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

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

Sarah Sahabi, M. Sc.
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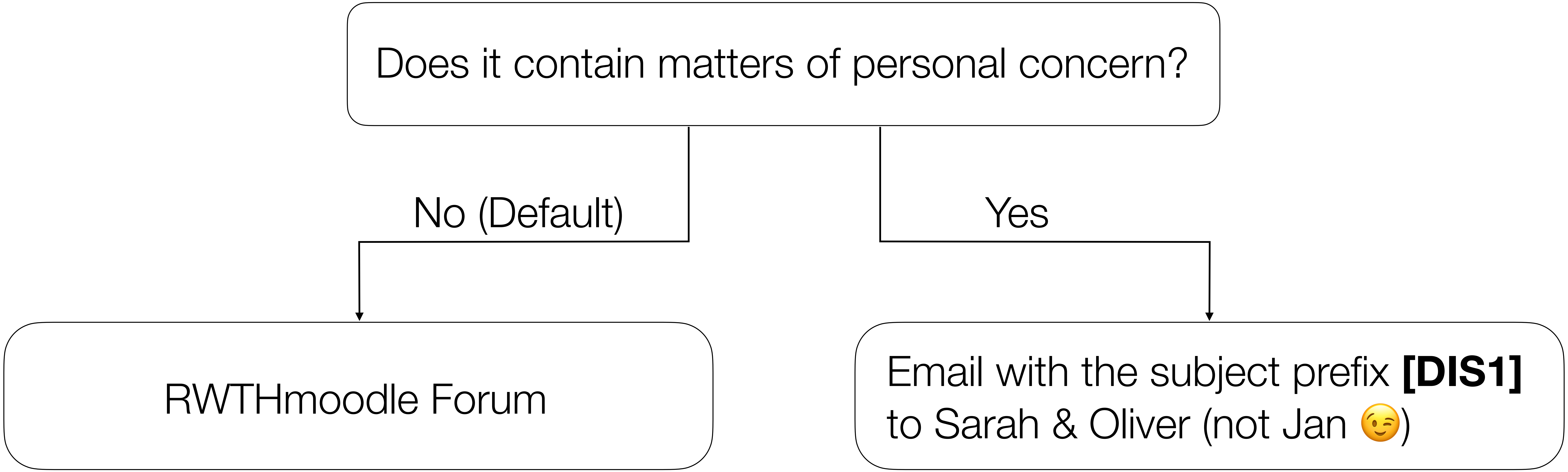
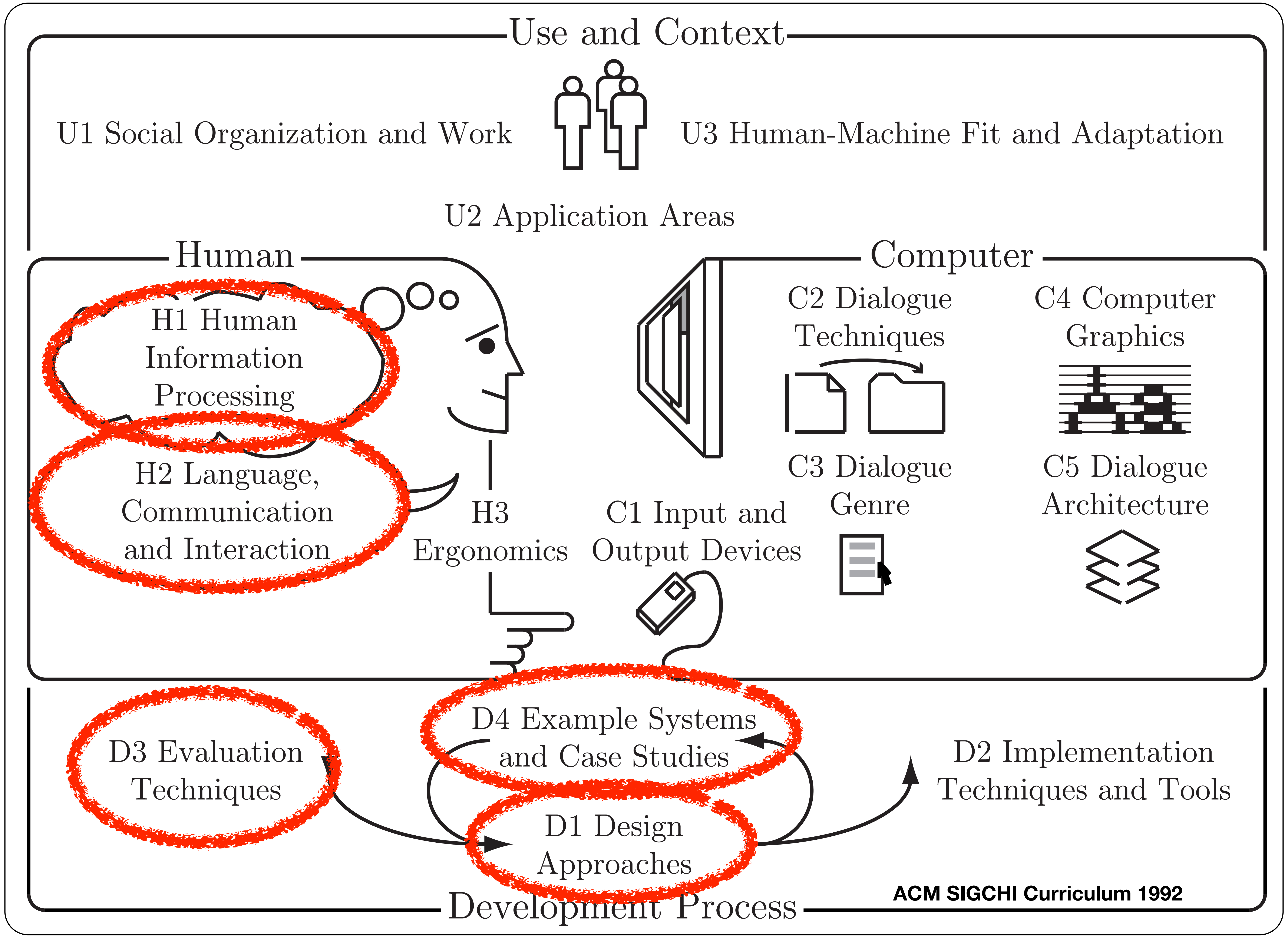
The Question Flow Chart :)



Alternatively: A quick chat after the lecture ☕

Human–Computer Interaction?

What is HCI?



Use and Context
U1 Social Organization and Work
U3 Human-Machine Fit and Adaptation
U2 Application Areas
Human
H1 Human Information Processing
H2 Language, Communication and Interaction
H3 Ergonomics
Computer
C1 Input and Output Devices
C2 Dialogue Techniques
C3 Dialogue Genre
C4 Computer Graphics
C5 Dialogue Architecture
D3 Evaluation Techniques
D4 Example Systems and Case Studies
D1 Design Approaches
D2 Implementation Techniques and Tools
Development Process
ACM SIGCHI Curriculum 1992

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

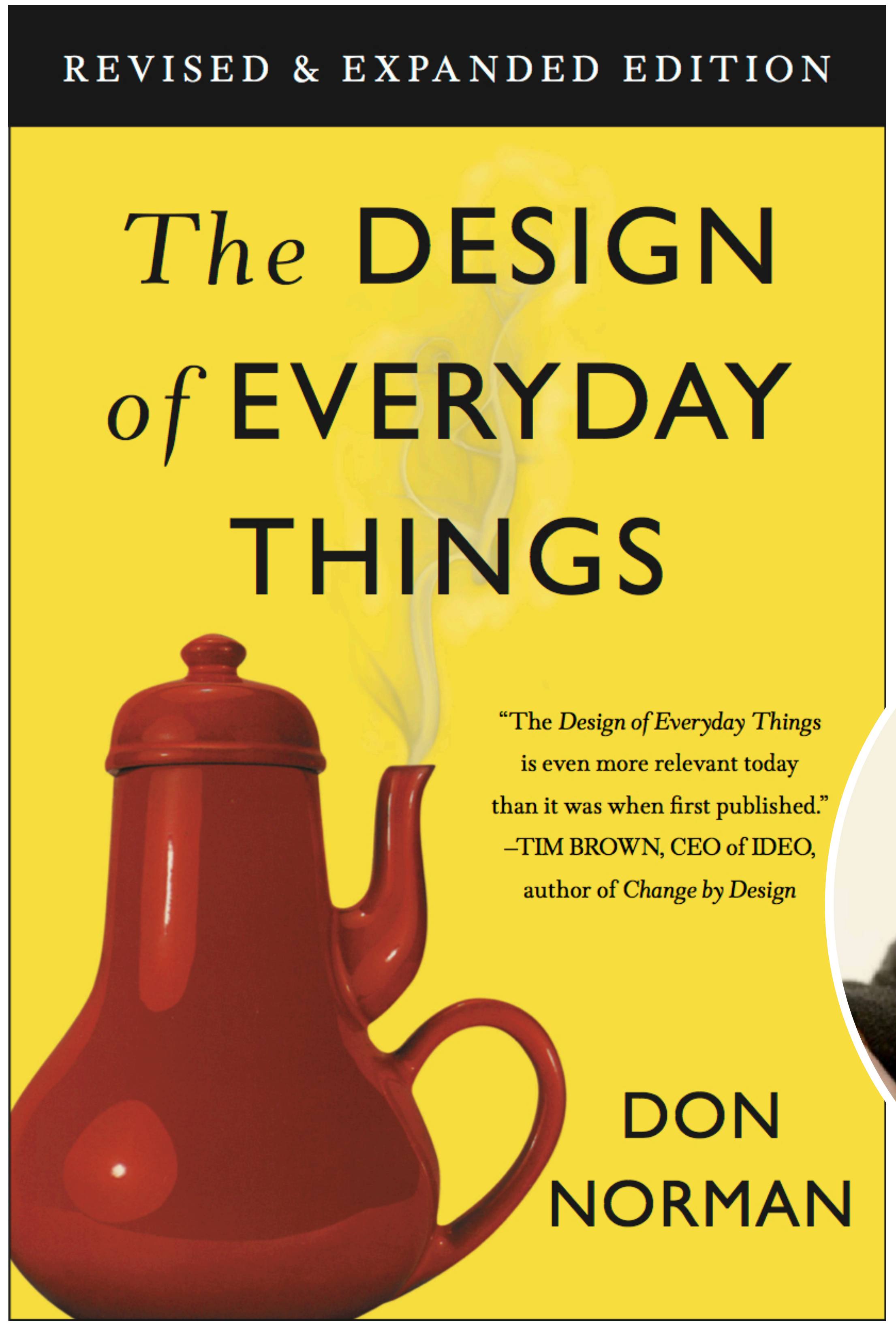
Development Process

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

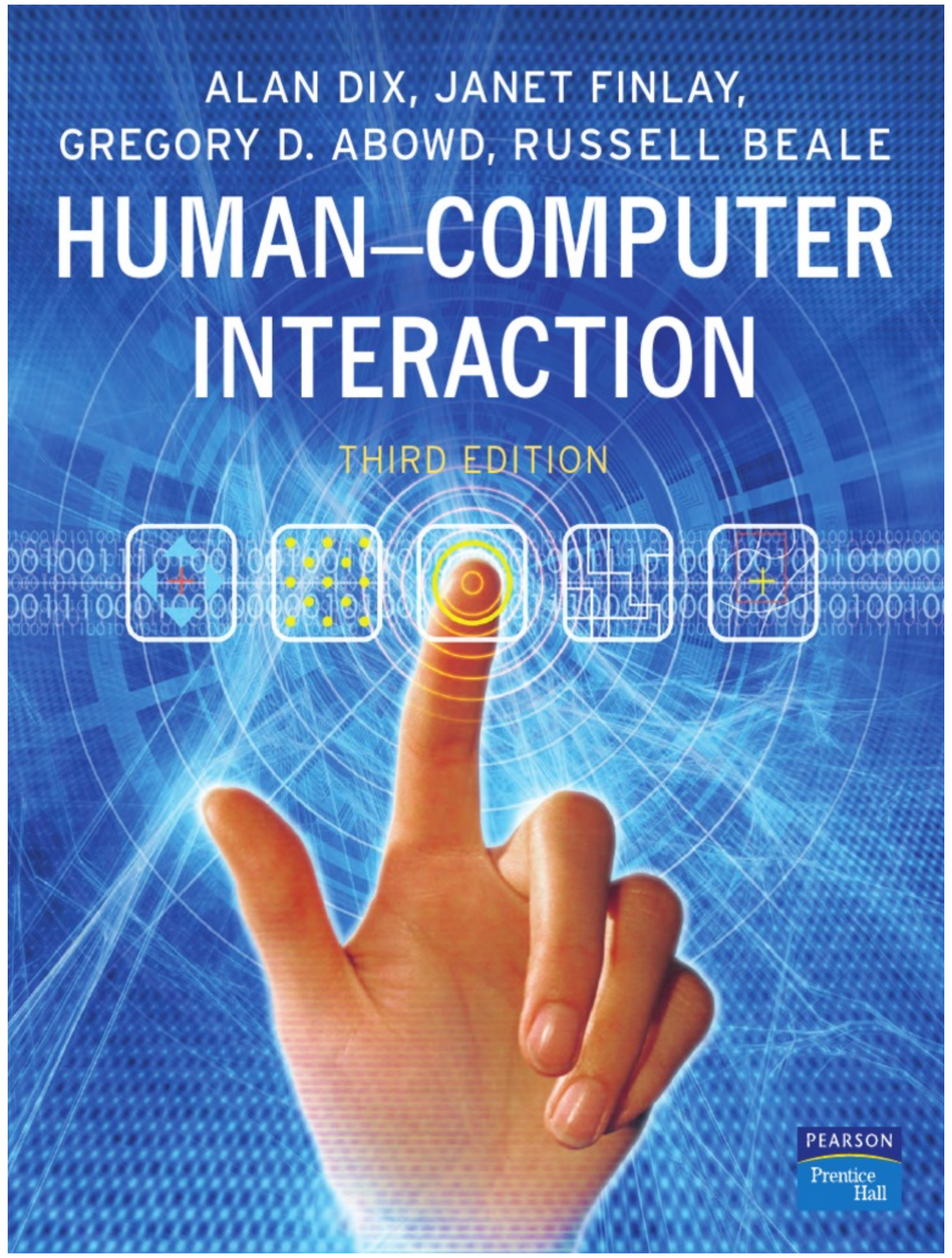
For more details, see hci.rwth-aachen.de/dis.

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

Course Structure

Course Structure

Flipped-Classroom Lecture

Watch videos at home; Discuss content in class

Lab

- Discuss assignments

Oct 24th – 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

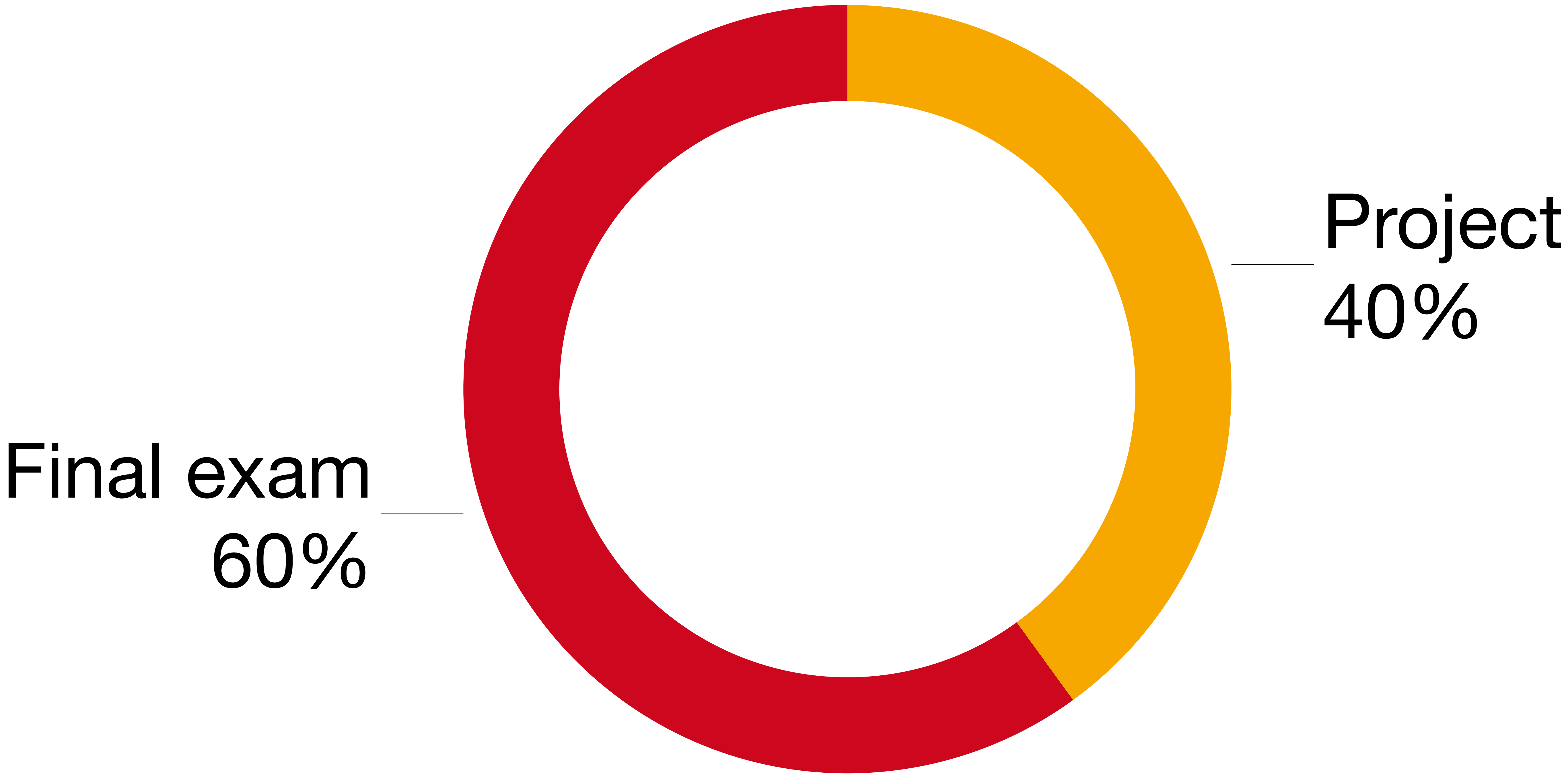
Final Exam

Feb 14th

Final Exam

Mar 12th

Final Grade Distribution



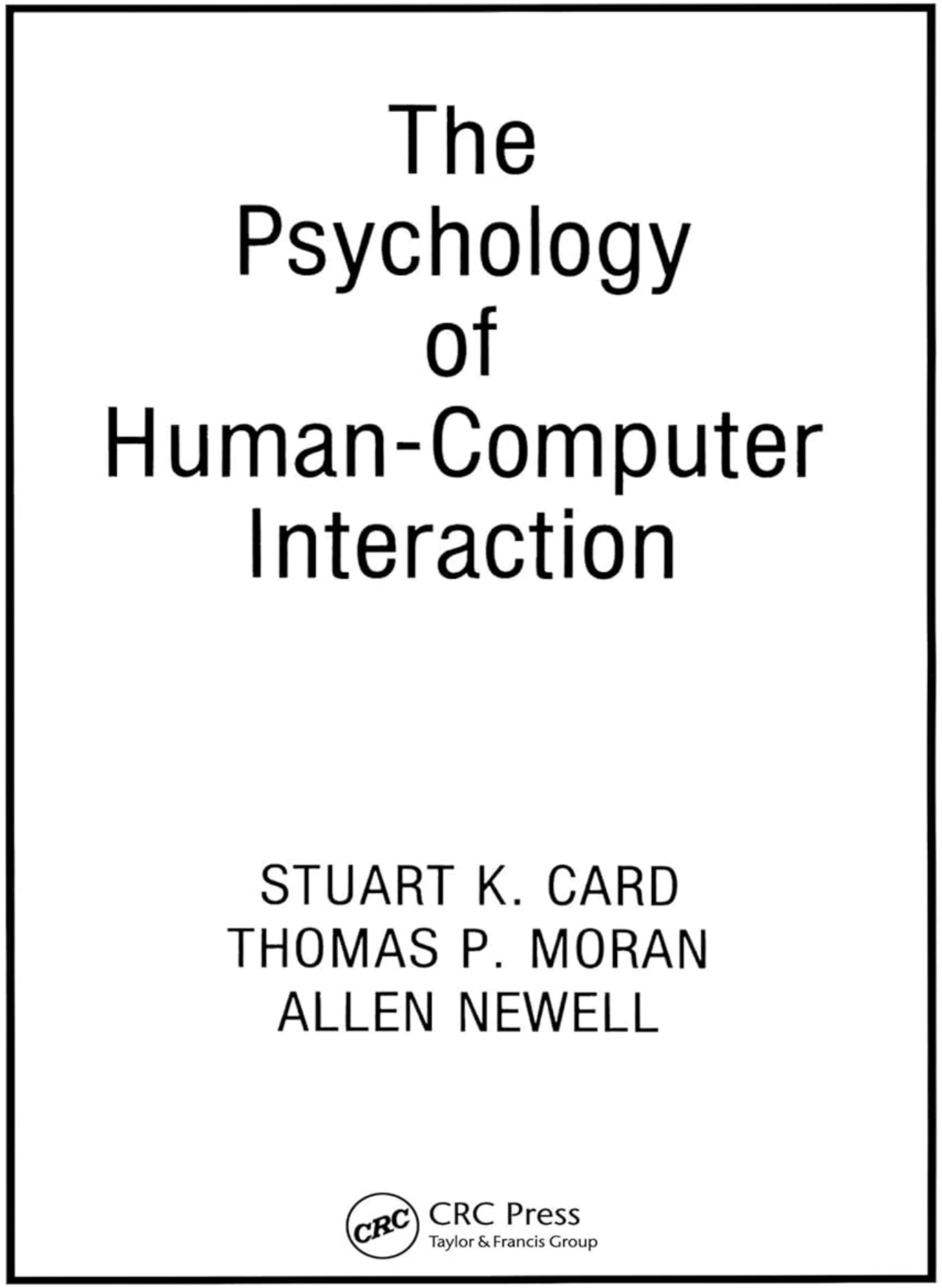
! To pass the course, you must pass both project and final exam.

Registering for this Class

- Register via RWTHonline and upload the **Declaration of Compliance** until **tomorrow, Oct 25, at 23:59**
    - You can also sign and submit it today
- If you want to, **you can visit the class in Aachen**, but it might happen that traveling to Bonn is necessary during the project
    - **Register for both** DIS1 courses in RWTHonline
    - **Write us an email** with the subject ***"[DIS1] Moodle Access for MI"*** with your name and matriculation number

The Human

Model Human Processor: The CMN Model



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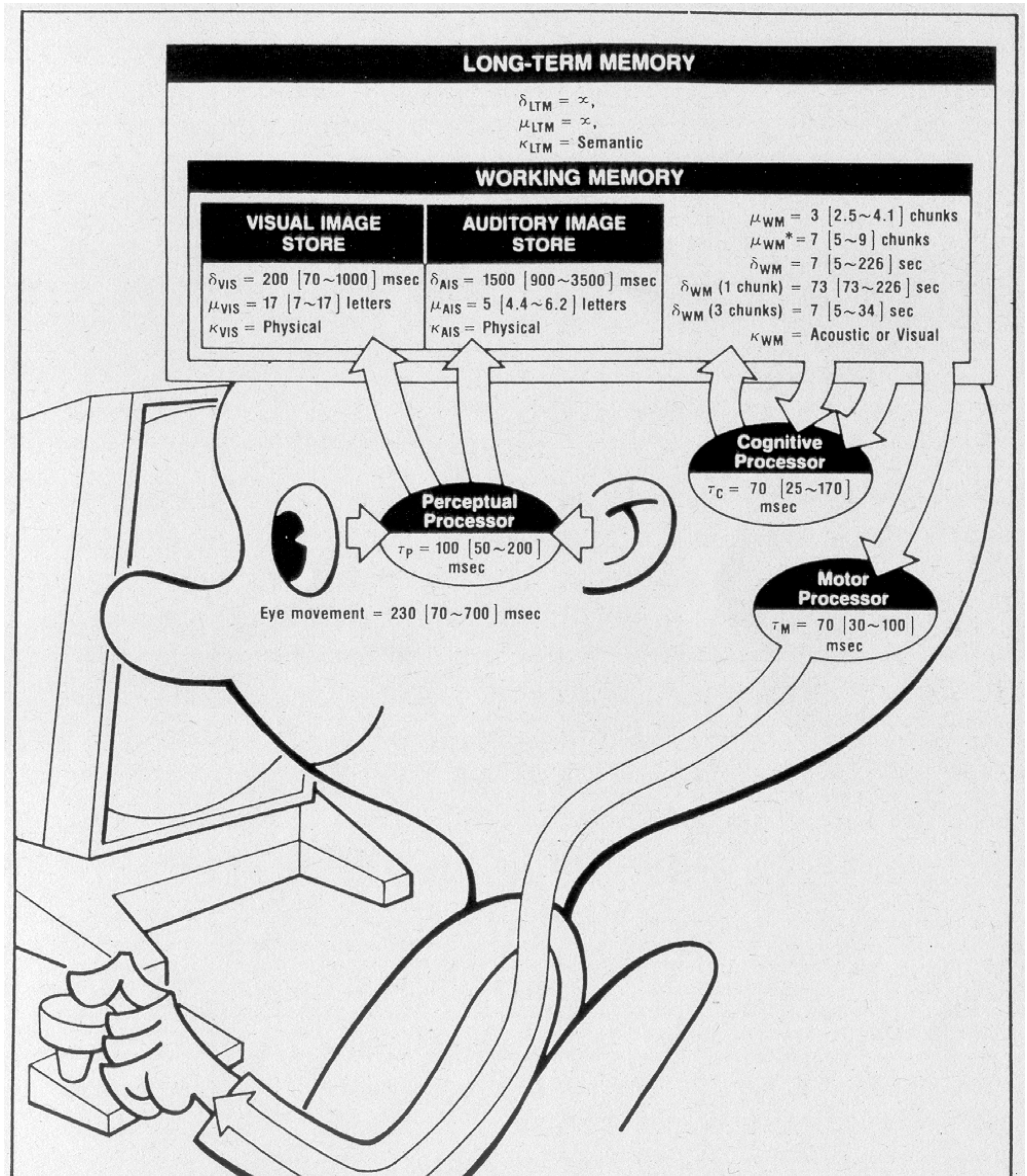
Model Human Processor

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



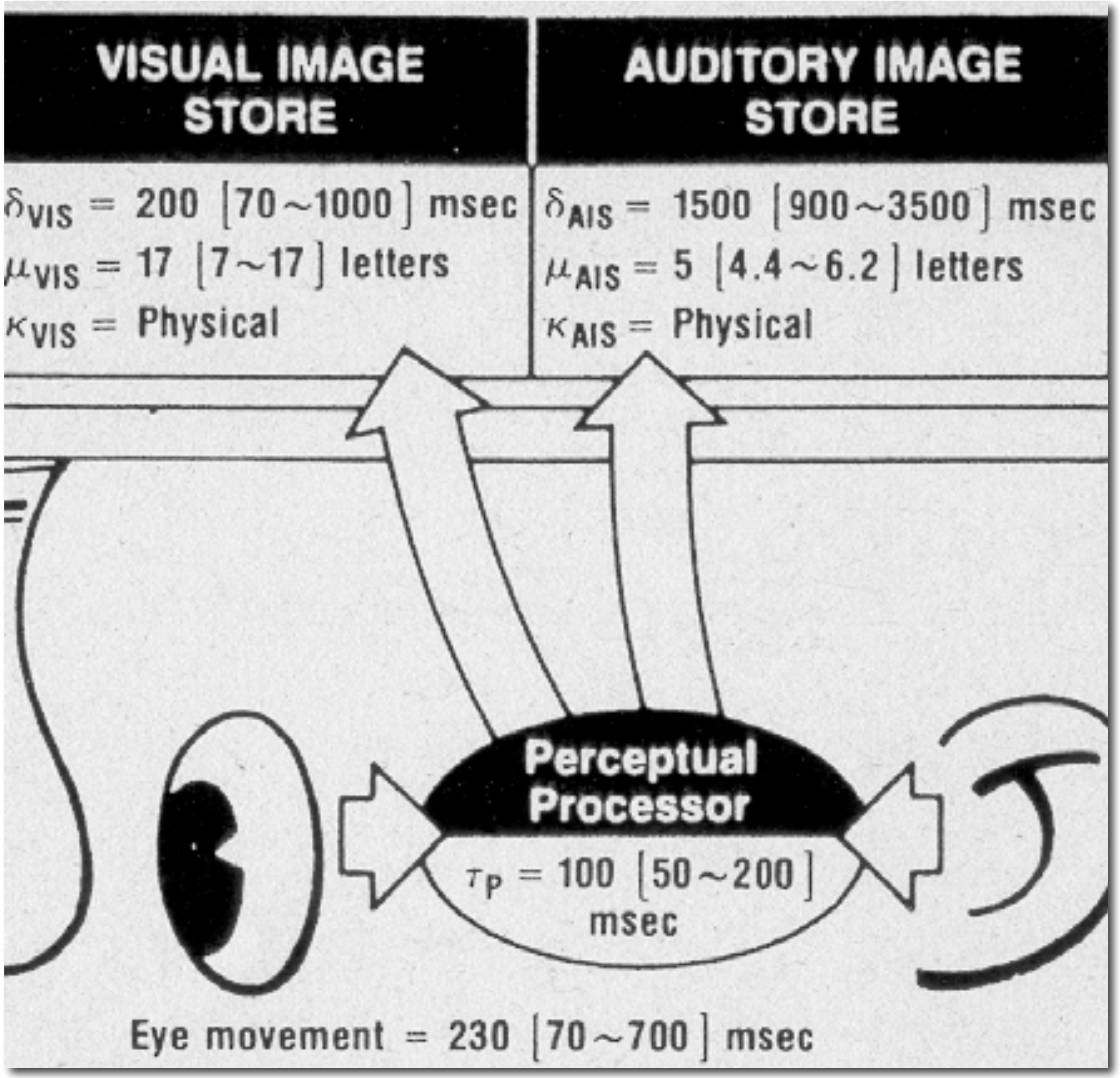
[Card et al. '81]

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?

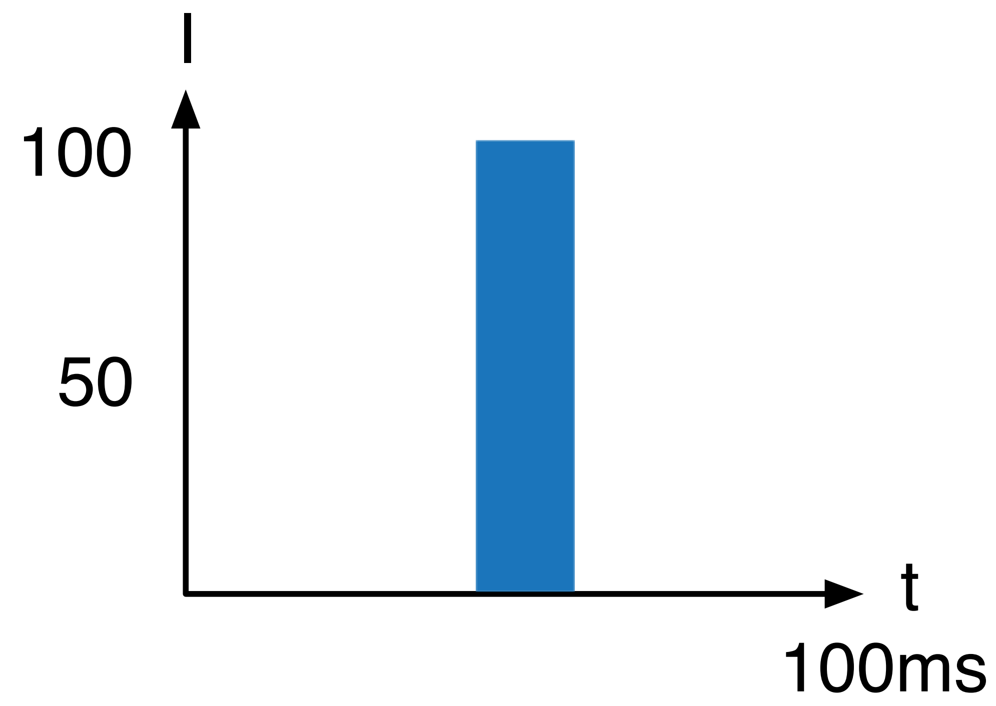
Perception

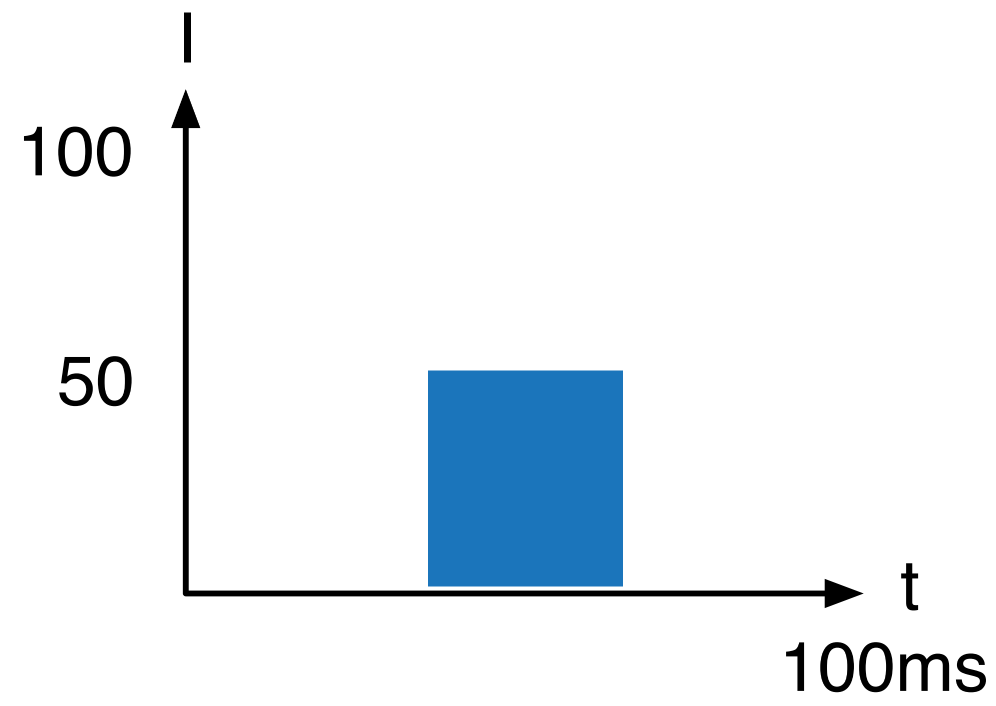
- Eye saccades: 230 ms
- Explains reading rates
  - Maximum:13 characters/saccade ⇒ 652 words/minute

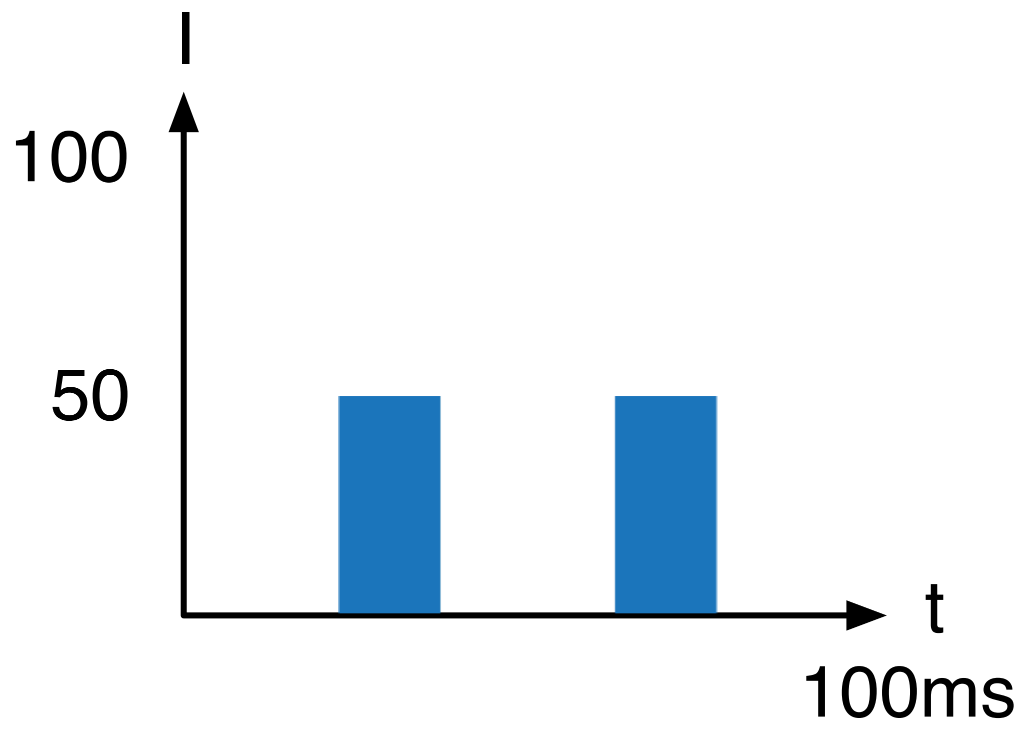


Perceptual Processor

- 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

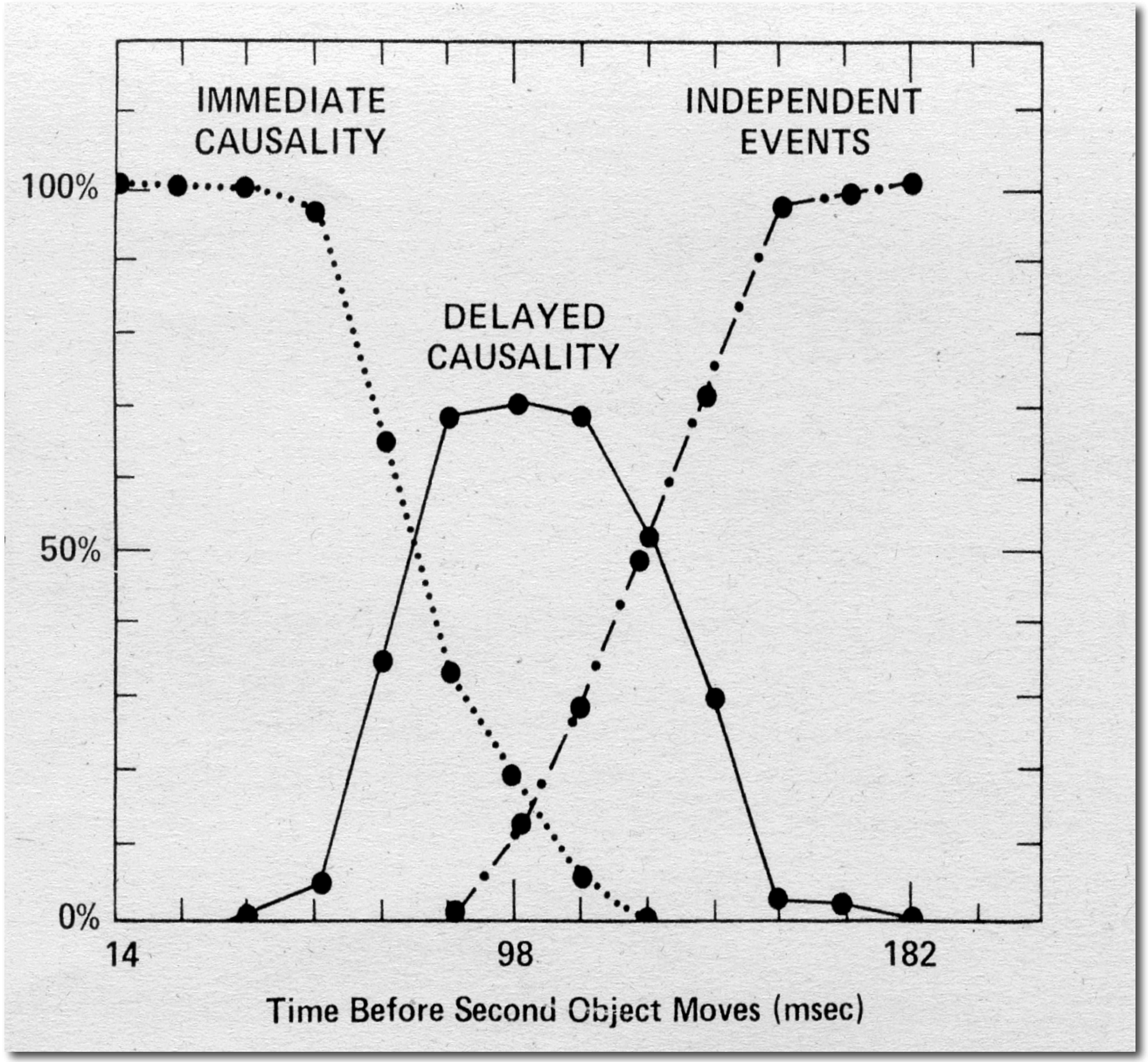
A: 0 ms delay

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



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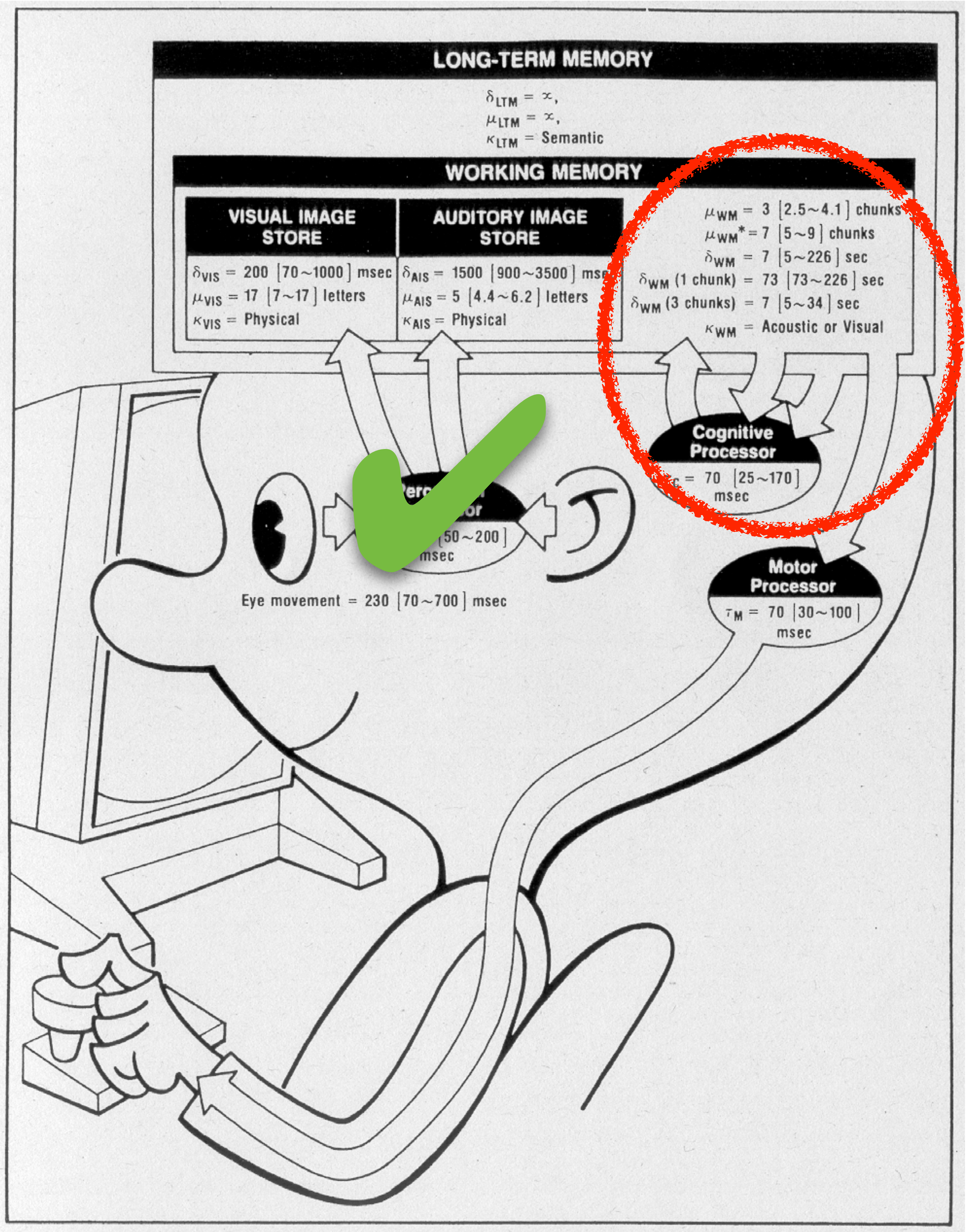
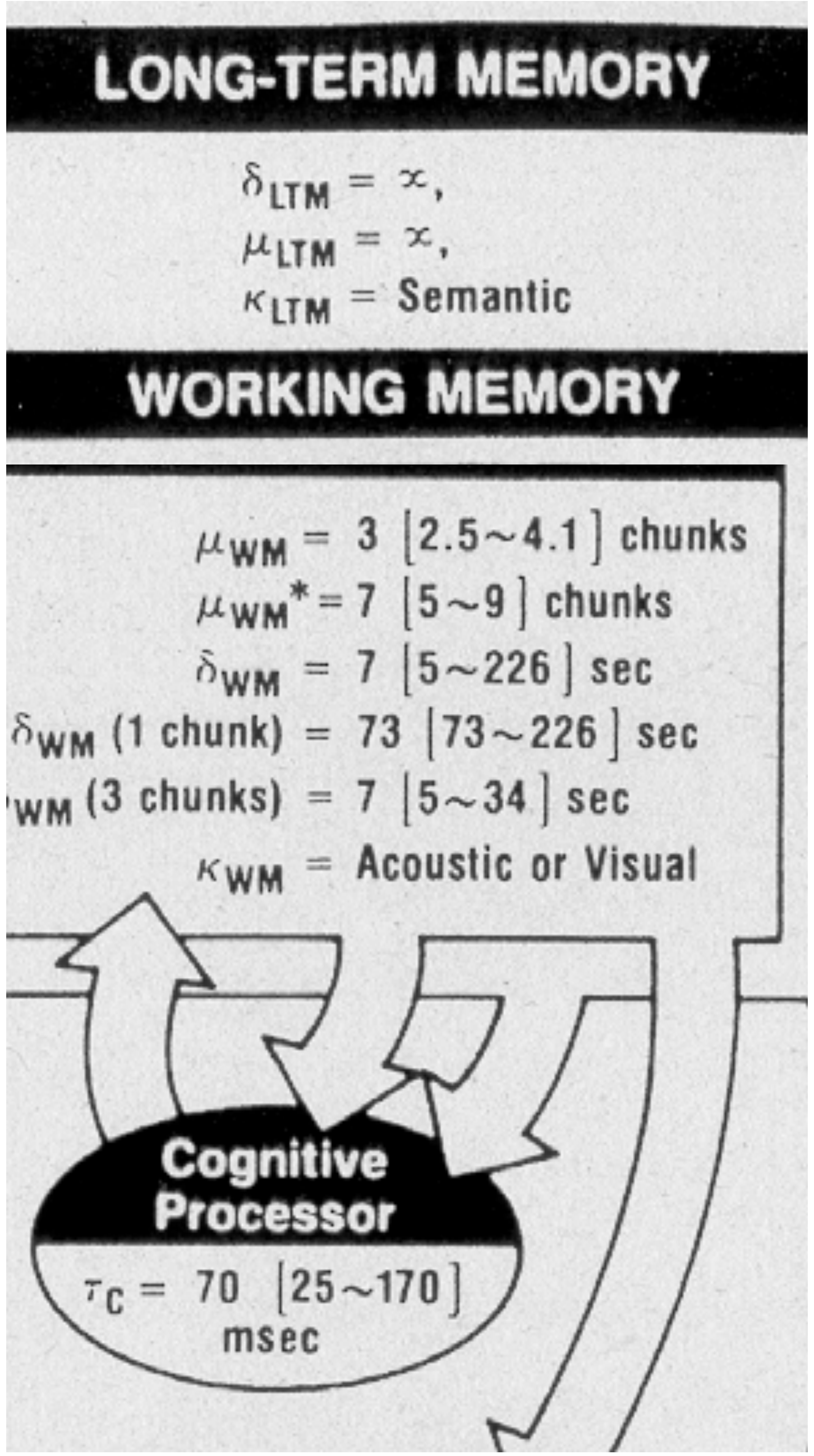

LONG-TERM MEMORY
δLTM = ∞,
μLTM = ∞,
κLTM = Semantic
WORKING MEMORY
VISUAL IMAGE STORE
δVIS = 200 [70~1000] msec
μVIS = 17 [7~17] letters
κVIS = Physical
AUDITORY IMAGE STORE
δAIS = 1500 [900~3500] msec
μAIS = 5 [4.4~6.2] letters
κAIS = Physical
μWM = 3 [2.5~4.1] chunks
μWM* = 7 [5~9] chunks
δWM = 7 [5~226] sec
δWM (1 chunk) = 73 [73~226] sec
δWM (3 chunks) = 7 [5~34] sec
κWM = Acoustic or Visual
Cognitive Processor
70 [25~170] msec
[50~200] msec
Eye movement = 230 [70~700] msec
Motor Processor
τM = 70 [30~100] msec

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

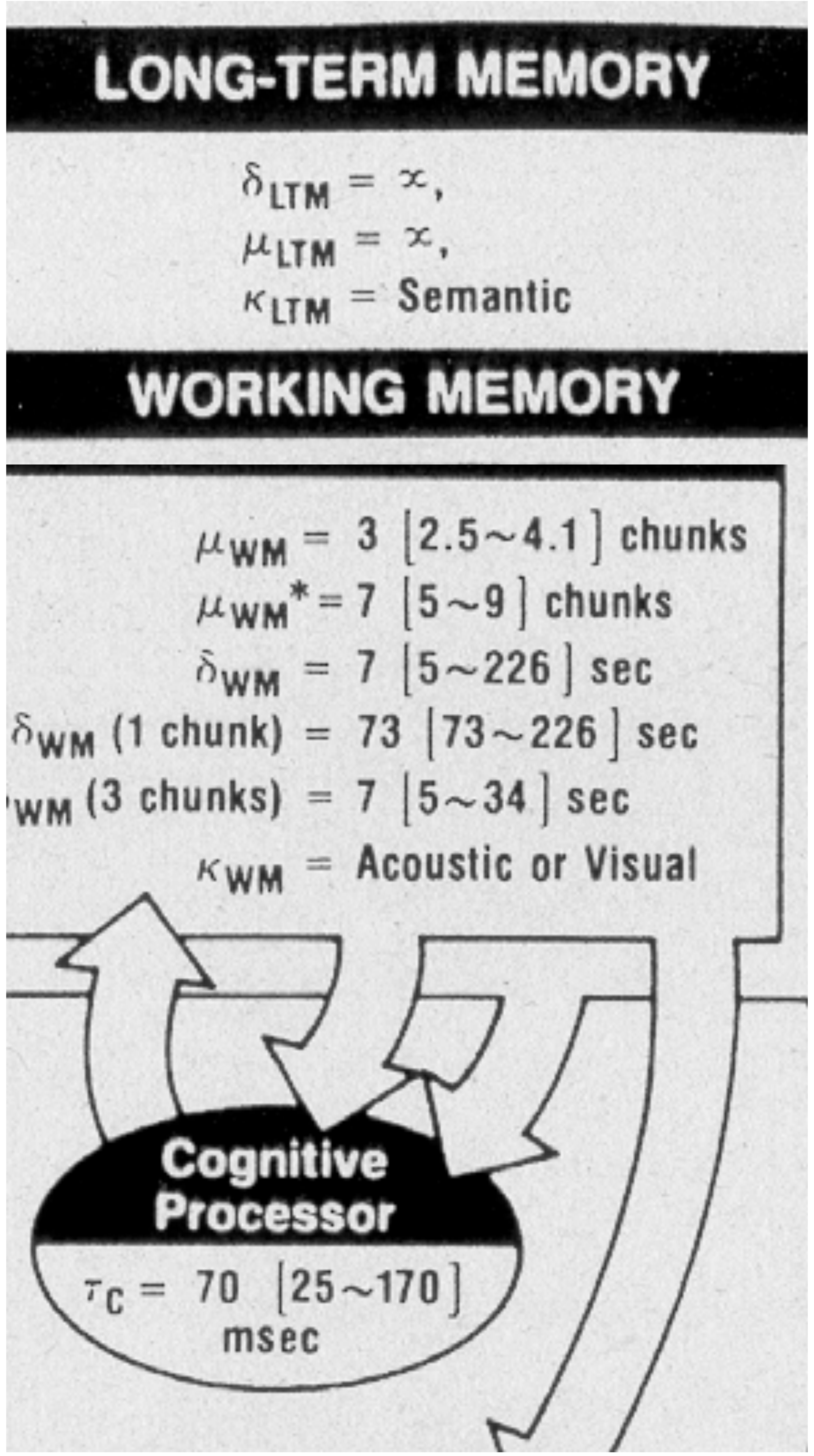
- Chunks depend on user & task
- Working memory:
  - Capacity: μ_{WM} = 7 ± 2 chunks (Miller '56)
  - Half life: $\delta_{1,WM}$ = 73 s (1 chunk)
    $\delta_{3,WM}$ = 7 s (3 chunk)
  - Visual/acoustic encoding
- In 2001, Nelson Cowen showed that μ_{WM} is actually 4±1 chunks.



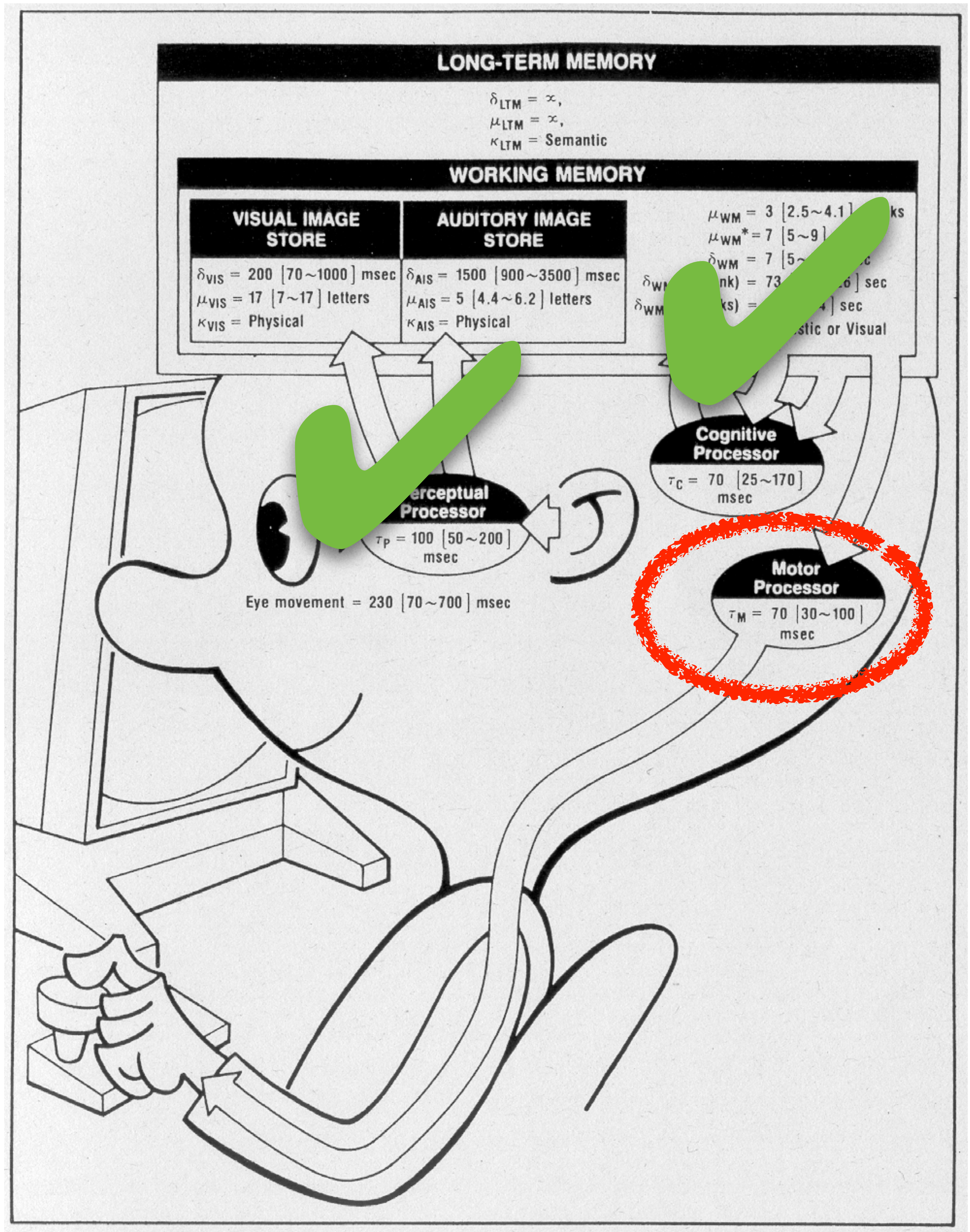
Cognitive System

- Cognitive processor:
  - Processing time τ_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



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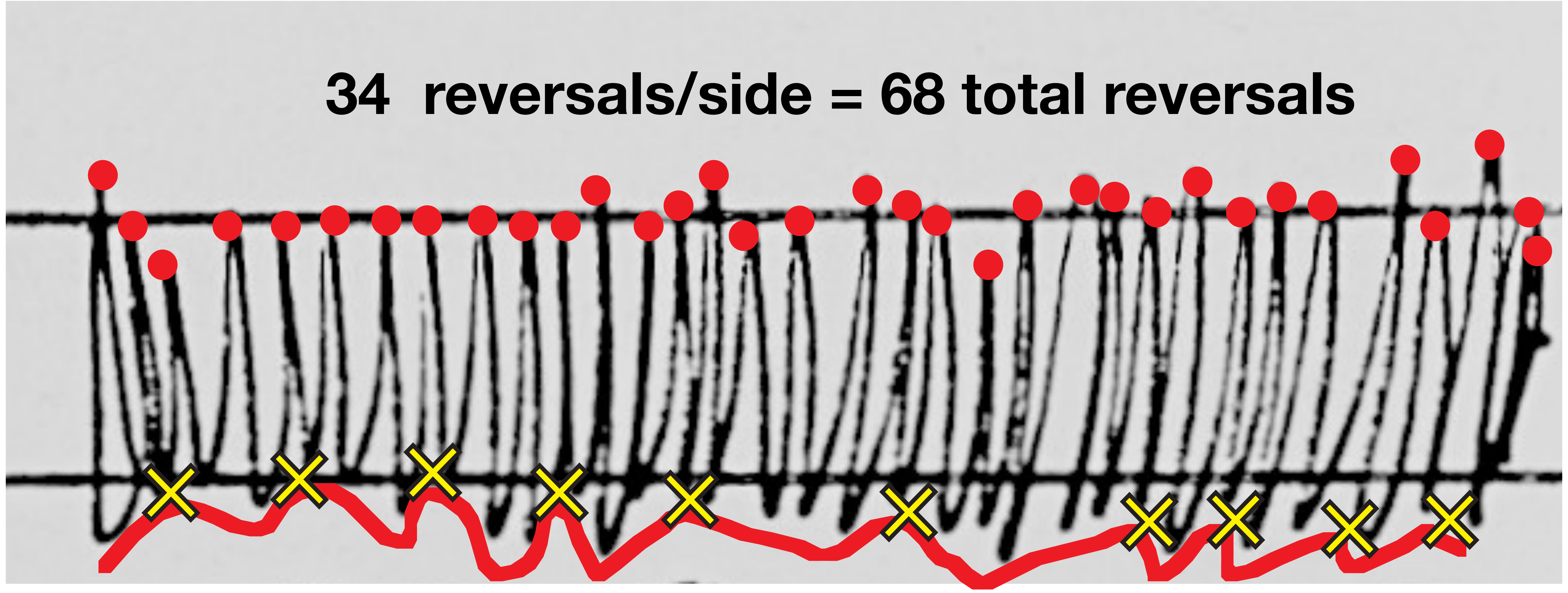
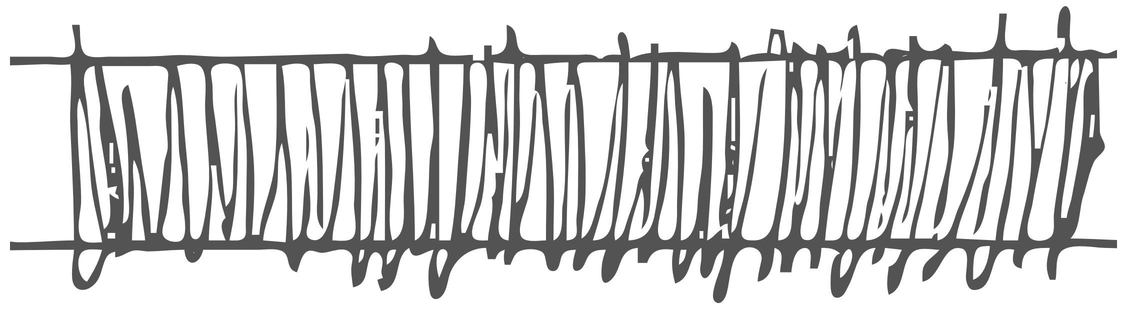
In-Class Experiment 3: Motor System

- 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?



10 corrections/side = 20 total corrections

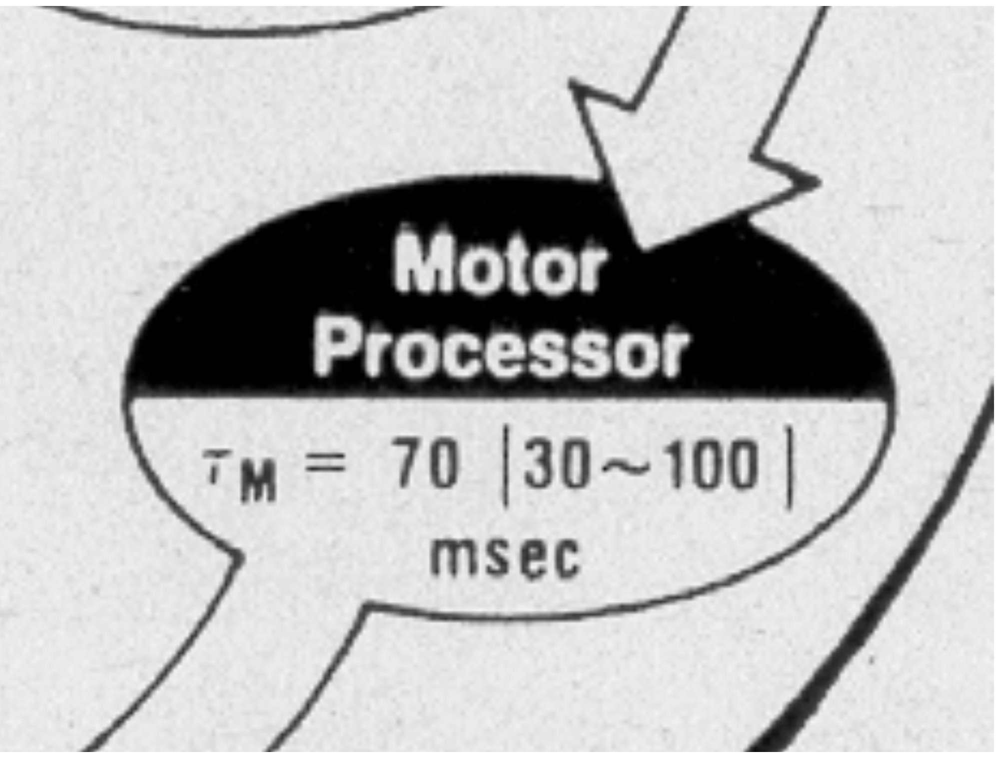
Motor System

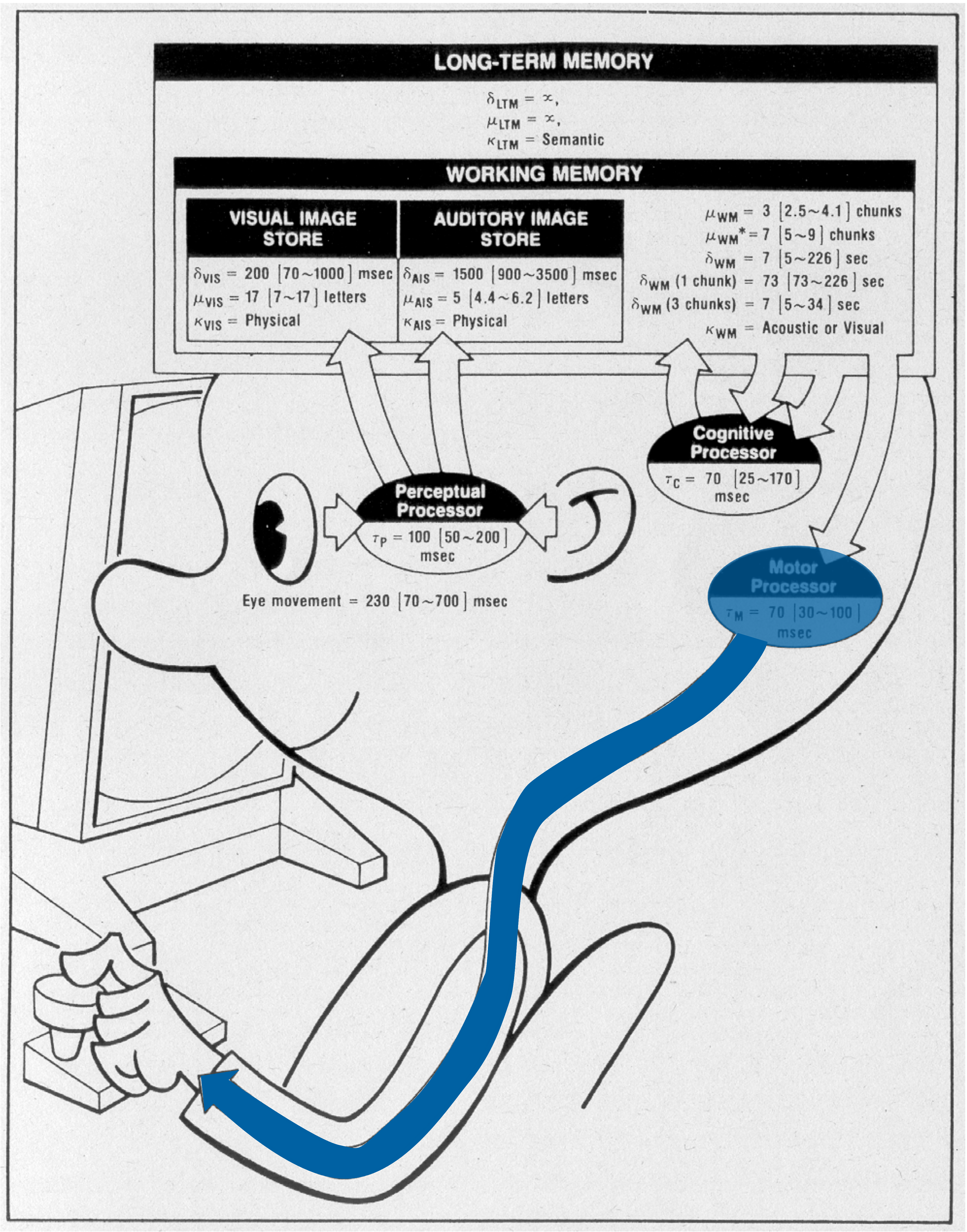


74 ms/reversal
250 ms/correction

- Motor processor (open loop)
  - τ_M = 70 ms

⇒ Average time between each reversal





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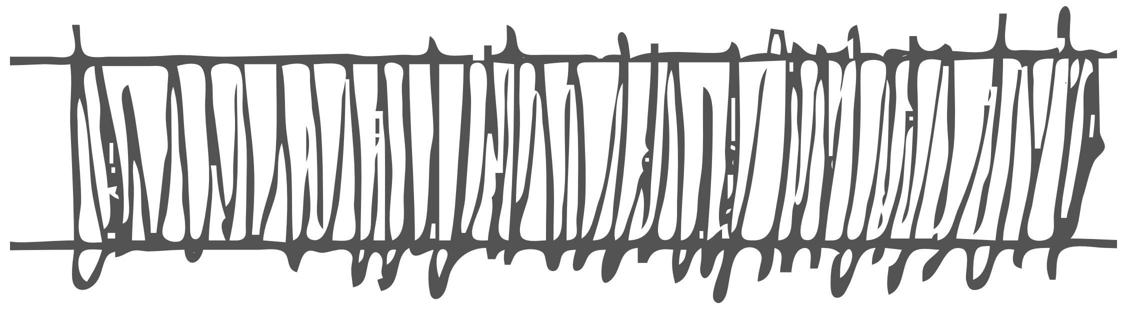
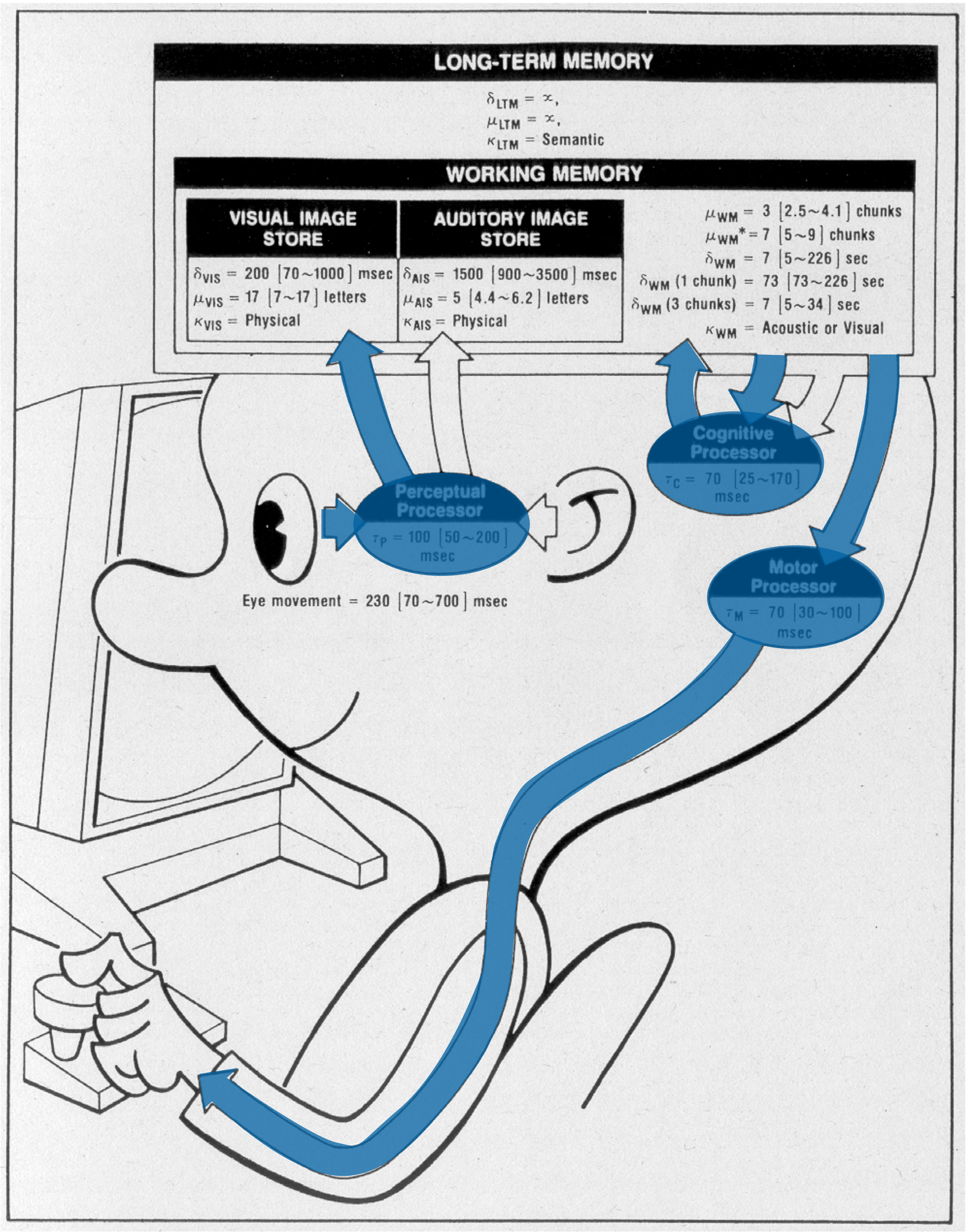
Motor System



74 ms/reversal
250 ms/correction

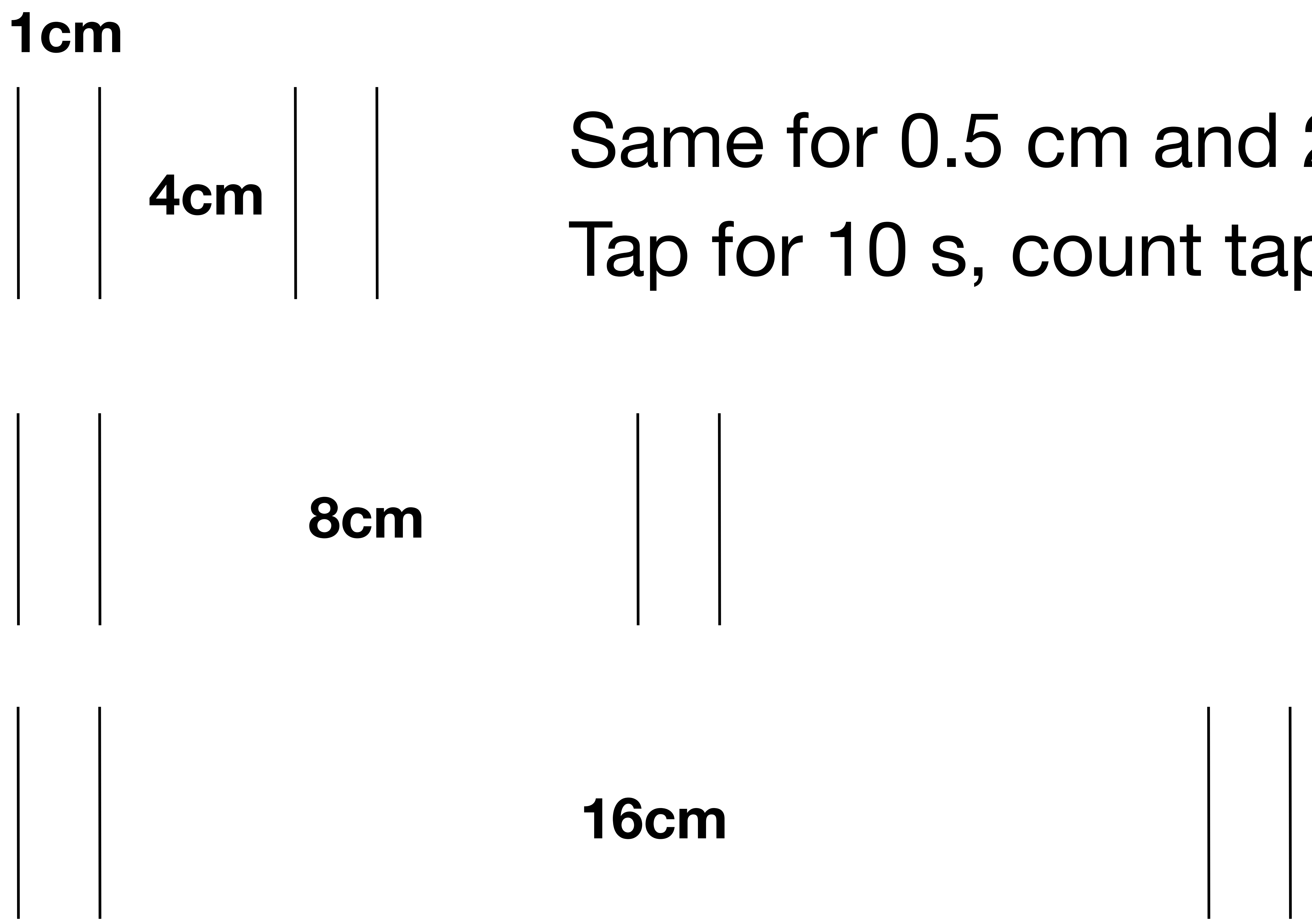
- Closed loop:
  - $\tau_P + \tau_C + \tau_M = 240$ ms

  $\Rightarrow$ Average time between each correction



Fitts' Law

In-Class Experiment 5: Tapping Task



Same for 0.5 cm and 2 cm wide strips

Tap for 10 s, count taps afterwards

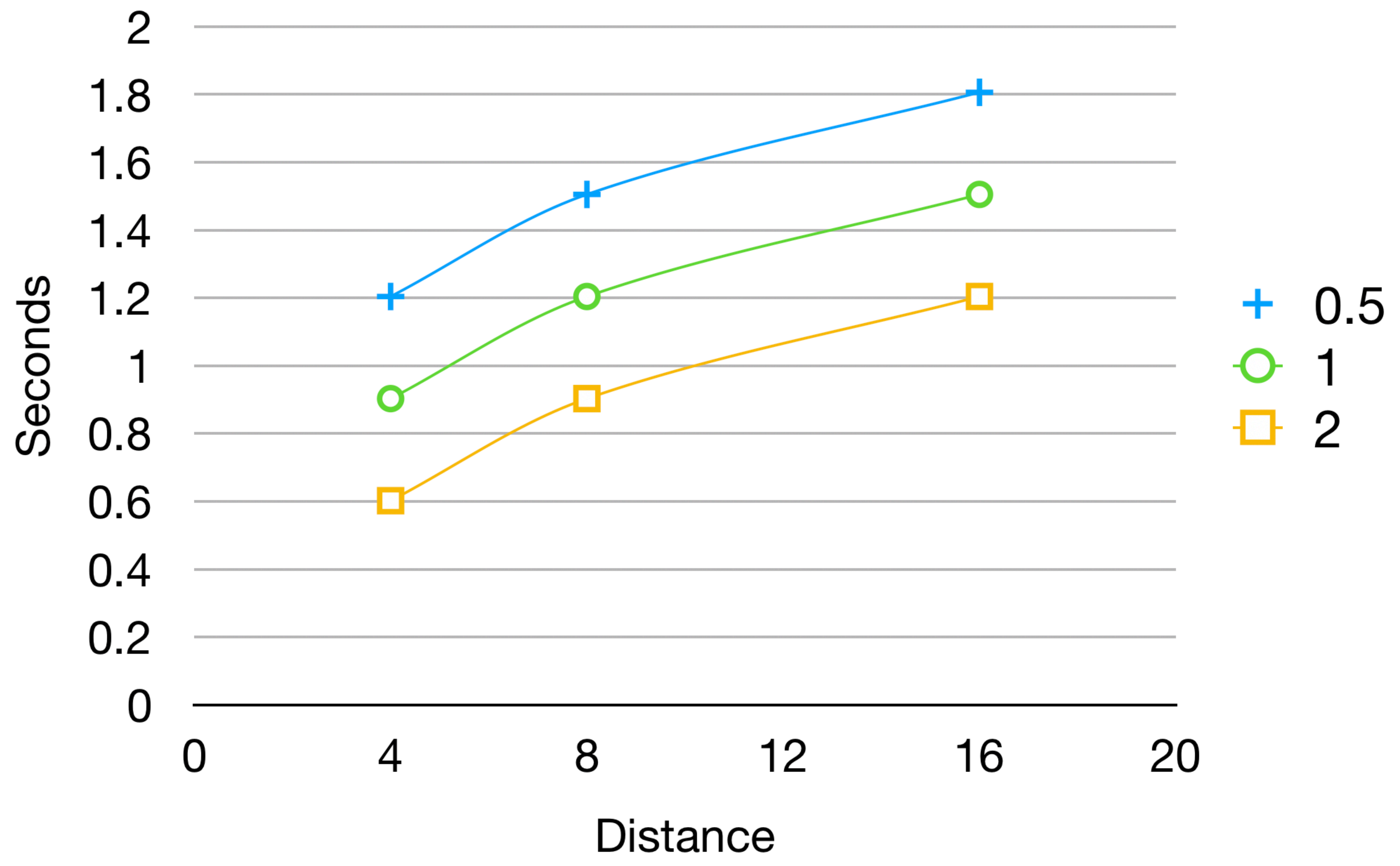
Tapping Task Results

- Doubling the distance adds roughly a constant to execution time

  ⇒ indicates logarithmic nature

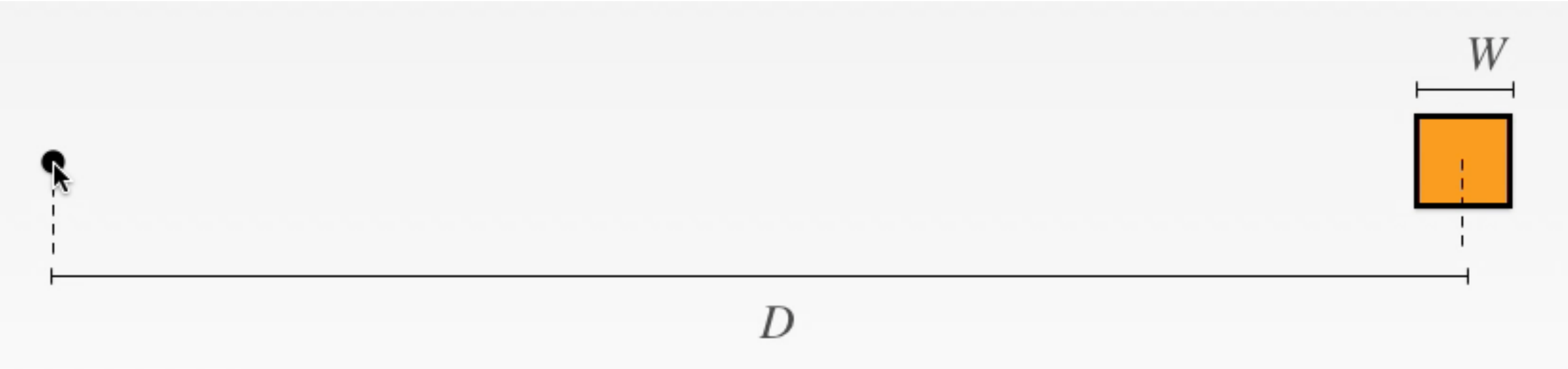
- Doubling the target width (W) gives about same results as halving the distance (D)

  ⇒ indicates connection of D/W in formula

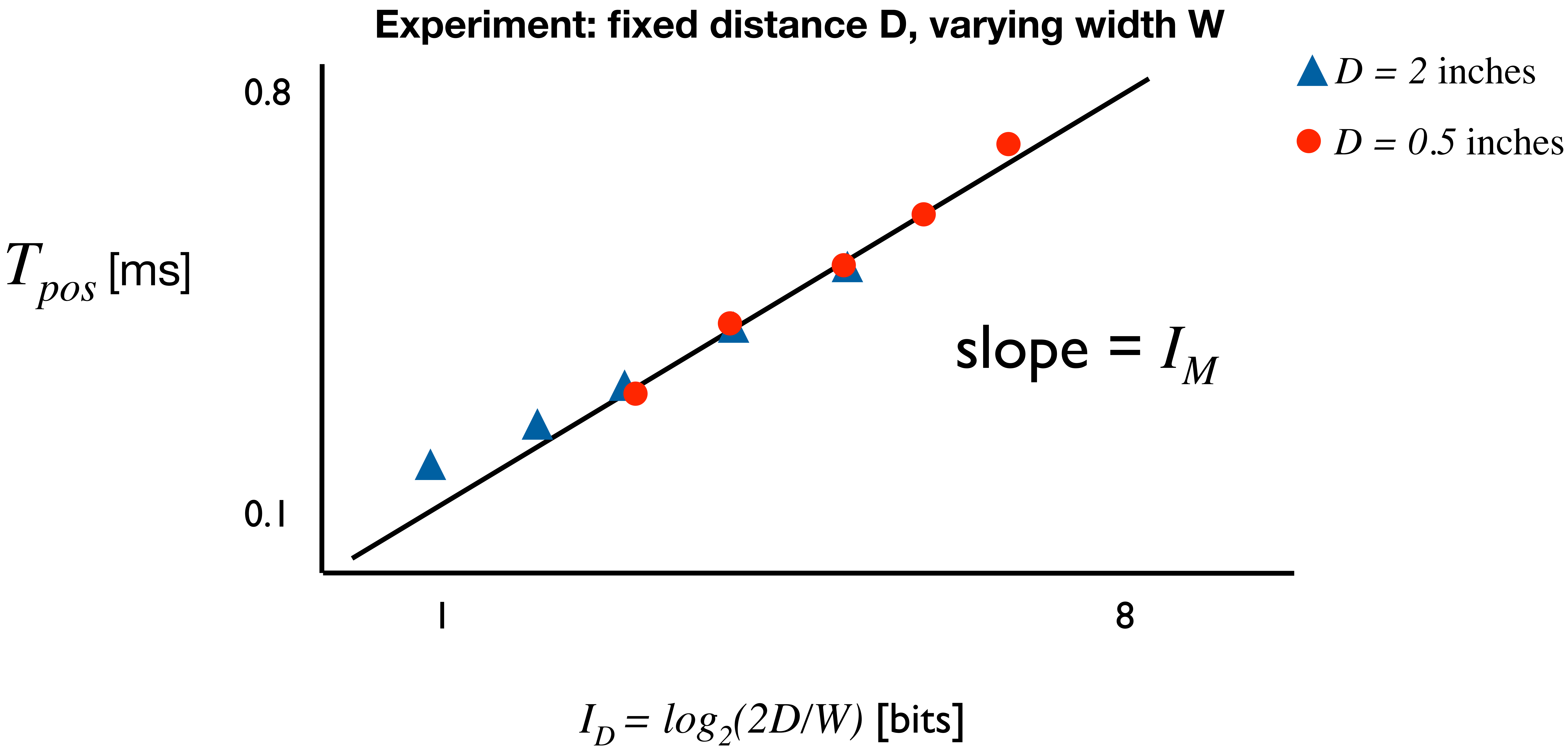


Motor System: Fitts' Law

- 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

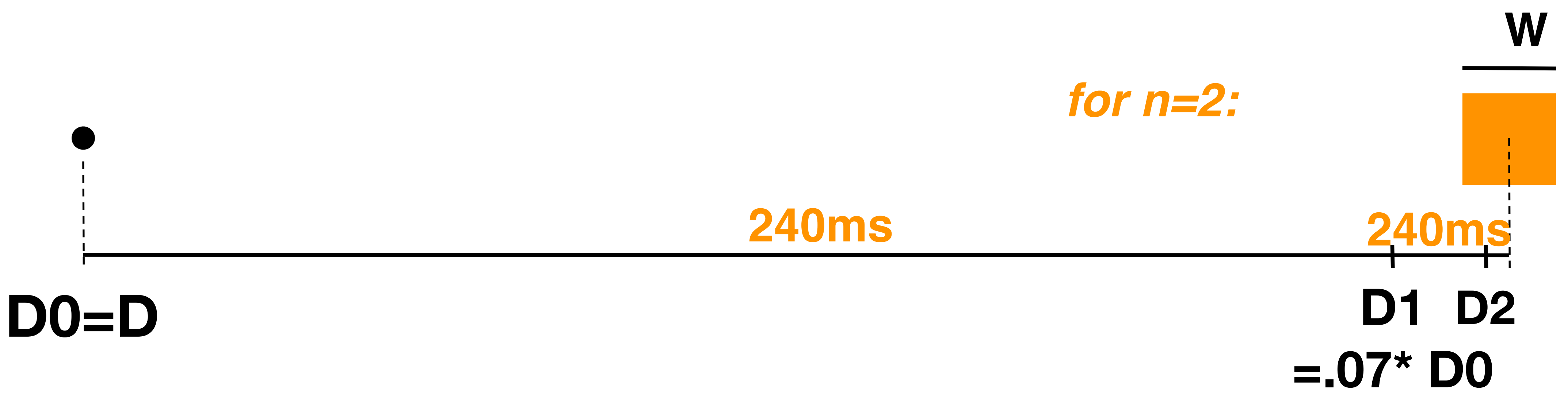


Deriving Fitts' Law from CMN (1)

$$D_i := \text{remaining distance to target after } i \text{ movements}$$

$$\epsilon := D_i / D_{i-1} < 1 \qquad \text{(relative movement precision, experiment shows)}$$

$$\epsilon = 0.07 \qquad \text{(constant according to CMN model)}$$



$$D_1 = \epsilon \cdot D_0 = \epsilon \cdot D$$

$$D_2 = \epsilon \cdot D_1 = \epsilon^2 \cdot D$$

$$\ldots$$

$$D_n = \epsilon \cdot D_{n-1} = \epsilon^n \cdot D \quad \leq W/2 \qquad \text{(hand reaches target after } n \text{ movements)}$$

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

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

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

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

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's 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:

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

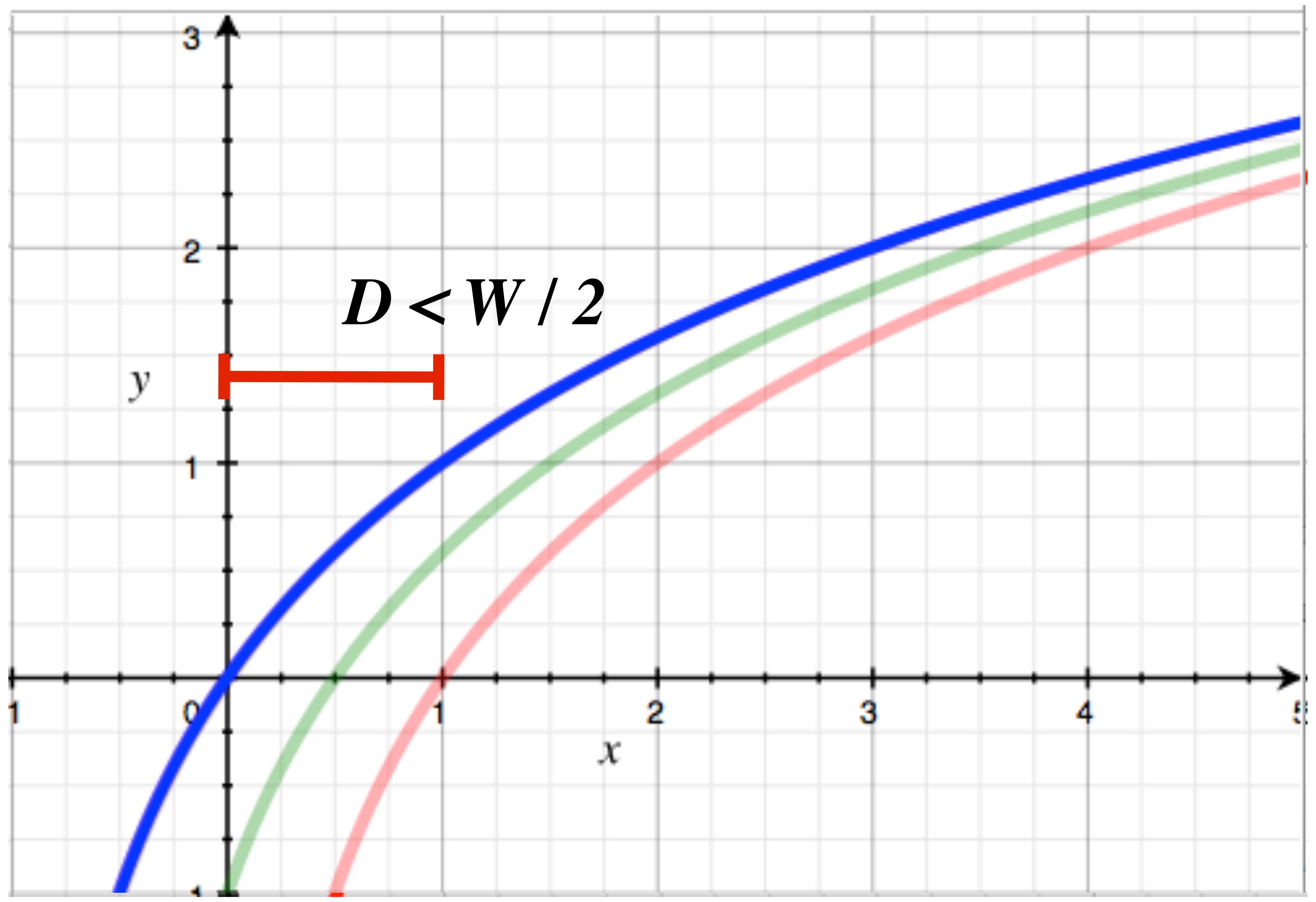
- Shannon's Formulation, ISO, 80's:

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

  - *a, b* depend on device, determine experimentally

Use *a = 0 ms, b =* I_M *= 100 ms* for quick and dirty estimates

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

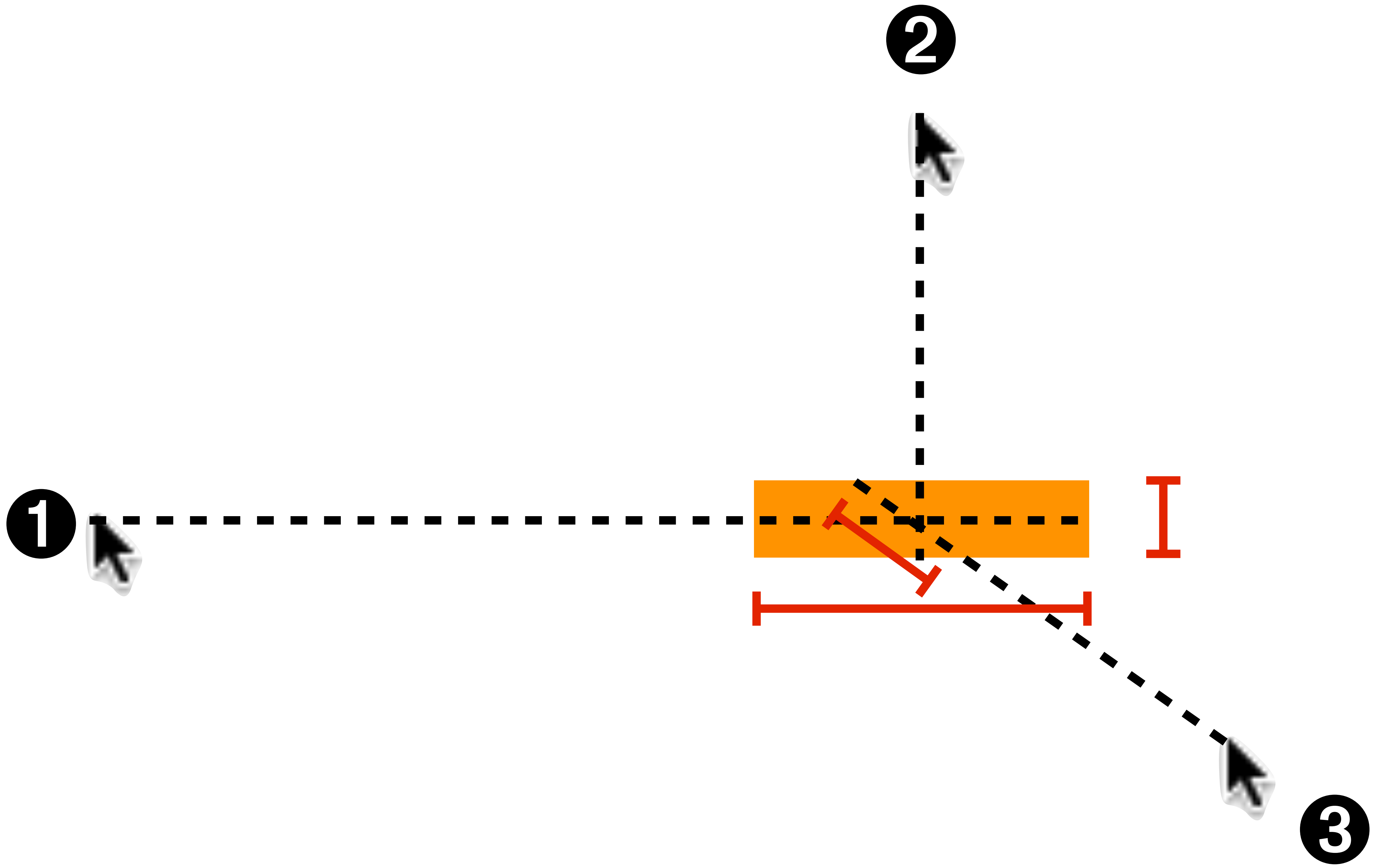


$$T_{pos} = I_M \cdot \log_2 \left(\frac{2D}{W} \right)$$

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

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

Target Width



[MacKenzie & Buxton, CHI’92]

Windows 10


Papierkorb
Laufwerktools
Dieser PC
Datei
Computer
Ansicht
Verwalten
Dieser PC
"Dieser PC" durchsuchen
Schnellzugriff
Desktop
Downloads
Dokumente
Bilder
DVD-RW-Laufwerk
Gespeicherte Bilder
Musik
Videos
OneDrive
Dieser PC
Netzwerk
Ordner (6)
Bilder
Desktop
Dokumente
Downloads
Musik
Videos
Geräte und Laufwerke (2)
Lokaler Datenträger (C:)
224 GB frei von 464 GB
DVD
DVD-RW-Laufwerk (E:)
8 Elemente
1 Element ausgewählt
Frag mich etwas
18:25
16.07.2015

Finder File Edit View Go Window Help

Tue 11. Oct 09:51

macOS Monterey

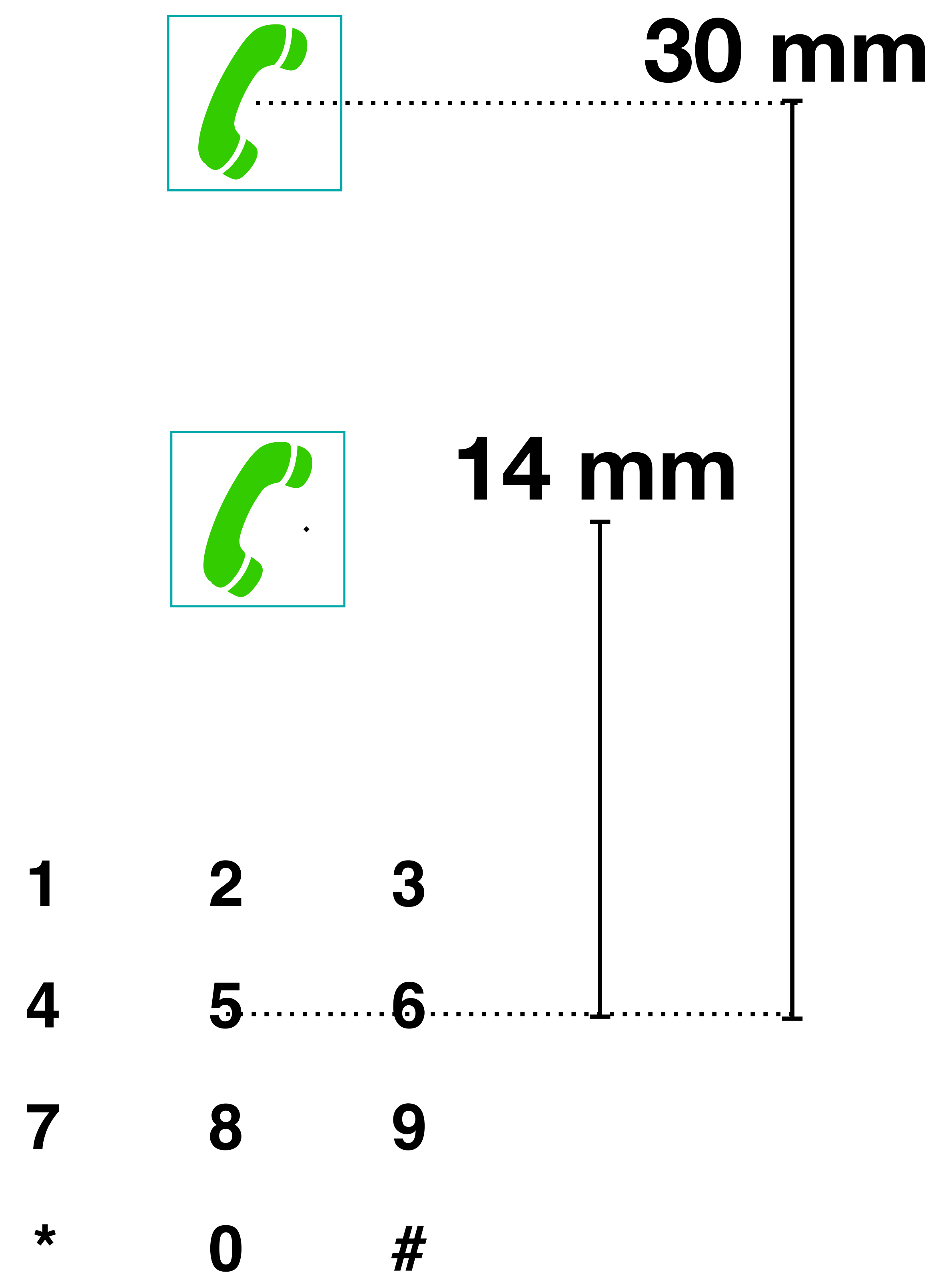
DIS1

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

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



Solution

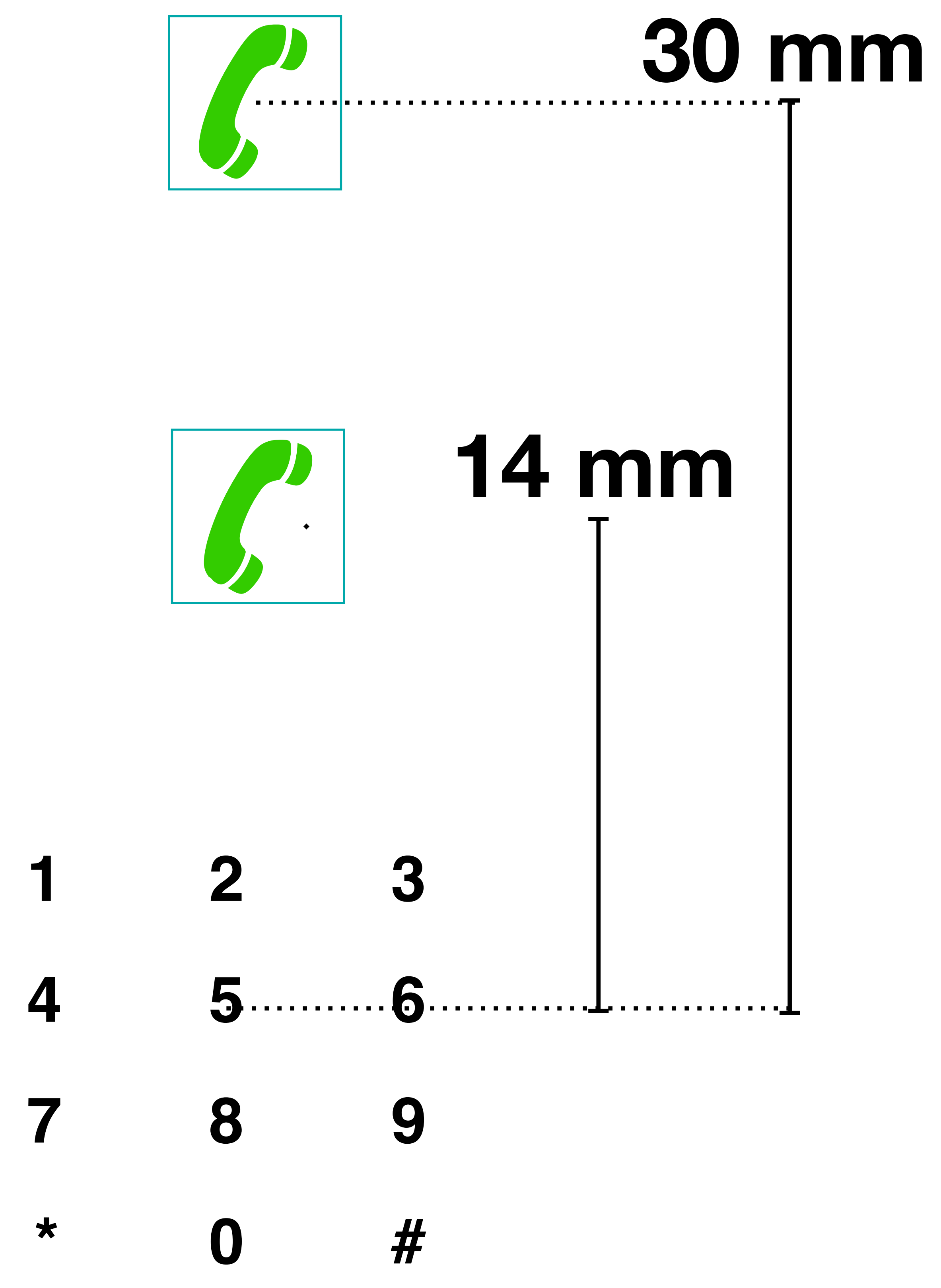
$$T_{pos1} = a + b \cdot \log_2(\frac{D_1}{W} + 1) \qquad T_{pos2} = a + b \cdot \log_2(\frac{D_2}{W} + 1)$$

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

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

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

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



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

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`

Before next Lab on Tuesday

- Buy Don Norman's The Design of Everyday Things (2nd edition, 2013)