

Designing Interactive Systems I

Introduction, The CMN Model, Fitts' Law

Prof. Dr. Jan Borchers
Media Computing Group
RWTH Aachen University

Winter Semester '23/'24

<https://hci.rwth-aachen.de/dis>



RWTHAACHEN
UNIVERSITY

Who am I?



Studied CS at Karlsruhe (& Imperial)

- Human-Computer Interaction

PhD CS, TU Darmstadt (& Linz, Ulm)

- Interaction with multimedia
- HCI design patterns

Assistant professor at Stanford & ETH Zurich

- Interactive rooms
- UbiComp user interfaces

Full professor at RWTH since Oct. 2003

- Augmented Reality, Wearable & Textile UIs
- Personal Fabrication, IDEs, Soft Robotics

Our Team

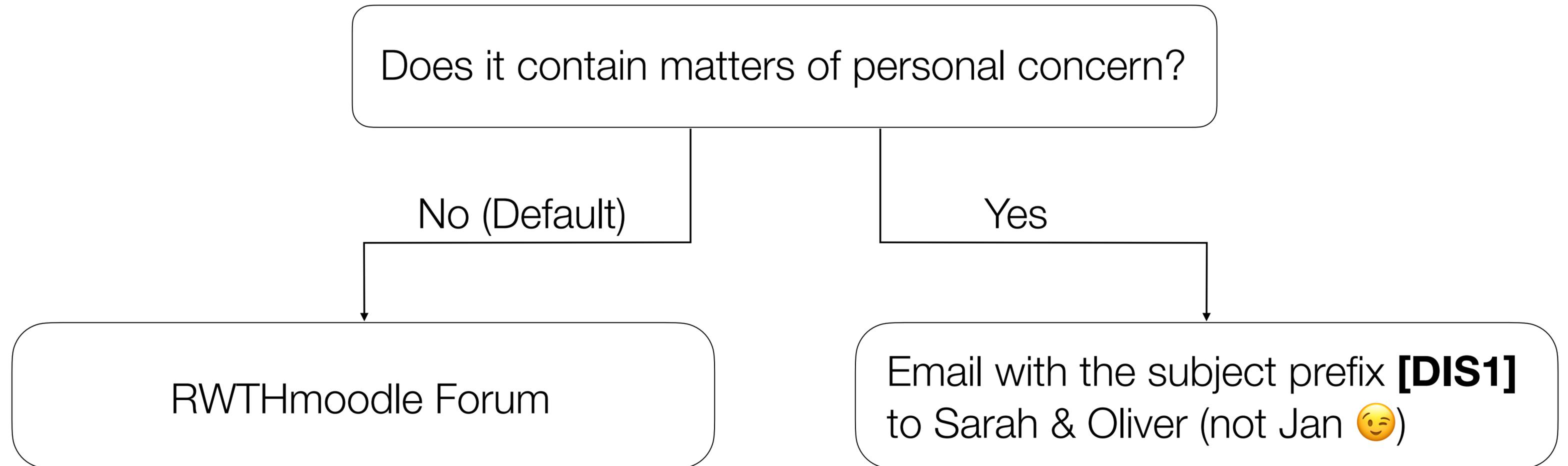


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The Question Flow Chart :)



Alternatively: A quick chat after the lecture ☕

Human–Computer Interaction?







Usability Sells!



350,000

DVD Player (1996)



1,000,000

iPhone (1st Q'07)



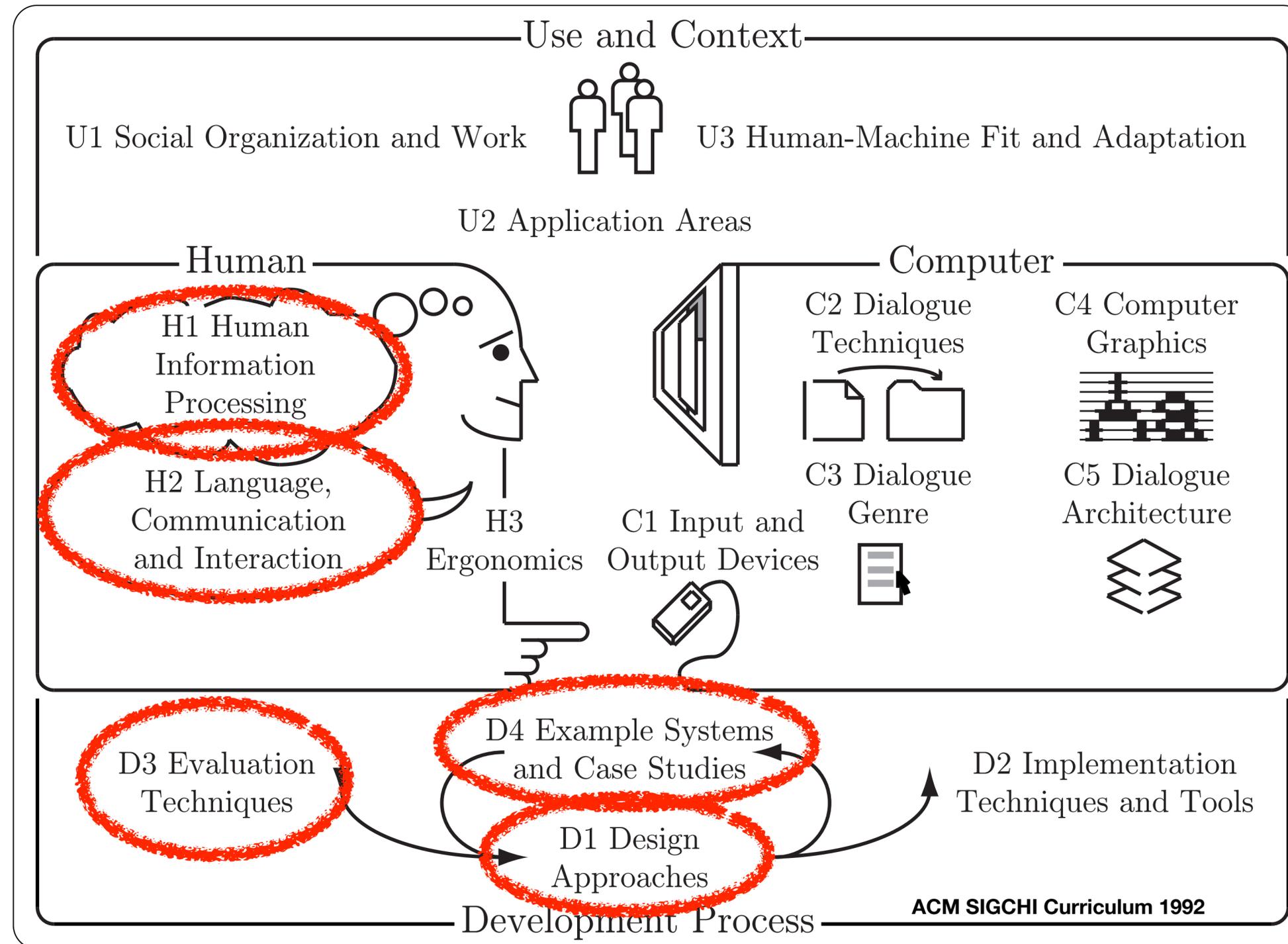
3,000,000

iPad (1st 80d '10)

Source: CNBC



What is HCI?



Class Topics

Human

- Performance
- Models of interaction
 - Affordances
 - Mappings
 - Constraints
 - Types of knowledge
 - Errors
- Design principles

Case Studies

- History of HCI
- Visions
- Phases of Technology

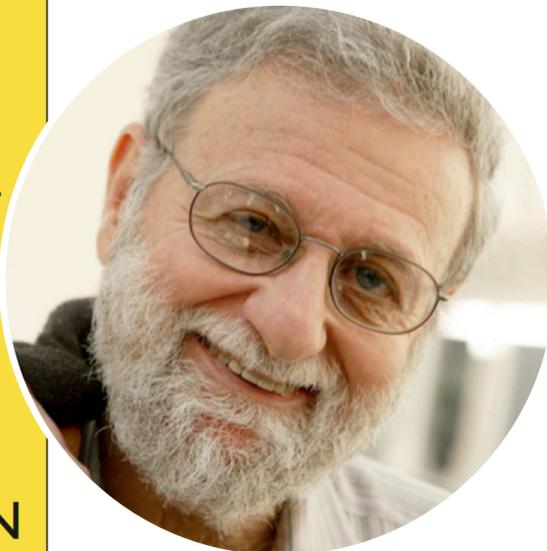
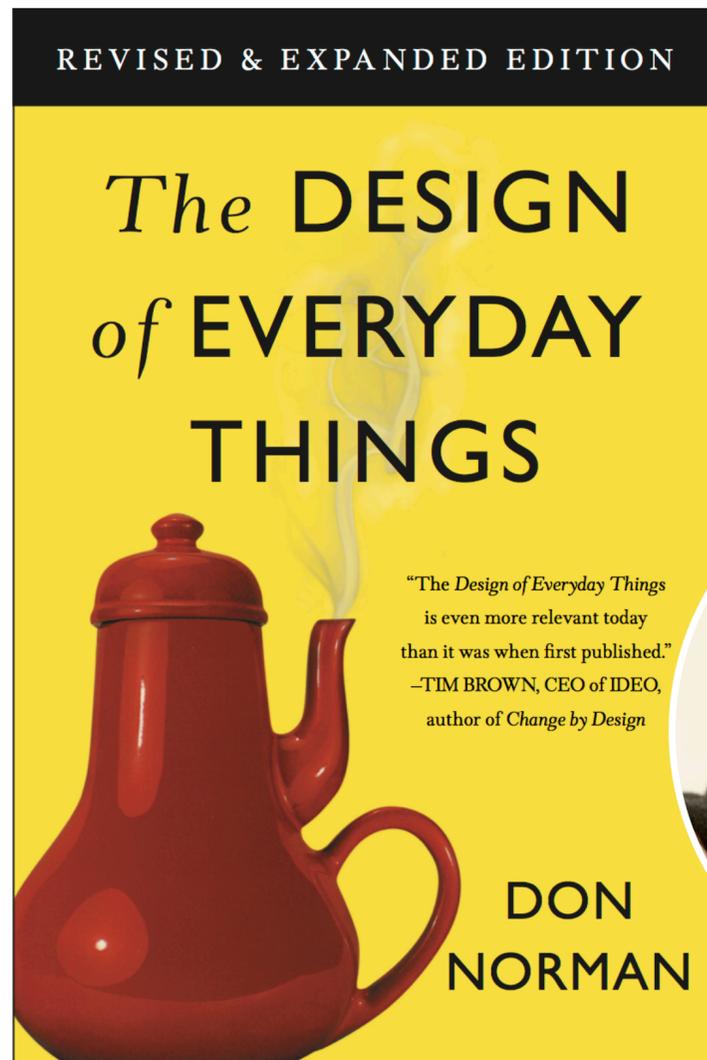
Development Process

- Iterative design
- User observation
- Ideation
- Prototyping
- User studies and evaluation
- Interaction design notation

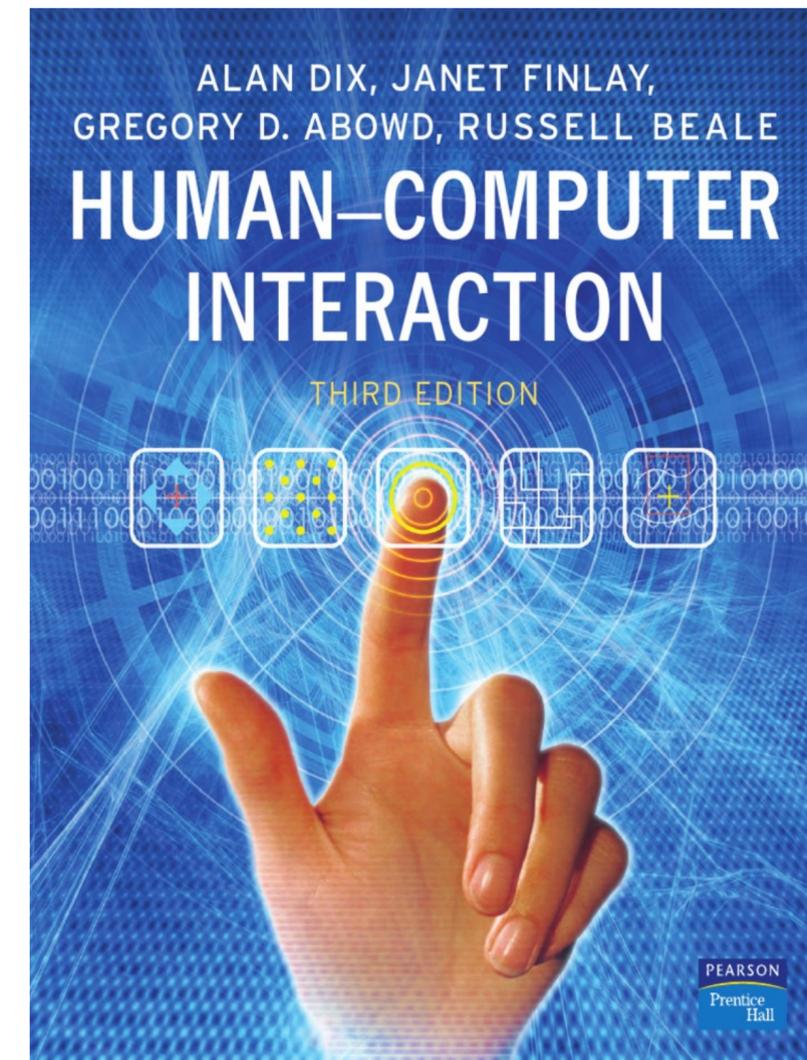
For more details, see hci.rwth-aachen.de/dis.

Textbooks

Required Reading



Recommended Reading



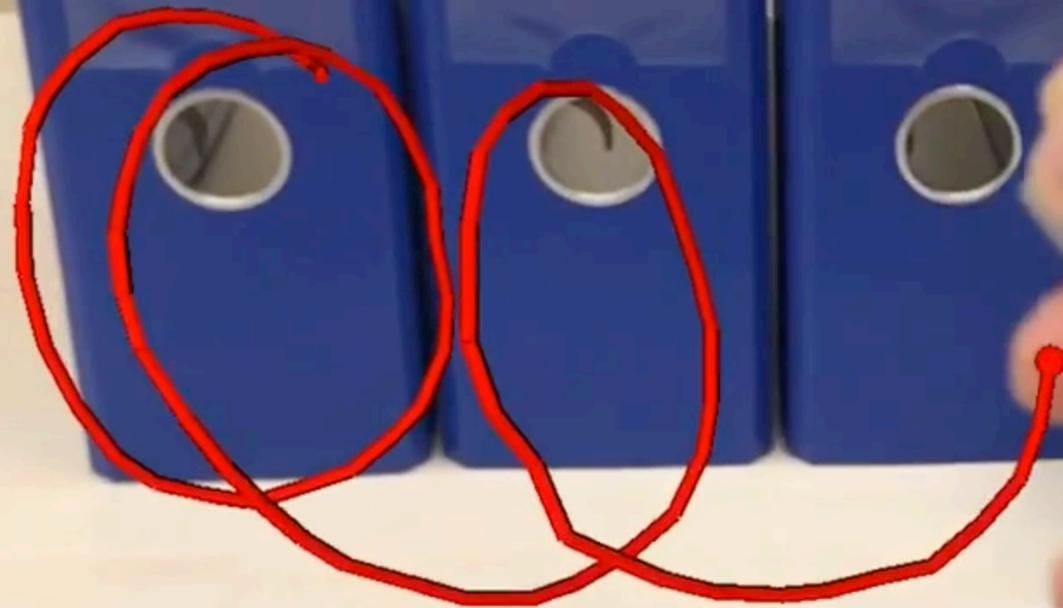
Media Computing Group



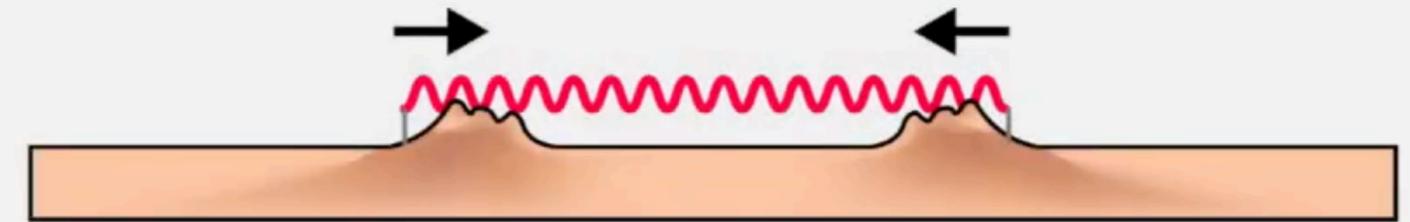
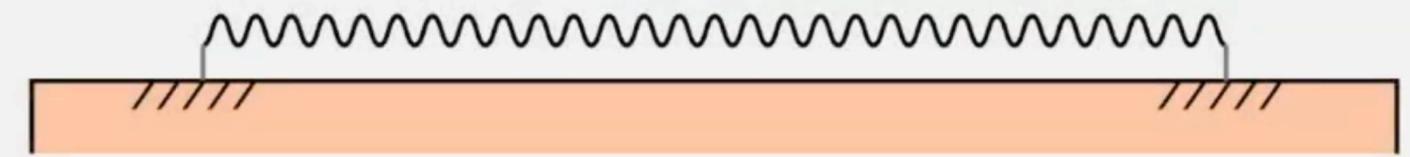
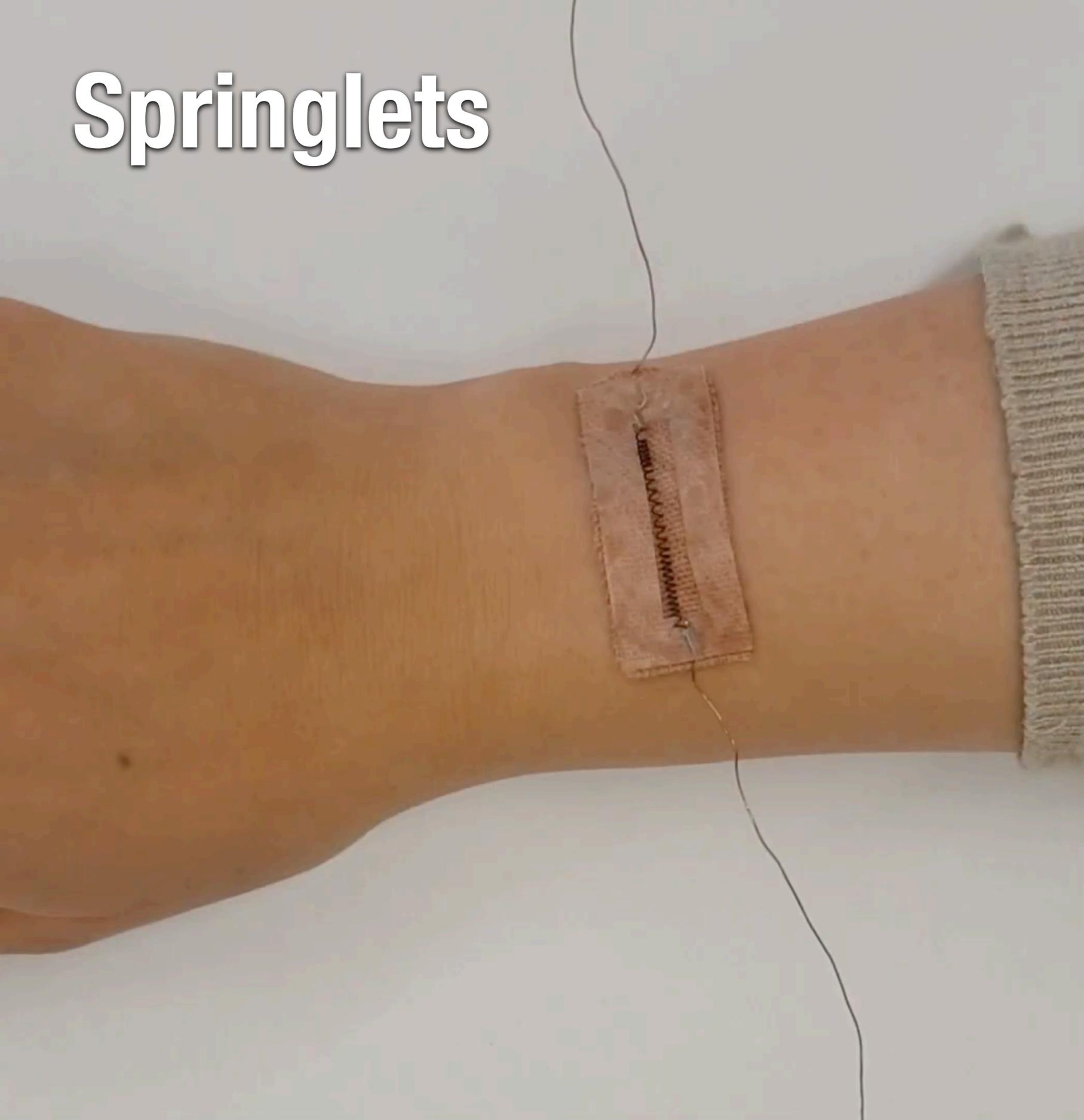
Our Classes

When?	Type	Credits (ECTS)	Name
WS	P	7	The Media Computing Project
WS, SS	S	4	Post-Desktop User Interfaces
SS	v/Ü	6	Current Topics in HCI
WS	v/Ü	6	iOS Application Development
SS	v/Ü	6	Designing Interactive Systems II
WS	v/Ü	6	Designing Interactive Systems I
Only for B.Sc. students			
SS	PS	4	Human-Computer Interaction
SS	SW-Pr	7	M3: Multimodal Media Madness

ARPen



Springlets



15mm X 40mm



5mm X 30mm

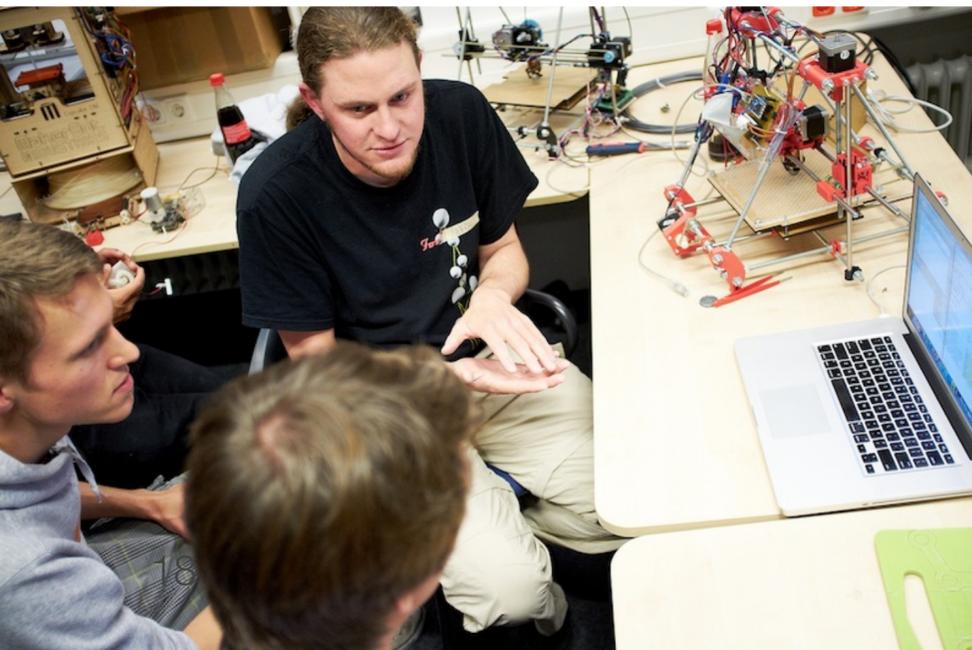


Student project from M3 B.Sc. lab, SS'19



Aachen Maker Meetup

- People doing strange things with electricity in Aachen
- 3rd Wednesday of every month
Next event: **Oct. 18, 2023, at 18:30**
- Sign up here: **hci.rwth-aachen.de/amm**



CocoaHeads Aachen



- CocoaHeads: International meet-ups about Apple's Cocoa Framework for macOS and iOS
- Last Thursday of every month
- Sign up here: hci.rwth-aachen.de/cocoaheads



Course Structure



Course Structure

Lecture

Interactive classes with Prof. Borchers

Lab

- Discuss assignments

Oct 17th – Dec 5th

Midterm

UX Project (graded)

- Create your own UX project in a group of six
- Finally, showcase your project in a video

Dec 12th – Jan 30st

Final Exam

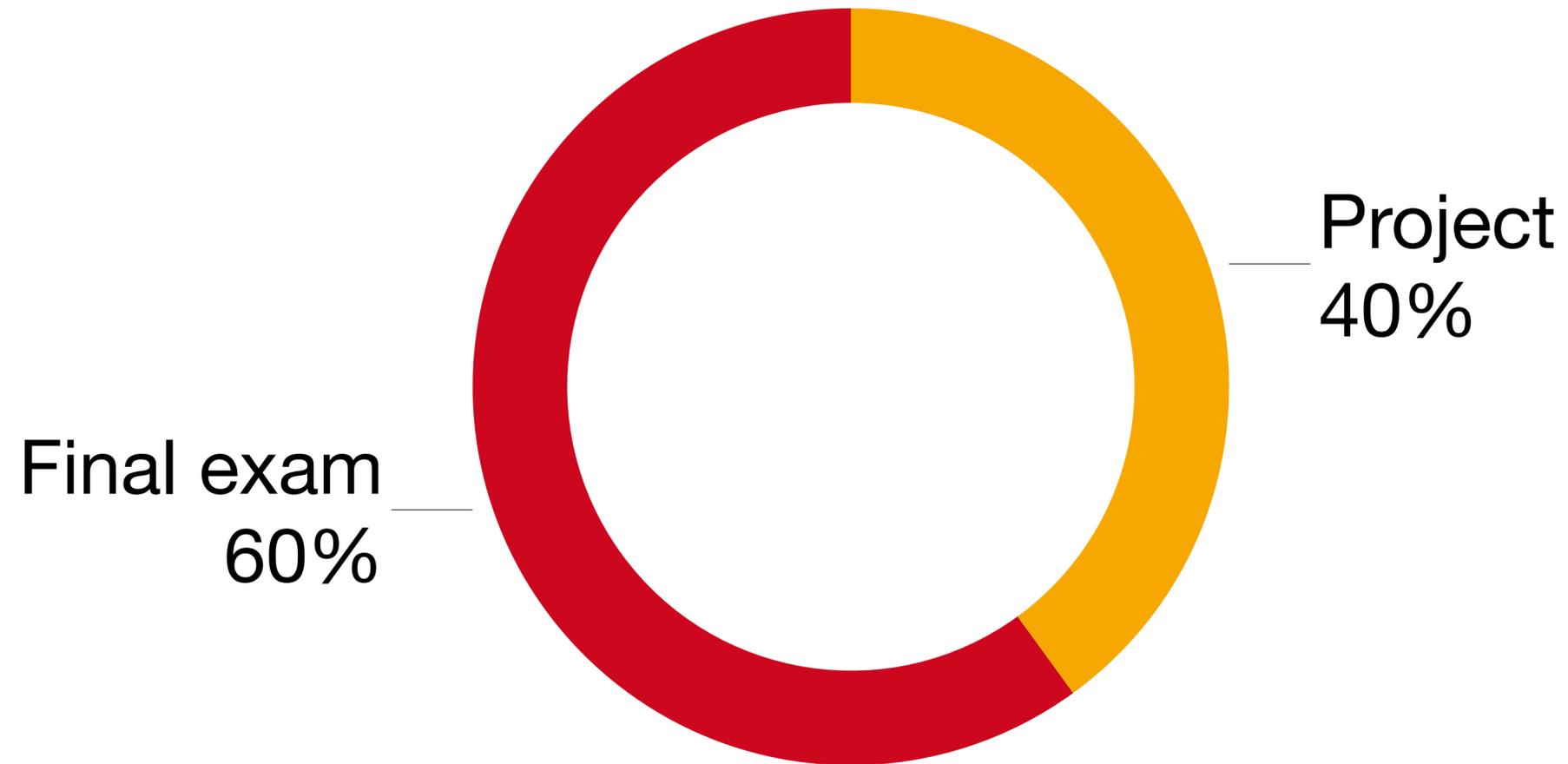
Feb
14th

Final Exam

Mar
12th



Final Grade Distribution



! To pass the course, you must pass both project and final exam.

Registering for this Class

- Limited to **120 seats**
 - Register via RWTHonline and upload the Declaration of Compliance until **tomorrow, Oct 12, at 23:59**
- Erasmus students, and others who cannot register via RWTHonline:
Email Sarah & Oliver your matriculation number and full name from your official *@rwth-aachen.de* email-address
- **Email subject: [DIS1] Registration <your name>**

The Human



Model Human Processor: The CMN Model

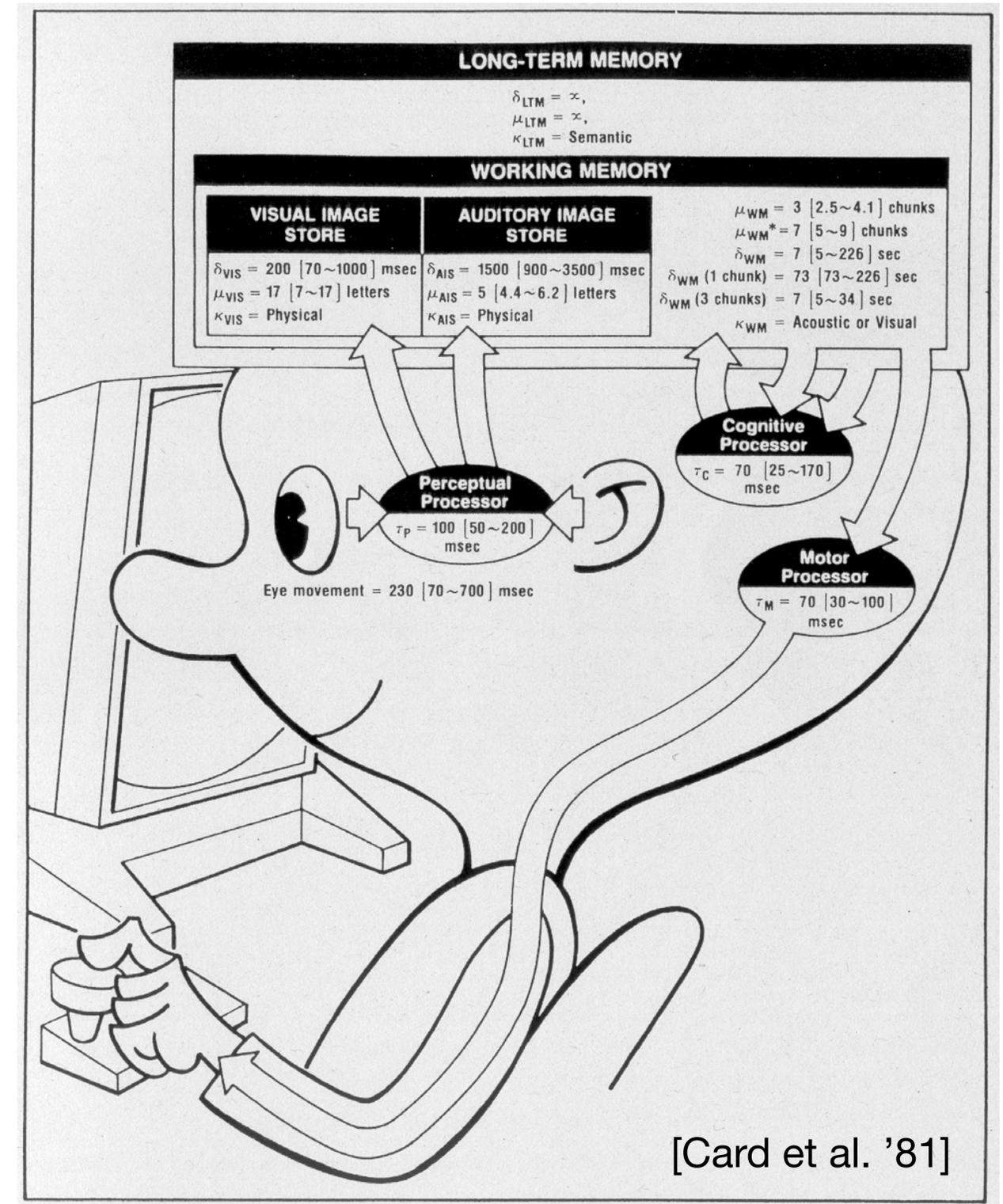
The
Psychology
of
Human-Computer
Interaction

STUART K. CARD
THOMAS P. MORAN
ALLEN NEWELL

 CRC Press
Taylor & Francis Group

Model Human Processor

- 3 processors with associated memory
- Slow, middle, fast performers

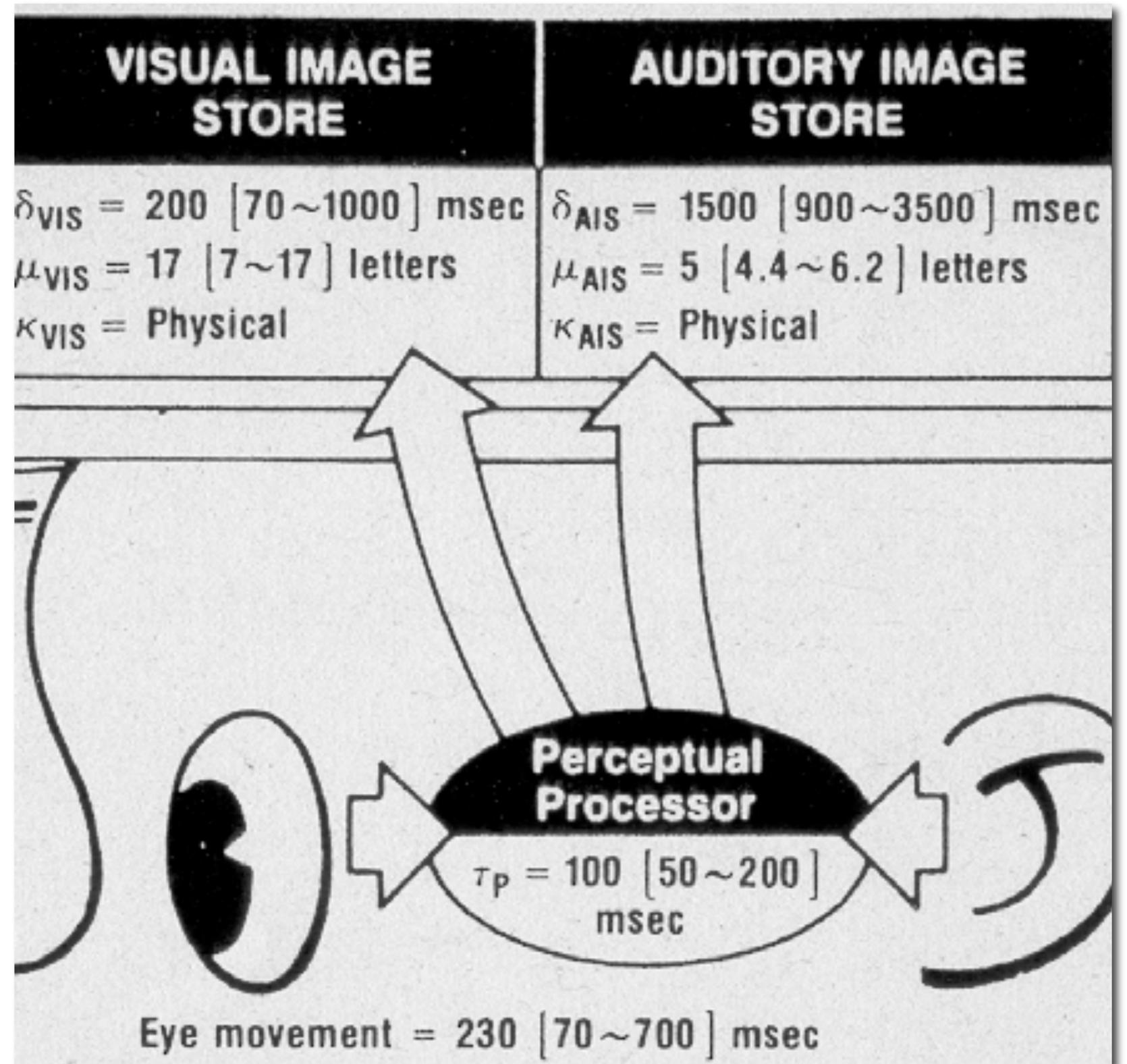


In-Class Experiment 1: Perceptual Processor

- Work in pairs of two
- Read out the text from *Experiment 1* to your group partner
- The other partner observes the eye movement of the reading person
- Then switch
- What did you observe?

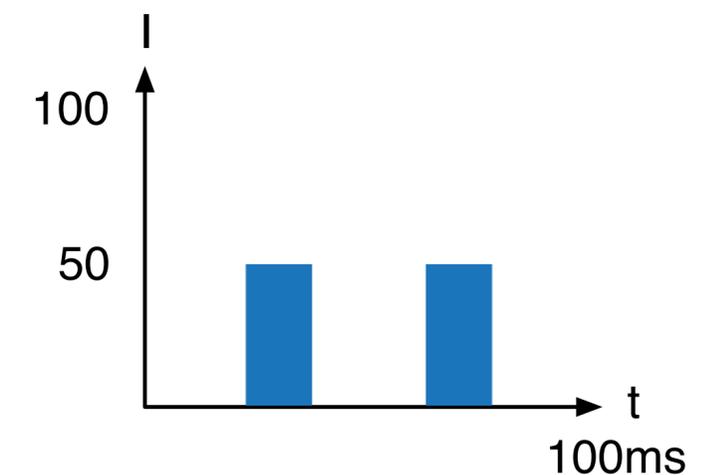
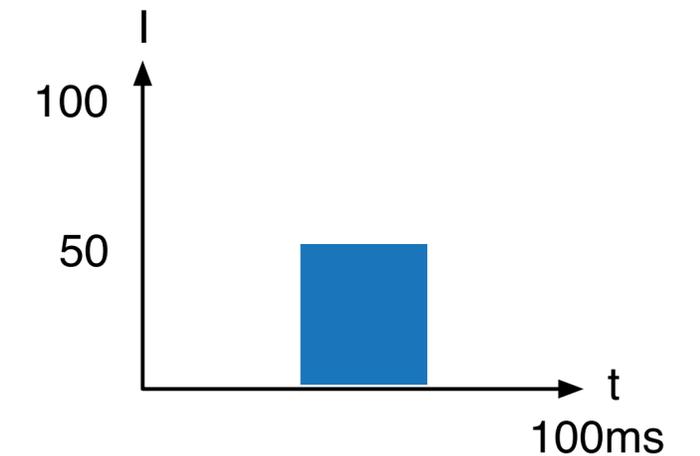
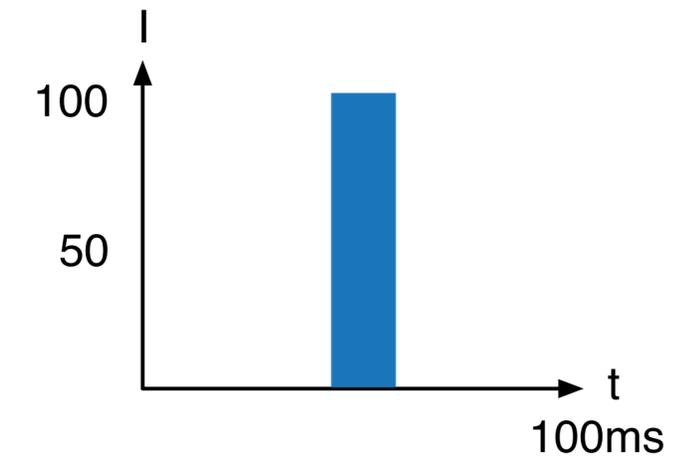
Perception

- Eye saccades: 230 ms
- Explains reading rates
 - Maximum: 13 characters/saccade
⇒ 652 words/minute

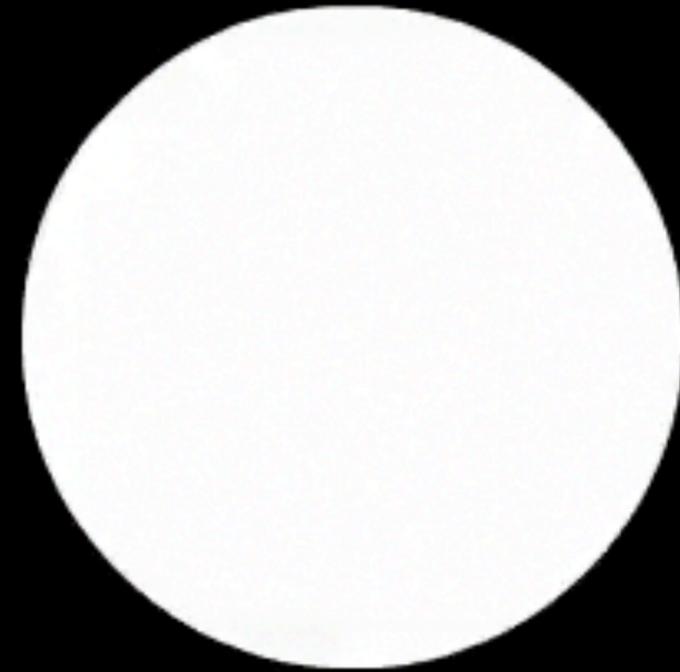


Perceptual Processor

- Stores sensor signals in visual & auditory stores
- Perception time: $\tau_P \approx 100$ ms
 - Explains Bloch's Law
 - $R = I \times t$
 - R is response
 - I is intensity
 - t is exposure time
 - Constant response for $t < 100$ ms

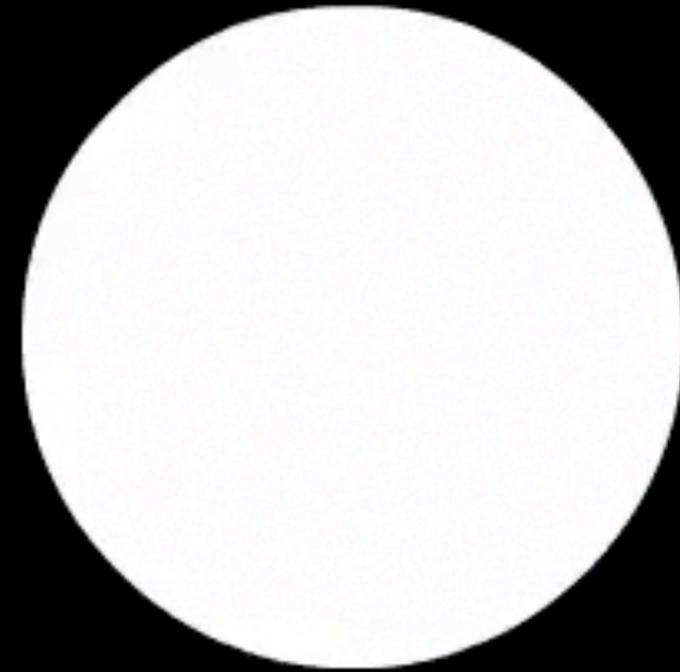


In-Class Experiment: Bloch's Law



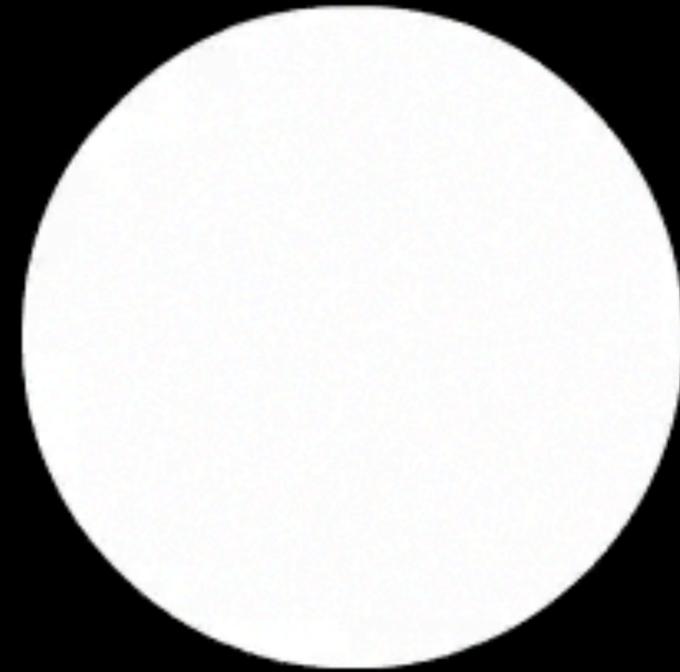
A

In-Class Experiment: Bloch's Law

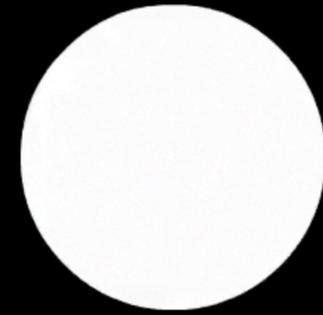


B

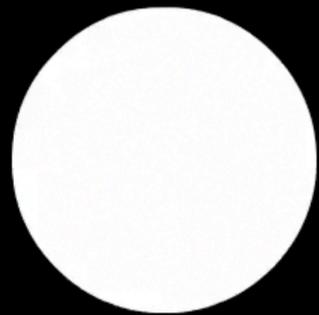
In-Class Experiment: Bloch's Law



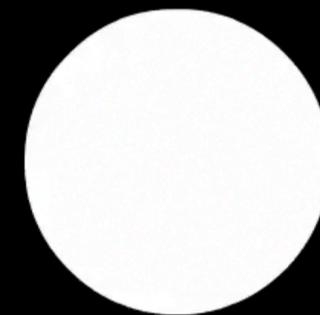
C



A: 0 ms delay



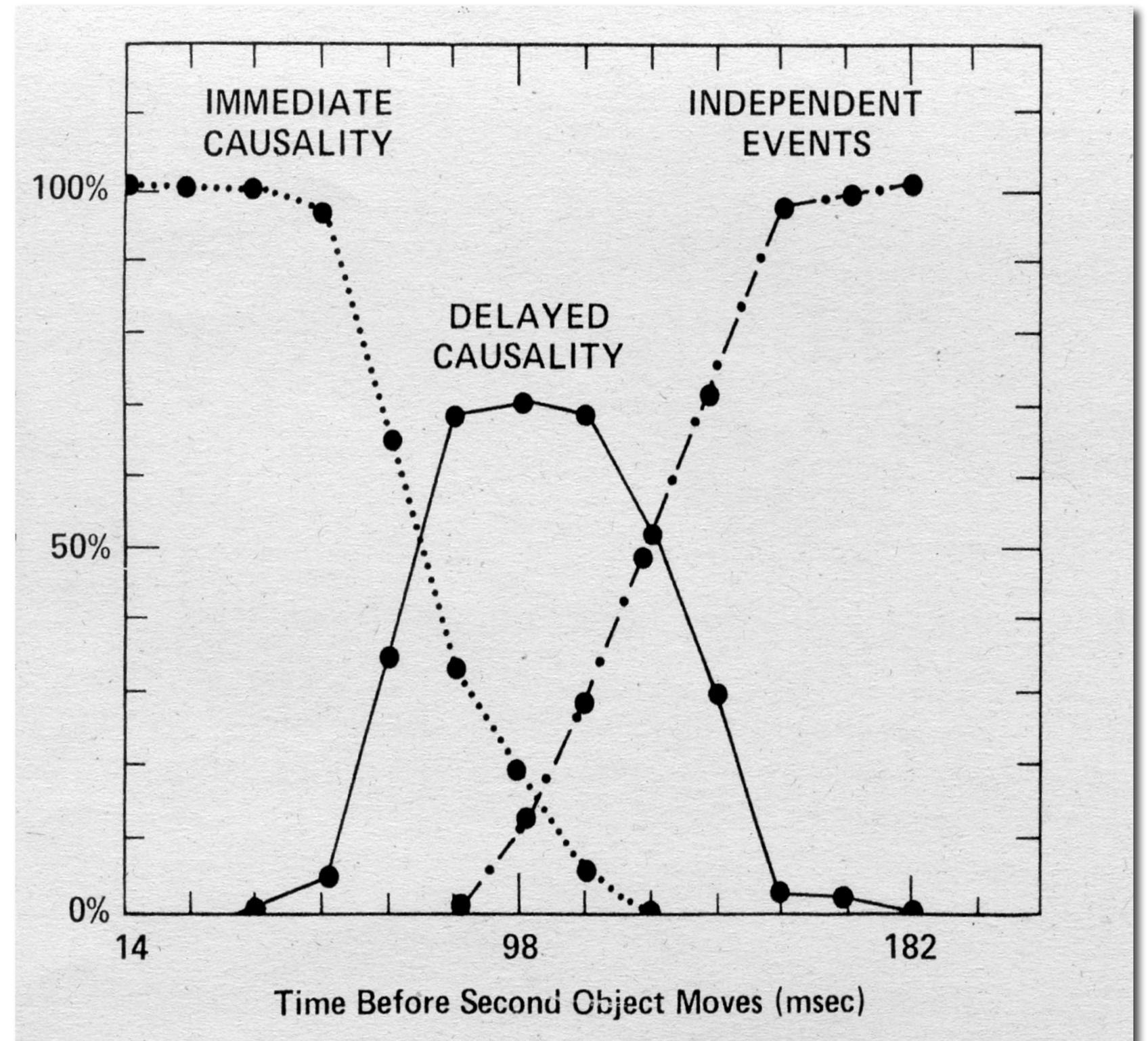
B: 50 ms delay

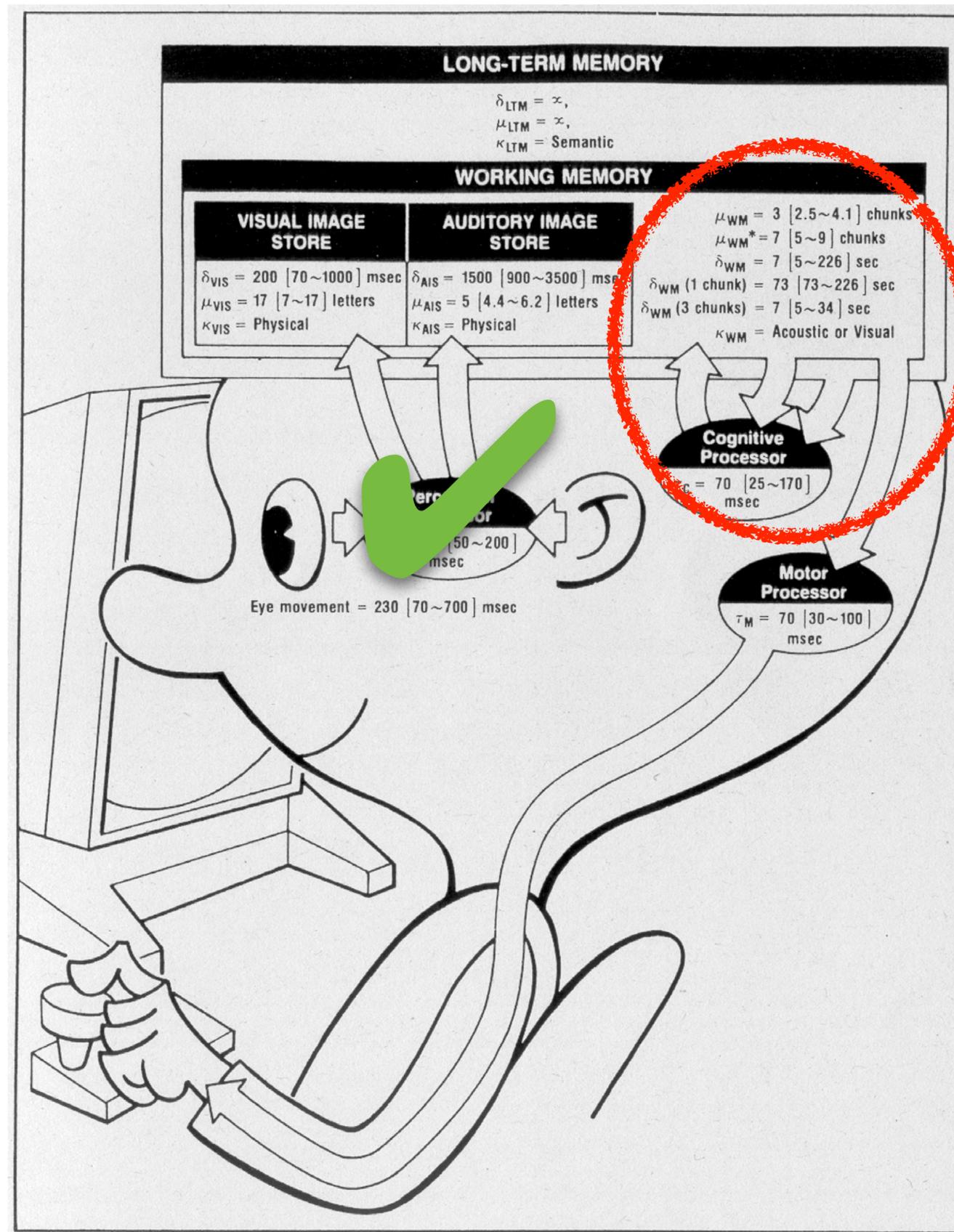


C: 100 ms delay

Perceptual Processor

- Perception time: $\tau_P \approx 100$ ms
 - Explains animation rates (10 fps for “MiddleMan”)
 - Explains max. delay before causality breaks down
 - Shortens with intensity





In-Class Experiment 2: Cognitive System

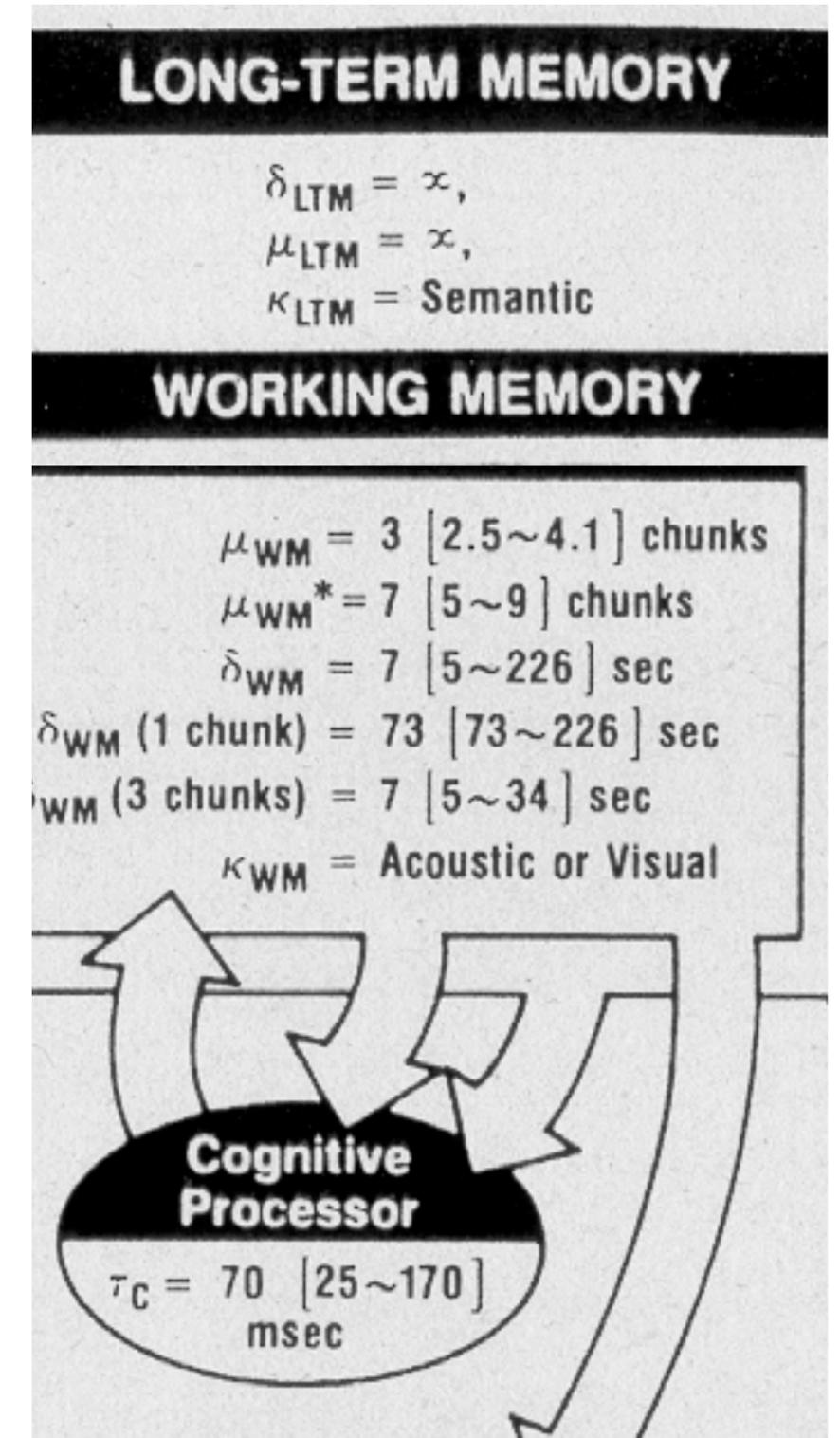


- As a group of two
 - One of you (P1) reads out a random sequence of 5 digits from your sheet to the other (P2)
 - Then P2 counts backwards aloud from 50
 - Then P1 asks P2 another question (like what they had for dinner three days ago?)
 - Then P2 writes down the numbers that they still remember.
- Switch roles, repeat with 9 digits.
- Finally, switching roles again, read the long sequence of numbers to your partner, stopping somewhere suddenly. See how many of the last numbers they can repeat immediately.



Cognitive System

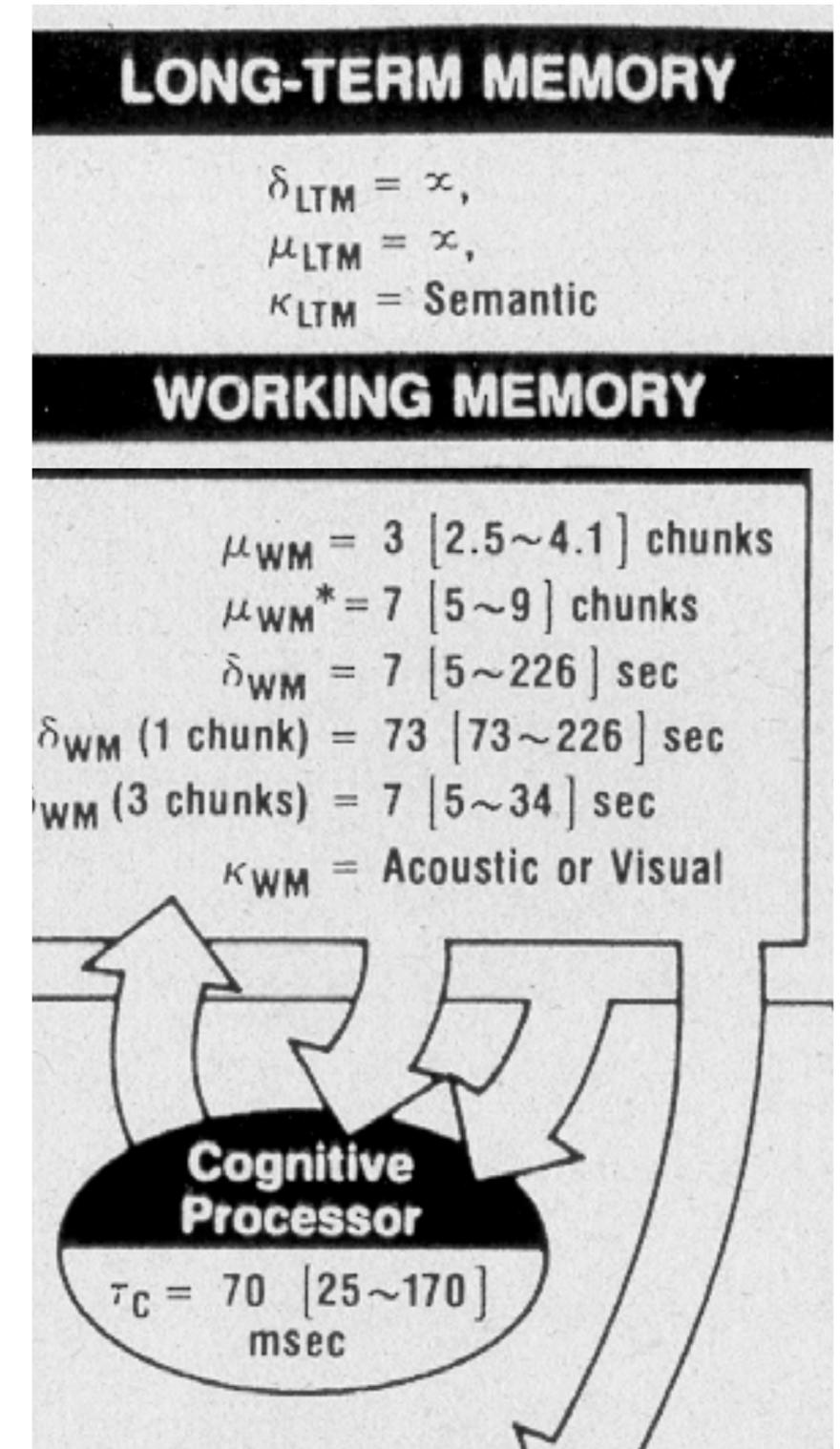
- Chunks depend on user & task
- Working memory:
 - Capacity: $\mu_{WM} = 7 \pm 2$ chunks (Miller '56)
 - Half life: $\delta_{1,WM} = 73$ s (1 chunk)
 $\delta_{3,WM} = 7$ s (3 chunk)
 - Visual/acoustic encoding
- In 2001, Nelson Cowen showed that μ_{WM} is actually 4 ± 1 chunks.



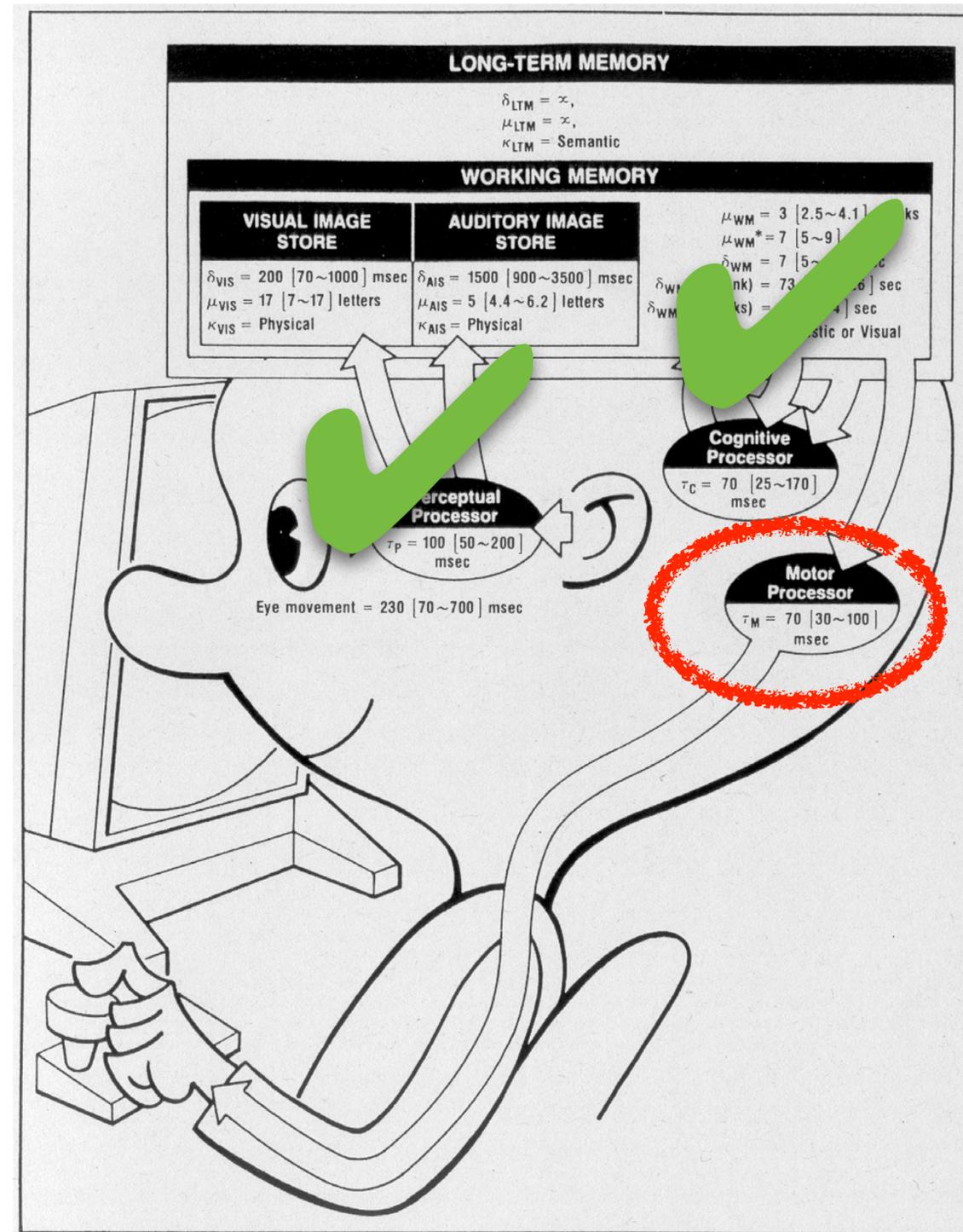
Cognitive System

- Cognitive processor:
 - Processing time $\tau_C = 70$ ms
- Long-term memory:
 - Infinite capacity and half life
 - Semantic encoding (associations)
 - Fast read, slow write

⇒ Remembering items maxes out at 7 s/chunk learning speed (1 pass)



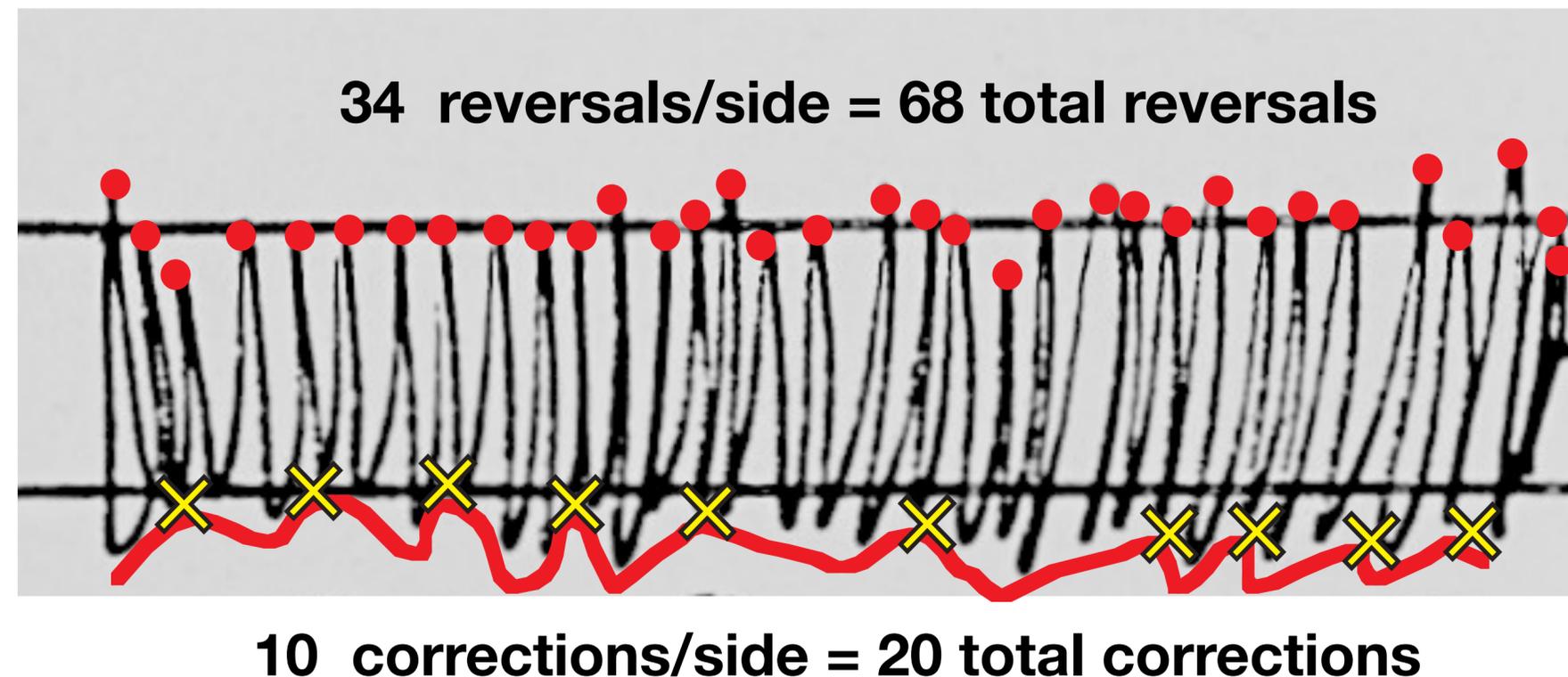
Model Human Processor



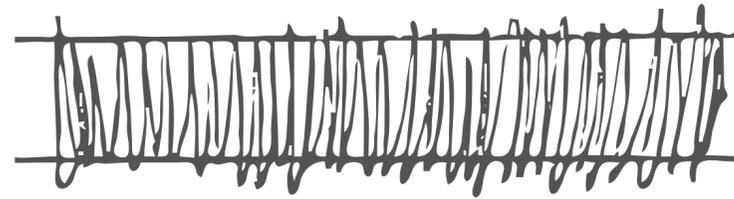
In-Class Experiment 3: Motor System



- Experiment: draw strokes between lines for 5s. Try to reach both lines.
- Count number of reversals
 - How many milliseconds per reversal?
- Create a contour of stroke bottoms, count number of corrections
 - How many milliseconds per correction?

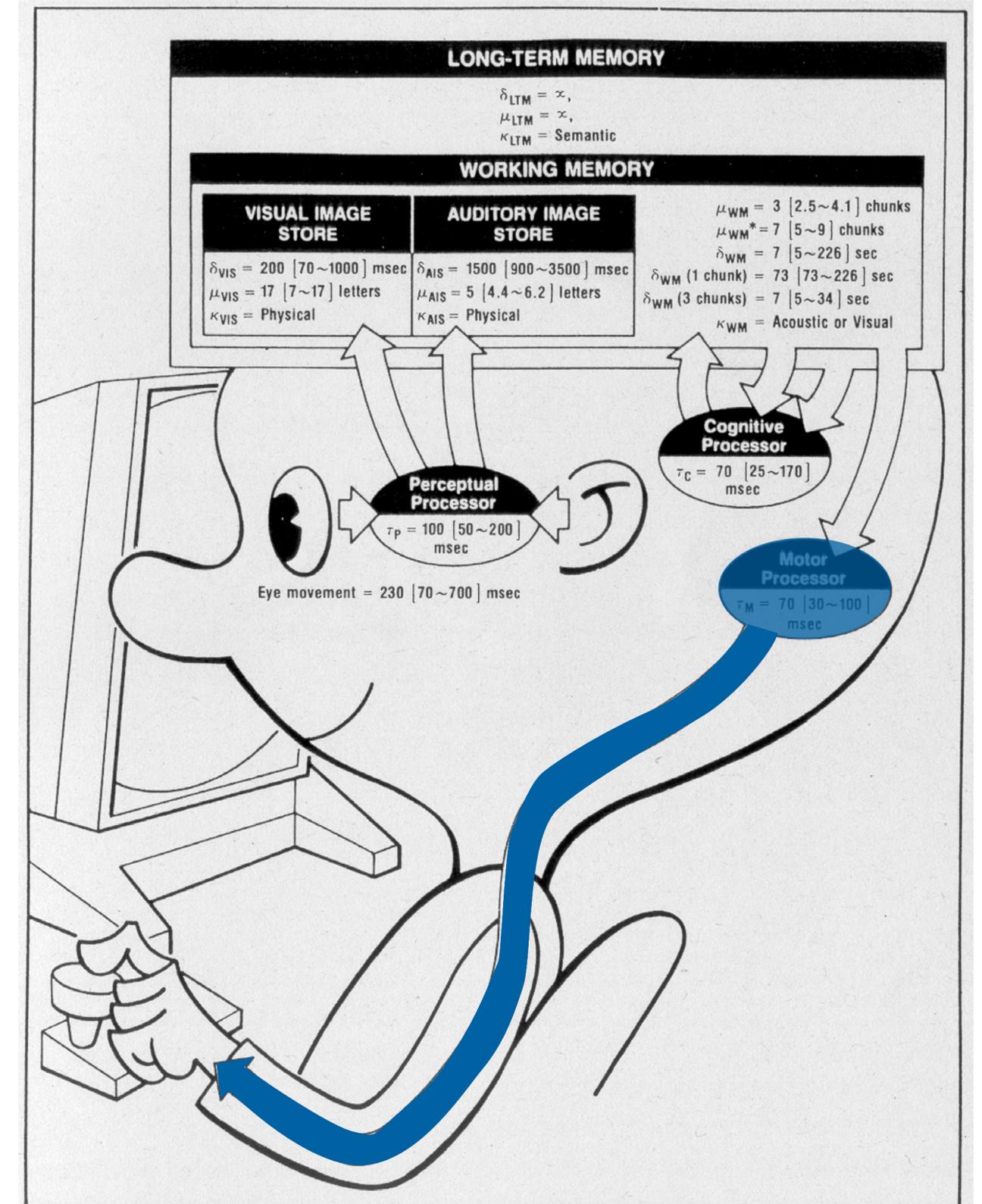
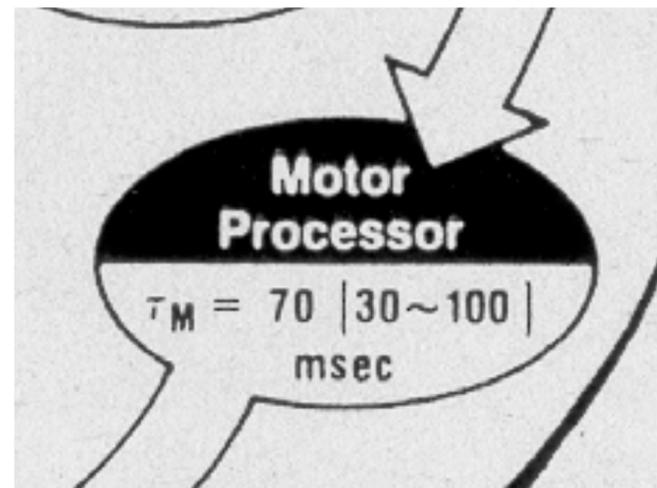


Motor System

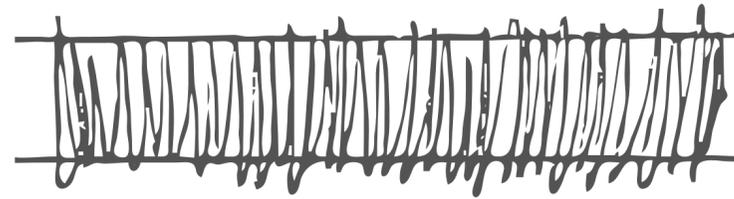


74 ms/reversal
250 ms/correction

- Motor processor (open loop)
 - $\tau_M = 70 \text{ ms}$
- ⇒ Average time between each reversal

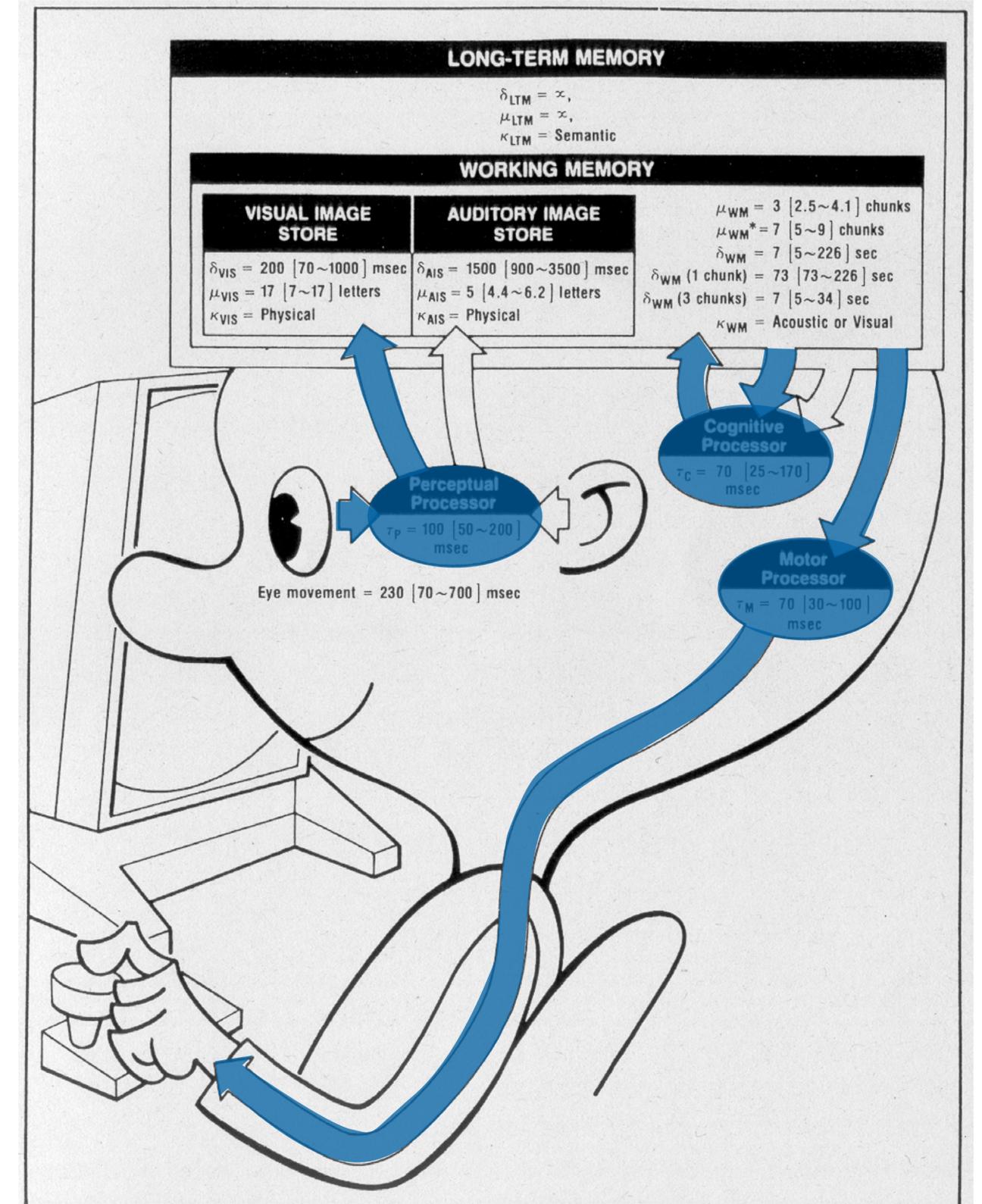


Motor System



74 ms/reversal
250 ms/correction

- Closed loop:
 - $\tau_P + \tau_C + \tau_M = 240 \text{ ms}$
- ⇒ Average time between each correction



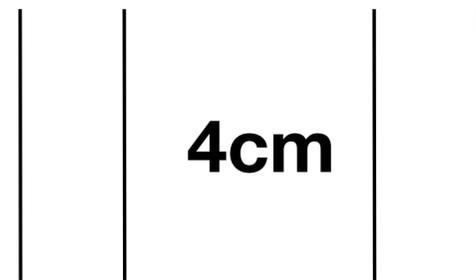
Fitts' Law



In-Class Experiment 5: Tapping Task



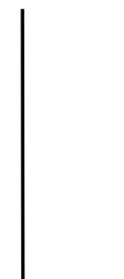
1cm



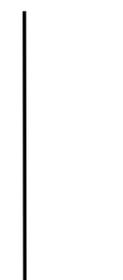
Same for 0.5 cm and 2 cm wide strips
Tap for 10 s, count taps afterwards



8cm

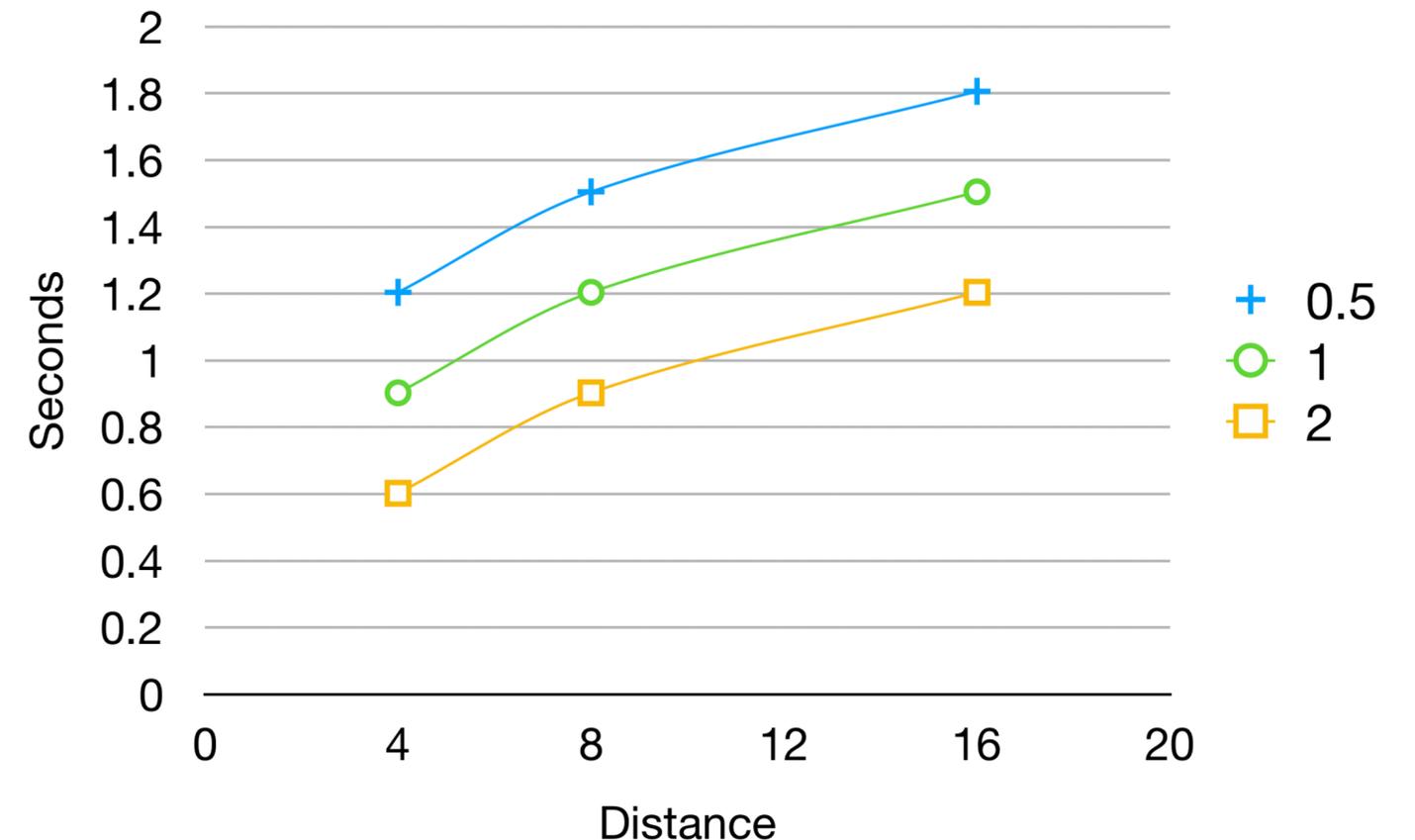


16cm



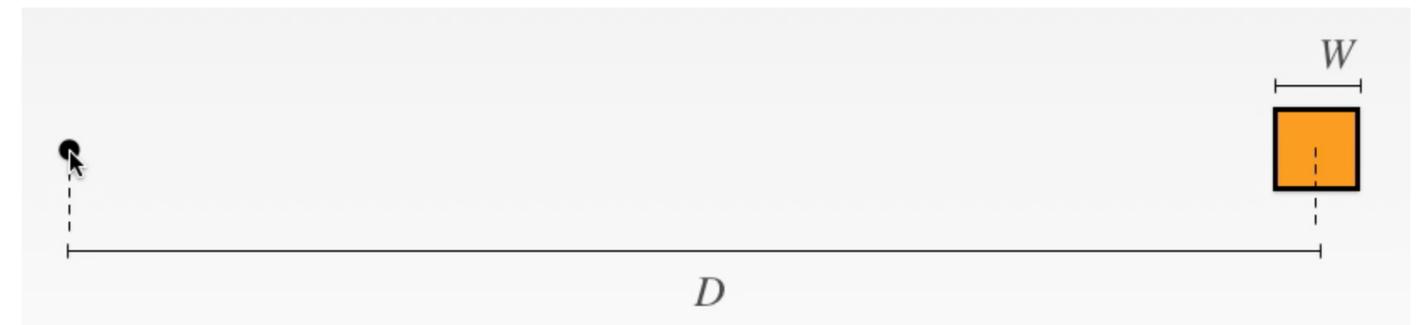
Tapping Task Results

- Doubling the distance adds roughly a constant to execution time
⇒ indicates logarithmic nature
- Doubling the target width (W) gives about same results as halving the distance (D)
⇒ indicates connection of D/W in formula



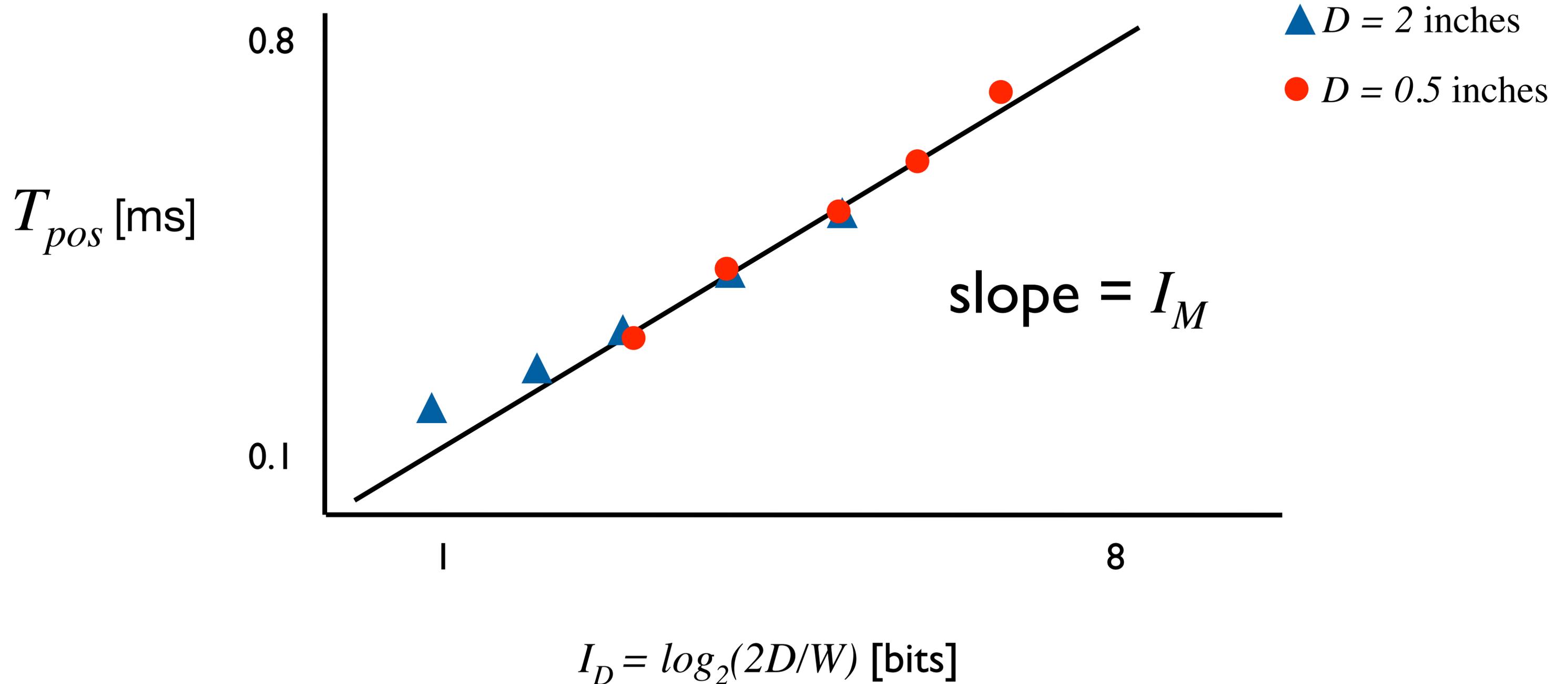
Motor System: Fitts' Law

- Goal: Predict time to press buttons (physical or on-screen) as function of distance and size
- Result (Fitts, 1954): $T_{pos} = I_M \cdot I_D$
 - T_{pos} time to reach button
 - $I_M = 100$ ms/bit index of movement, constant
 - $I_D = \log_2(2D / W)$ index of difficulty, in bits
- Fitts' law can be derived from CMN model



Visualizing Fitts' Law

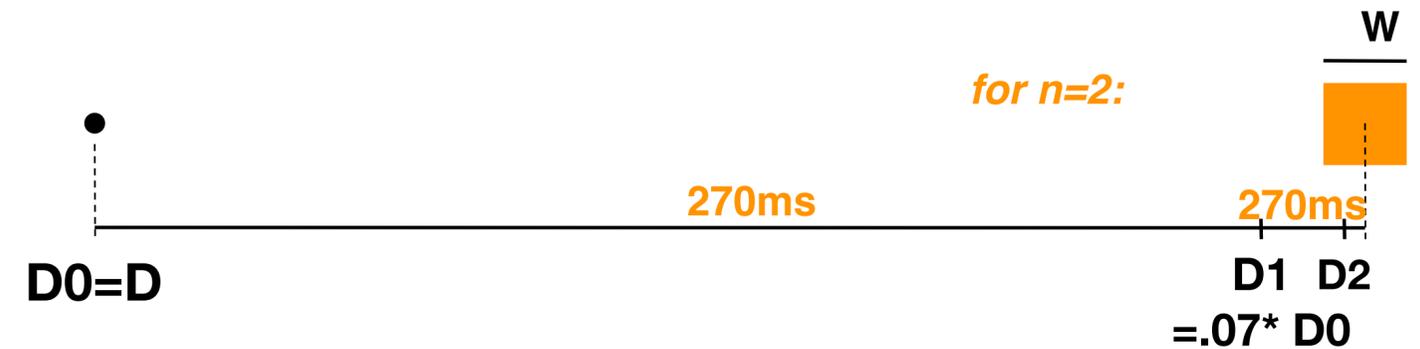
Experiment: fixed distance D , varying width W



Deriving Fitts' Law from CMN (1)

D_i := remaining distance to target after i movements
 ϵ := $D_i/D_{i-1} < 1$ (relative movement precision, experiment shows)
 $\epsilon = 0.07$ (constant according to CMN model)

$D_1 = \epsilon \cdot D_0 = \epsilon \cdot D$
 $D_2 = \epsilon \cdot D_1 = \epsilon^2 \cdot D$
...
 $D_n = \epsilon \cdot D_{n-1} = \epsilon^n \cdot D \leq W/2$ (hand reaches target after n movements)



$$\epsilon^n \leq \frac{W}{2D}$$

$$\Leftrightarrow n \geq \log_{\epsilon} \left(\frac{W}{2D} \right) \quad (\text{log for base } < 1 \text{ turns inequality sign})$$

$$\Leftrightarrow n \geq \frac{\log_2 \left(\frac{W}{2D} \right)}{\log_2 \epsilon}$$

$$\Leftrightarrow n \geq - \frac{\log_2 \left(\frac{2D}{W} \right)}{\log_2 \epsilon}$$

Deriving Fitts' Law from CMN (2)

Total positioning time is $T_{pos} = n \cdot (t_{WP} + t_{KP} + t_{MP})$

Insert n to arrive at Fitts' Law:

$$\begin{aligned} T_{pos} &= -\frac{\log_2\left(\frac{2D}{W}\right)}{\log_2 \epsilon} \cdot (t_{WP} + t_{KP} + t_{MP}) && \text{(rearrange)} \\ &= -\frac{(t_{WP} + t_{KP} + t_{MP})}{\log_2 \epsilon} \cdot \log_2\left(\frac{2D}{W}\right) \\ &= -\frac{240 \text{ ms}}{\log_2(0.07)} \cdot \log_2\left(\frac{2D}{W}\right) && \text{(240 ms is CMN estimate)} \\ &\approx 100 \text{ ms} \cdot \log_2\left(\frac{2D}{W}\right) \\ &= I_M \cdot I_D && \text{q.e.d.} \end{aligned}$$



Improvements

- Welford's Formulation, 1968:

$$T_{pos} = I_M \cdot \log_2 \left(\frac{D}{W} + \frac{1}{2} \right)$$

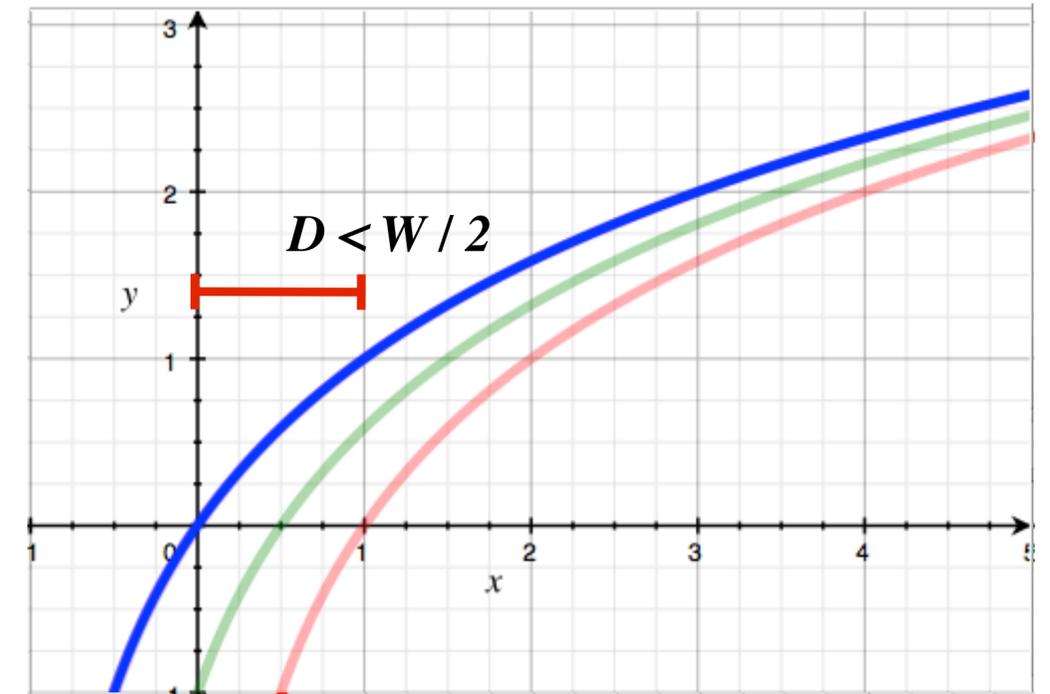
- Shannon's Formulation, ISO, 80's:

$$T_{pos} = a + b \cdot \log_2 \left(\frac{D}{W} + 1 \right)$$

- a, b depend on device, determine experimentally

Use $a = 0 \text{ ms}$, $b = I_M = 100 \text{ ms}$ for quick and dirty estimates

Improved curve fit, no negative times for infinite-size targets

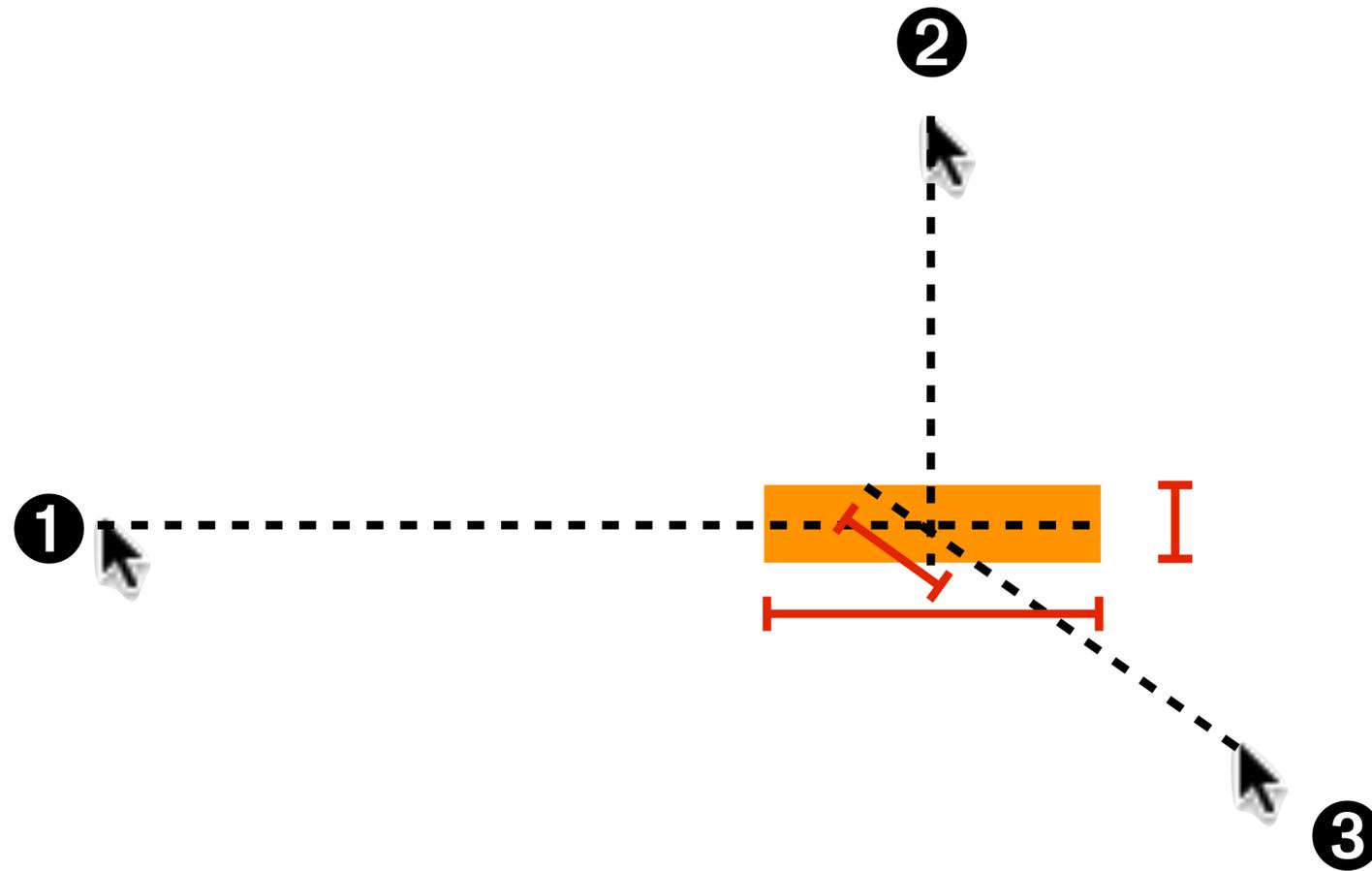


— $T_{pos} = I_M \cdot \log_2 \left(\frac{2D}{W} \right)$

— $T_{pos} = I_M \cdot \log_2 \left(\frac{D}{W} + \frac{1}{2} \right)$

— $T_{pos} = a + b \cdot \log_2 \left(\frac{D}{W} + 1 \right)$

Target Width



[MacKenzie & Buxton, CHI'92]



Papierkorb

Windows Explorer window titled "Dieser PC" with the ribbon menu set to "Laufwerktools".

Navigation pane (left):

- Schnellzugriff
 - Desktop
 - Downloads
 - Dokumente
 - Bilder
 - DVD-RW-Laufwerk
 - Gespeicherte Bilder
 - Musik
 - Videos
- OneDrive
- Dieser PC**
- Netzwerk

Main pane (center):

Ordner (6):

- Bilder
- Desktop
- Dokumente
- Downloads
- Musik
- Videos

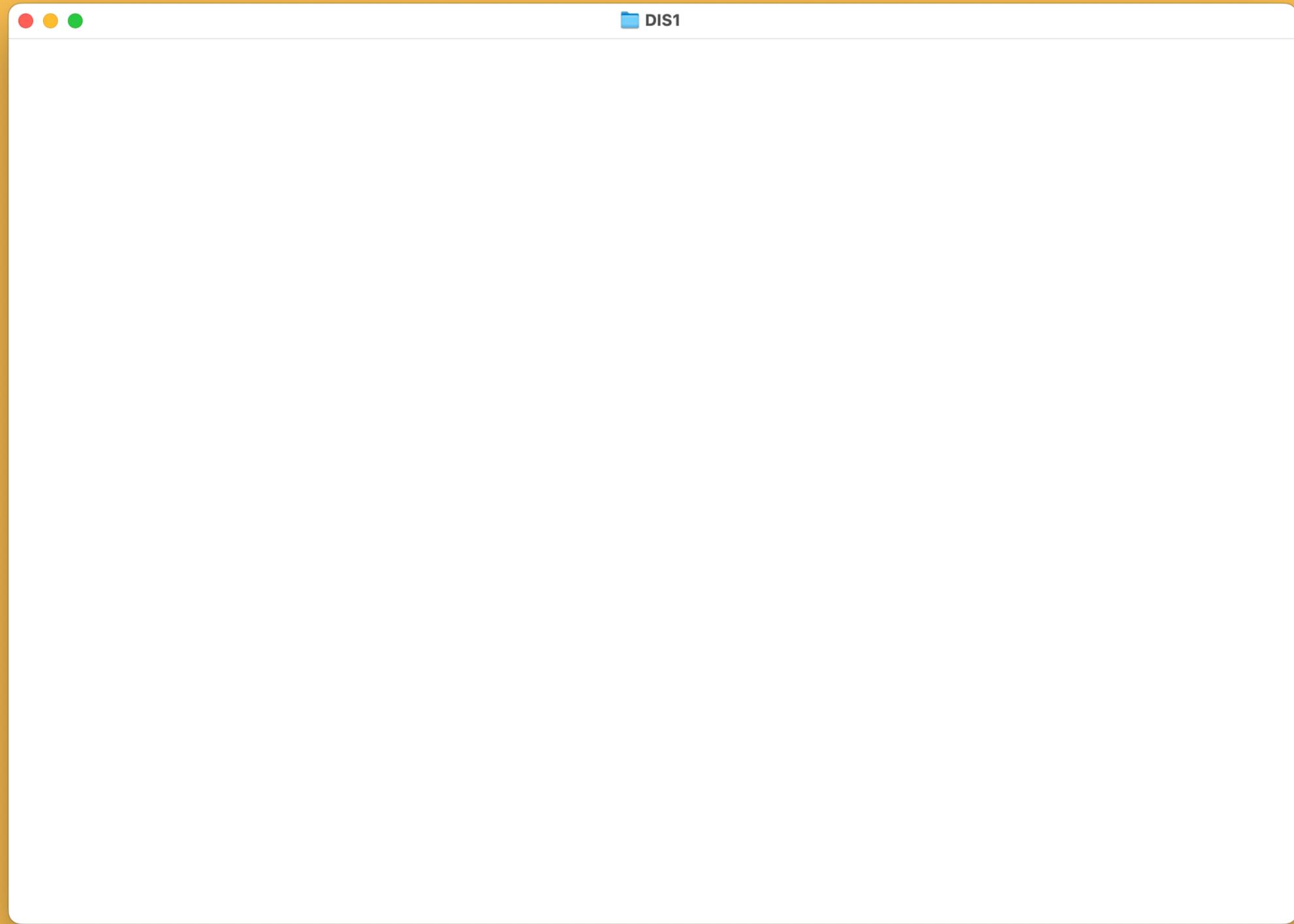
Geräte und Laufwerke (2):

- Lokaler Datenträger (C:)
 - 224 GB frei von 464 GB
- DVD-RW-Laufwerk (E:)

Status bar (bottom): 8 Elemente | 1 Element ausgewählt



macOS Monterey



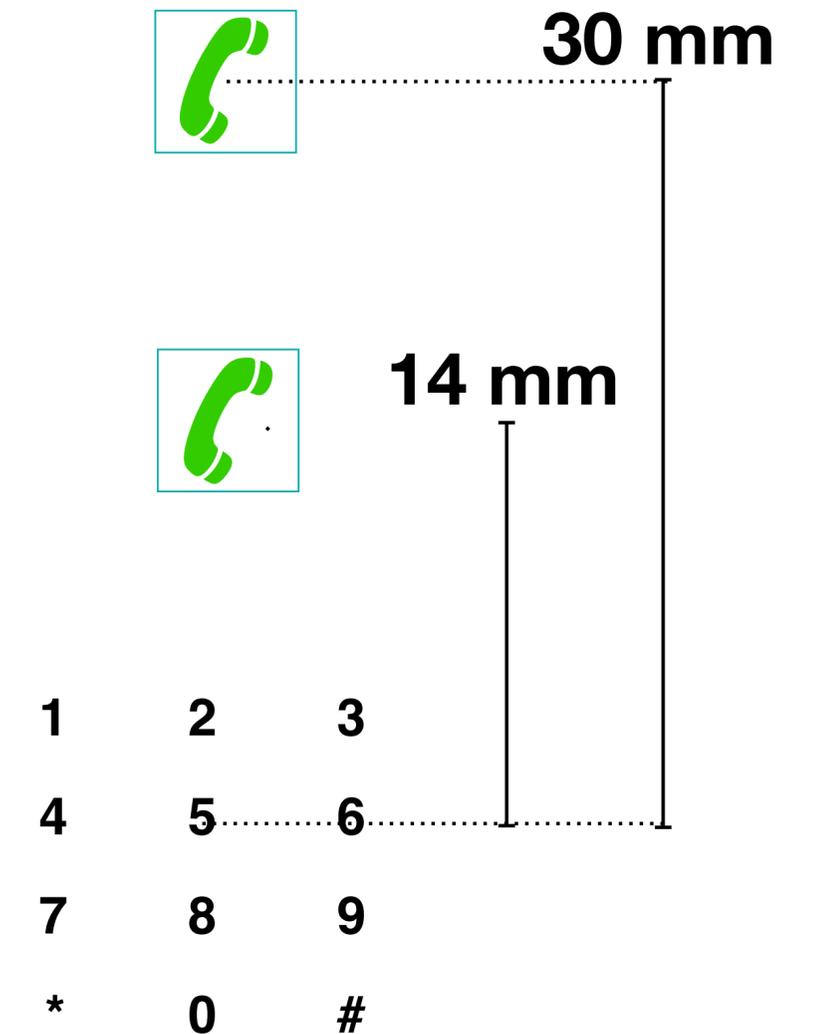
In-Class Exercise: Mobile Phone



- How much faster does calling become by moving the “call” button from 30 mm distance to 14 mm distance, measured from the middle of the keypad? The size of the call button is 2 x 2 mm

- Shannon’s Formulation: $T_{pos} = a + b \cdot \log_2\left(\frac{D}{W} + 1\right)$

- Use $a = 0$ ms, $b = 100$ ms/bit



Solution

$$T_{pos1} = a + b \cdot \log_2\left(\frac{D_1}{W} + 1\right) \quad T_{pos2} = a + b \cdot \log_2\left(\frac{D_2}{W} + 1\right)$$

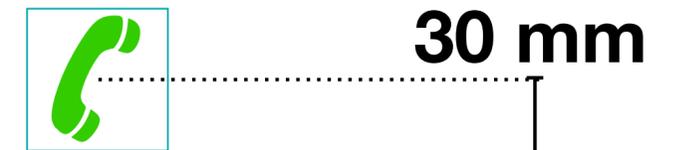
$$T_{Diff} = T_{pos1} - T_{pos2} = a + b \cdot \log_2\left(\frac{D_1}{W} + 1\right) - (a + b \cdot \log_2\left(\frac{D_2}{W} + 1\right))$$

$$= b \cdot (\log_2\left(\frac{D_1}{W} + 1\right) - \log_2\left(\frac{D_2}{W} + 1\right))$$

$$= b \cdot (\log_2\left(\frac{30}{2} + 1\right) - \log_2\left(\frac{14}{2} + 1\right)) = b \cdot (\log_2(16) - \log_2(8))$$

$$= b \cdot (4bit - 3bit) = b \cdot 1bit = 100 \frac{ms}{bit} \cdot 1bit = 100ms$$

⇒ Moving the call button speeds up each call by an average of about 100ms.



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

Summary

- The Media Computing Group does cool stuff
- HCI is about humans, computers, the design process, and the social context
- The CMN model allows estimating reaction times and memory performance
- You can calculate the average movement time of pointing devices using Fitts' Law
- You've experienced that mathematical laws seem to govern your perception, memory, and movement



What to Do Now

Today

1. Register for the course on RWTHonline
2. Upload your signed Declaration of Compliance on our website
(If you have done this already, you don't need to upload it again)

File Name: DIS1_DoC_<your last name>_<matriculation number>.pdf

3. Feel free to check out our other class, iOS Application Development

Before next Lab on Tuesday

- Buy Don Norman's The Design of Everyday Things (2nd edition, 2013)
- Start working on the assignment

Before next Lecture

- Read Dix' Human-Computer Interaction, chapter "The Human" (pp. 11–59)
(PDF available on RWTHmoodle)

