Designing Interactive Systems I

Introduction, The CMN Model, Fitts' Law

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

Winter Semester ’22/’23

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

- Interaction with audio & video
- Wearable & Tangible UIs, Personal Fabrication, IDEs,…

Our Team

Ricarda Rahm, M. Sc.
rahm@cs.rwth-aachen.de

Marcel Lahaye, M. Sc.
lahaye@cs.rwth-aachen.de

The Question Flow Chart :)

Does it contain matters of personal concern?

- No (Default) → RWTHmoodle Forum
- Yes → Email with the subject prefix **[DIS1]** to Ricarda & Marcel (Not Jan 😉)

Alternatively: A quick chat after the lecture ☕

Human–Computer Interaction?

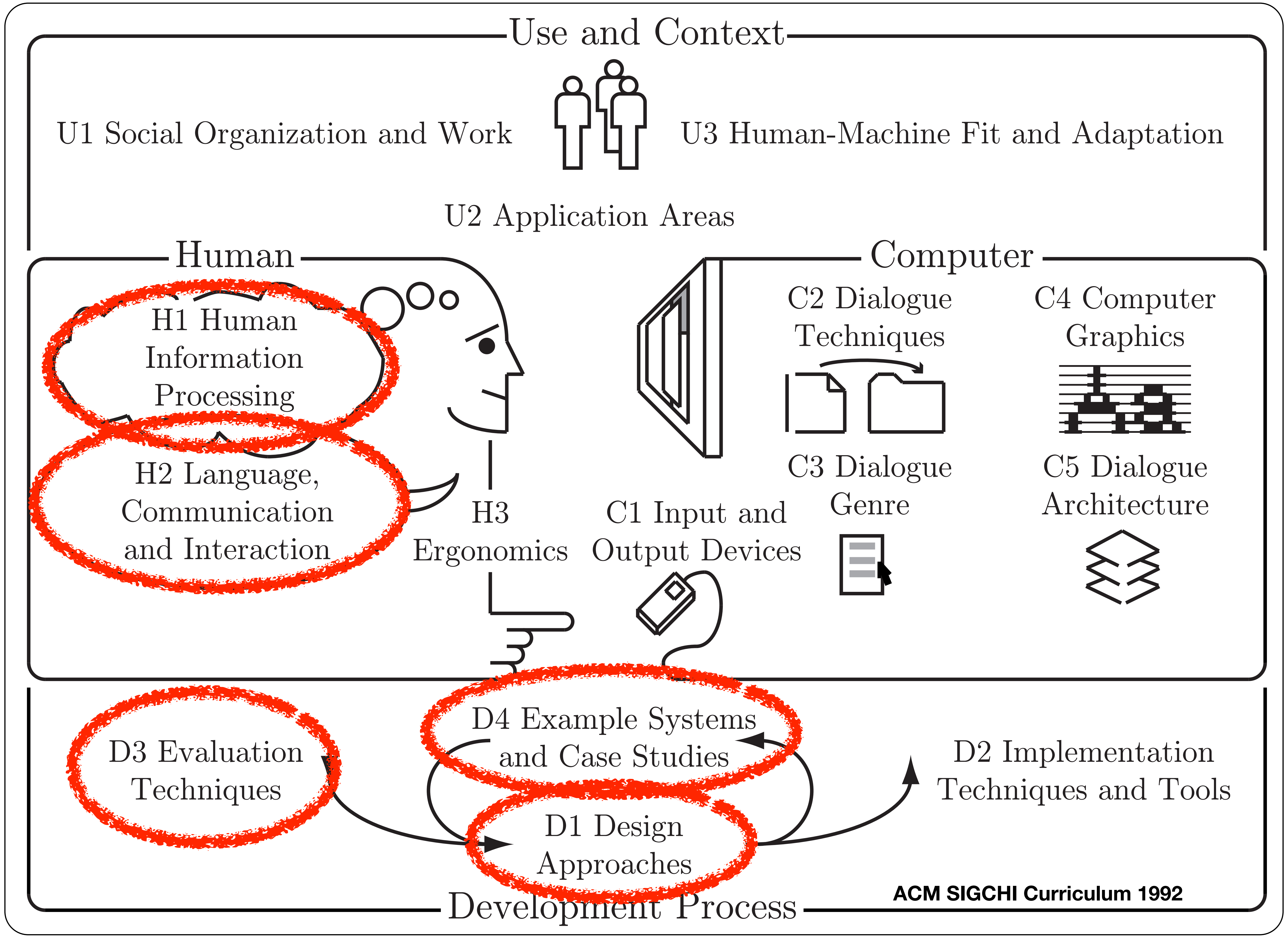
Source: https://ux.stackexchange.com/questions/15471/any-actual-reason-for-complicated-uis/15479

Source: https://www.pexels.com/de-de/foto/mann-hande-laptop-macbook-3777572/

Source: Yovko Lambrev - commons.wikimedia.org

Usability Sells!

What is HCI?



Use and Context
U1 Social Organization and Work
U3 Human-Machine Fit and Adaptation
U2 Application Areas
Human
Computer
H1 Human Information Processing
H2 Language, Communication and Interaction
H3 Ergonomics
C1 Input and Output Devices
C2 Dialogue Techniques
C3 Dialogue Genre
C4 Computer Graphics
C5 Dialogue Architecture
D4 Example Systems and Case Studies
D3 Evaluation Techniques
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

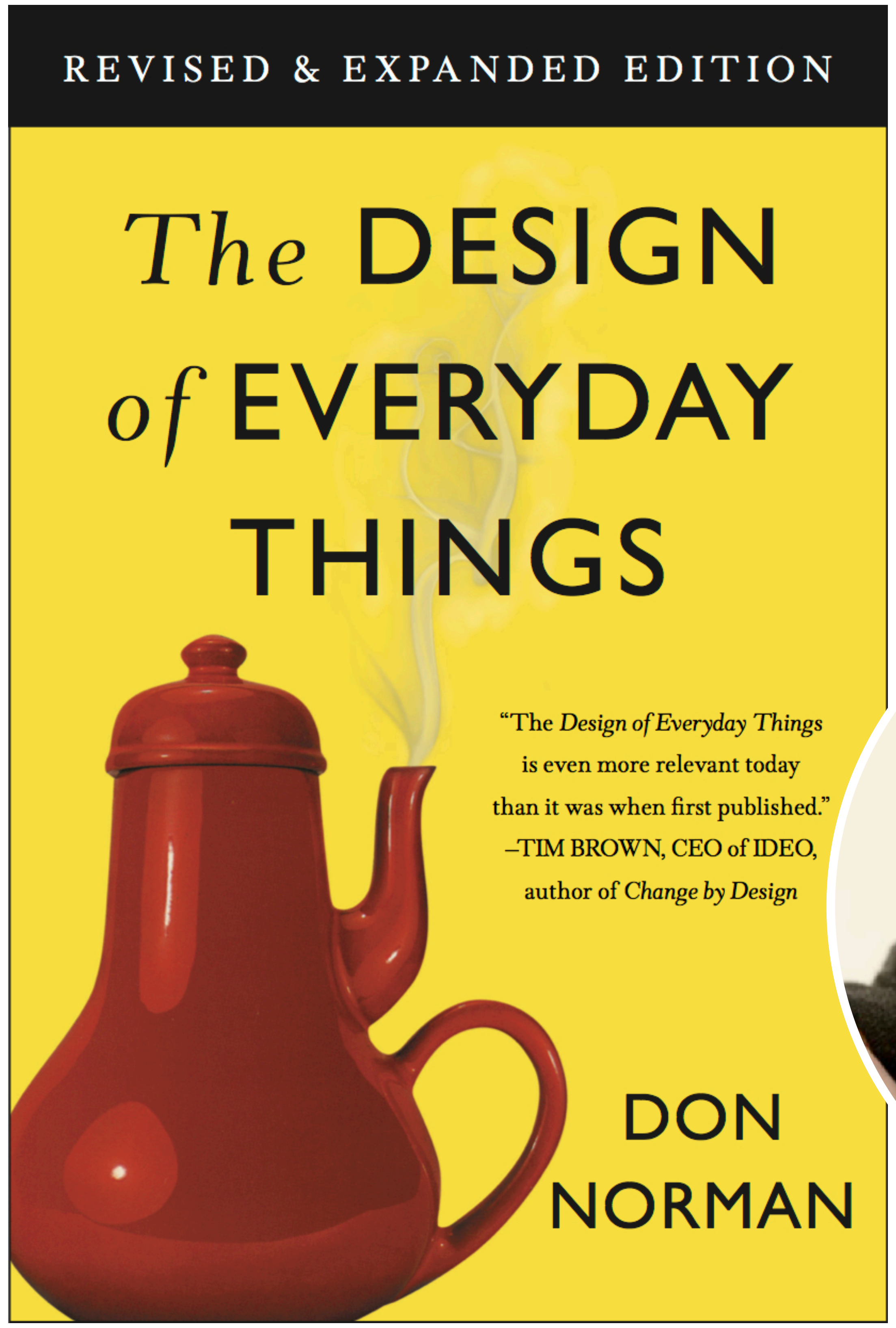
Development Process

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

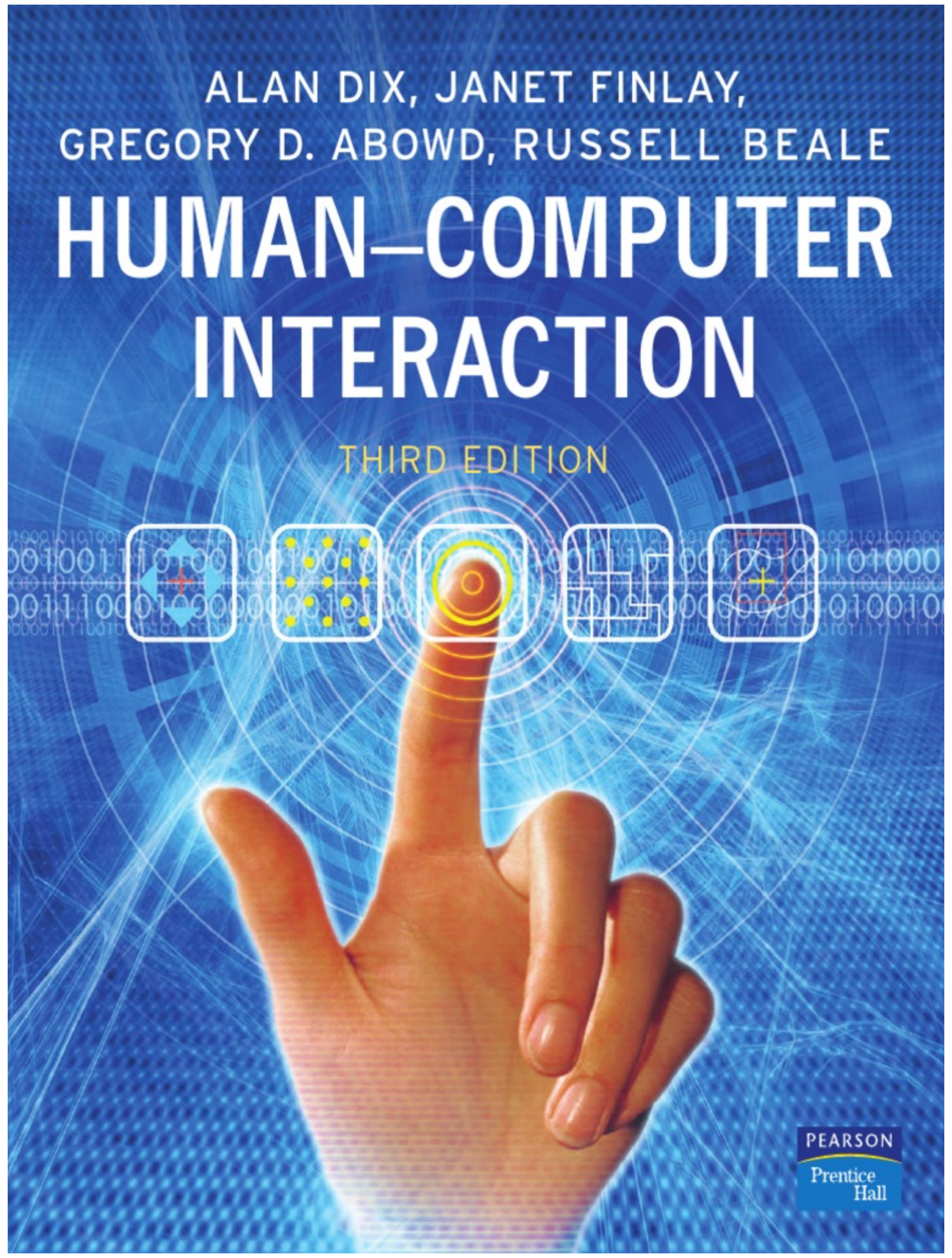
For more details, see www.hci.rwth-aachen.de/dis#syllabus.

Textbooks

Required Read



Recommended Read



Media Computing Group

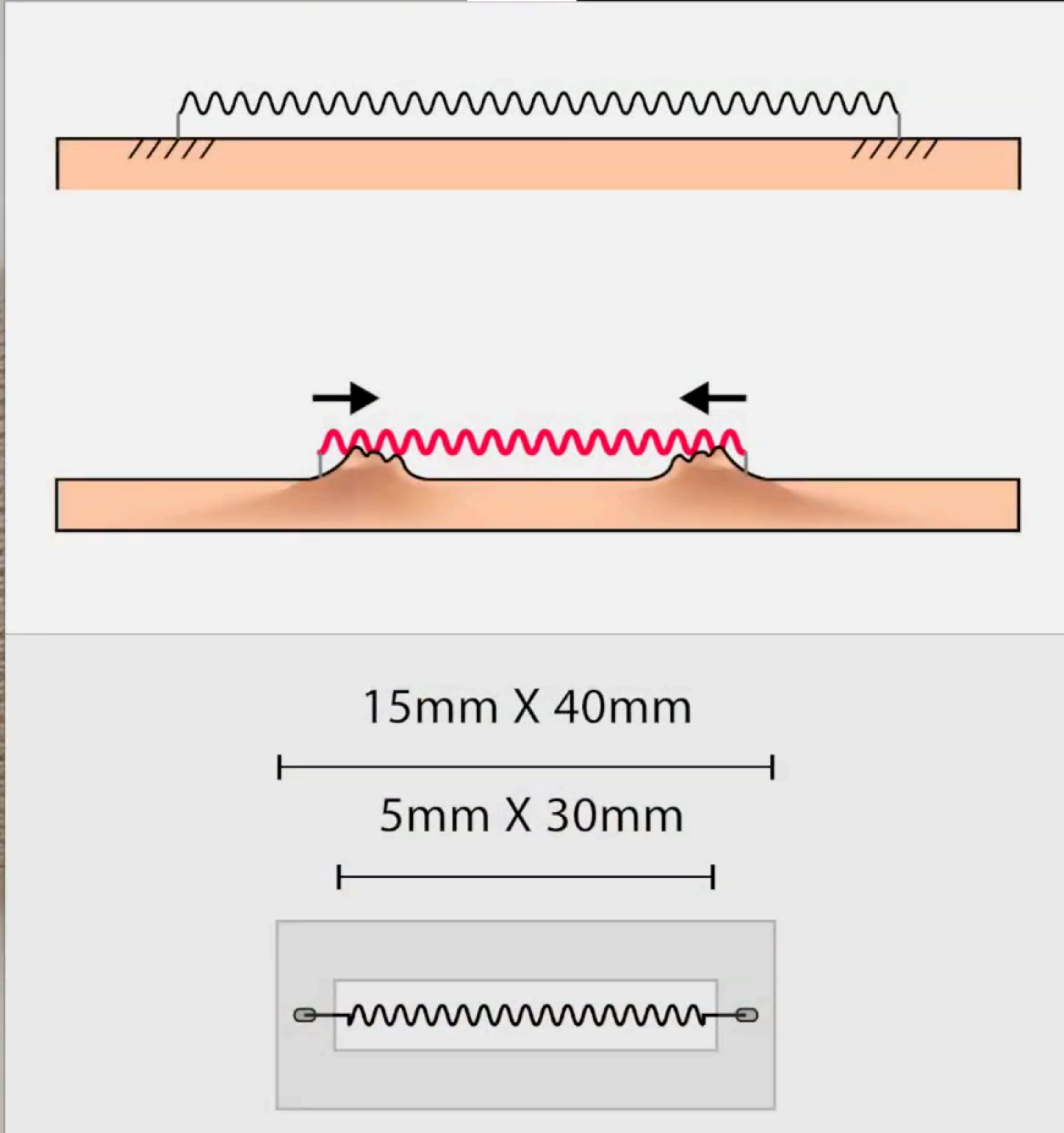
Our Classes

When?	Type	Credits (ECTS)	Name
WS, SS	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

https://hci.rwth-aachen.de/arpen

Springlets



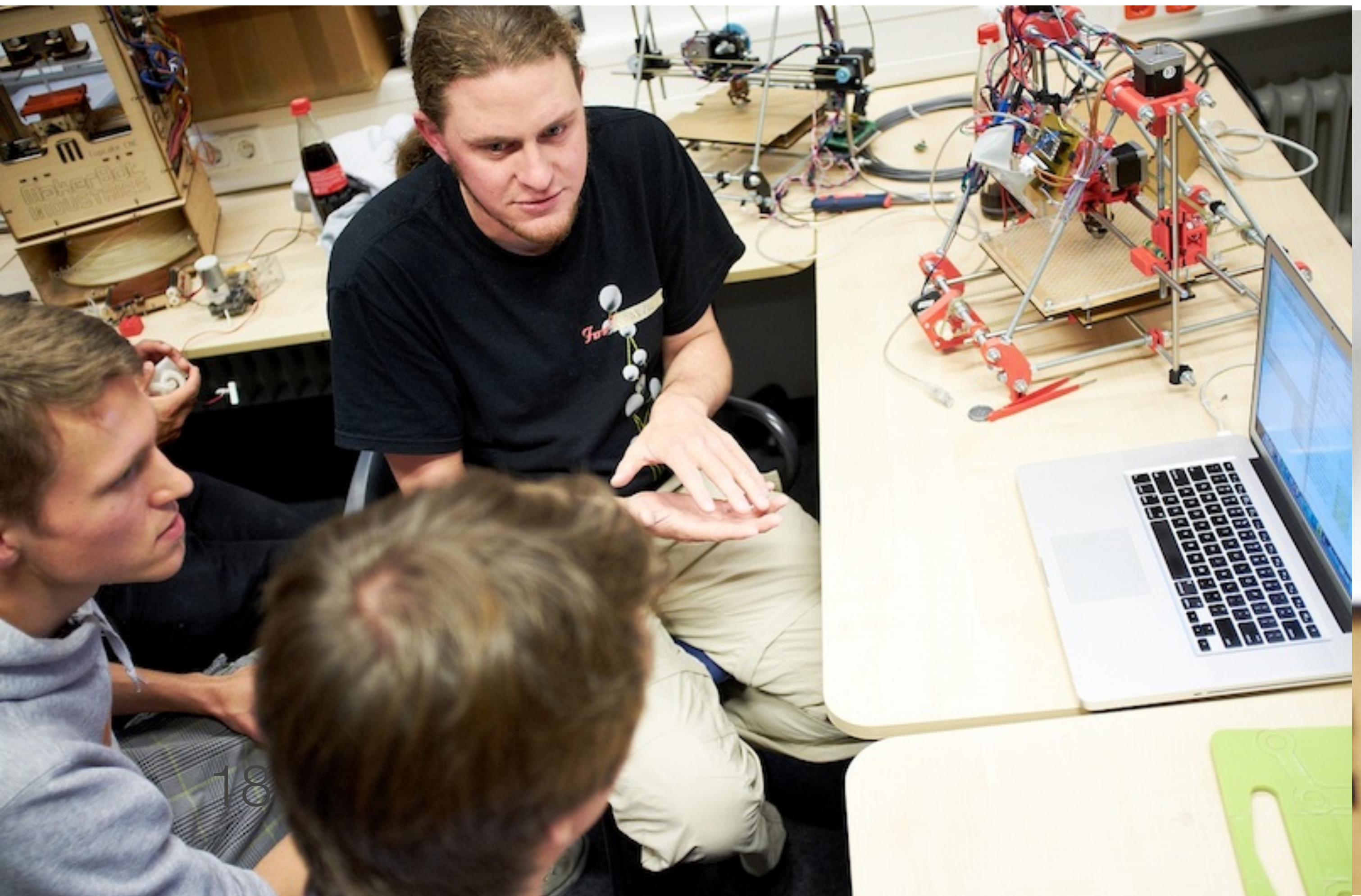
https://hci.rwth-aachen.de/springlets

Student project "Safe" from M3, SS 2019

https://hci.rwth-aachen.de/m3

Aachen Maker Meetup

- People doing strange things with electricity in Aachen
- 3rd Wednesday every month
  Next event: **Oct. 19, 18:30**
- Sign up here: https://www.meetup.com/Aachen-Maker-Meetup/




CocoaHeads Aachen

- CocoaHeads: International meet-ups about Apple's Cocoa Framework for macOS and iOS
- Last Thursday every month
- Sign up here: https://www.meetup.com/cocoaheads_ac/

Course Structure

Course Structure

Lecture

Interactive classes with Prof. Borchers

Lab

- Assignments handed in in groups of three
- Discuss lecture content and assignments

Oct 18th – Nov 29th

Midterm
13:00-15:00
Dec 6th

UX Project

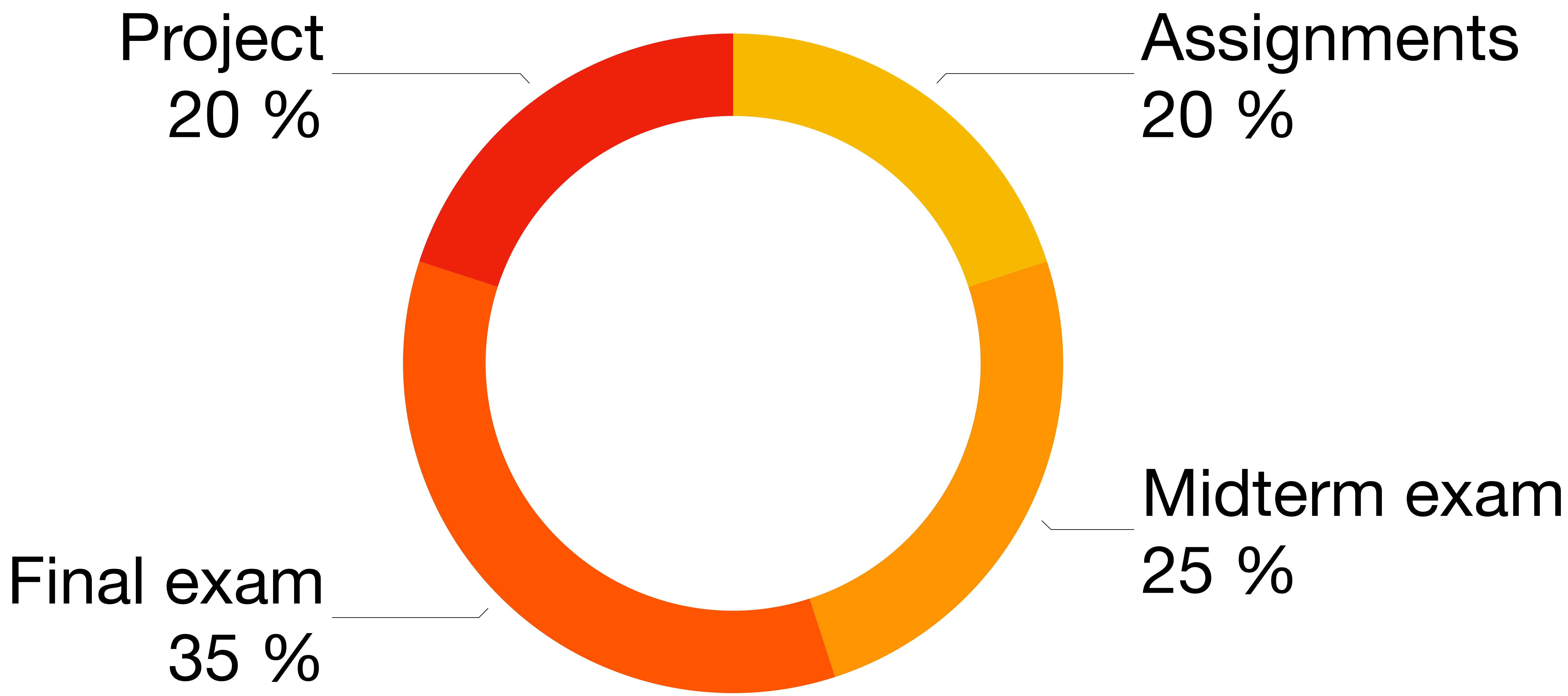
- Create your own UX project in a group of six
- Finally, showcase your project in a video

Dec 13th – Jan 31st

Final Exam
Feb 10th

Final Exam
Mar 17th

Final Grade Distribution



! To pass the course, you must pass the final exam and have an average grade of at least 4.0

Registering for this Class

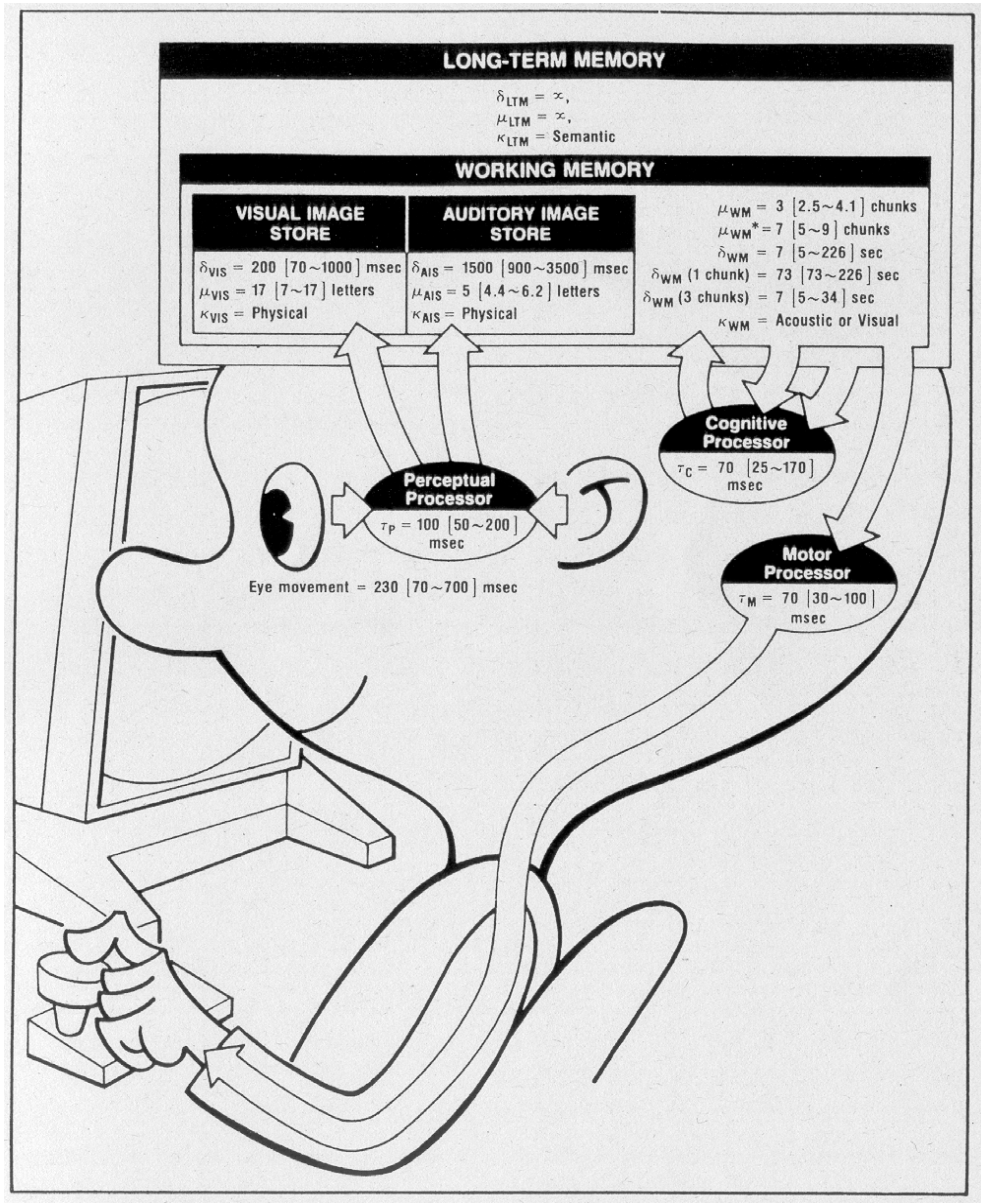
- Limited to **120 seats**
  - Register via RWTHonline and send the Declaration of Compliance to us **today**
- Erasmus students, and others who cannot register via RWTHonline:
  Email Ricarda & Marcel your matriculation number and full name from your official @rwth-aachen.de email-address
- **Email subject: [DIS1] Registration <your name>**

The Human

Model Human Processor

Model Human Processor

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

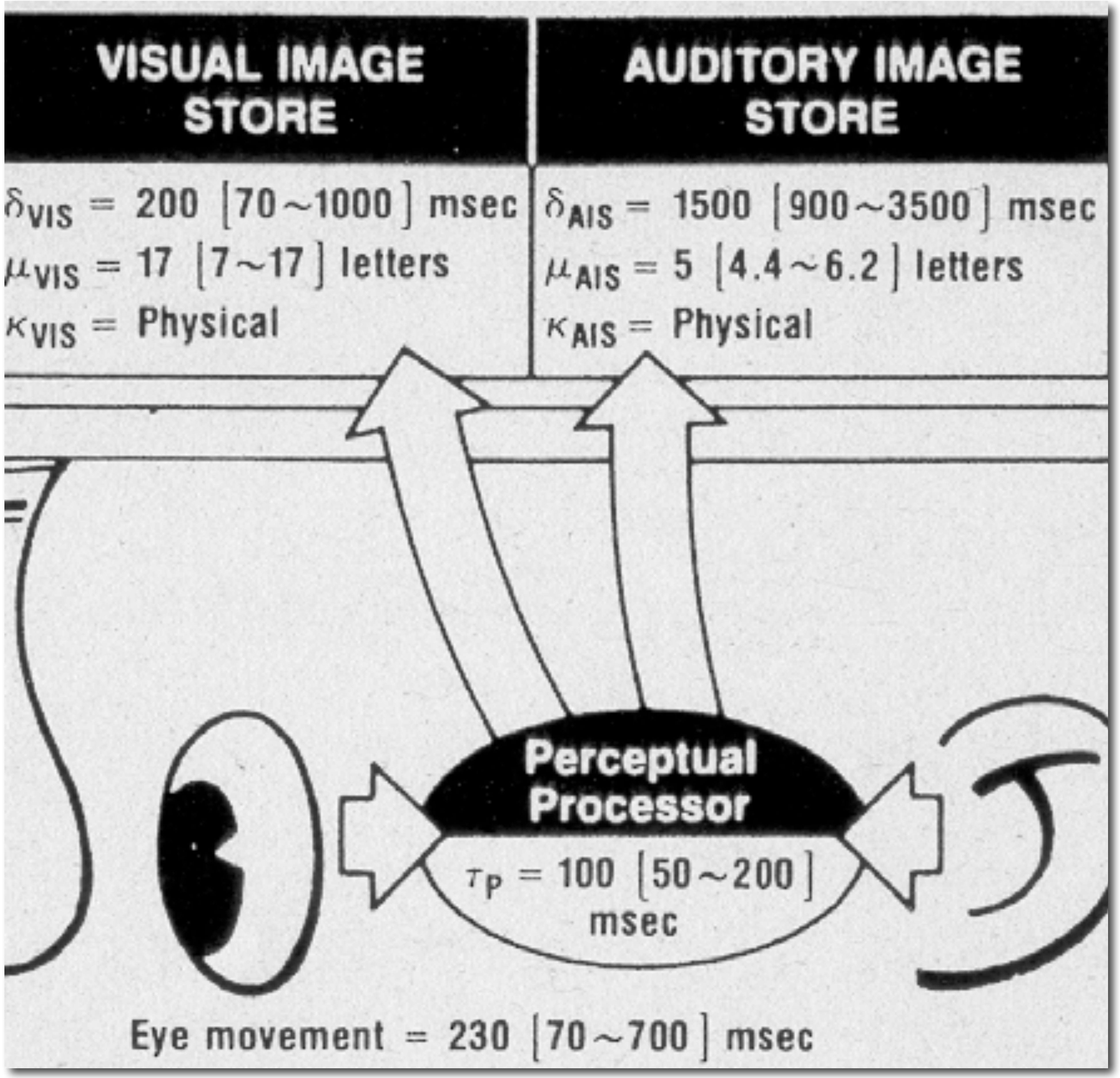


In-Class Experiment 1: Perceptual Processor

- 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



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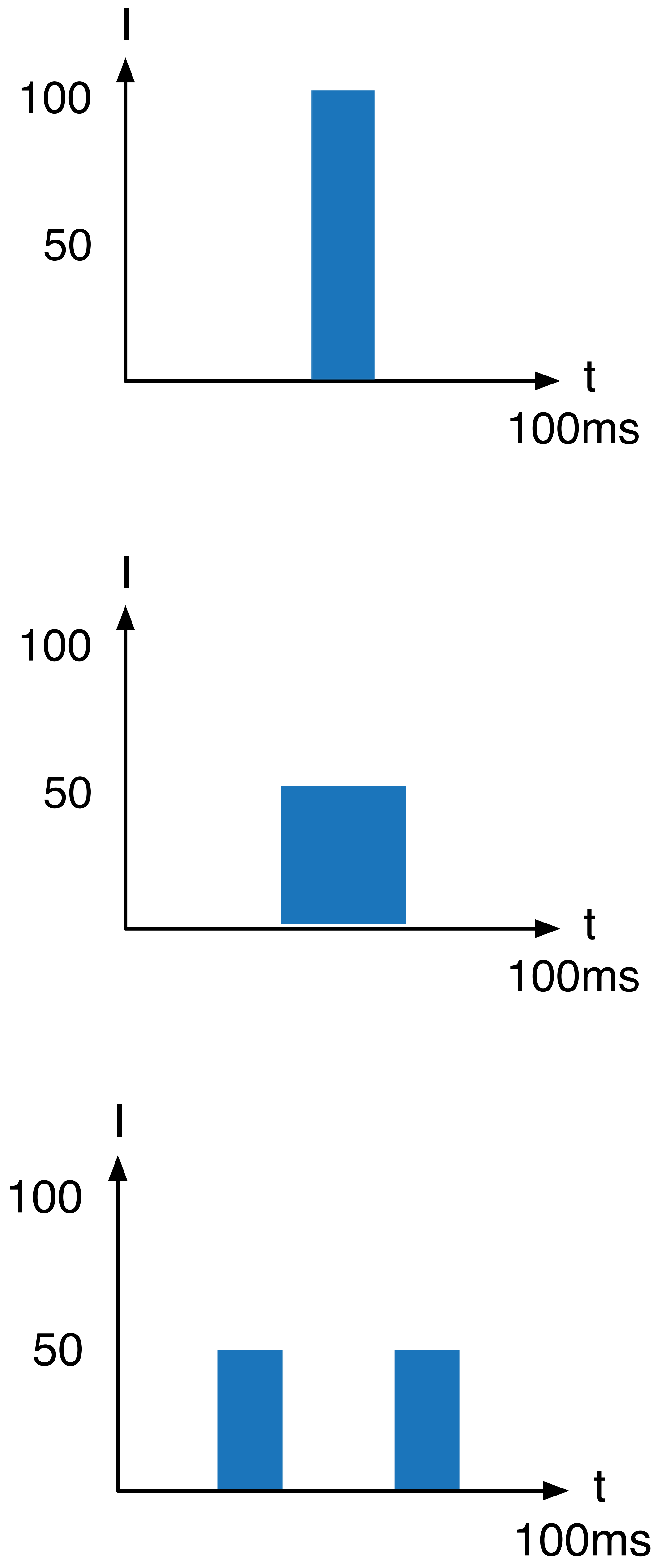
Perceptual Processor

- 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 2: Bloch’s Law

A

In-Class Experiment 2: Bloch's Law

B

In-Class Experiment 2: Bloch's Law

C

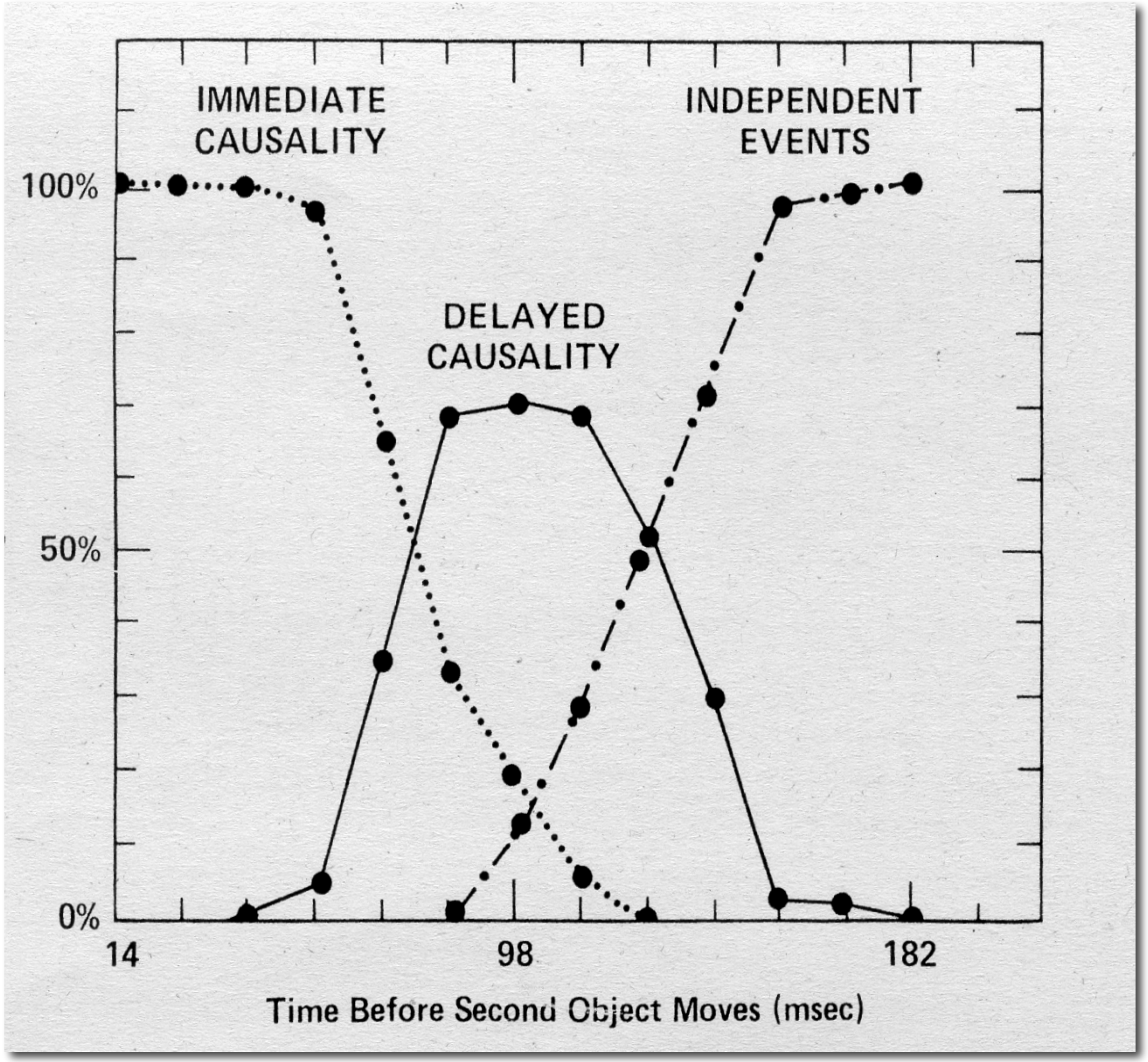
A: 0 ms delay

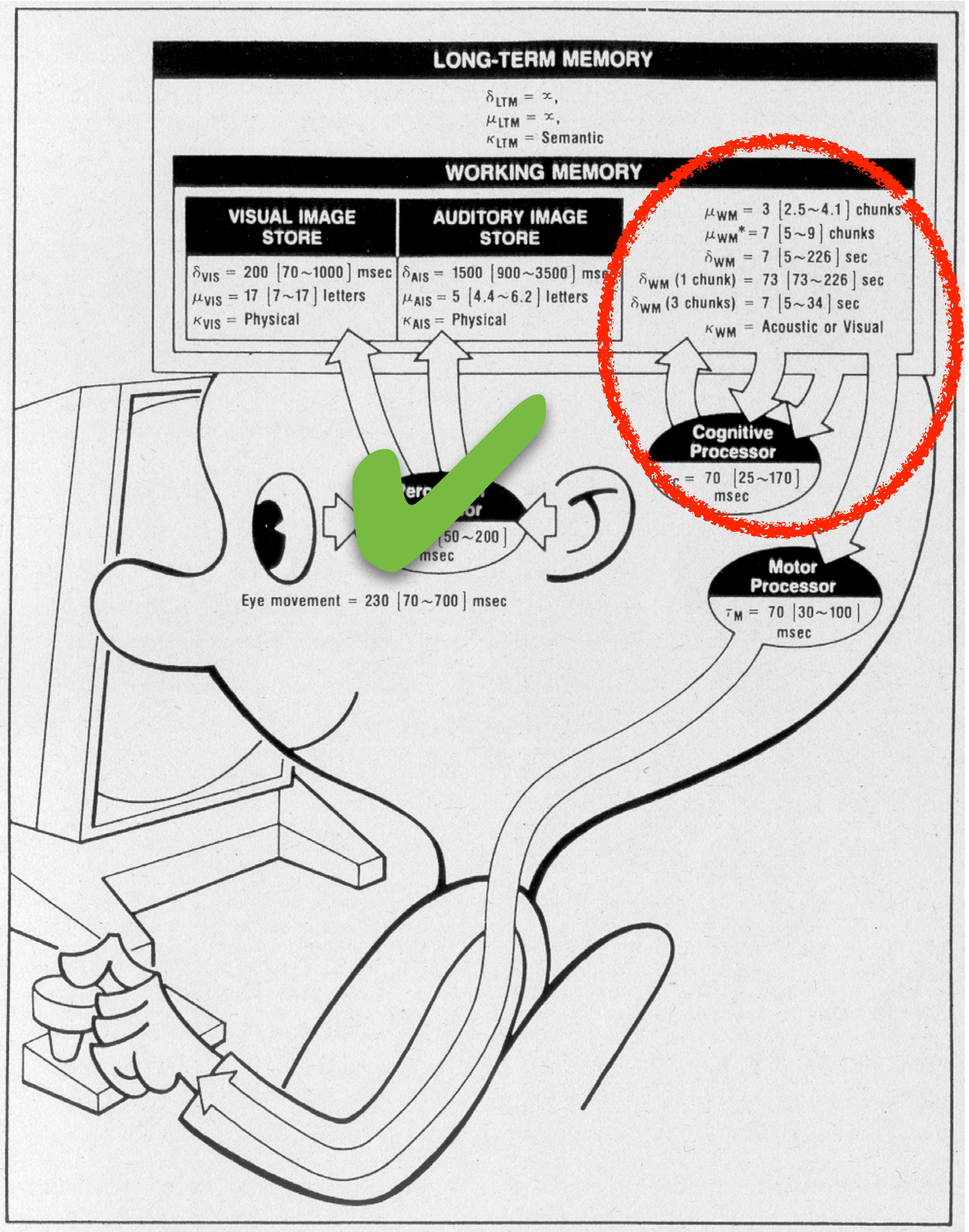
B: 50 ms delay

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



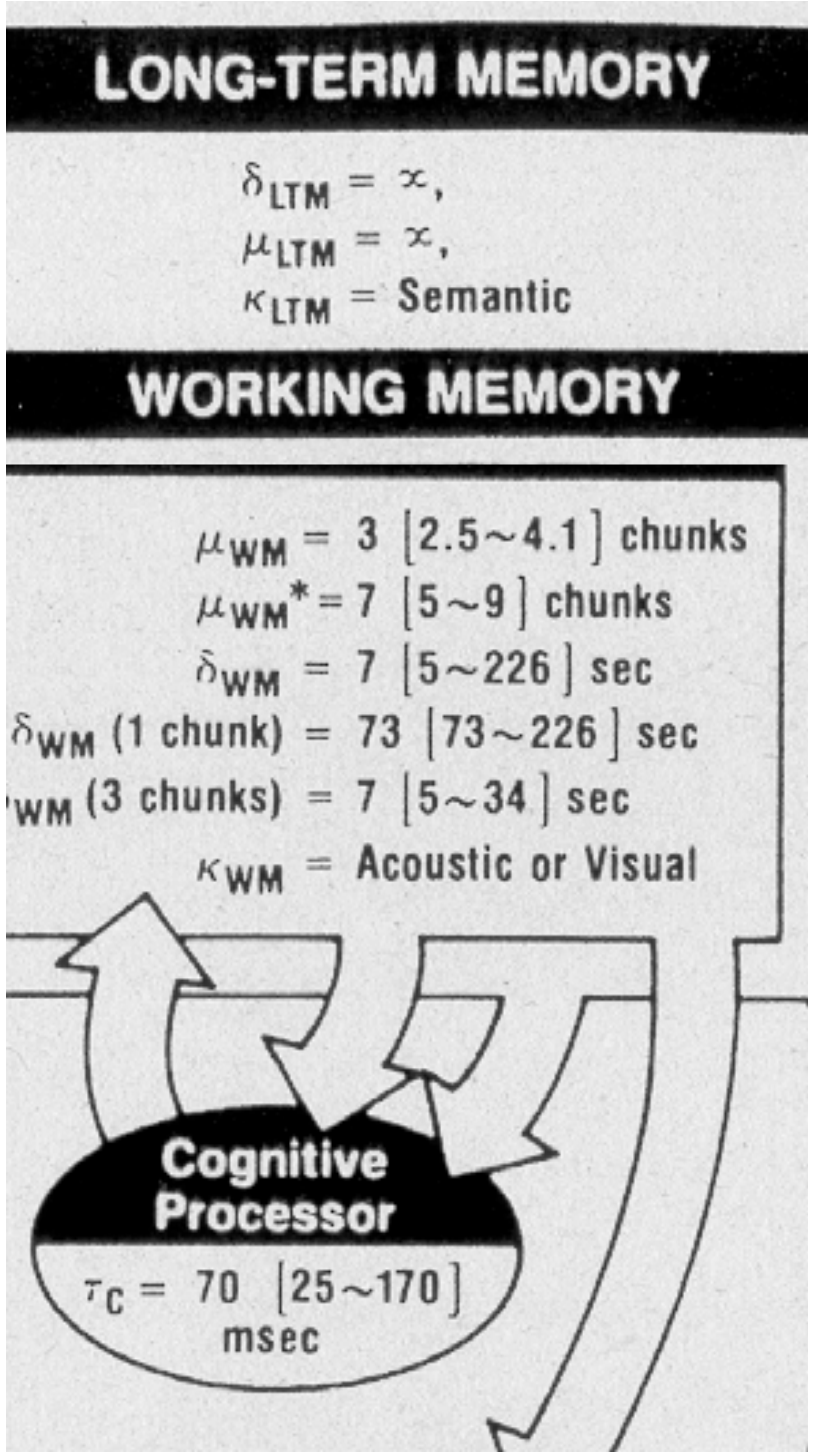

LONG-TERM MEMORY
δLTM = ∞,
μLTM = ∞,
κLTM = Semantic
WORKING MEMORY
VISUAL IMAGE STORE
δVIS = 200 [70~1000] msec
μVIS = 17 [7~17] letters
κVIS = Physical
AUDITORY IMAGE STORE
δAIS = 1500 [900~3500] msec
μAIS = 5 [4.4~6.2] letters
κAIS = Physical
μWM = 3 [2.5~4.1] chunks
μWM* = 7 [5~9] chunks
δWM = 7 [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 3: 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

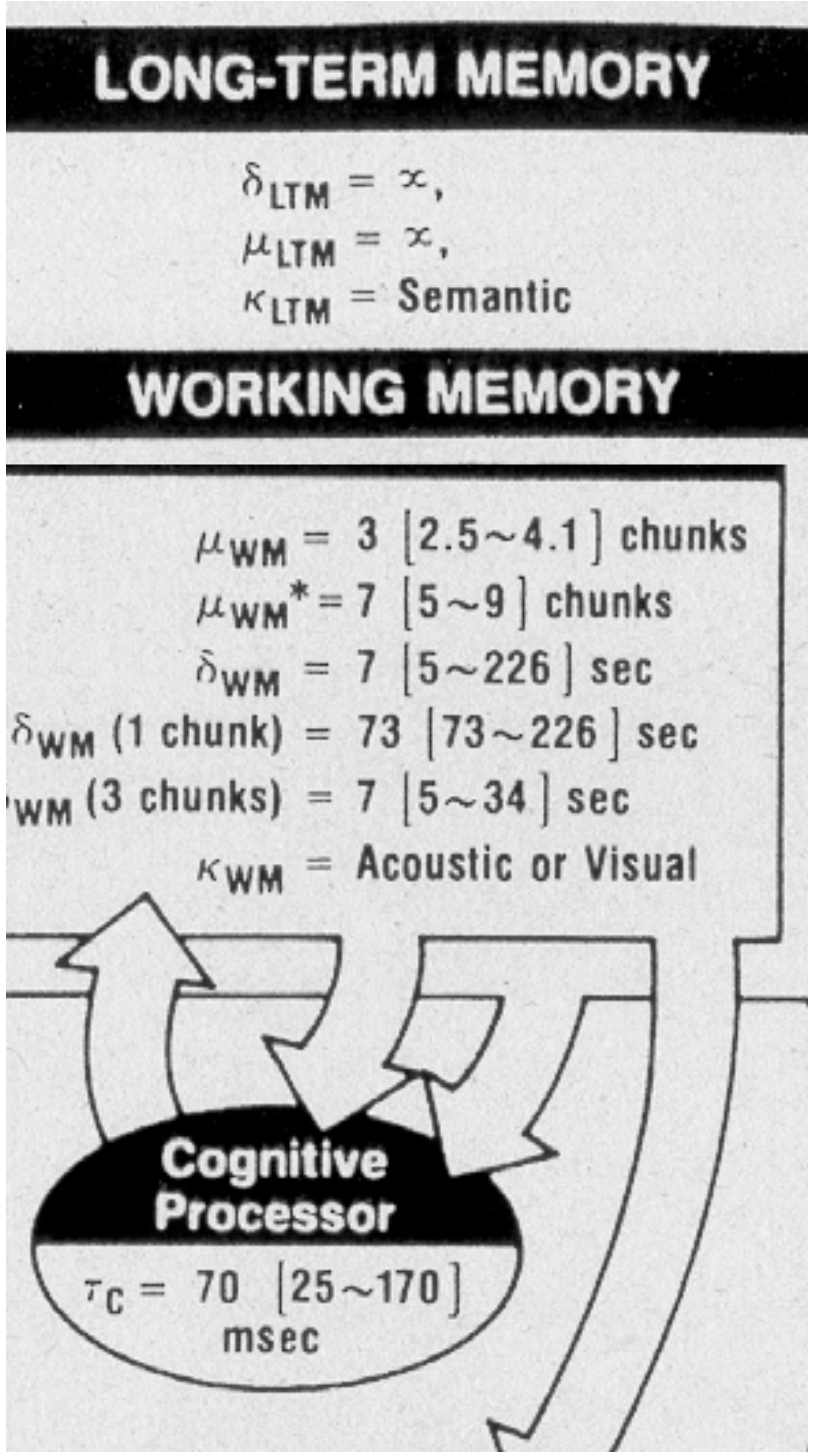
- Chunks depend on user & task
- Working memory:
    - Capacity: μ_{WM} = 7 ± 2 chunks (Miller '56)
    - Half life: $\delta_{1,WM}$ = 73 s (1 chunk)
$\delta_{3,WM}$ = 7 s (3 chunk)
    - Visual/acoustic encoding
- In 2001, Nelson Cowen showed that μ_{WM} is actually 4±1 chunks.



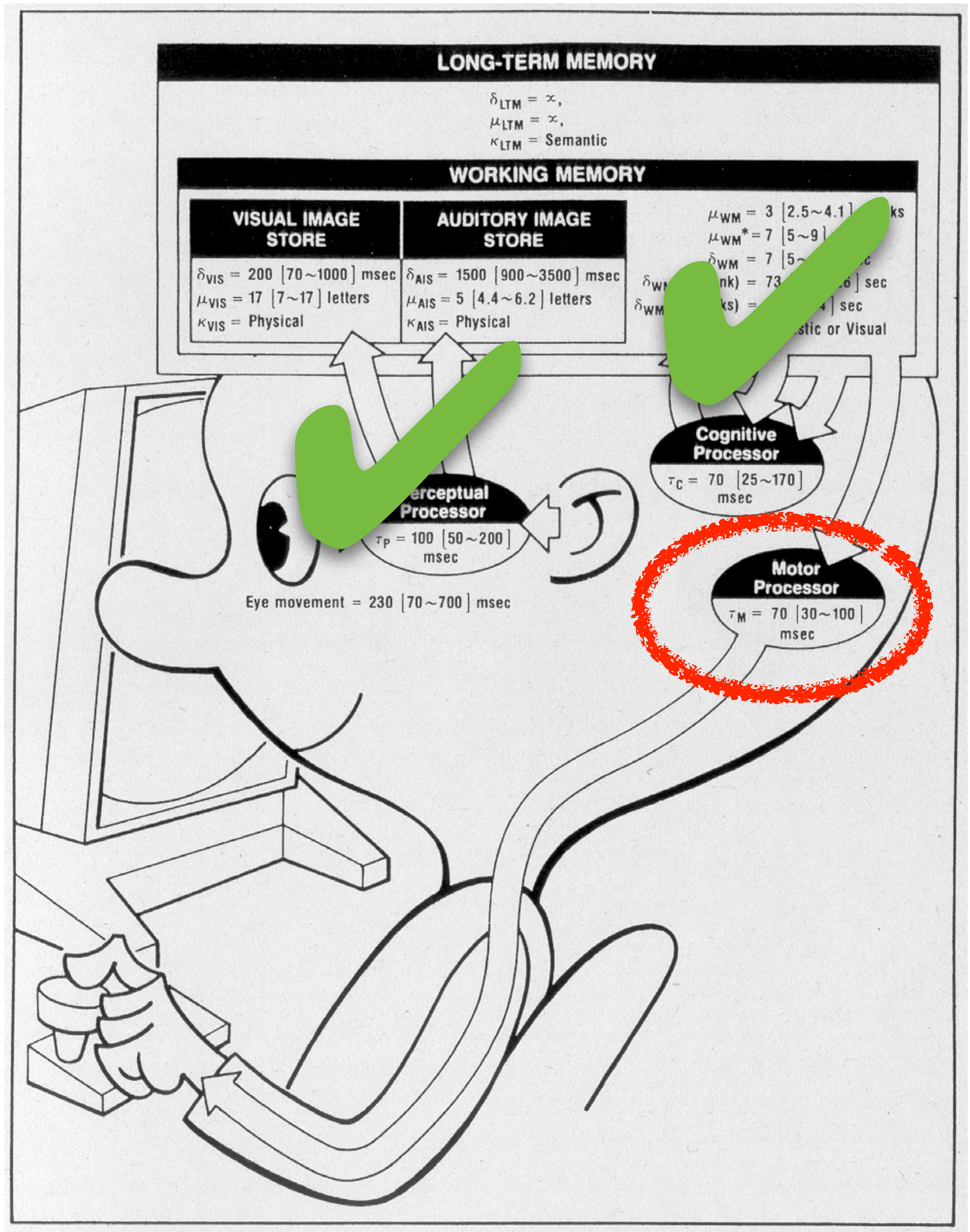
Cognitive System

- 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)



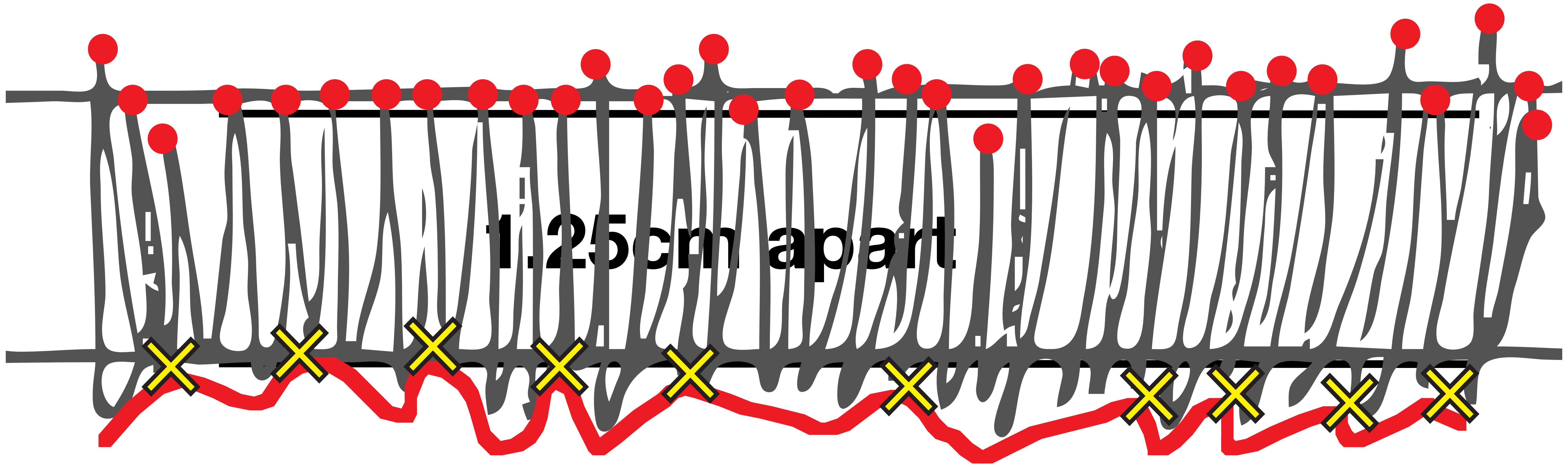
Model Human Processor



In-Class Experiment 4: Motor System

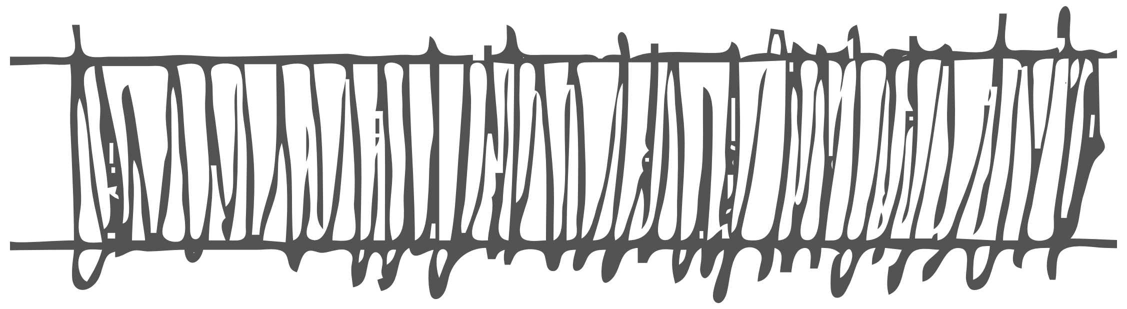
- Experiment: draw strokes between lines for 5s. Try to reach both lines.
- Count number of reversals
  - How many milliseconds per reversal?
- Create a contour of stroke bottoms, count number of corrections
  - How many milliseconds per correction?

34 reversals/side = 68 total reversals



10 corrections/side = 20 total corrections

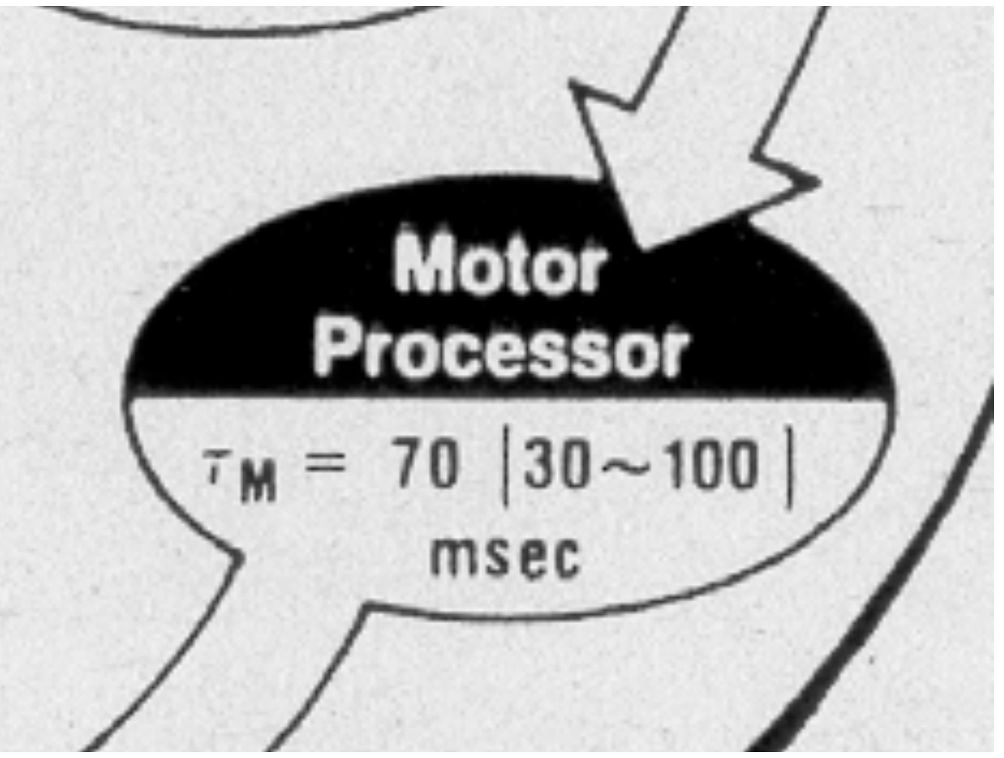
Motor System

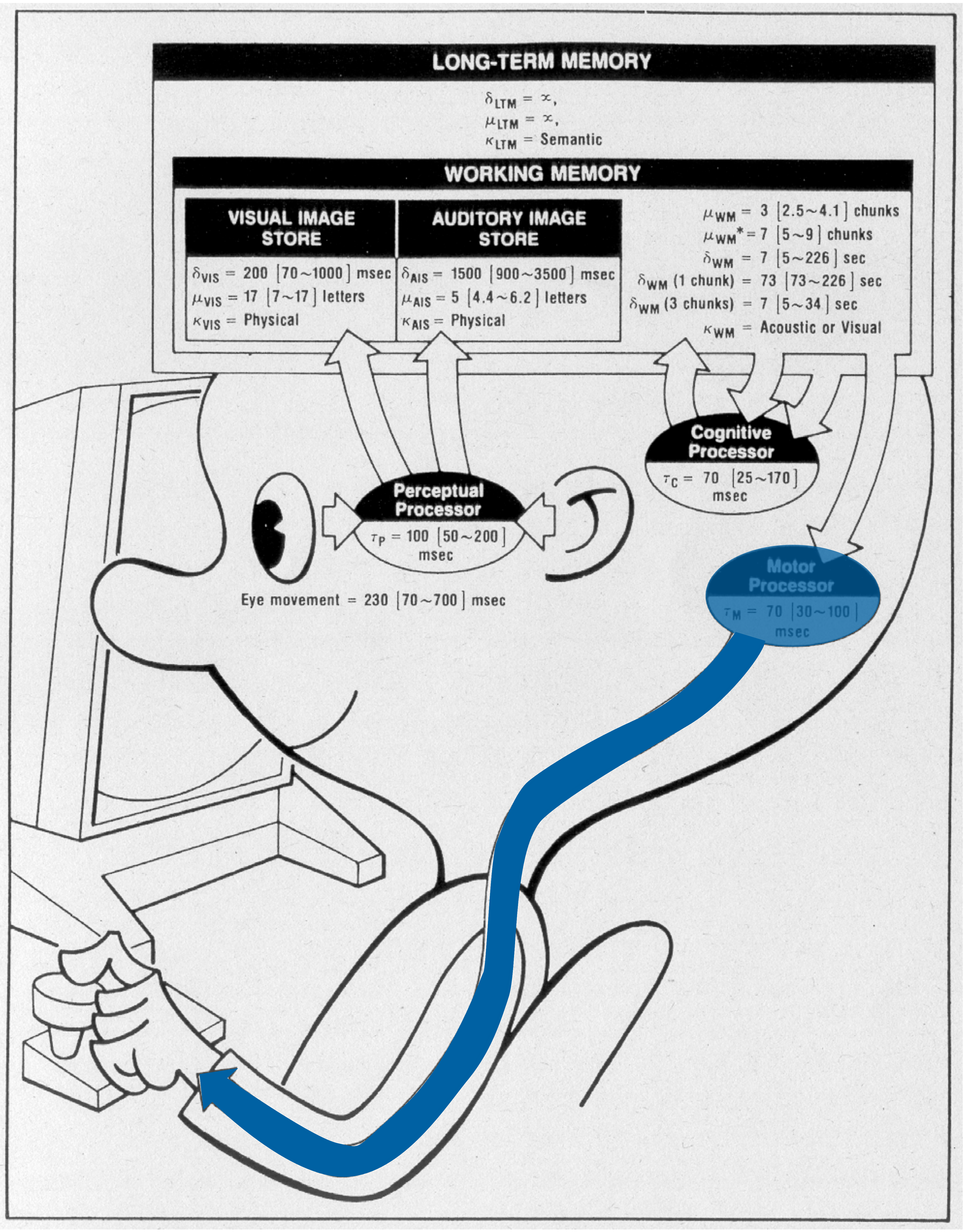


74 ms/reversal
250 ms/correction

- Motor processor (open loop)
  - $\tau_M = 70$ ms

$\Rightarrow$ Average time between each reversal





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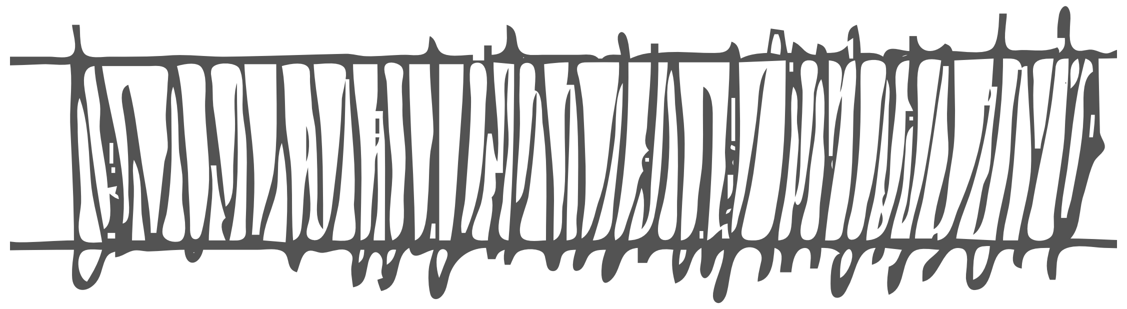
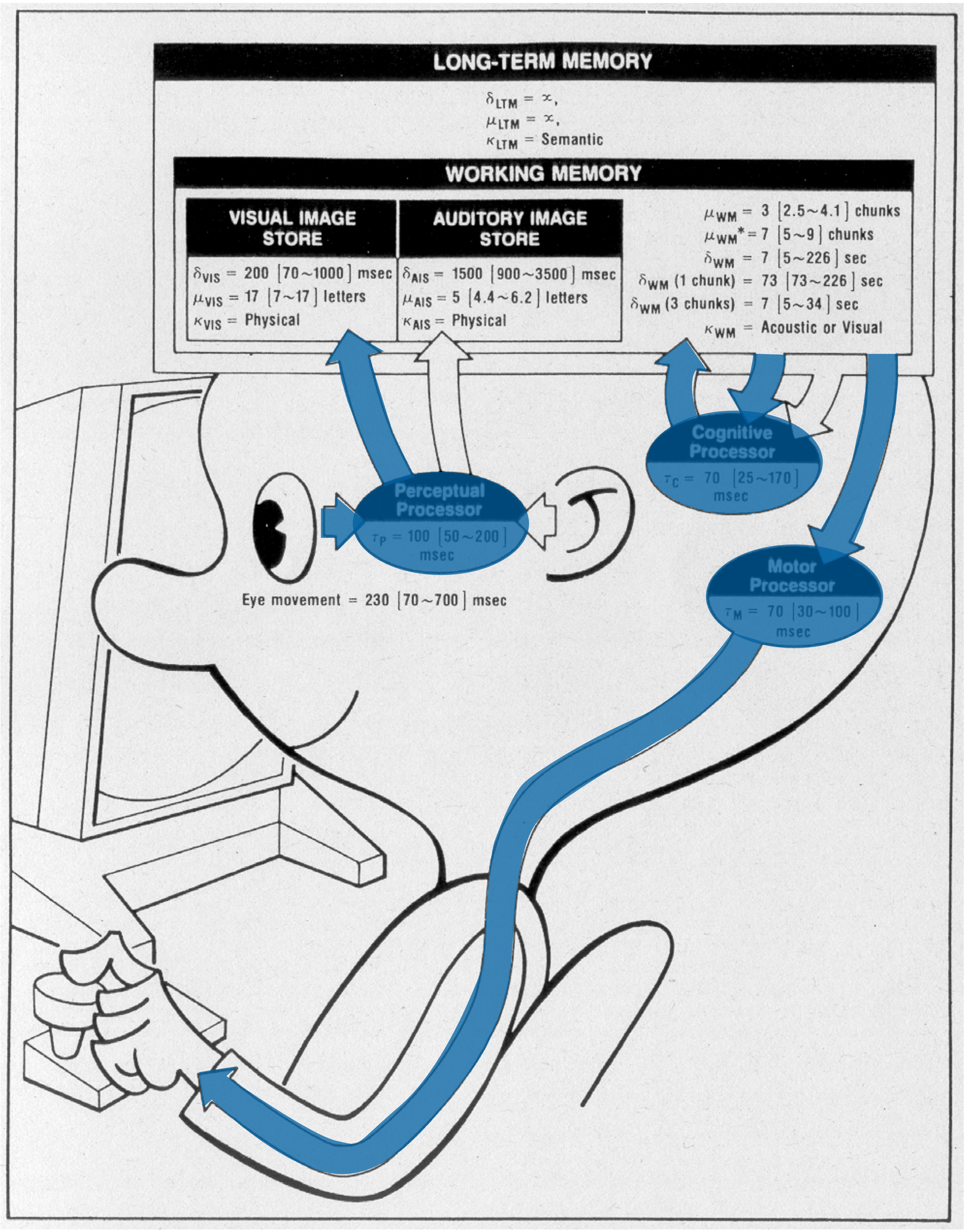
Motor System



74 ms/reversal
250 ms/correction

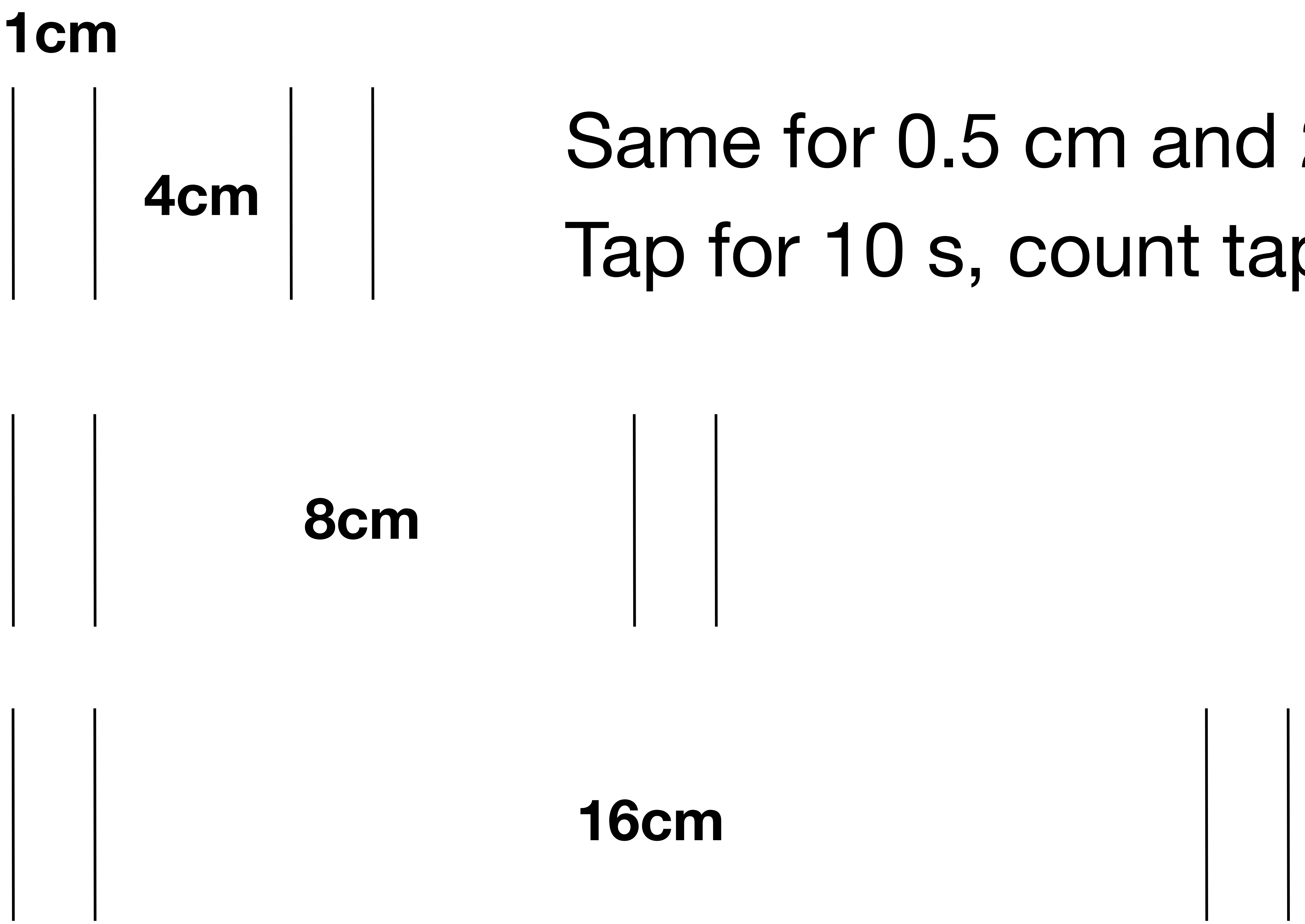
- Closed loop:
  - $\tau_P + \tau_C + \tau_M = 240$ ms

$\Rightarrow$ 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

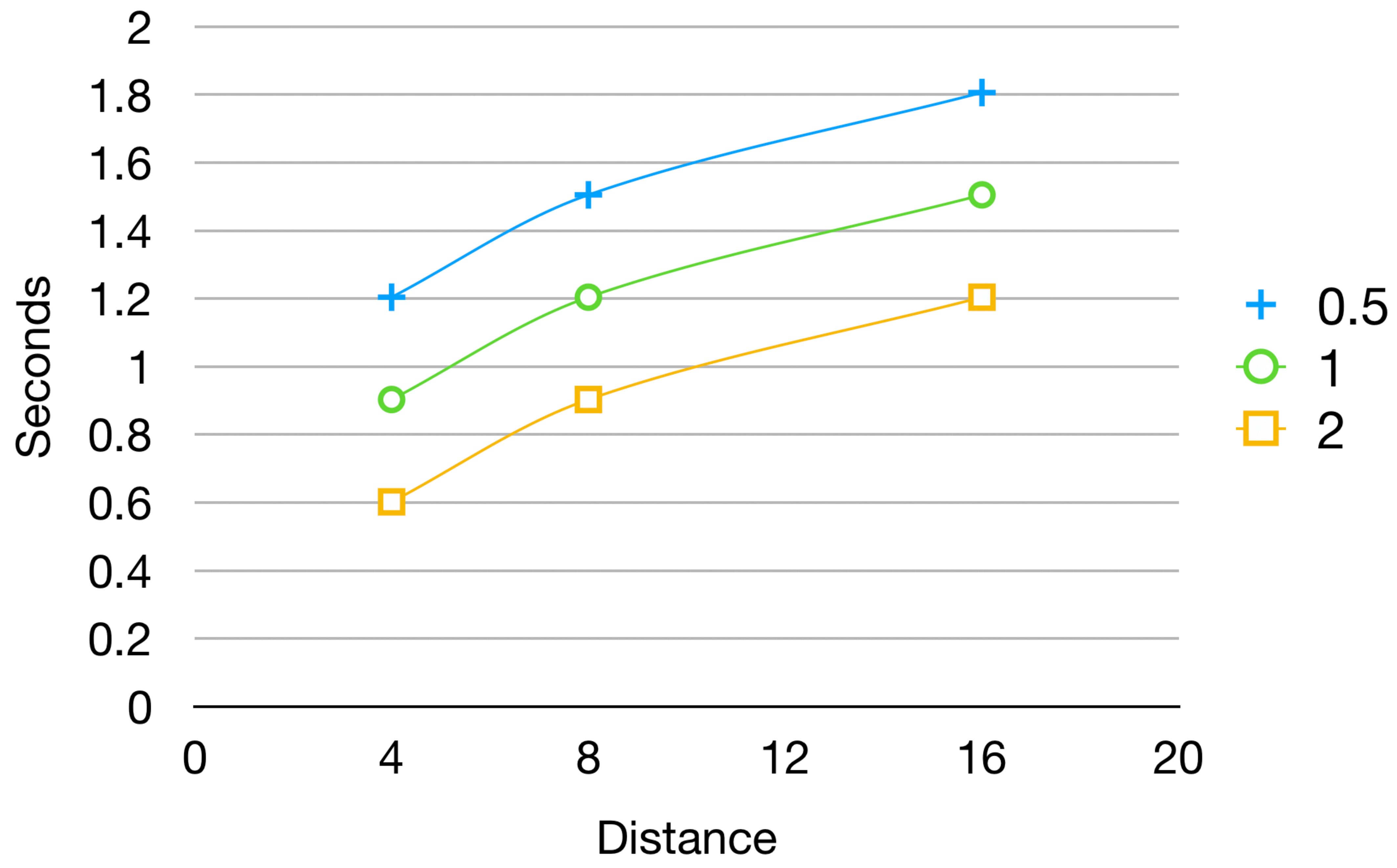
- Doubling the distance adds roughly a constant to execution time

  ⇒ indicates logarithmic nature

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

  ⇒ indicates connection of D/W in formula

- Fitts' Law, 1954: $T_{pos} = I_M \cdot log_2(\frac{2D}{W})$



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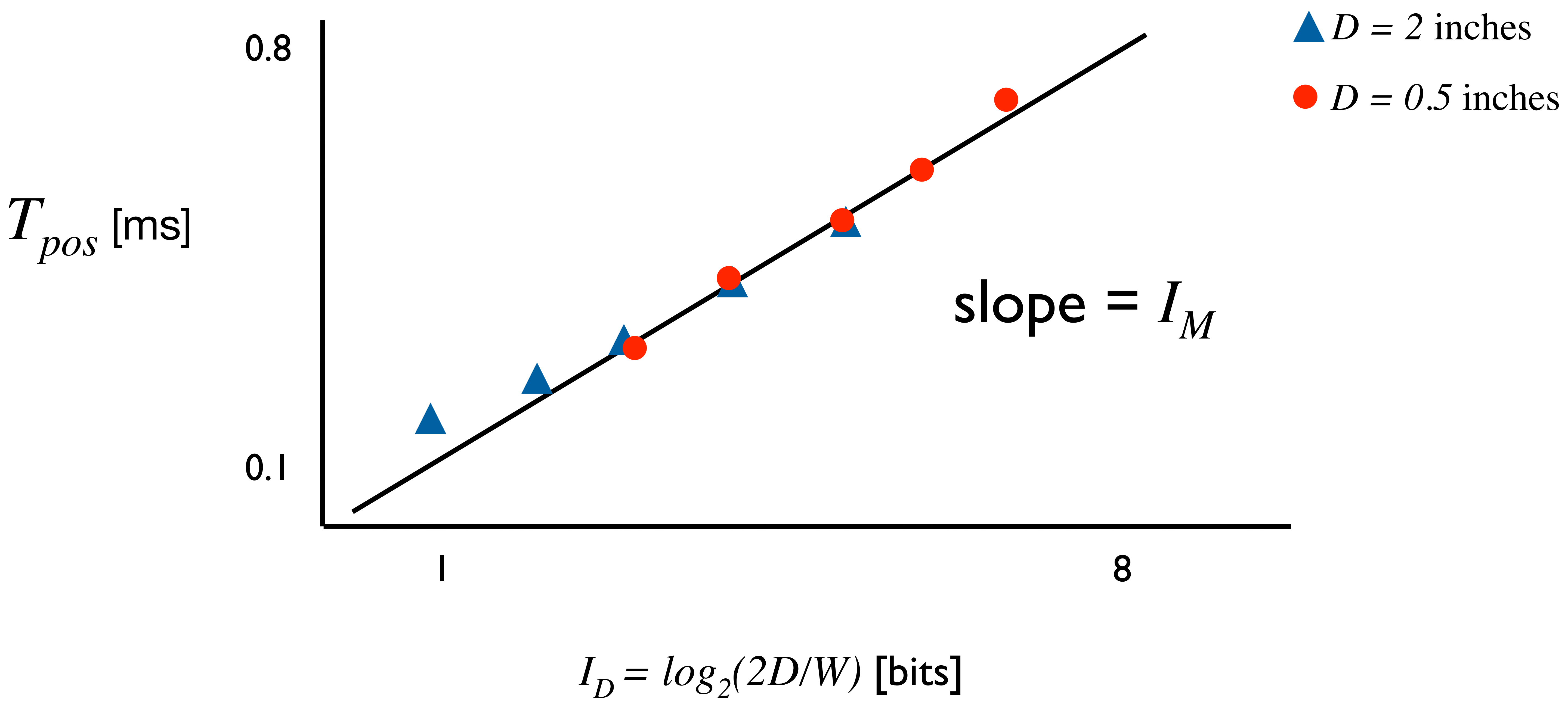
Visualizing Fitts' Law

Experiment: fixed distance D, varying width W



Improvements

- Welford's Formulation, 1968:

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

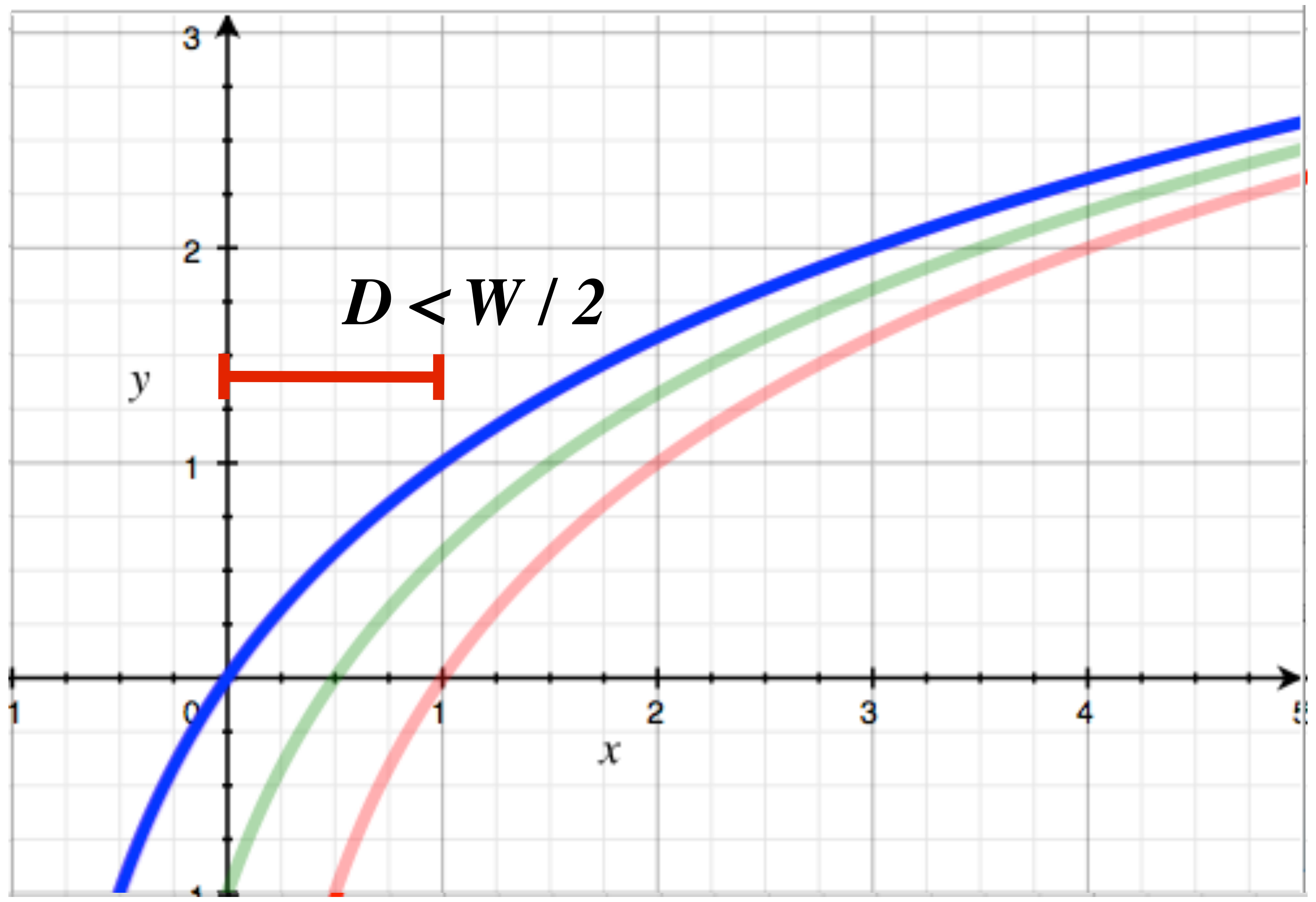
- Shannon's Formulation, ISO, 80's:

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

  - *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

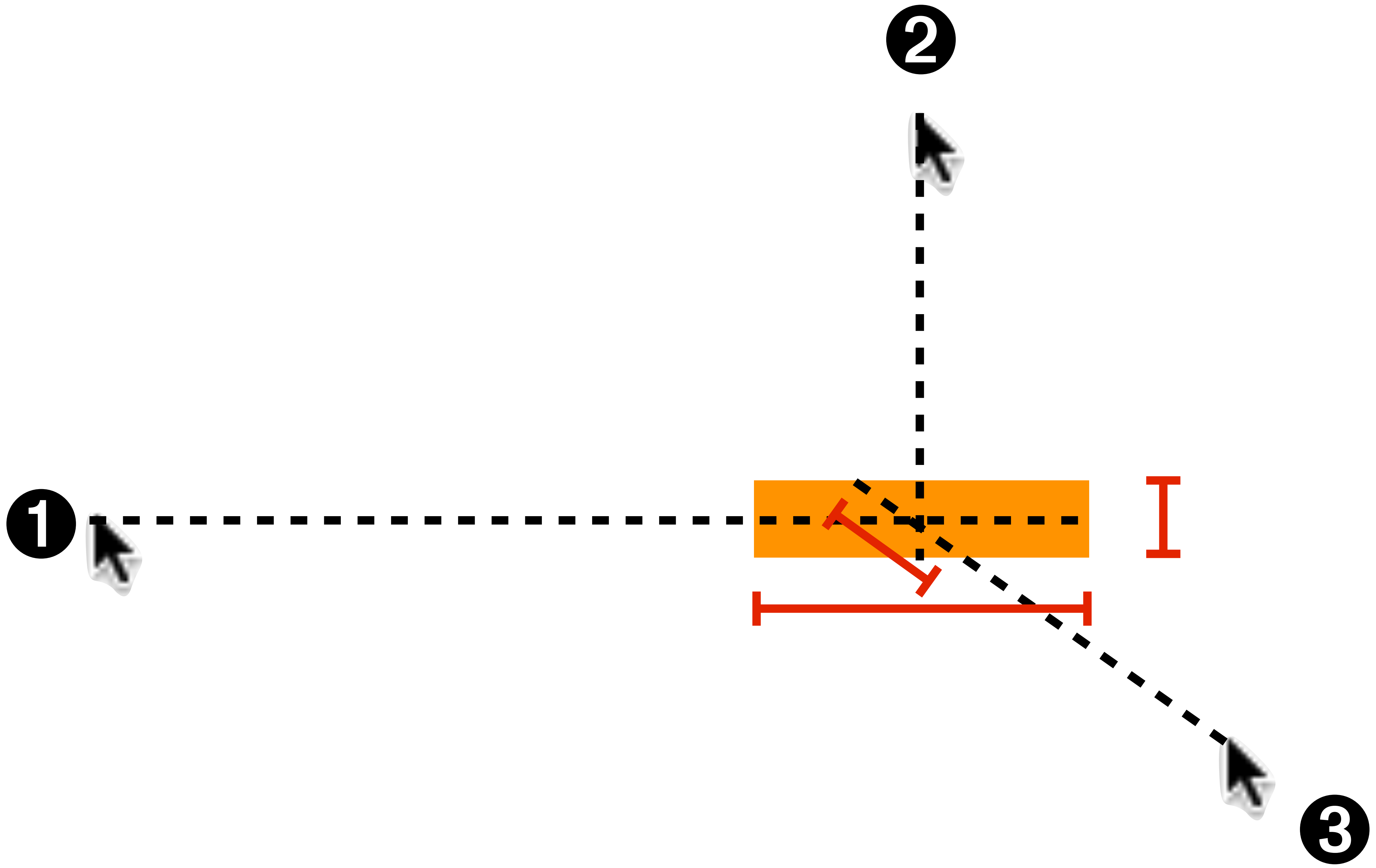


$$T_{pos} = I_M \cdot \log_2\left(\frac{2D}{W}\right)$$

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

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

Target Width



✴ **Alternative measures are compared by [MacKenzie & Buxton, CHI'92]**

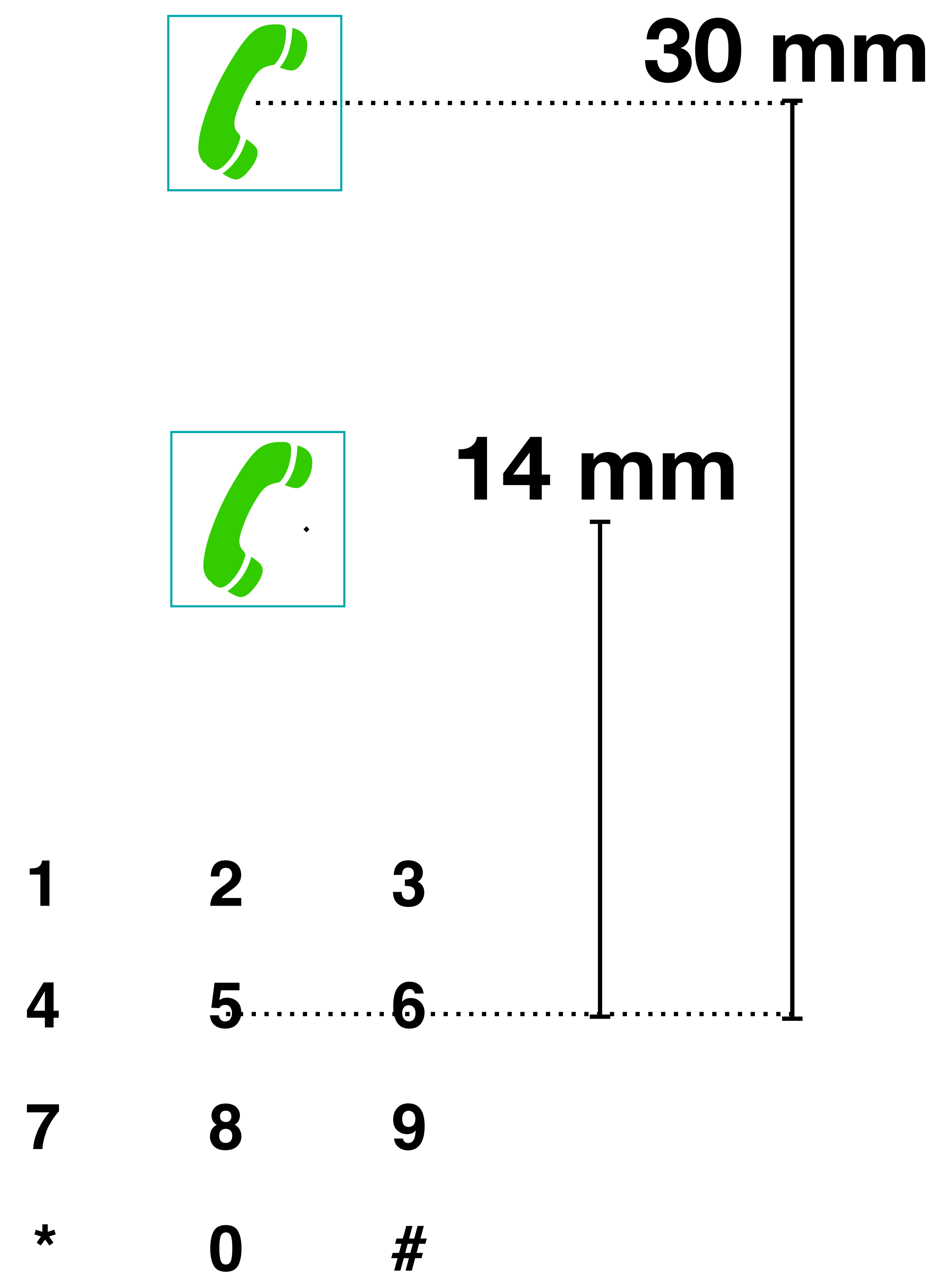
Windows 10

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

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: $T_{pos} = a + b \cdot \log_2(\frac{D}{W} + 1)$
- Use a = 0 ms, b =100 ms/bit



Solution

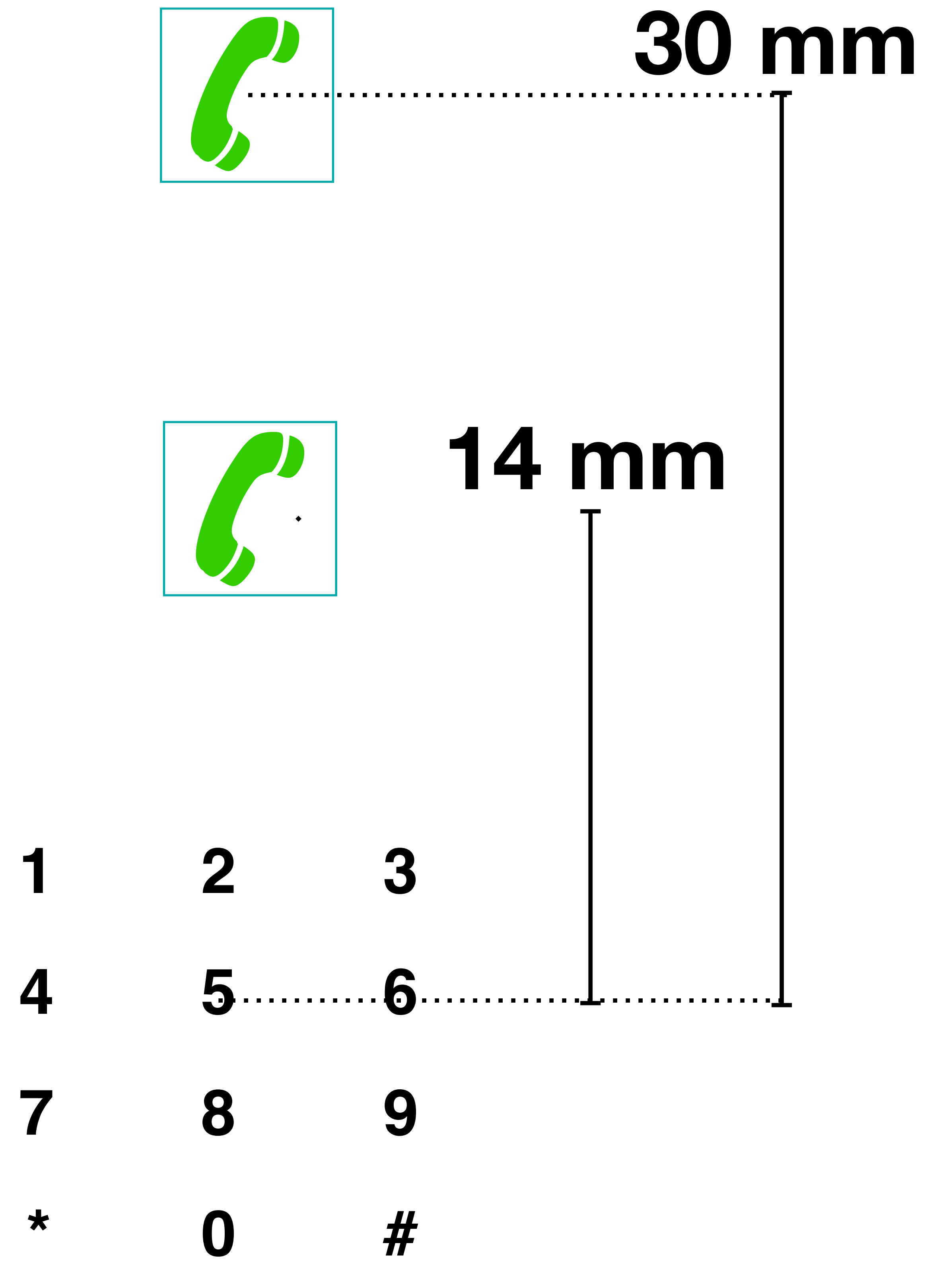
$$T_{pos1} = a + b \cdot \log_2(\frac{D_1}{W} + 1) \qquad T_{pos2} = a + b \cdot \log_2(\frac{D_2}{W} + 1)$$

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

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

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

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



⇒ 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. Send your signed Declaration of Compliance via mail to Ricarda and Marcel
   (If you have already sent us the DoC you don't need to send it again)

   Email title: `[DIS1] DoC <Your Full Name>`
   File Name: `DIS1_WS22_<your MatrNr>_<your last name>.pdf`

3. Feel free to check out our other classes

Before next Lab on Tuesday

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

Before next Lecture

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