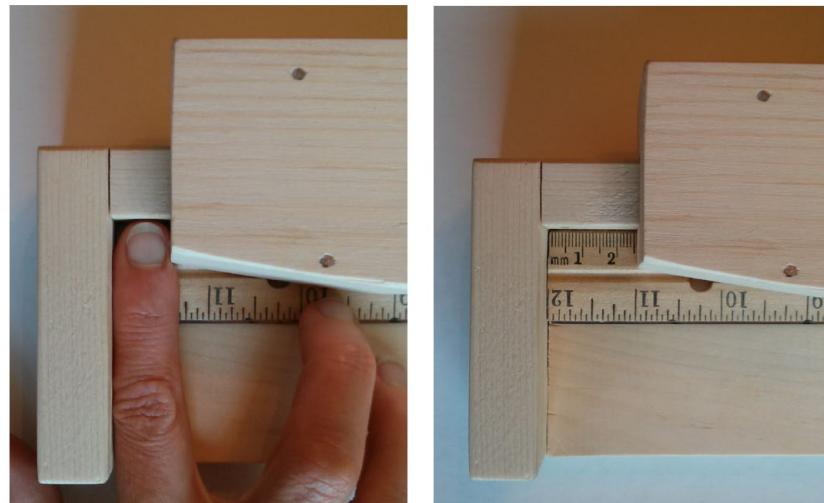


Figure-of-eight method<sup>1</sup>

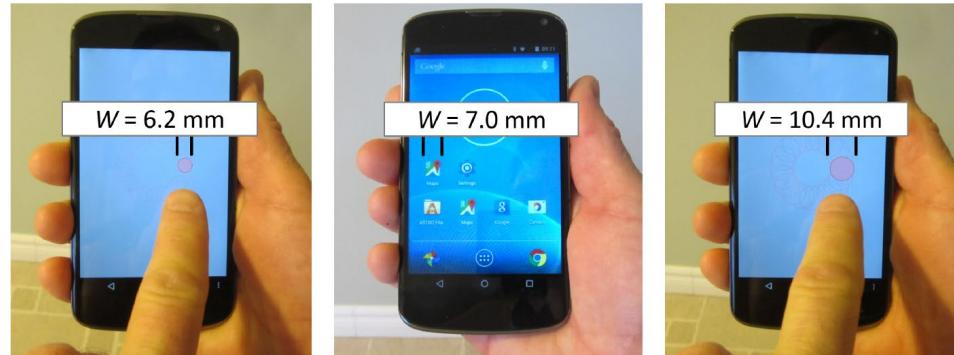


Caliper<sup>2</sup>

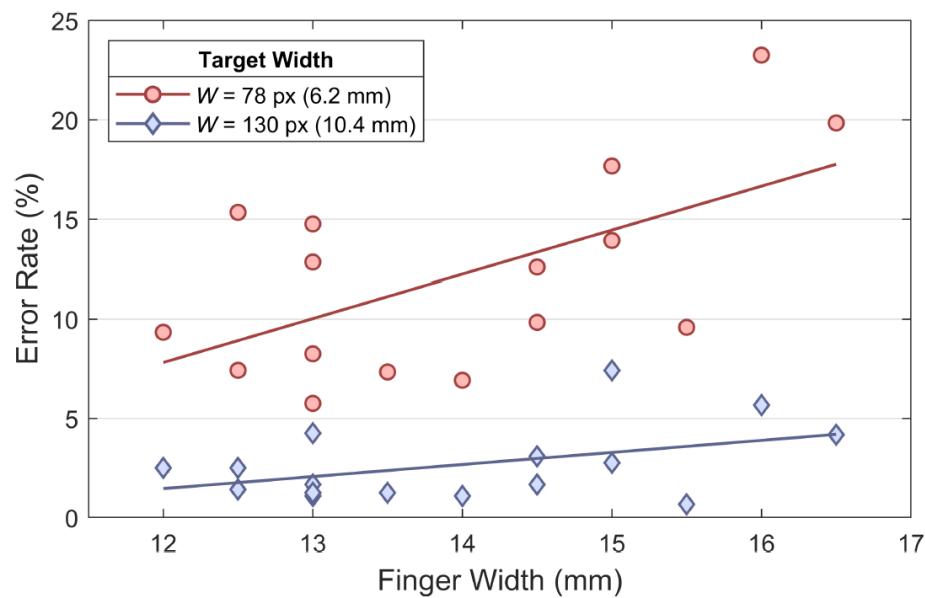
<sup>1</sup> M.A. Brown, I.S. MacKenzie, Evaluating video game controller usability as related to user hand size, in: Proc MHCI '13, ASET, Ottawa, Canada, 2013, pp. 114.1–114.8.

<sup>2</sup> I.S. MacKenzie, Fitts' throughput and the remarkable case of touch-based target selection, in: Proc HCII '15 (LNCS 9170), Springer, Berlin, 2015, pp. 238–249. 49

# Finger Size – Performance Issues



Finger size vs. target width



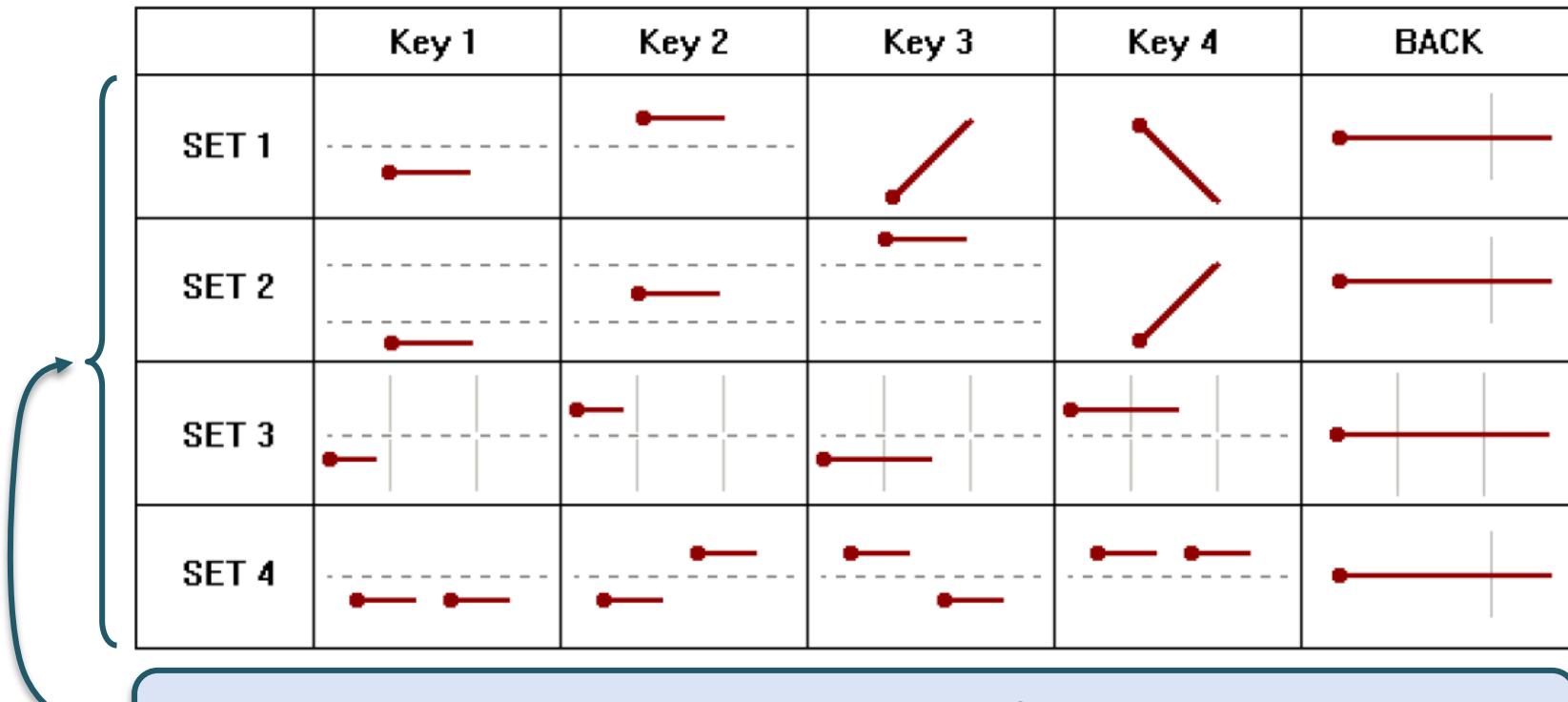
Error rate vs. finger width and target width

# 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.)

# Non-speech Example<sup>1</sup>

- NVVI = non-verbal voice interaction

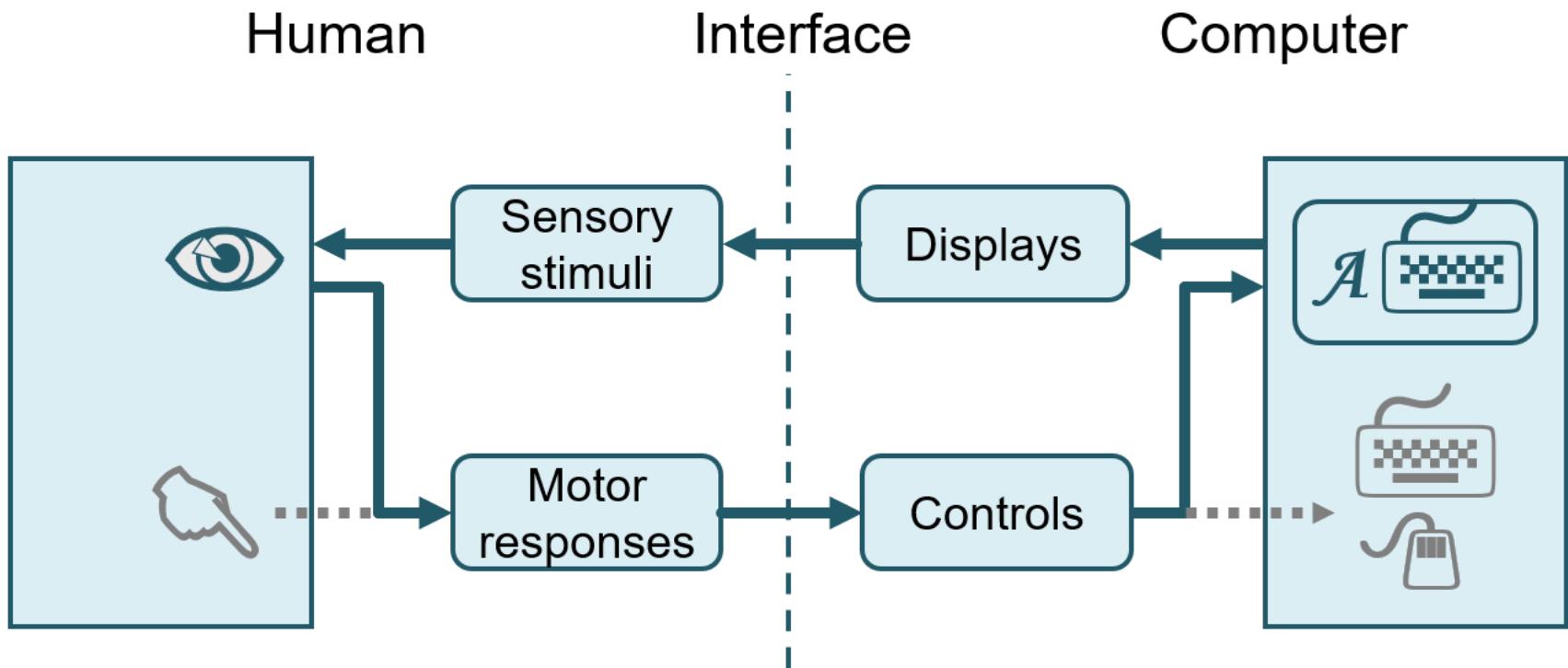


<sup>1</sup> A.J. Sporka, T. Felzer, S.H. Kurniawan, P. Ondrej, P. Haiduk, I.S. MacKenzie, CHANTI: predictive text entry using non-verbal vocal input, in: Proc CHI '11, ACM, New York, 2011, pp. 2463–2472. 52

# The Eye as a Responder

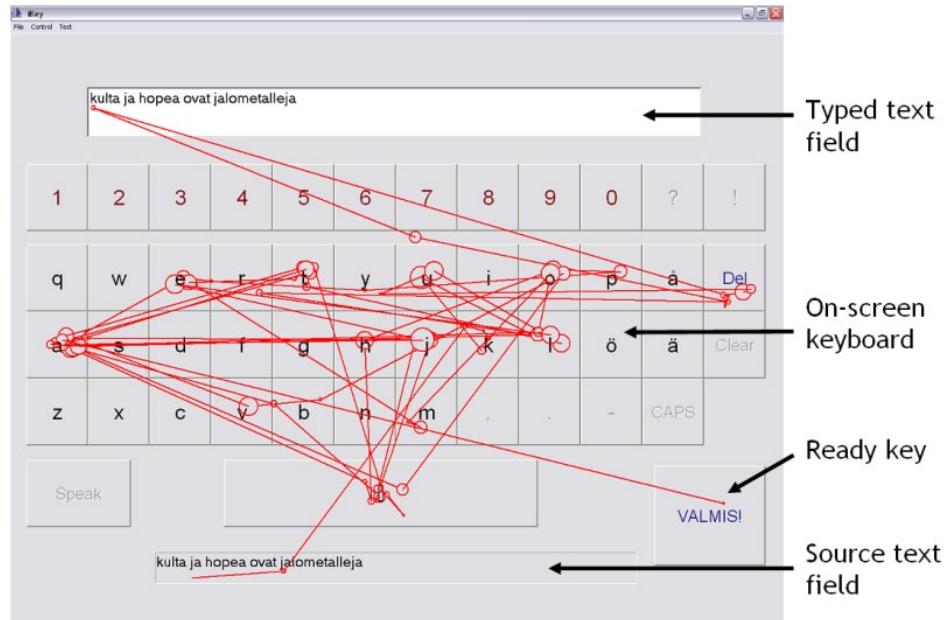
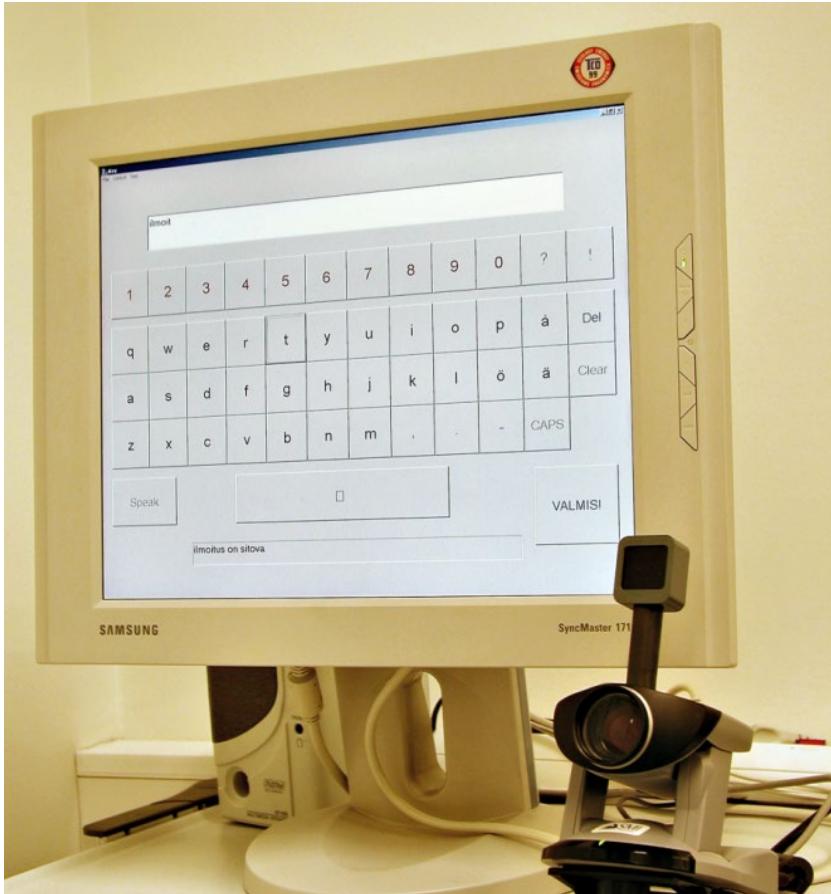
- As a responder, the eye is called upon to do “double duty”
  1. Sense and perceive the environment/computer
  2. Act as a controller via saccades and fixations
- This suggests a modification to the human factors model presented earlier (next slide)

# Modified Human Factors Model<sup>1</sup>



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

# Example - Eye Typing<sup>1</sup>



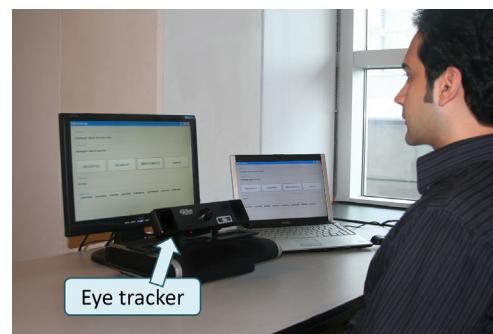
<sup>1</sup> P. Majaranta, I.S. MacKenzie, A. Aula, K.-J. Räihä, Effects of feedback and dwell time on eye typing speed and accuracy, Universal Access in the Information Society (UAIS) 5 (2006) 199–208.

# Blinking

- Blinking is an eye response that can be used for computer control:



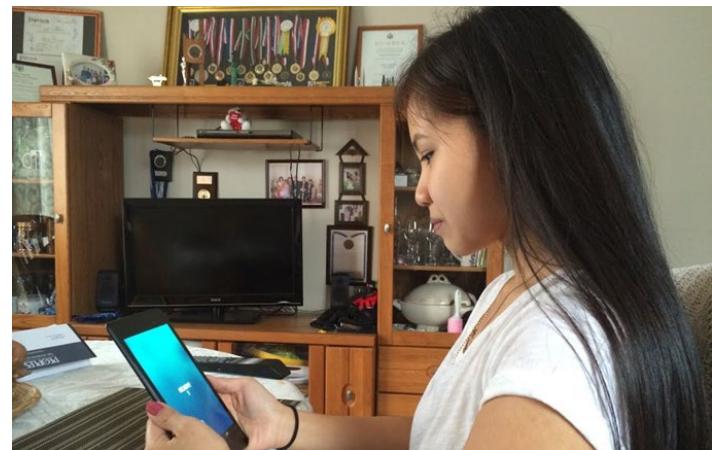
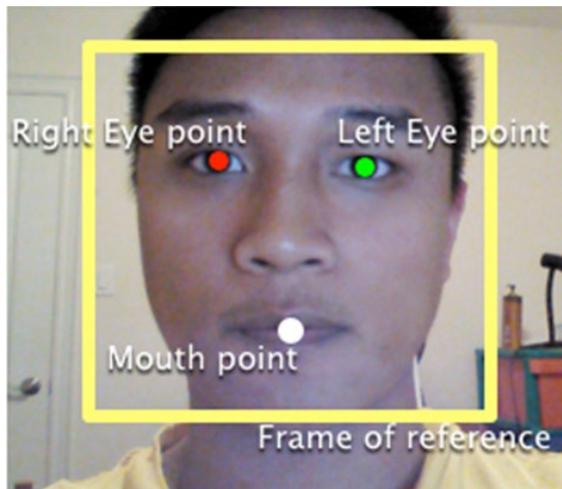
- E.g., BlinkWrite:



(click image to view video)

<sup>1</sup> I.S.MacKenzie, B. Ashtiani, BlinkWrite: efficient text entry using eye blinks, Universal Access in the Information Society 10 (2011) 69–80.

# Face Tracking



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

<sup>1</sup> J. Cuaresma, J., & I.S. MacKenzie, A comparison between tilt-input and facial tracking as input methods for mobile games. Proc IEEE-GEM 2014, New York: IEEE, 2014, pp. 70-76.

# Language

- The mental faculty that allows humans to communicate
- As speech, available to (almost) all humans without effort
- As writing, only available with considerable effort
- HCI interest: primarily in writing, creation of text

*Humankind is defined by language; but civilization is defined by writing.<sup>1</sup>*

<sup>1</sup> P.T. Daniels, W. Bright, *The World's Writing Systems*, Oxford University Press, New York, 1996.

# Corpus

- One way to characterise written text is a corpus
- Large collection of representative text samples
- A corpus may be reduced to a word-frequency list:

Word Rank	English	French	German	Finnish	SMS English	SMS Pinyin
1	the	de	der	ja	u	wo (我)
2	of	la	die	on	i	ni (你)
3	and	et	und	ei	to	le (了)
4	a	le	in	että	me	de (的)
5	in	à	den	oli	at	bu (不)
...	...	...	...	...	...	...
1000	top	ceci	konkurrenz	muista	ps	jiu (舅)
1001	truth	mari	stieg	paikalla	quit	tie (贴)
1002	balance	solution	notwendig	varaa	rice	ji (即)
1003	heard	expliquer	sogenannte	vie	sailing	jiao (角)
1004	speech	pluie	fahren	seuran	sale	ku (裤)
...	...	...	...	...	...	...

# Part-of-speech Tagging

- Some corpora include part-of-speech (POS) tagging
- Each word is tagged by its category (e.g., noun, verb, adjective)
- Used in word prediction to narrow search space<sup>1</sup>
- Example:

The *paint* is dry. (noun)

Children *paint* with passion. (verb)

<sup>1</sup> J. Gong, P. Tarasewich, I.S. MacKenzie, Improved word list ordering for text entry on ambiguous keyboards, in: Proc NordiCHI '08, ACM, New York, 2008, pp. 152–161.

# Statistics and Language

- Native speakers intuitively understand the statistical nature of their language

- We...

- Insert words that are omitted or obscured:

Ham and \_\_\_\_\_ sandwich.

- Anticipate words:

A picture is worth a thousand \_\_\_\_\_.

- Anticipate letters:

Questio\_

- Anticipate entire phrases:

To be or \_\_ \_\_ \_\_.

# Redundancy and Language

- Since humans can fill in missing parts, perhaps the missing parts can be eliminated
- This shortens the text (efficient)
- Example: 243 characters of text with vowels removed...

Th std ws flld wth th rch dr f rss,  
nd whn th lght smmr wnd strrd mdst th  
trs f th grdn, thr cm thrgh th pn  
dr th hvy scnt f th llc, r th mr  
dlct prfm f th pnk-flwrng thrn.

- 71 vowels removed
- Text shortened by 29.2%

Meaning of the text?

smmr → summer, thrgh → through, etc.

# Redundancy and Language (2)

- Vowels at beginning of words intact:

Th std ws flld wth th rch odr of rss,  
and whn th lght smmr wnd strrd amdst th  
trs of th grdn, thr cm thrgh th opn  
dr th hvy scnt of th llc, or th mr  
dlct prfm of th pnk-flwrng thrn.

- 62 vowels removed
- Text shortened by 25.5%

Easier to understand.

- Original:

The studio was filled with the rich odour of roses,  
and when the light summer wind stirred amidst the  
trees of the garden, there came through the open  
door the heavy scent of the lilac, or the more  
delicate perfume of the pink-flowering thorn.

- Original

Oscar Wilde: *The Picture of Dorian Gray*

# Recoding

- Other ways to shorten text
- Recoding: replacing words/characters with shortened tags using linguistic tricks<sup>1</sup>
- Examples
  - Sound:  
th@s → that's  
gr8 → great
  - Invented acronyms:  
w → with  
gf → girlfriend  
x → times

<sup>1</sup> R. Grinter, M. Eldridge, Wan2tlk? Everyday text messaging, in: Proc CHI '03, ACM, New York, 2003, pp. 441–448.

# SMS Shorthand

- The final frontier!
- A 13-year-old student's essay (excerpt)<sup>1</sup>

My smmr hols wr CWOT.  
B4, we used 2go2 NY 2C  
my bro, his GF & thr 3 :-  
kids FTF. ILNY, it's a gr8  
plc.

- 102 characters

- Original (for the teacher to deduce)

My summer holidays were a complete waste of time. Before, we used to go to New York to see my brother, his girlfriend and their three screaming kids face to face. I love New York. It's a great place.

- 199 characters

<sup>1</sup> [http://news.bbc.co.uk/2/hi/uk\\_news/2814235.stm](http://news.bbc.co.uk/2/hi/uk_news/2814235.stm)

# Entropy in Language

- If redundancy is what we know, entropy is what we don't know
  - Entropy is the uncertainty about forthcoming letters, words, phrases, ideas, etc.
  - Shannon demonstrated entropy and redundancy in a letter guessing experiment<sup>1</sup>
    - Subject shown text with letters blocked
    - Subject guesses letters one at a time
    - Letters revealed as guessing proceeds:
      - Incorrect guess → show correct letter
      - Correct guess → show “-”
- (next slide)

<sup>1</sup> C.E. Shannon, Prediction and entropy of printed English, Bell System Technical Journal 30 (1) (1951) 50–64,

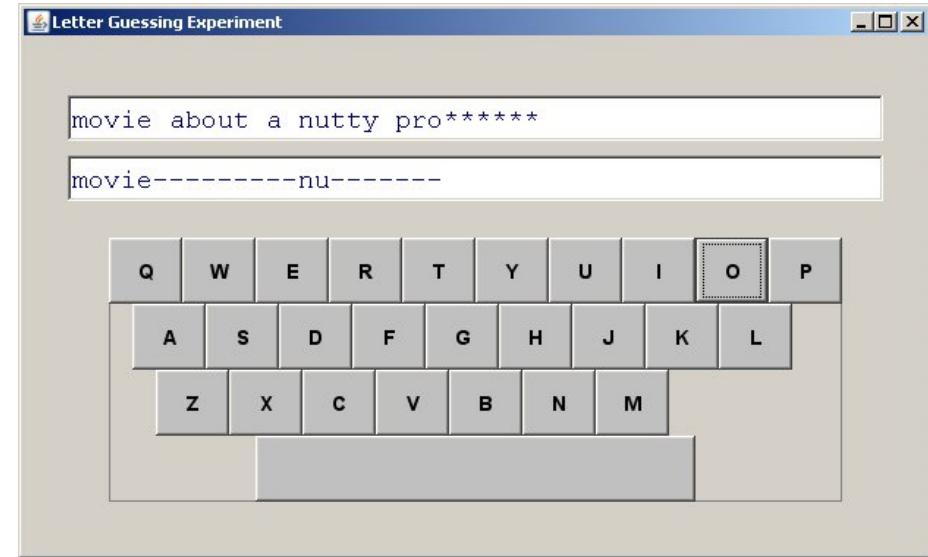
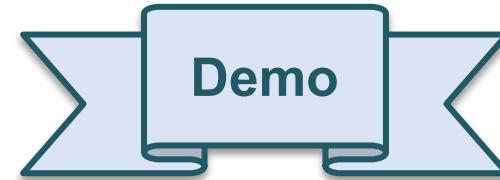
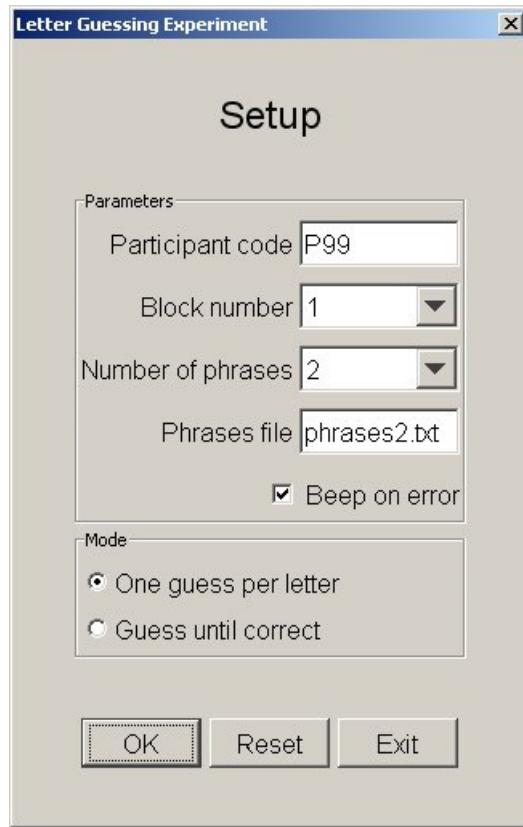
# Letter Guessing Experiment

THE ROOM WAS NOT VERY LIGHT A SMALL OBLONG  
-----ROO-----NOT-V-----I-----SM----OB----

READING LAMP ON THE DESK SHED GLOW ON  
REA-----O-----D---SHED-GLO--0-

POLISHED WOOD BUT LESS ON THE SHABBY RED CARPET  
P-L-S-----O---BU--L-S--O-----SH----RE--C-----

# Letter Guessing Experiment (2)



Use software from the book's web site:  
<http://www.yorku.ca/mack/HCIbook2e/>

# Letter Guessing Experiment (3)

- Observations:
  - Errors most common at beginning of words
  - Errors less common as a word progresses
  - Errors even less common as a phrase progresses
- Entropy discussion:
  - The two phrases (original and “reduced”) contain the same information
  - With a good statistical model, the original text can be obtained from the reduced text
  - Therefore, it is only necessary to transmit the reduced text

# Entropy of Printed English

- Shannon demonstrated how to calculate the entropy ( $H$ ) of printed English
- If all 26 letters were equally probable (i.e., no redundancy),

$$H = \log_2(26) = 4.70 \text{ bits per letter}$$

- Considering single letter frequencies ( $e$  is common,  $z$  is rare),

$$H = 4.25 \text{ bits per letter}^1$$

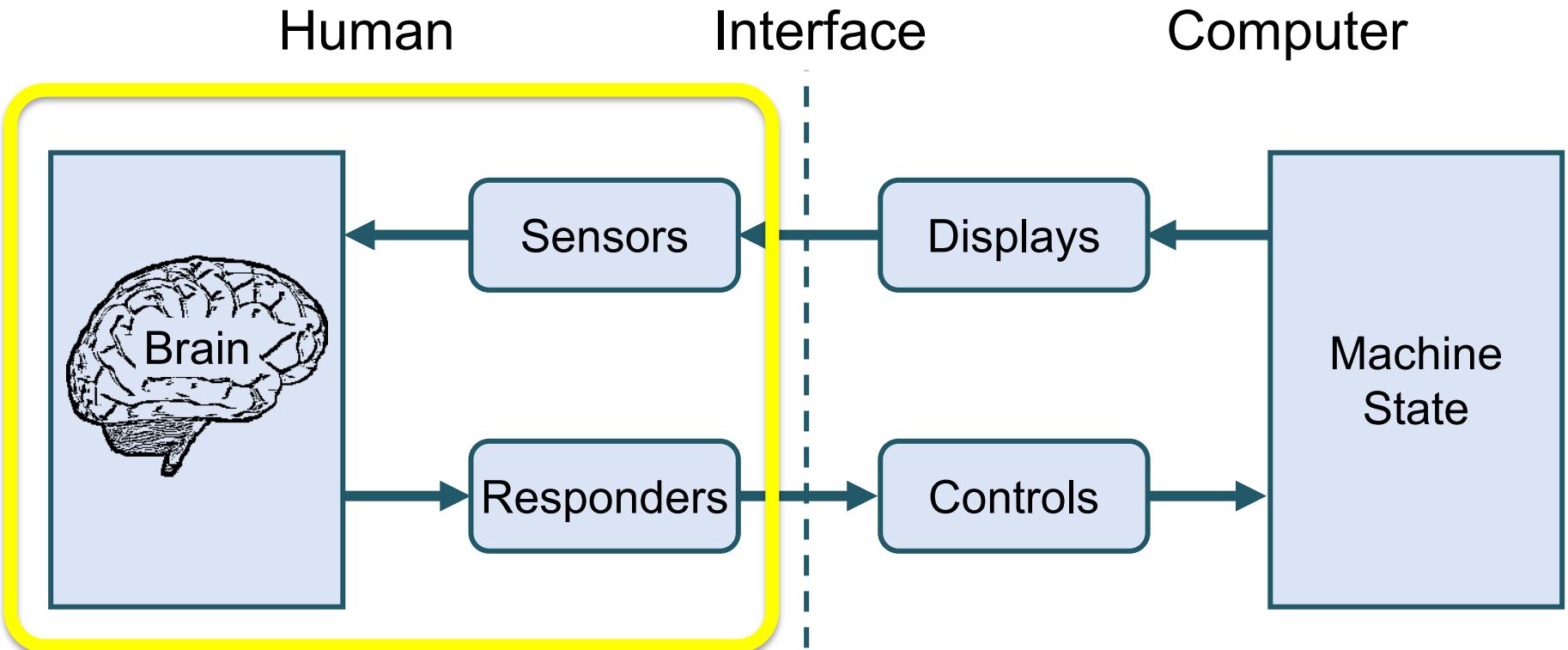
- $H$  (uncertainty) goes down as more letters are considered (1 previous letter, 2 previous letters, etc.)
- In the extreme (considering up to about 100 letters),

$$H \approx 1 \text{ bit per letter}$$

$$\text{Redundancy} \approx 75\%$$

<sup>1</sup> Calculation and further discussion in Chapter 7 (see Figure 7-25).

# Human Factors Model



**Human Performance**  
**Skilled Behaviour**  
**Attention**  
**Human Error**

# Human Performance

- Humans uses their sensors, brain, and responders to do things
- When the three work together to achieve a *goal*, human performance arises
- Examples:
  - Tying shoelaces
  - Folding clothes
  - Searching the web
  - Entering a text message on a smartphone

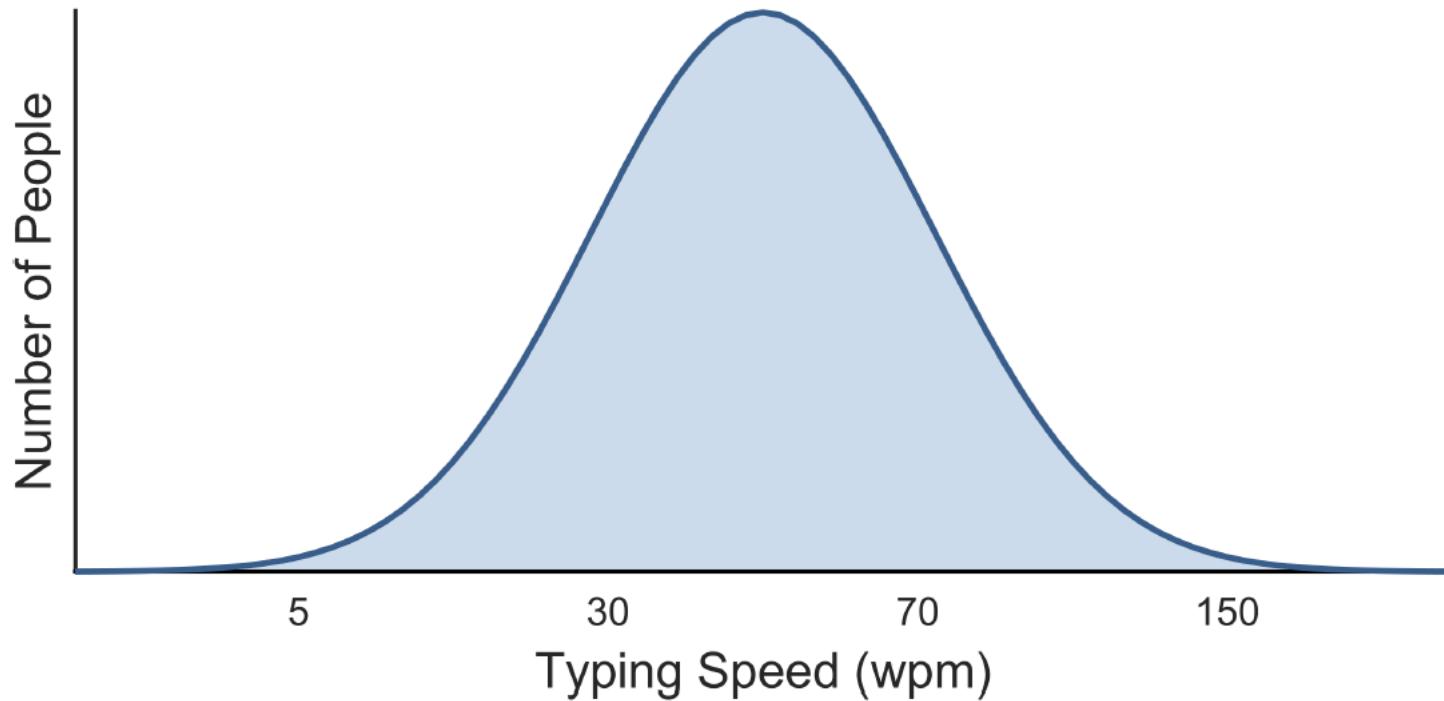
# Speed-accuracy Trade-off

- Fundamental property of human performance
- Go faster and errors increase
- Slow down and accuracy improves
- HCI research on a new interface or interaction technique must consider both the speed in doing tasks (achieving the goal!) and the accompanying accuracy

# Human Diversity

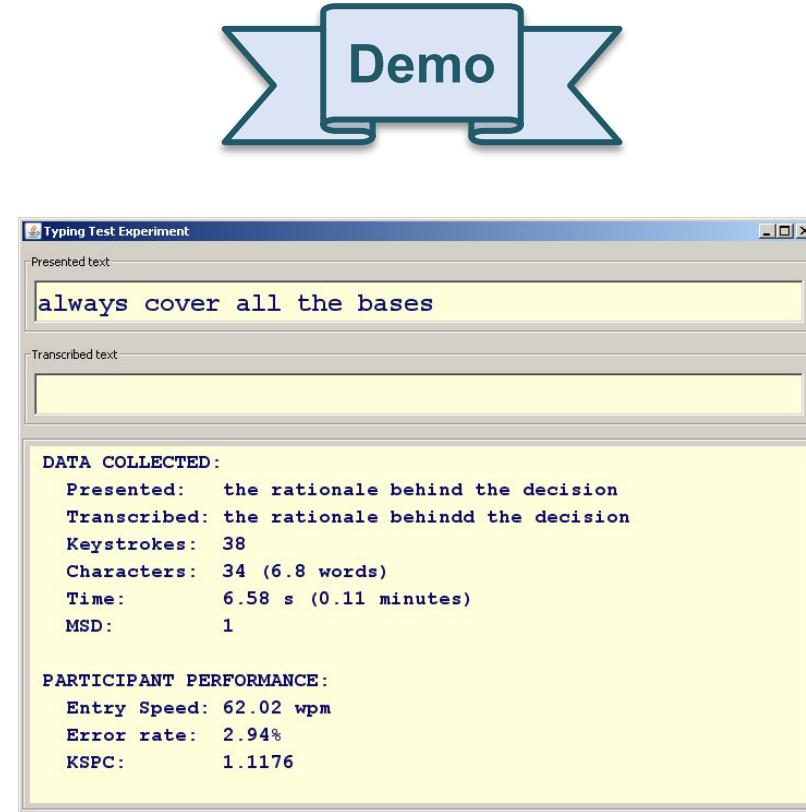
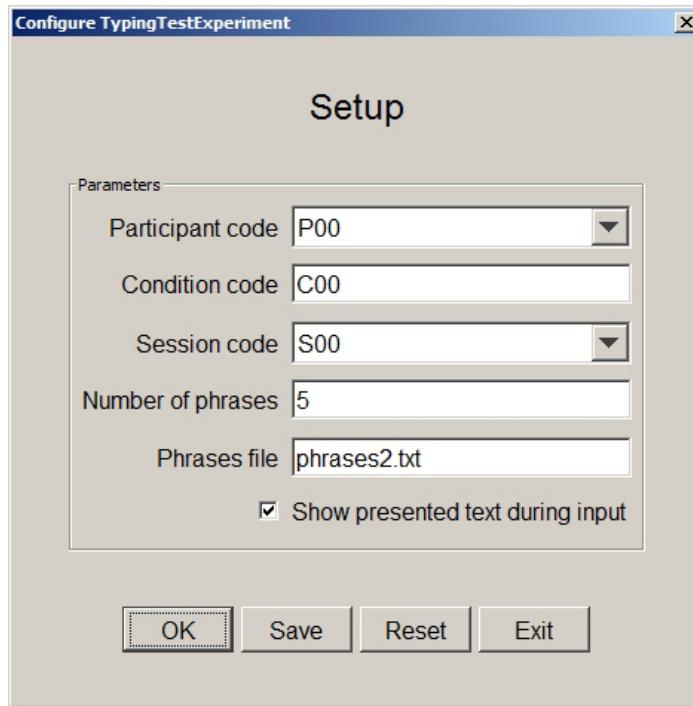
- Human performance is highly complex:
  - Humans differ (age, gender, skill, motivation, etc.)
  - Environmental conditions affect performance
  - Secondary tasks often present
- Human diversity and human performance often shown in a distribution (next slide)

# Human Diversity and Performance



Where are you on this chart?  
Where is your mother or grandmother?  
Where is an 8-year-old, just learning to use a computer?  
Where is someone with a physical disability?  
Where are you while using your mobile phone on a crowded bus (standing!)?

# Typing Test Experiment



Use software from book's web site:  
<http://www.yorku.ca/mack/HCIbook2e/>

# 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<sup>1</sup>
- Example: pressing a button in response to the onset of a stimulus light

<sup>1</sup> P.M. Fitts, M.I. Posner, Human Performance, Brooks/Cole Publishing Company, Belmont, CA, 1968.

# Sensory Stimuli and Reaction Time

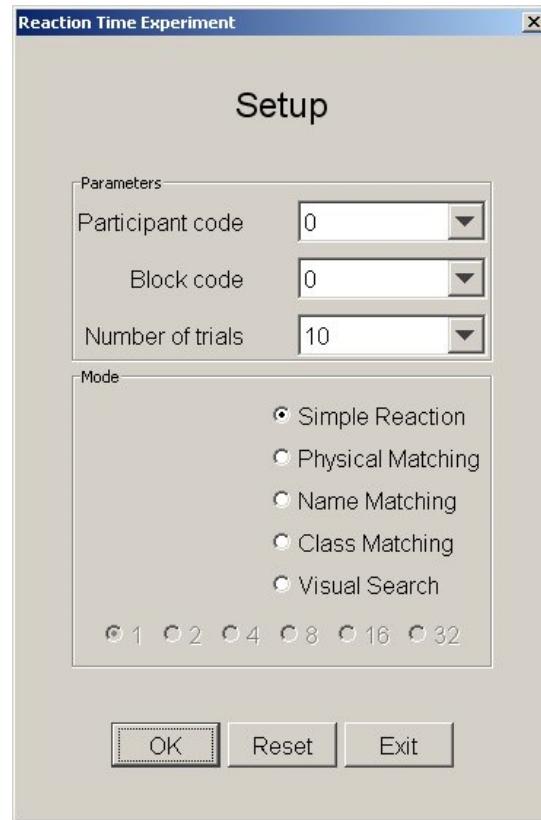
- Delay time varies by type of sensory stimuli
- Approximate values<sup>1,2</sup>
  - Auditory → 150 ms
  - Visual → 200 ms
  - Smell → 300 ms
  - Pain → 380 ms

100 ms minimum, perhaps less.  
See **HCI:ERP2e** for discussion.

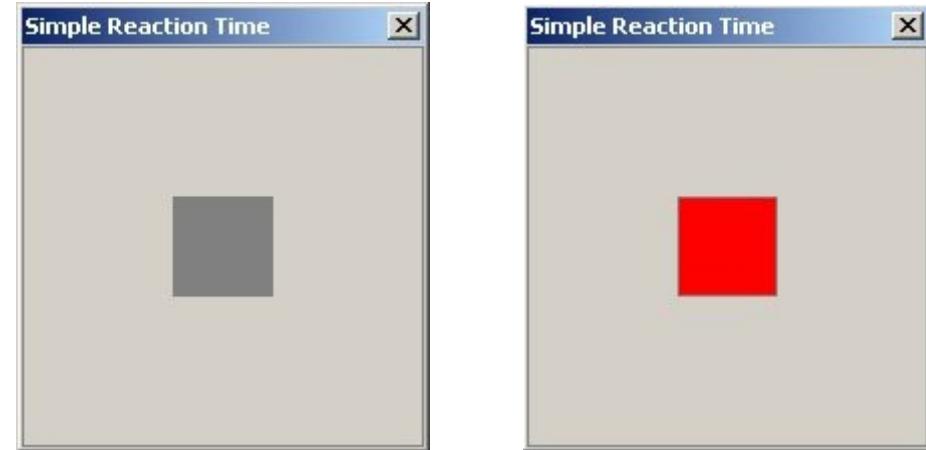
<sup>1</sup> R.W. Bailey, Human Performance Engineering: Designing High Quality, Professional User Interfaces for Computer Products, Applications, and Systems, 3rd ed. Edition, Prentice Hall, Upper Saddle River, NJ, ISBN 978-0131496347, 1996.

<sup>2</sup> M. Ploner, J. Gross, L. Timmermann, A. Schnitzler, Pain processing is faster than tactile processing in the human brain, Journal of Neuroscience 26 (42) (2006) 10879–10882,

# Reaction Time Experiment



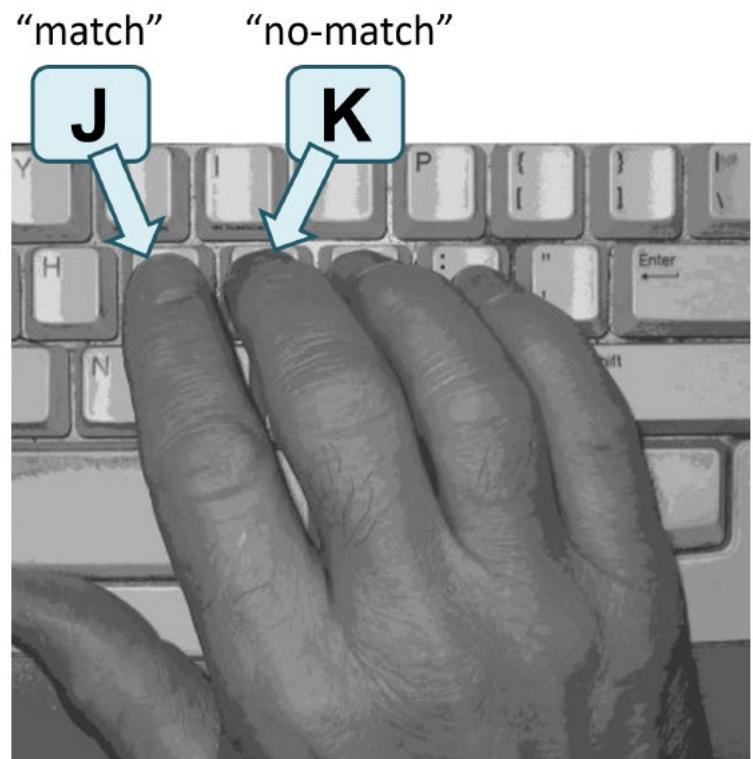
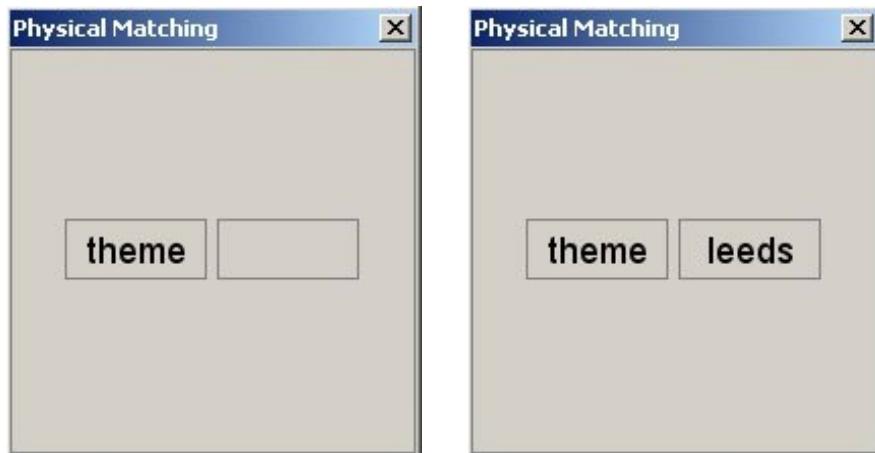
## Simple Reaction Time



Use software from the book's web site:  
<http://www.yorku.ca/mack/HCIbook2e/>

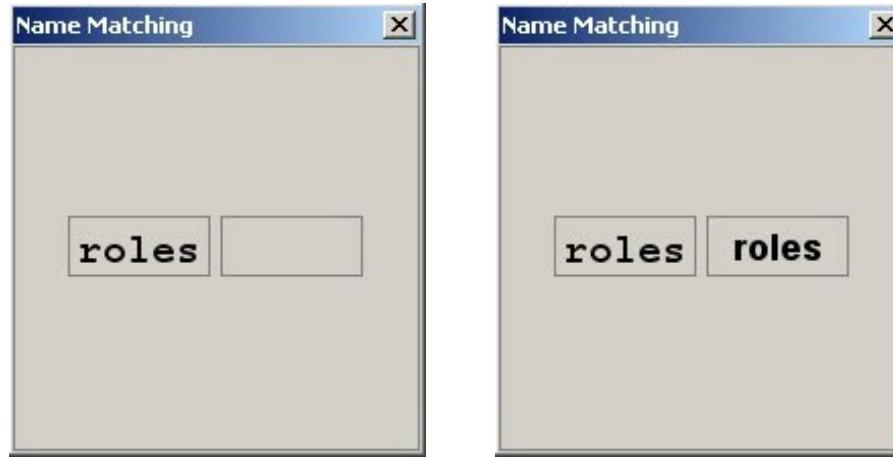
# Reaction Time Experiment (2)

## Physical Matching

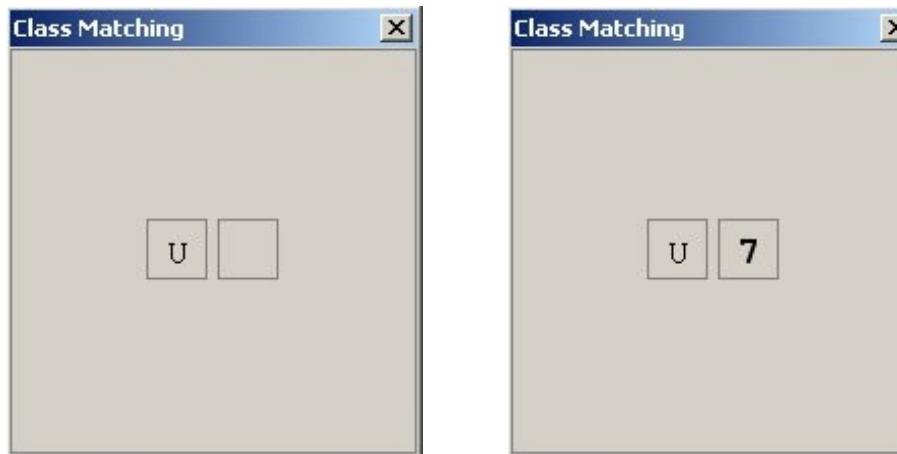


# Reaction Time Experiment (3)

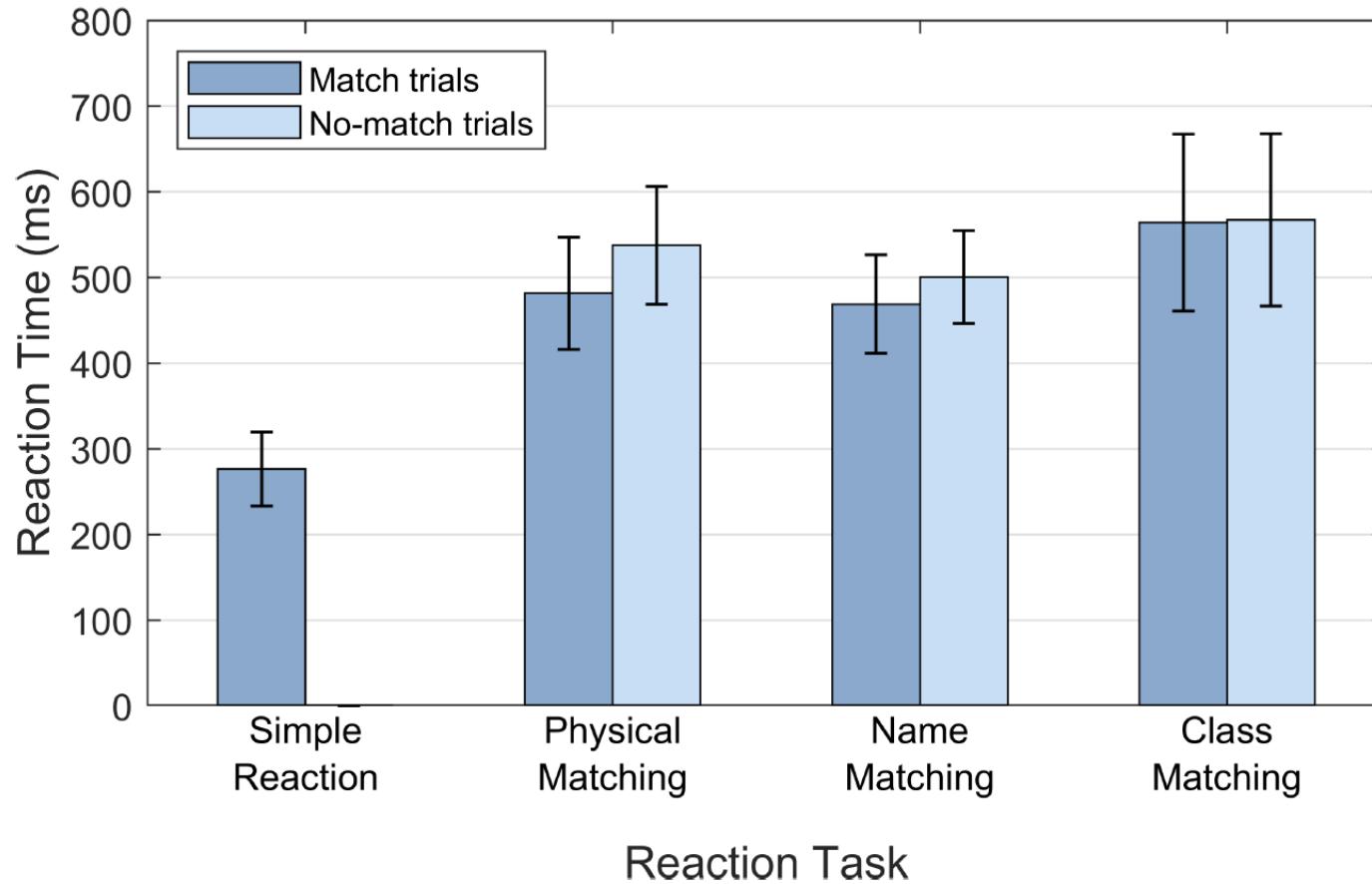
## Name Matching



## Class Matching

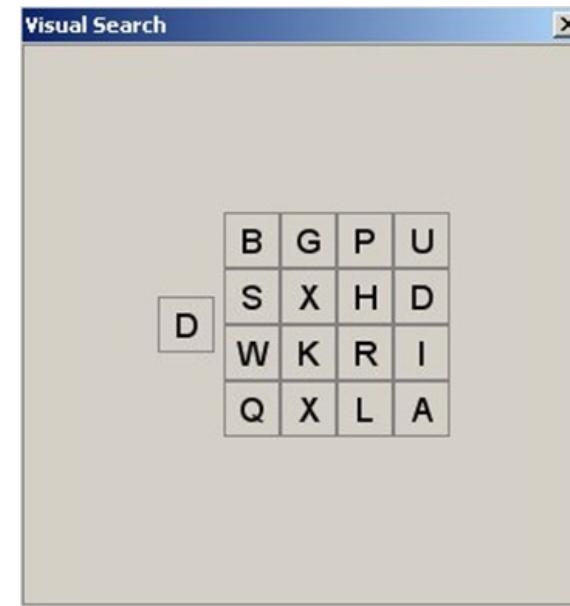
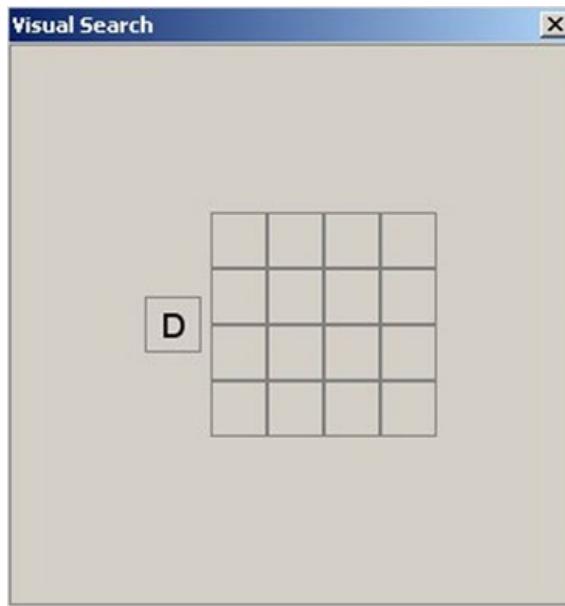


# Experiment Results

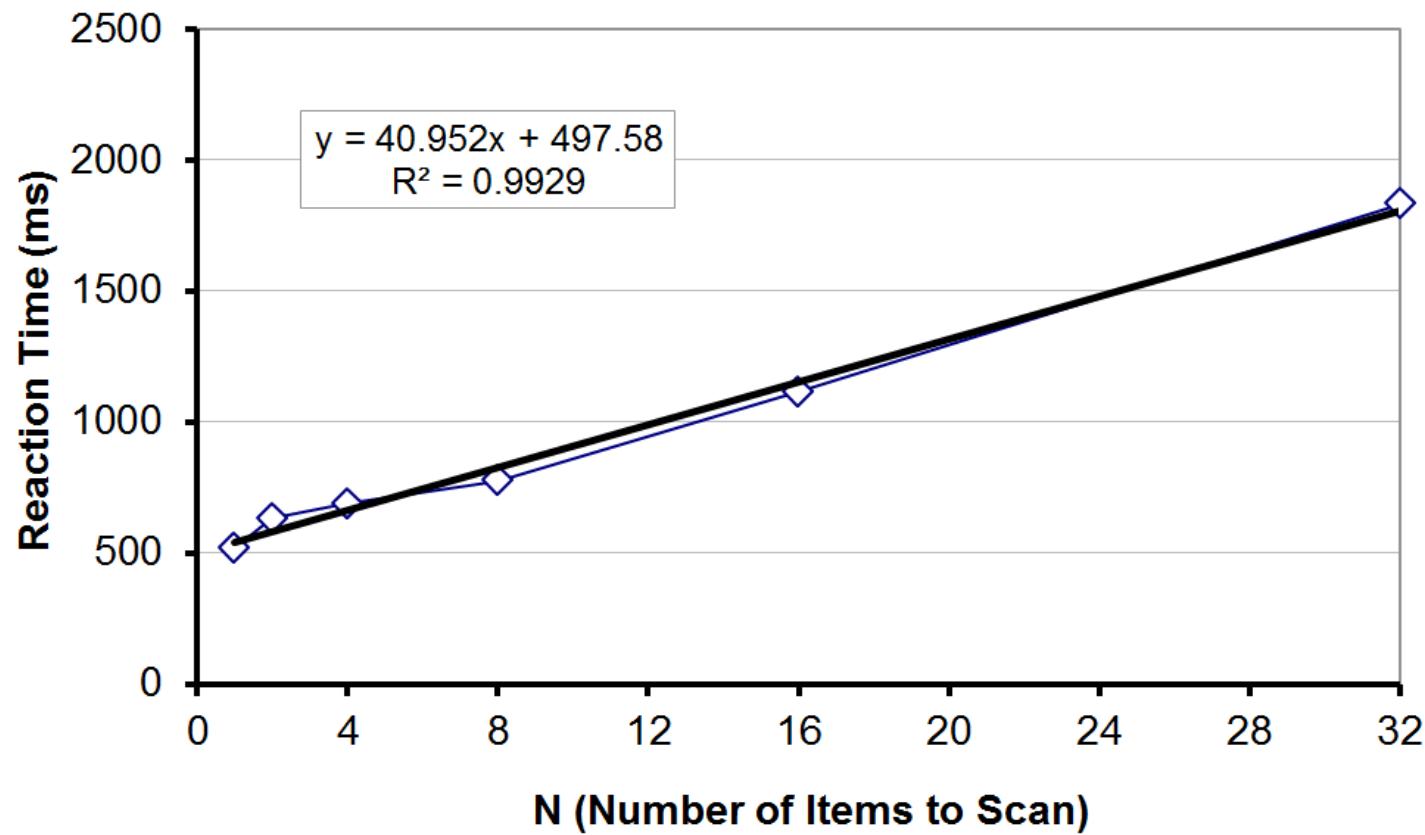


# Visual Search

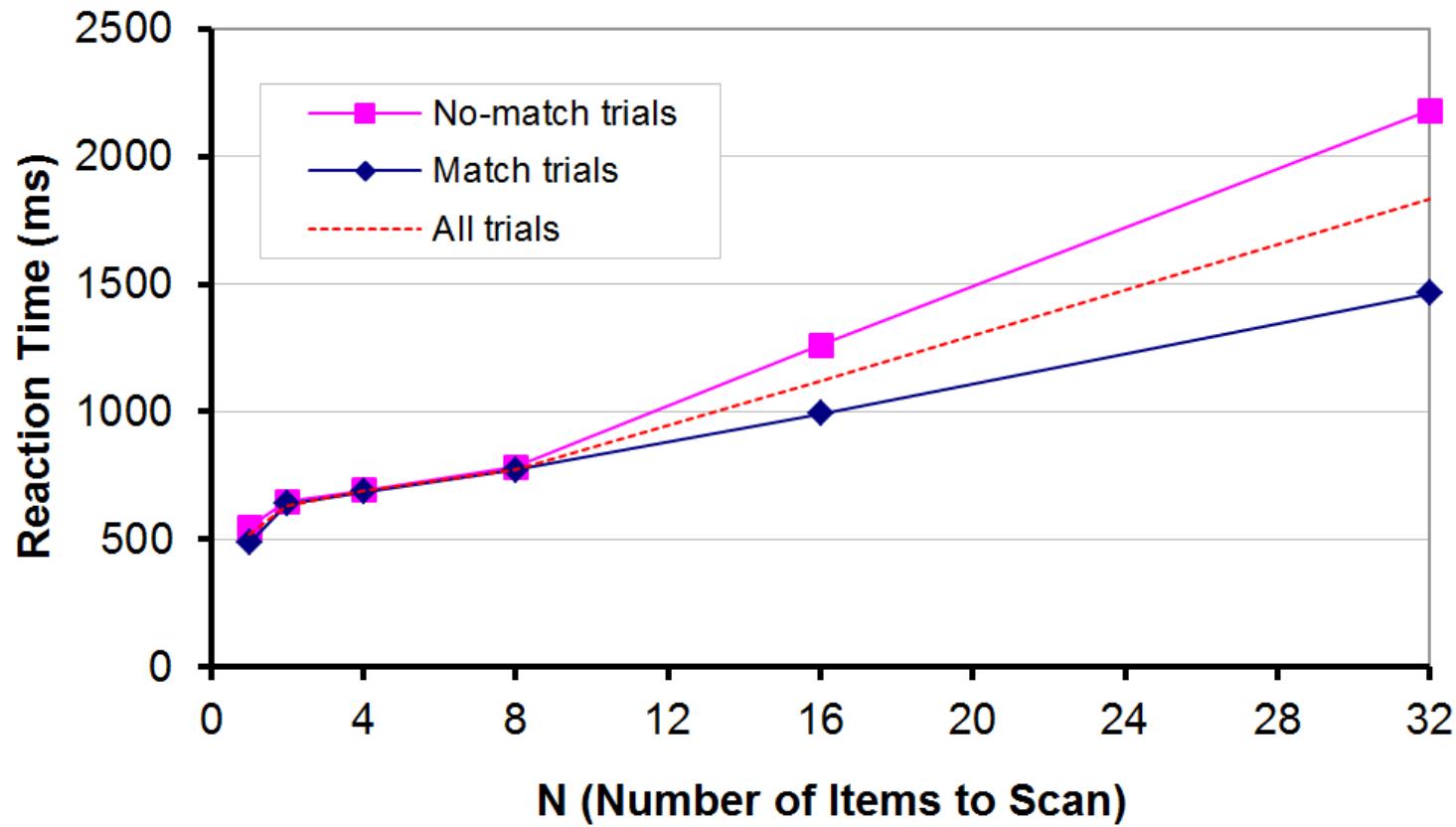
- A variation on simple reaction time
- User scans a collection of items looking for desired item
- Time increases with the number of items to scan
- Included in the demo software with  $N = 1, 2, 4, 8, 16$ , or  $32$  items



# Experiment Results (1)



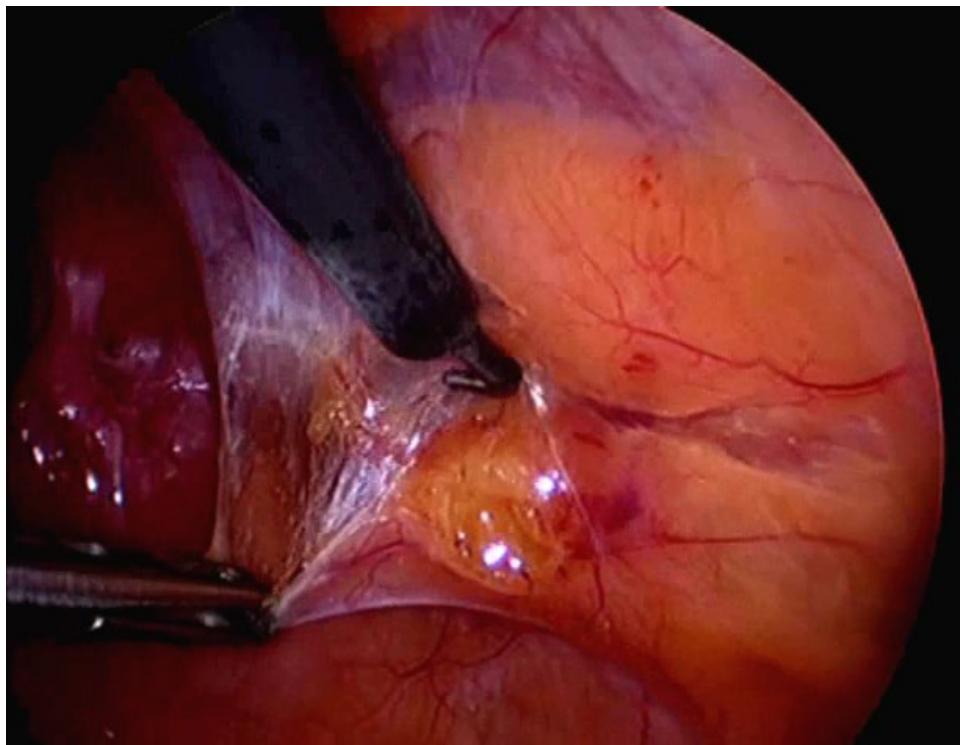
# Experiment Results (2)



# Skilled Behaviour

- For many tasks, human performance improves considerably and continuously with practice
- (Note: Very little improvement with practice in simple reaction time tasks)
- In these tasks, there is interest in studying the progression of learning and the performance achieved according to the amount of practice
- Categories of skilled behavior:
  1. Sensory-motor skill (e.g., darts, gaming)
  2. Mental skill (e.g., chess, programming)
    - Some tasks require a lot of both (next slide)

# Laparoscopic Surgery<sup>1</sup>



<sup>1</sup> Photos courtesy of The Centre of Excellence for Simulation Education and Innovation at Vancouver General Hospital.

# Attention

- *Texting while driving!*
- Attention is complex:
  - Divided attention, secondary tasks, distractions
  - Which tasks require attention?
    - Can't talk and type
  - Which tasks do not require attention?
    - Can talk and walk
  - What are the human limits? *What is attention?*
- Two categories of attention
  - Divided attention (attending to more than one task)
  - Selected attention (attending to one task to the exclusion of others)

# Selected Attention Example

- The Stroop Effect<sup>1</sup>
  - The user is asked to name the colour of a word stimulus
  - The words are colours, but are not necessarily set in the colour suggested by the word (e.g., **RED** vs. **GREEN**)
  - The response takes longer when there is a mismatch
  - The primary task (attend to the colour) is affected by the secondary task (ignore the meaning of the word)

*Stimulus 1: Purple Brown Red Blue Green*

*Stimulus 2: Brown Green Blue Green*

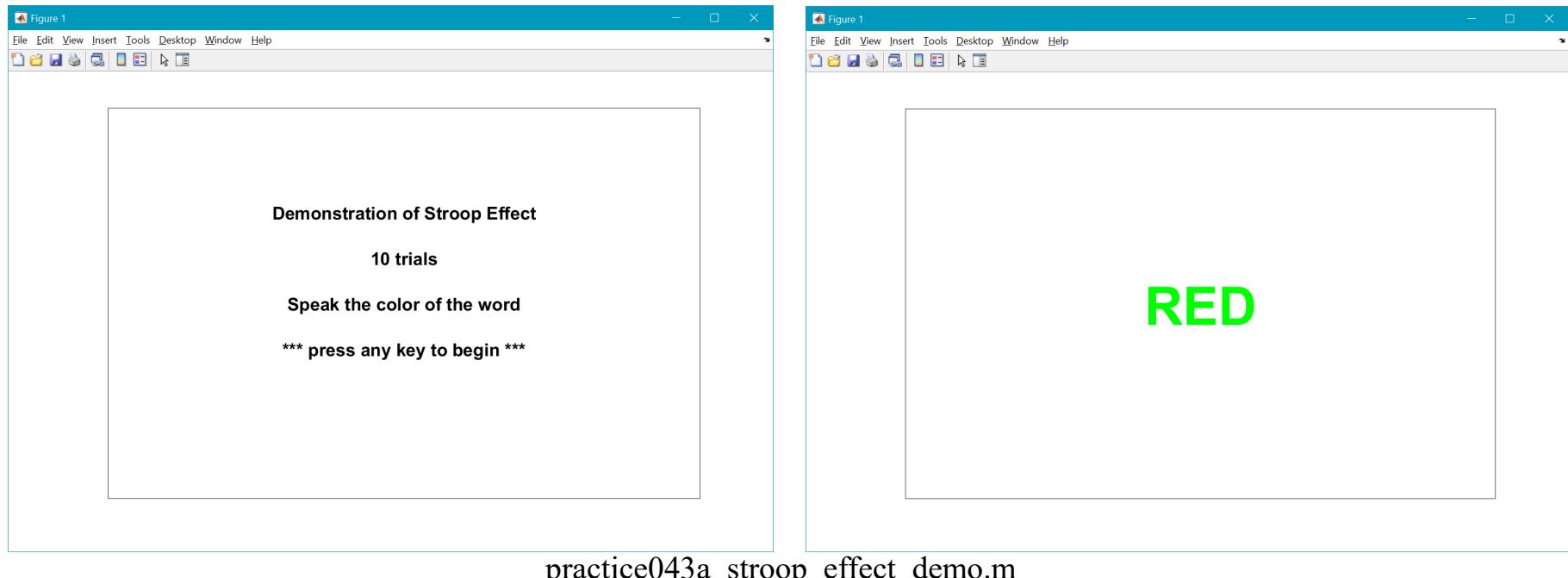
*Stimulus 3:* 

Examples of the three stimuli and colors used for each of the activities of the original Stroop article.

<sup>1</sup> [https://en.wikipedia.org/wiki/Stroop\\_effect](https://en.wikipedia.org/wiki/Stroop_effect)

# Example (1)

- Stroop Effect<sup>1</sup>



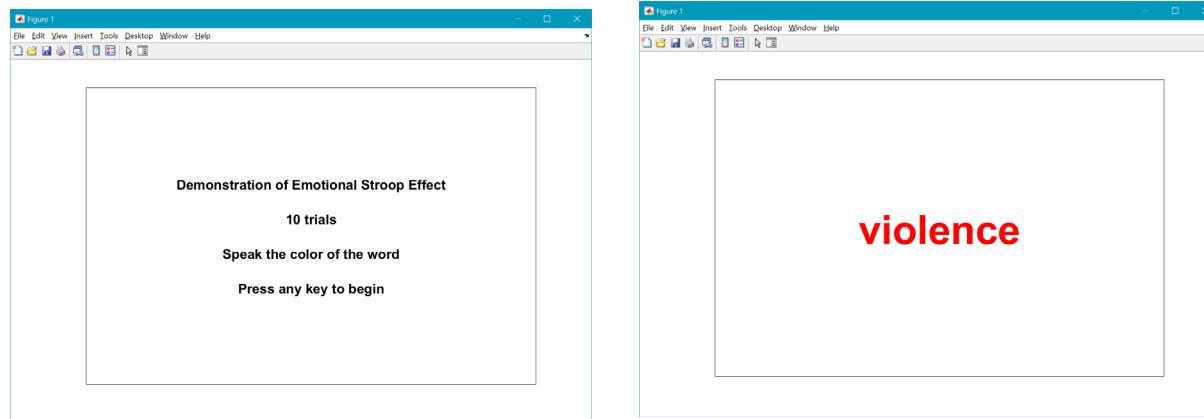
Note: Created in MATLAB



<sup>1</sup> [https://en.wikipedia.org/wiki/Emotional\\_Stroop\\_test](https://en.wikipedia.org/wiki/Emotional_Stroop_test)

# Example (2)

- Emotional Stroop Effect<sup>1</sup>
  - Same task: speak the colour of the word
  - Words are neutral (e.g., house, beaver) or emotional (e.g., disease, murder)
  - RT for emotional words is longer for depressed people



practice043b\_stroop\_effect\_demo.m

Note: Created in MATLAB

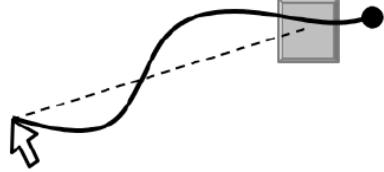
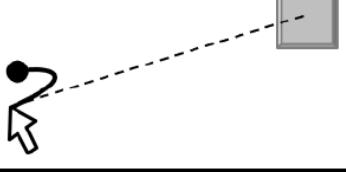


<sup>1</sup> [https://en.wikipedia.org/wiki/Emotional\\_Stroop\\_test](https://en.wikipedia.org/wiki/Emotional_Stroop_test)

# Human Error

- Human error can be studied from many levels
- Simple view: An error is a discrete event where the outcome deviated from the desired outcome
- But, tasks in error are often at least partly correct (next slide)

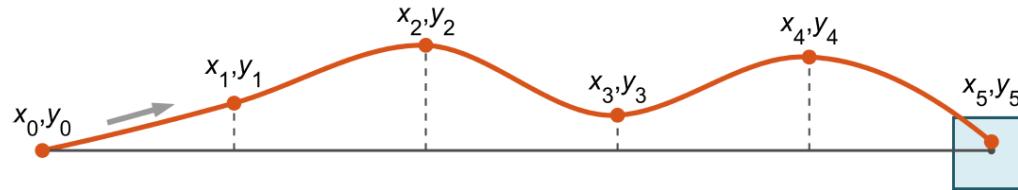
# Variability and Error

Outcome	Task	
	Target Selection	Text Entry
Correct		<b>quickly</b>
Corrected		<b>quiczkly</b>
Incorrect		<b>qucehkly</b>
Outlier		<b>xq</b>

What went wrong and why?

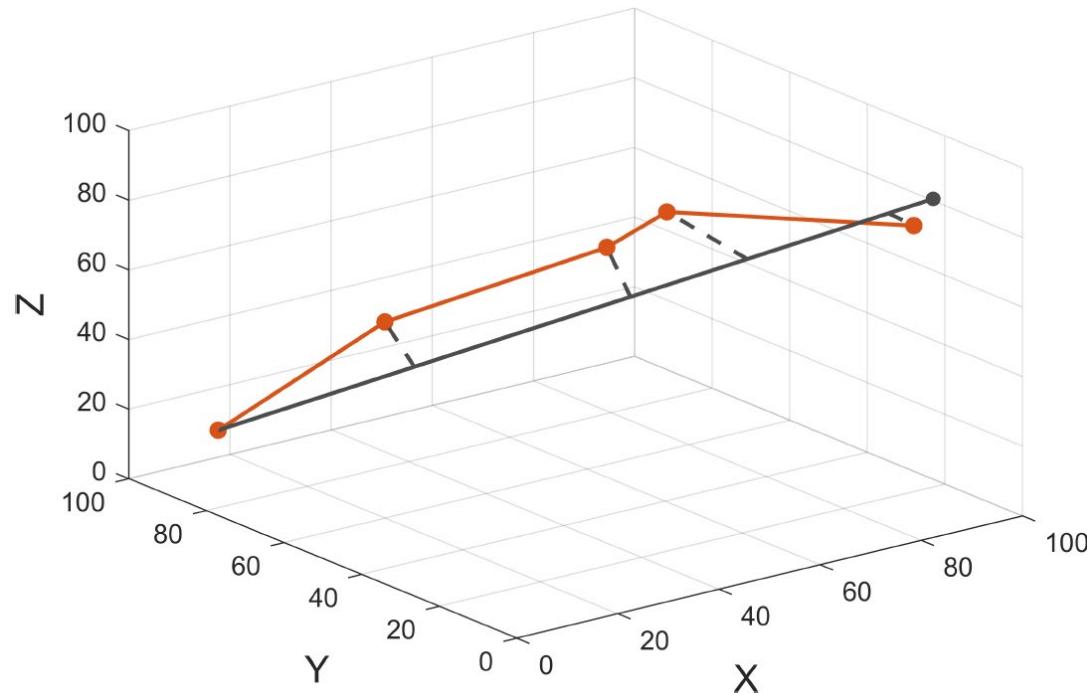
# Pointer Movement Variability

- 2D



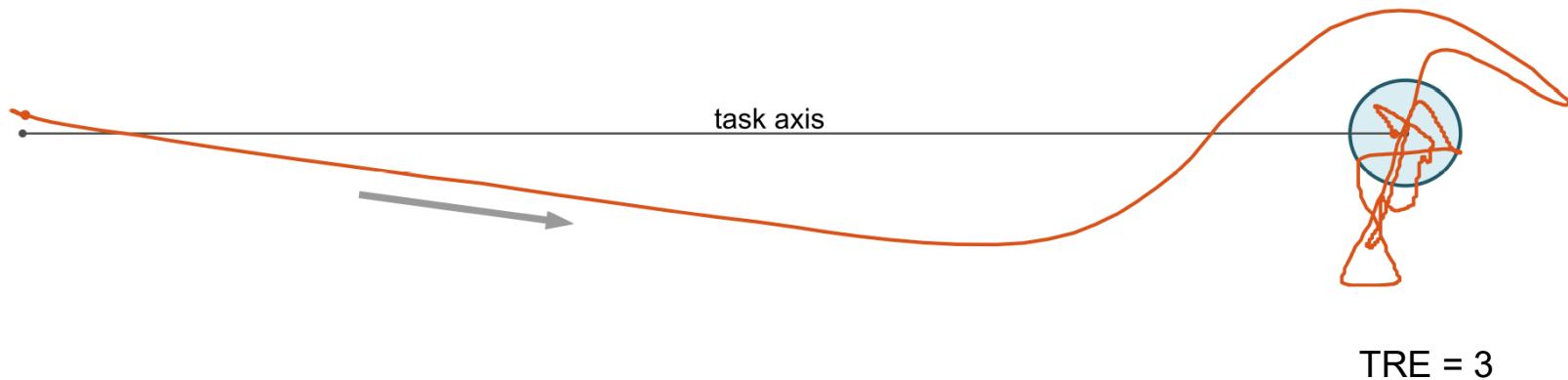
$$MV = \sqrt{\frac{\sum (y_i - \bar{y})^2}{n - 1}}$$

- 3D



# Other Performance Measures

- TRE (target re-entries)<sup>1</sup>



- See **HCI:ERP2e** for additional measures for pointer path accuracy

<sup>1</sup> I.S. MacKenzie, T. Kauppinen, M. Silfverberg, Accuracy measures for evaluating computer pointing devices, in: Proc CHI '01, ACM, New York, 2001, pp. 9–16.

# Text Entry Metrics

- Keystrokes per character (KSPC)

$$\text{KSPC} = \frac{\text{len}(quicz < kly)}{\text{len}(quickly)} = \frac{9}{7} = 1.286$$

- MSD Error rate

Types of errors:

- Substitution
- Deletion
- Insertion

q	u	c	e	h	k	l	y
0	1	2	3	4	5	6	7
q	1	0	1	2	3	4	5
u	2	1	0	1	2	3	4
i	3	2	1	1	2	3	4
c	4	3	2	1	2	3	4
k	5	4	3	2	2	3	3
l	6	5	4	3	3	3	4
y	7	6	5	4	4	4	4

Minimum String Distance

3 ← MSD

Alignments

quic--kly  
qu-cehkly

quic-kly  
qucehckly

qui-cckly  
quceehkly

qu-ickly  
quceehkly

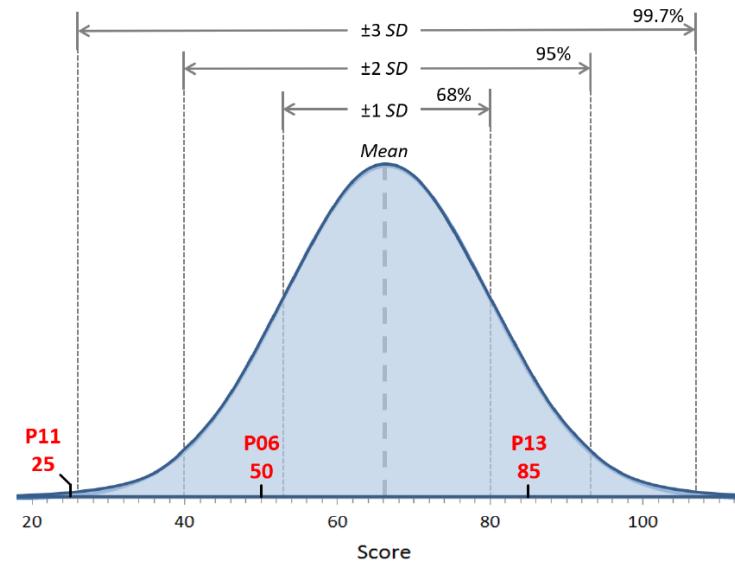
$$\text{ER} = \frac{\text{MSD}(A, B)}{\max(\text{len}(A), \text{len}(B))} = \frac{3}{8} = 0.125 = 12.5\%$$

# Outliers

- Wildly deviate scores may be classified as outliers and possibly removed from analyses
- May apply to individual trials, blocks of trials, or participants
- Must have a criterion (quantitative) and a rationale (qualitative)

# Outlier Example

Participant	Score
P01	71
P02	70
P03	69
P04	67
P05	70
P06	50
P07	71
P08	69
P09	71
P10	67
P11	25
P12	67
P13	85
P14	75
P15	69
Mean	66.4
SD	13.4

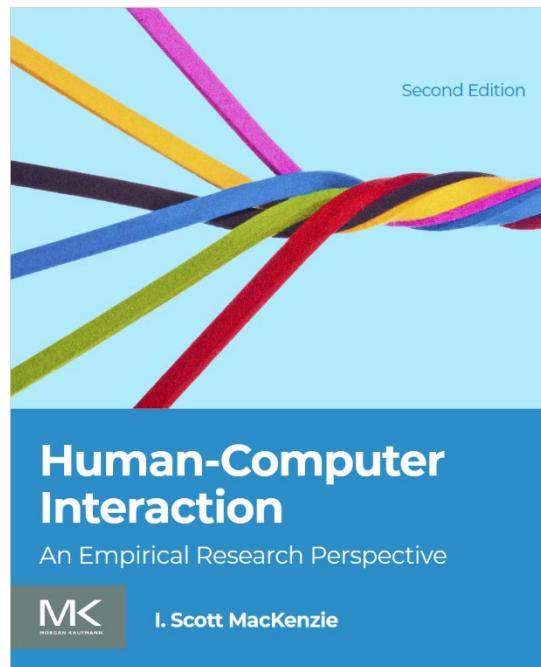


- Perhaps remove data for P11 (outlier)
  - Criterion: score  $> \pm 3\text{ }SD$  from mean
  - Rationale: participant distracted, participant didn't understand, etc.

# Accidents

- A broader perspective is often necessary
- 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 (e.g., an operator pressing the wrong button or entering a wrong value) are not only possible, they are, in time, likely, and must be anticipated in the design

# Thank You



<https://www.yorku.ca/mack/HCIbook2e/>