

Designing Interactive Systems I

Introduction, The CMN Model, Fitts' Law

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Media Computing Group
RWTH Aachen University

Winter Semester '25/'26

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



RWTHAACHEN
UNIVERSITY

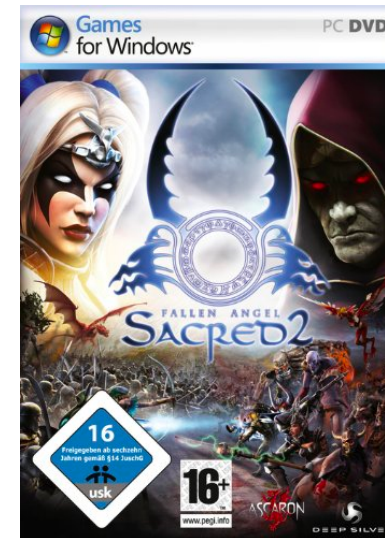
Who am I?



Studied CS at RWTH

- Human-Computer Interaction

Worked at Ascaron on Sacred 2



PhD in CS at RWTH

- Interactive System

Deputy-Head at the Media Computing Group

Head of the Study Center CS

Our Team

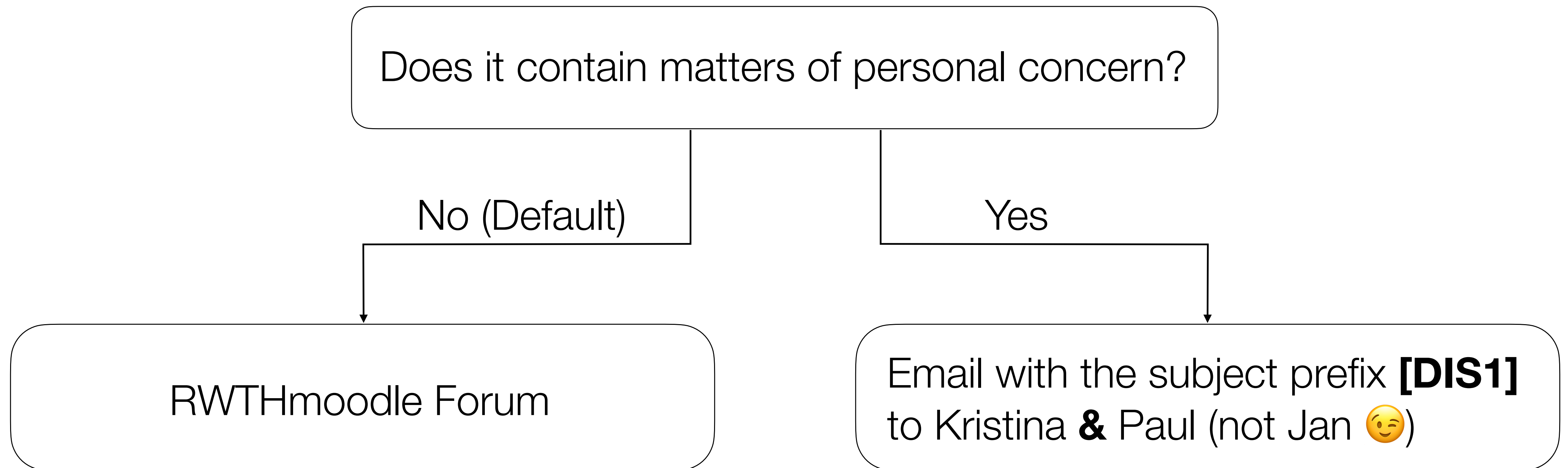


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The Question Flow Chart :)



Alternatively: A quick chat after the lecture ☕

Human–Computer Interaction?







Abschlussarbeiten - Verwaltung

Abschlussarbeit - Bearbeiten

Status: Angemeldet /

21.01.2025 / Versuch Nr.: 1 / Diese Arbeit bitte beurteilen bis zum: 18.04.2025

Matrikelnummer/Name

Name / Geburtsdatum

Studium

1480 88 839 Europastudien (Status:'Z', Ende: 30.09.2013) ▾

Typ

Masterarbeit ▾

Anerkannt / Zweiterfassung bei interuniversitären Studien ☐

Vorbehaltlich angemeldet ☐

Sprache des Volltextes

Deutsch ▾

Thema bei der Anmeldung

max. 2000 Zeichen
1974 Zeichen frei

Thema am Leistungsnachweis/Titel
(in der Sprache des Volltextes)

max. 2000 Zeichen
1992 Zeichen frei

Thema in Englisch
(für engl. Transcript of Records)

max. 2000 Zeichen
1996 Zeichen frei

Thema ist sichtbar

☒

Datum

Themenbekanntgabe/Beginn

21.01.2025

Späteste Abgabe

21.02.2025

Abgabe noch auszufüllen

Datum der Beurteilung noch auszufüllen

Datum der spätesten Beurteilung: 18.04.2025

Gesamtbeurteilung noch auszufüllen

Durchschnitt - Notenfreigabe-Studierendenbenachrichtigung ☐

ECTS-Credits

Funktionen/Personen

Funktion	Person
Betreuende Person	

Usability Sells!



350,000

DVD Player (1996)



1,000,000

iPhone (1st Q'07)



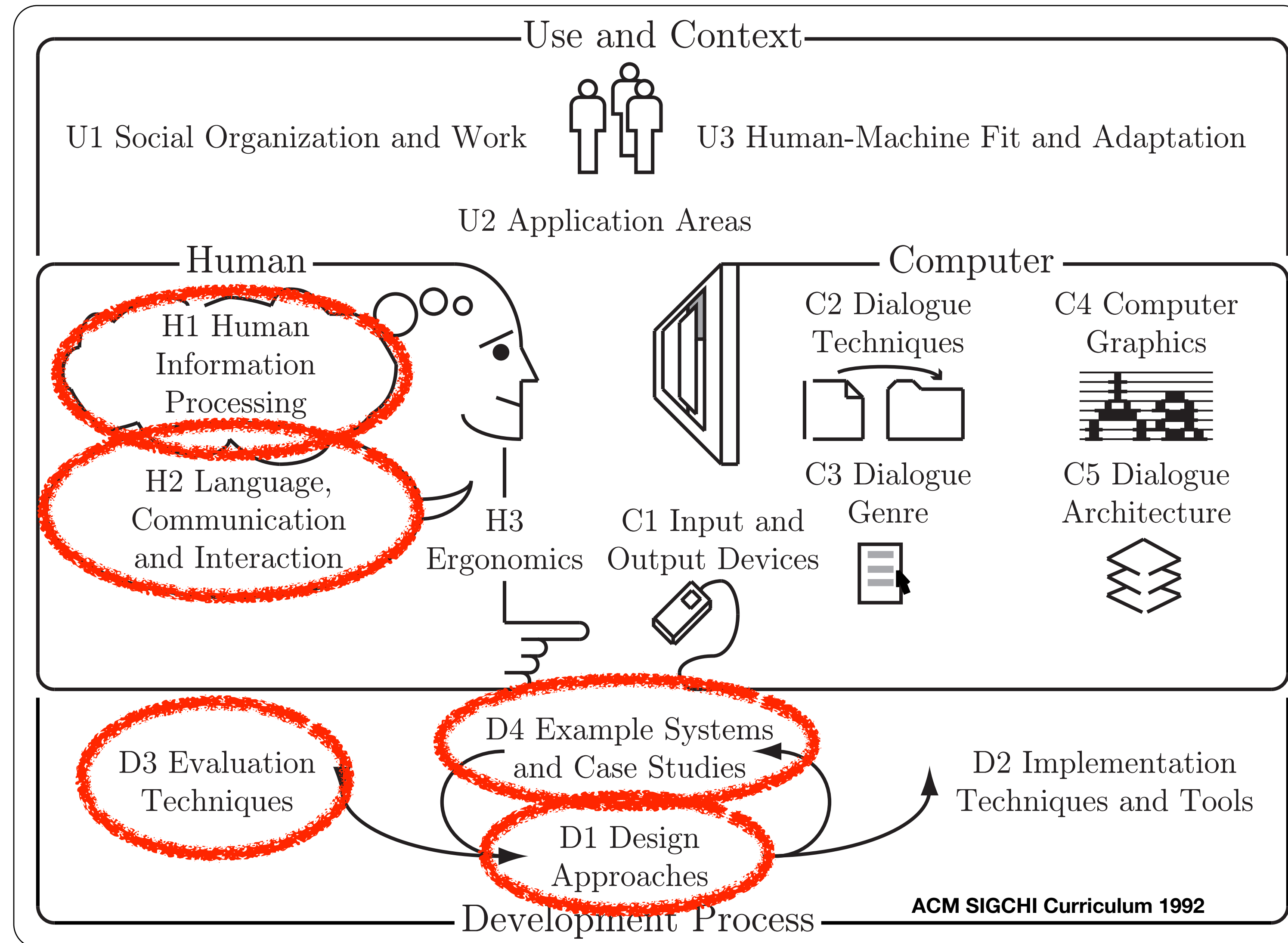
3,000,000

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 of HCI
- Phases of Technology

Development Process

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

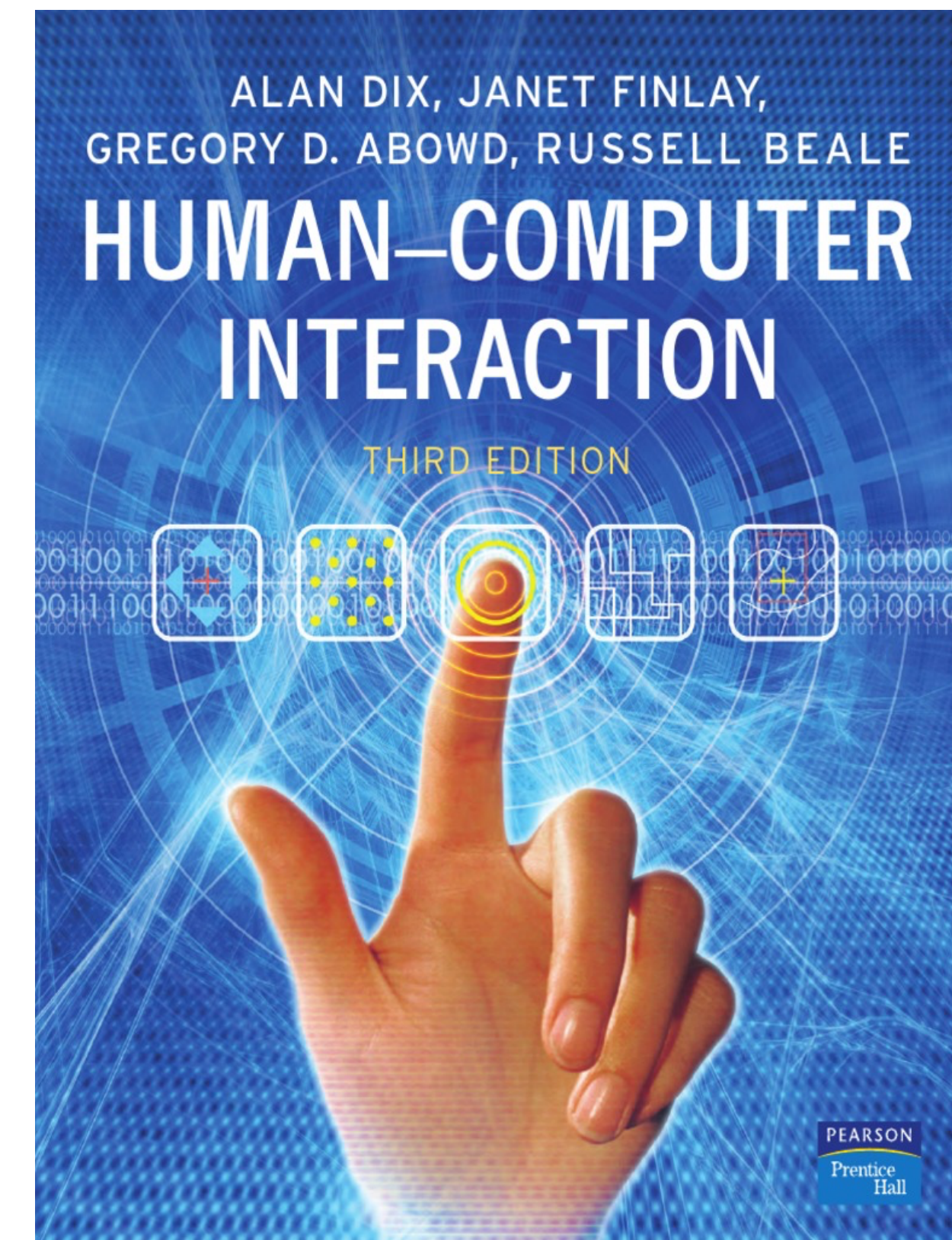
For more details, see hci.rwth-aachen.de/dis

Textbooks

Required Reading



Recommended Reading



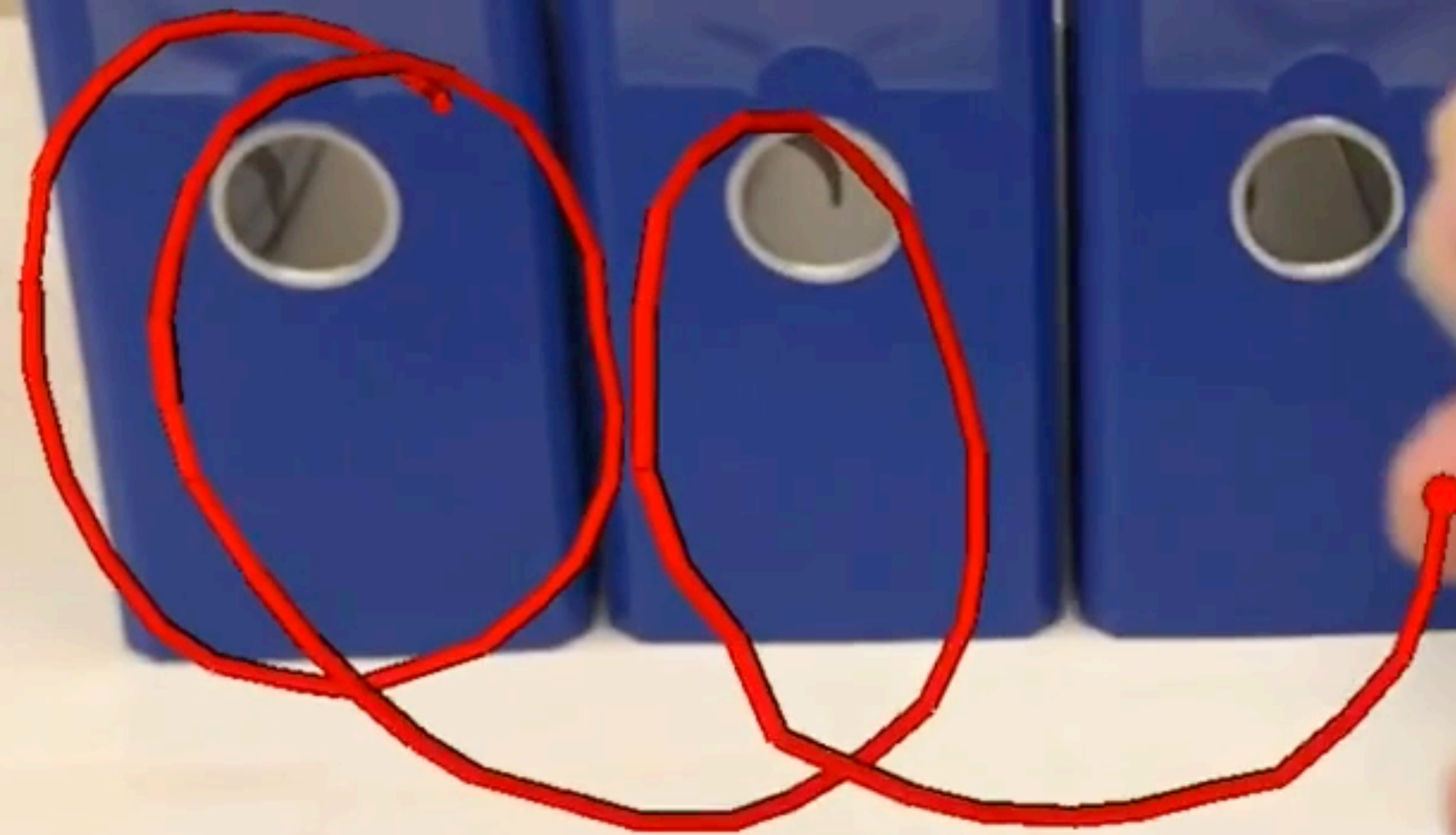
Media Computing Group



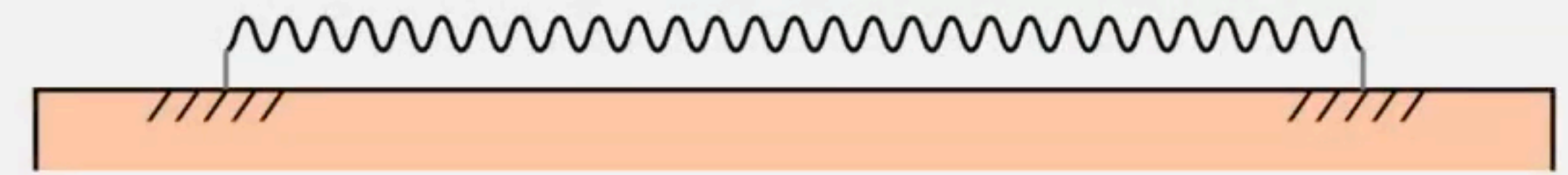
Our Classes

When?	Type	Credits (ECTS)	Name
Winter	Practical Lab	7	The Media Computing Project
Winter+ Summer	Seminar	4	Post-Desktop User Interfaces
Summer	Lecture	6	Current Topics in HCI
Winter	Everything :)	6	iOS Application Development
Summer	Lecture	6	Designing Interactive Systems II
Winter	Lecture	6	Designing Interactive Systems I
Only for B.Sc. students			
Summer	Proseminar	4	Human-Computer Interaction
Summer	Practical Lab	7	M3: Multimodal Media Madness

ARPen



Springlets



15mm X 40mm



5mm X 30mm

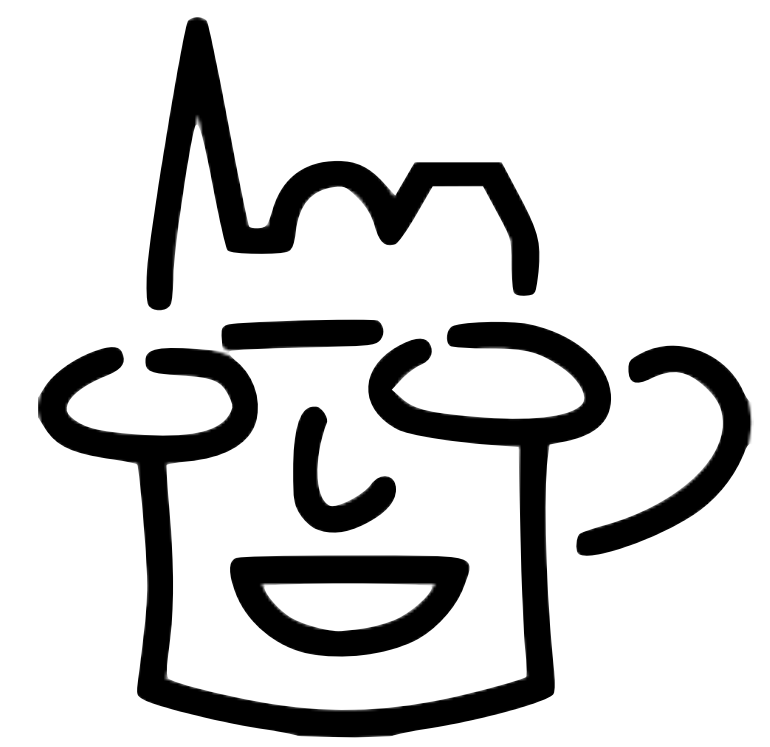


Student Project in Multimodal Media Madness



CocoaHeads Aachen

- CocoaHeads: International meet-ups for macOS and iOS developers
- Last Thursday of every month
- Sign up here: hci.rwth-aachen.de/cocoaheads



DIS I: Course Structure

Course Structure

Lecture

Interactive classes with Simon Voelker

Lab

- Discuss assignments

Oct 9th – Nov 26th

UX Project (graded)

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

Dec 3rd – Jan 30th

Final Exam

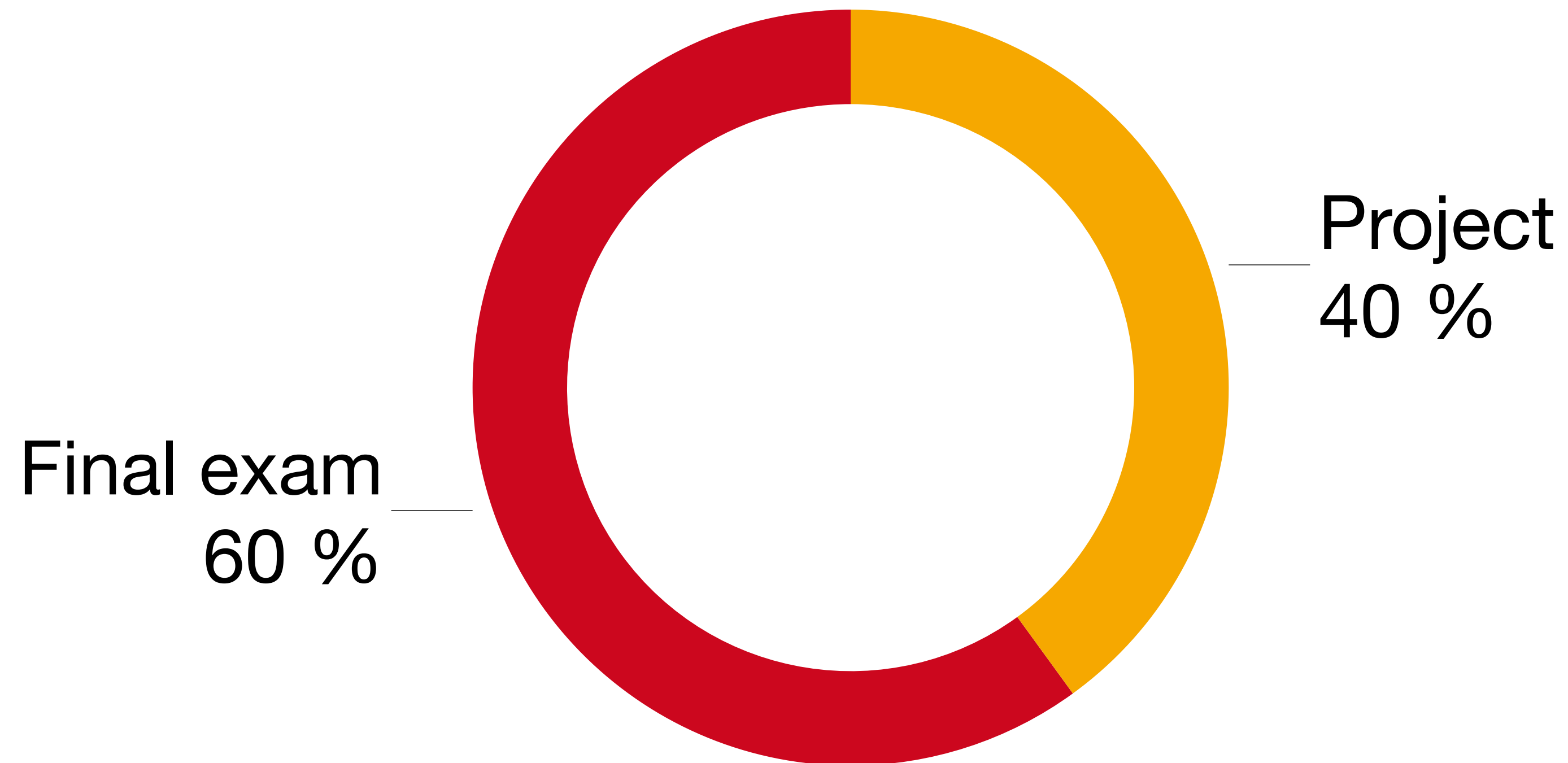
Feb
5th

Final Exam

Mar
6th



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** (Thu Oct 10, 2024, 23:59)
- Erasmus students, and others who cannot register via RWTHonline:
Email Sarah & Paul your matriculation number and full name from your official *@rwth-aachen.de* email address with the following subject:

[DIS1] Registration <Firstname Lastname>

Exam Registration

Deadline to register: **December 7th, 2024**

- If you fail the first final exam, there will be a short period to register for the second chance
- You won't be registered for the second final exam automatically!

The Human



Model Human Processor: The CMN Model

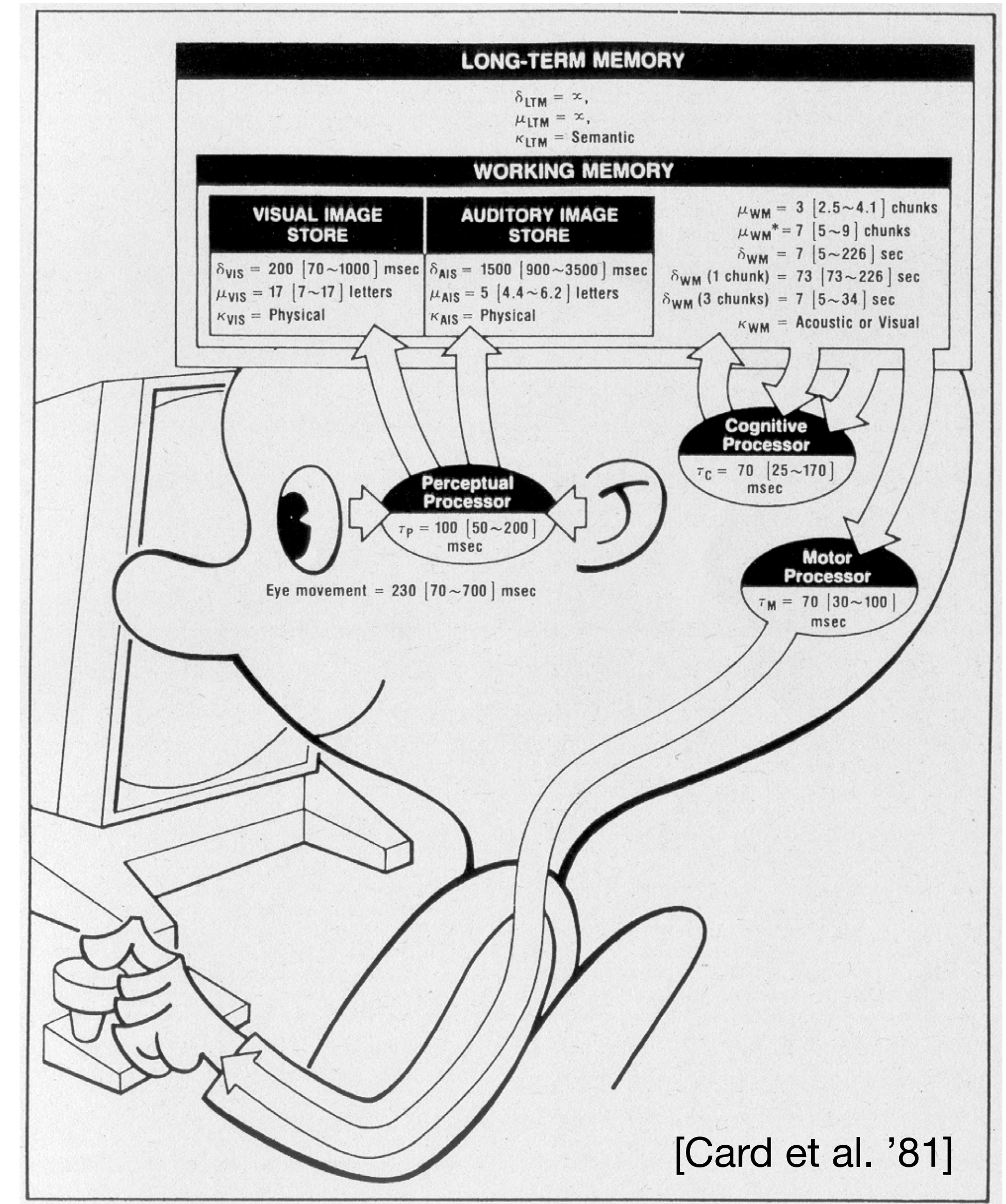
The Psychology of Human-Computer Interaction

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?

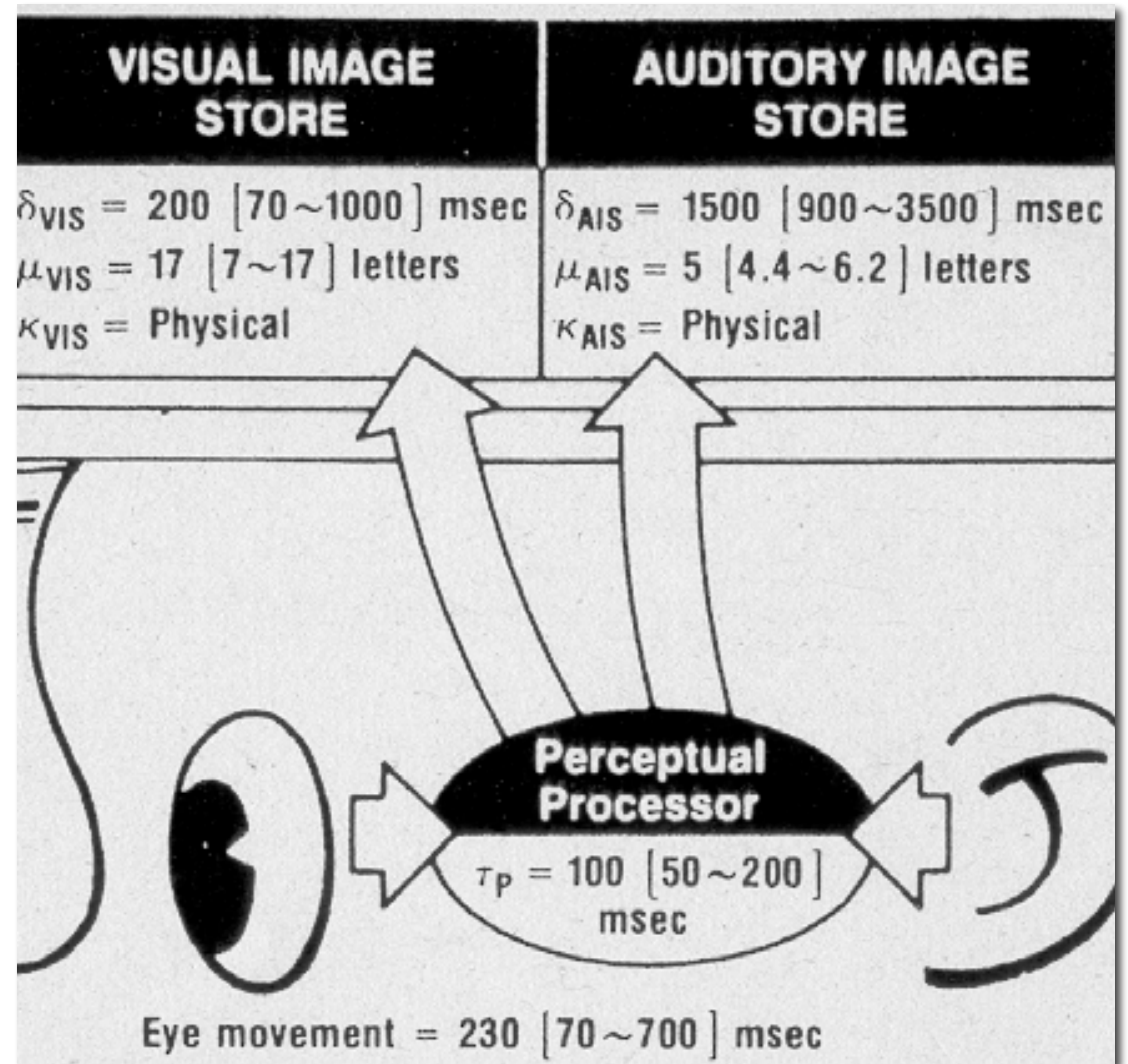
The Eiffel Tower is an iron tower built in 1889 in Paris, France. It was named after its designer, Gustave Eiffel, and is the tallest building in Paris. It was originally supposed to be built in Barcelona, Spain. The entire building weighs about 10,000 tons.

**How your eyes
move when
you are
reading**

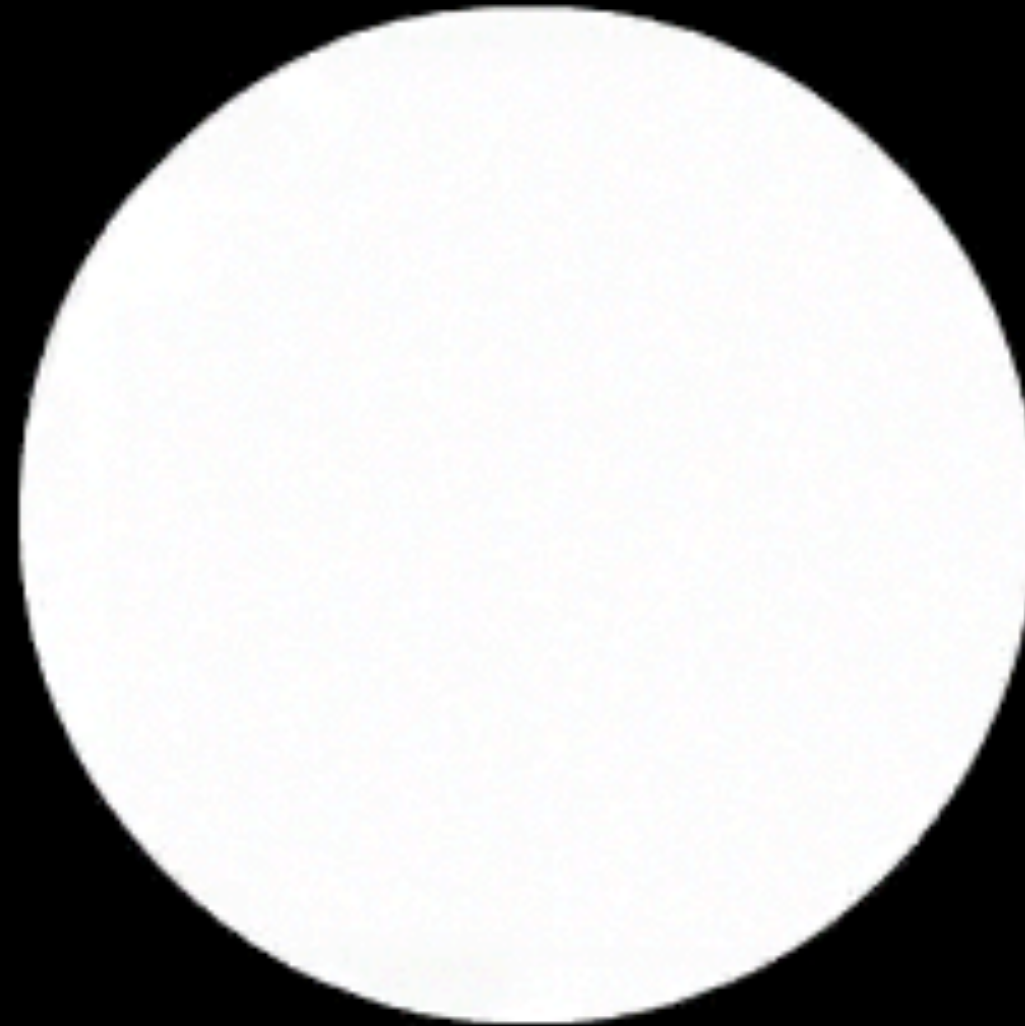
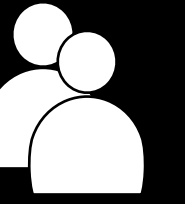
**(Recorded
using an
eyetracker)**

Perception

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



In-Class Experiment 2: Bloch's Law



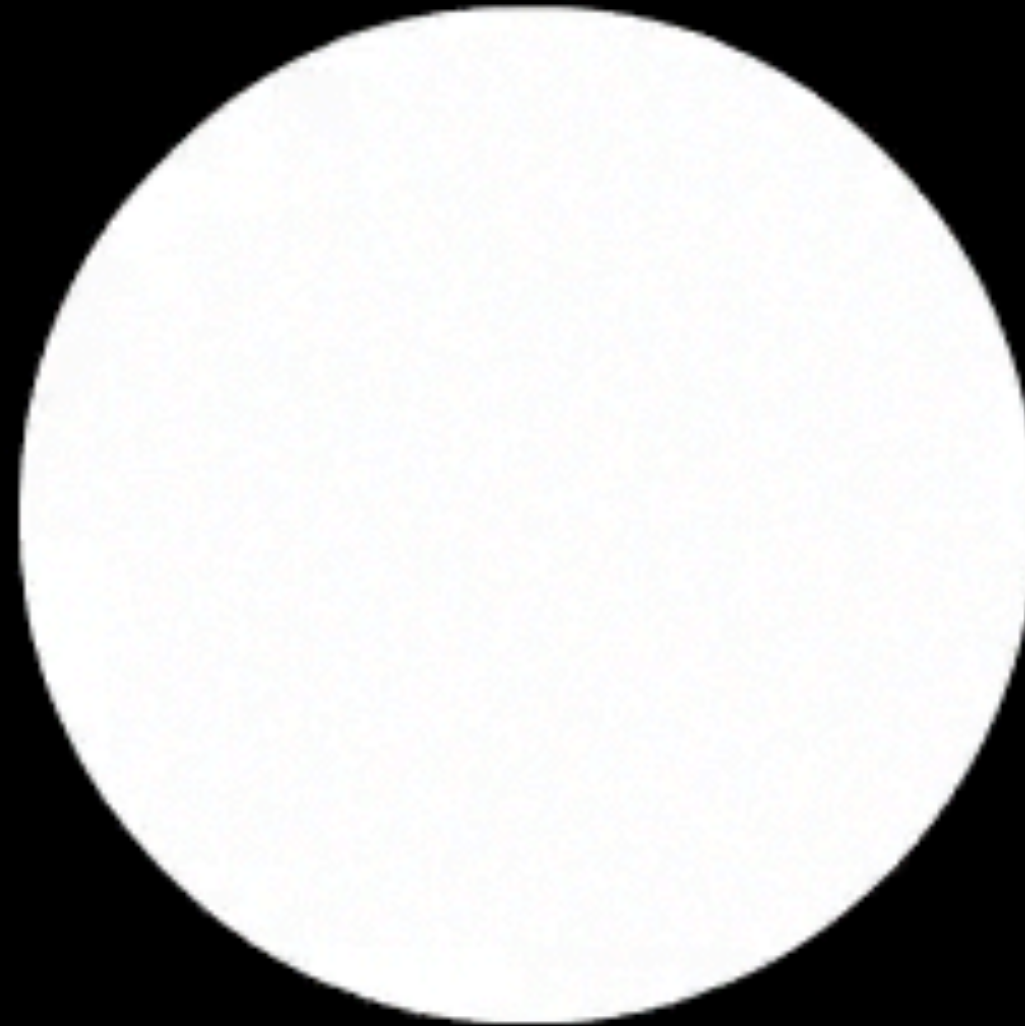
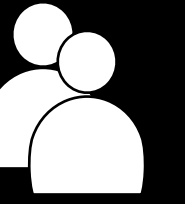
A

In-Class Experiment 2: Bloch's Law

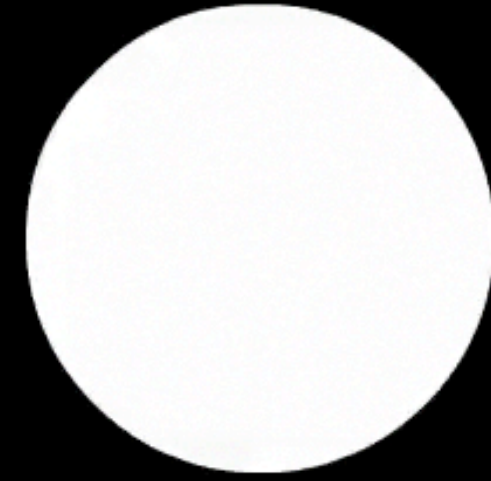


B

In-Class Experiment 2: Bloch's Law



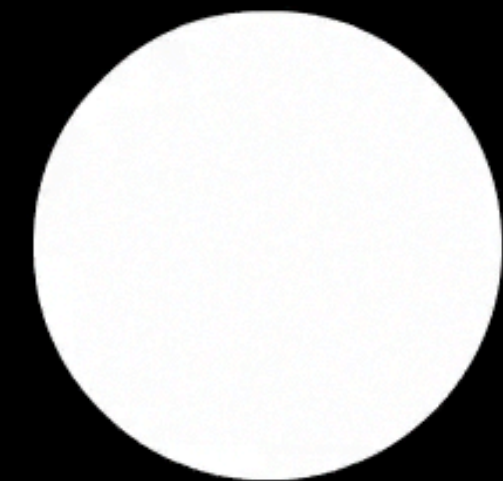
C



A: 0 ms delay



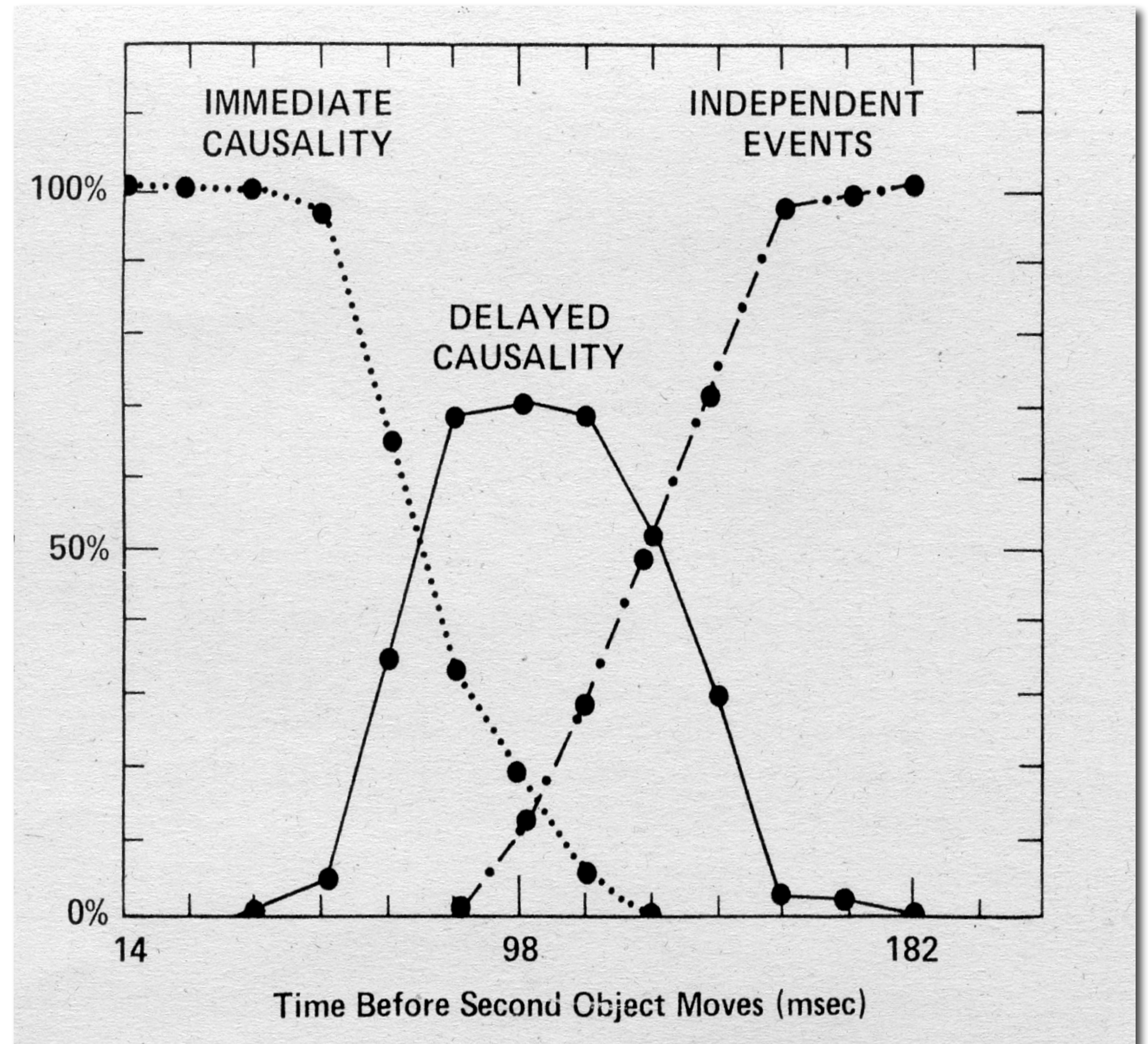
B: 50 ms delay



C: 100 ms delay

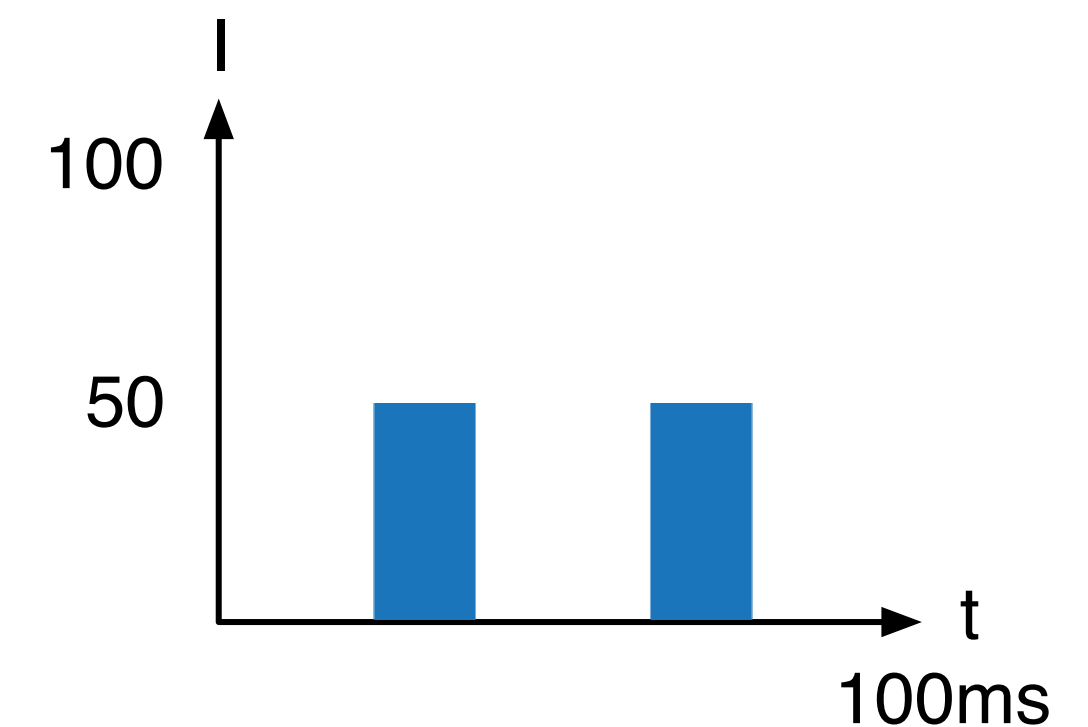
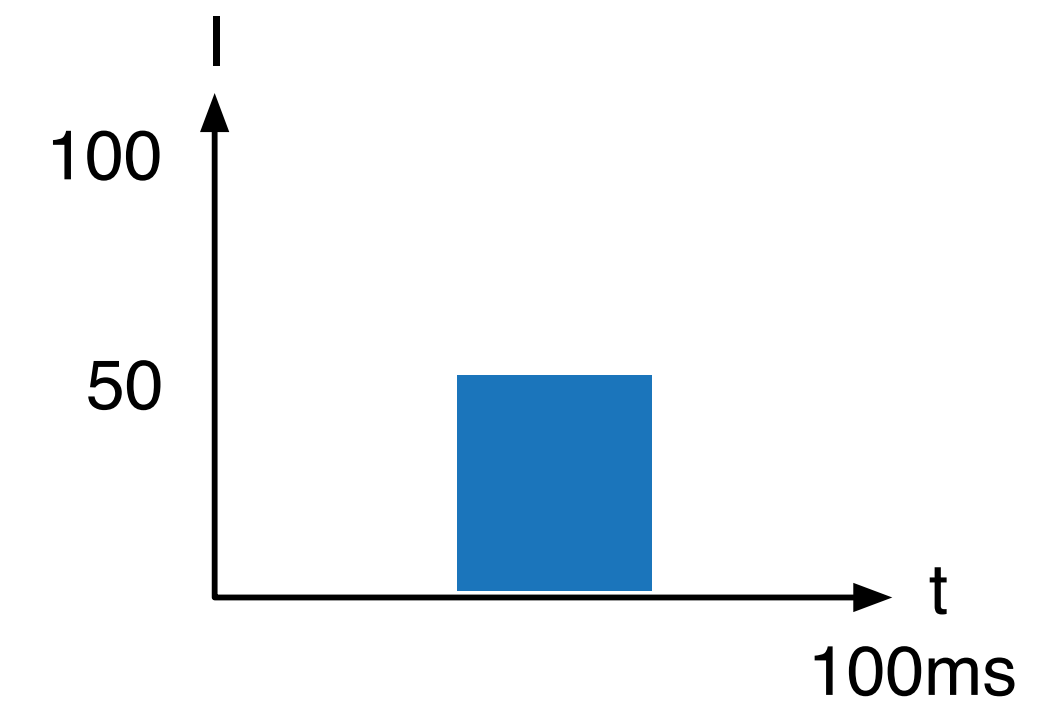
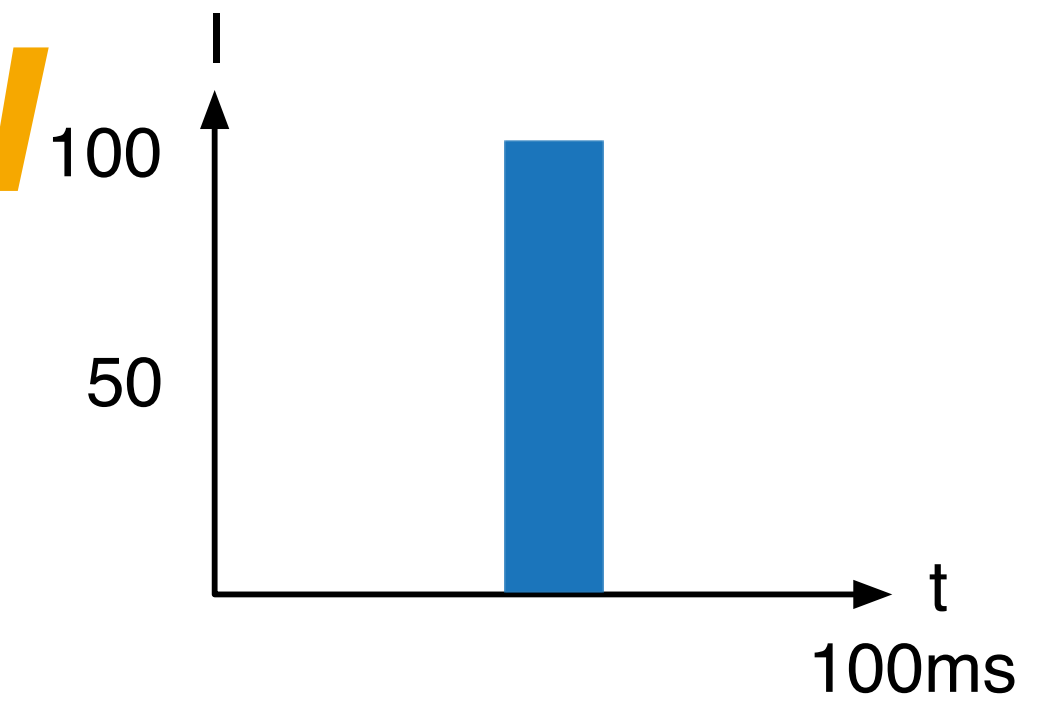
Perceptual Processor

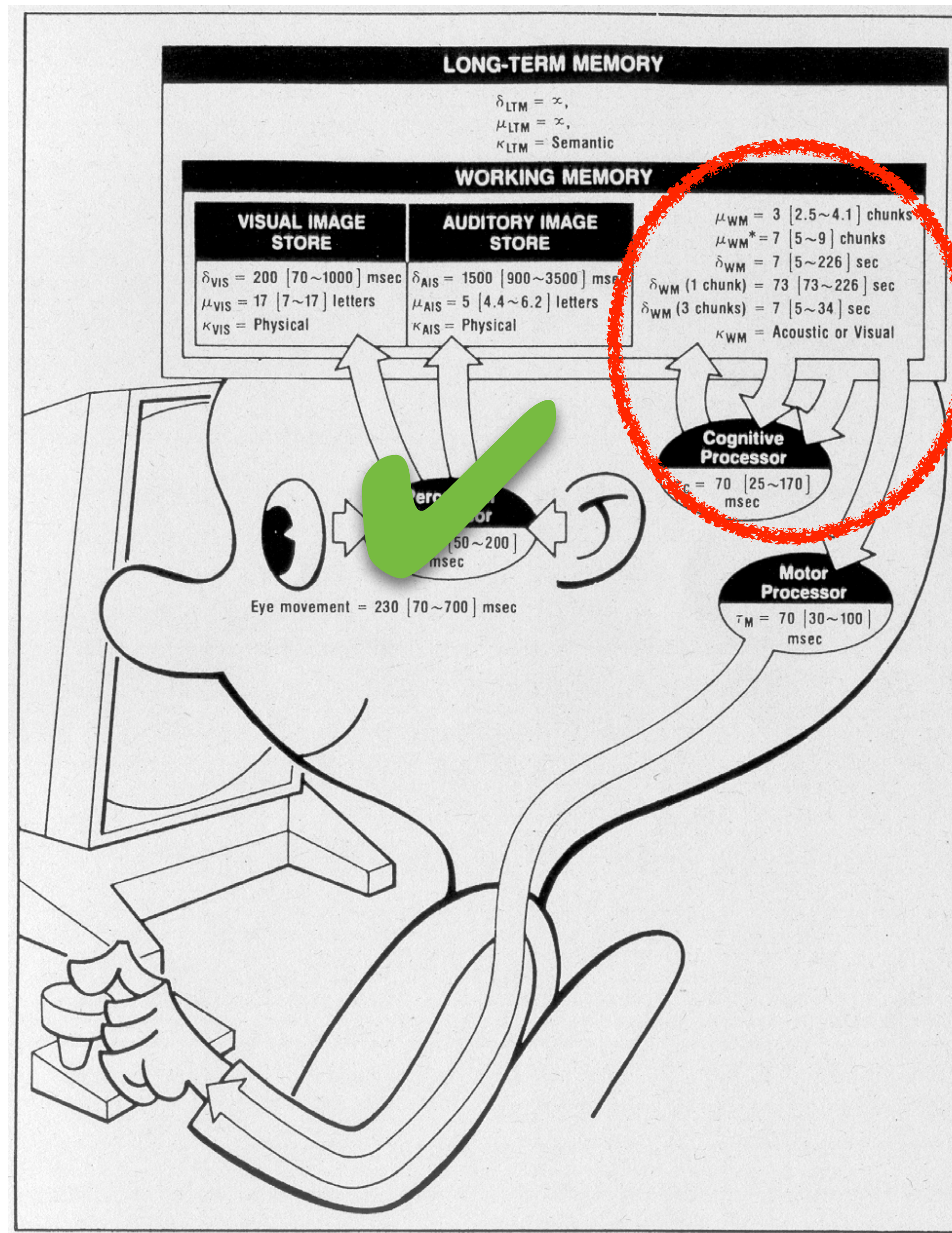
- Stores sensor signals in visual & auditory stores
- Perception time: $\tau_P \approx 100 \text{ ms}$
 - Explains animation rates (10 fps for “MiddleMan”)
 - Explains max. delay before causality breaks down
 - Shortens with intensity



Perceptual Processor & Bloch's Law

- Bloch's Law: $R = I \times t$
 - R response
 - I intensity
 - t exposure time
- The eye integrates stimuli over a time window τ_P
- Bloch's Law only holds for $t < \tau_P$ (“exposure time”)





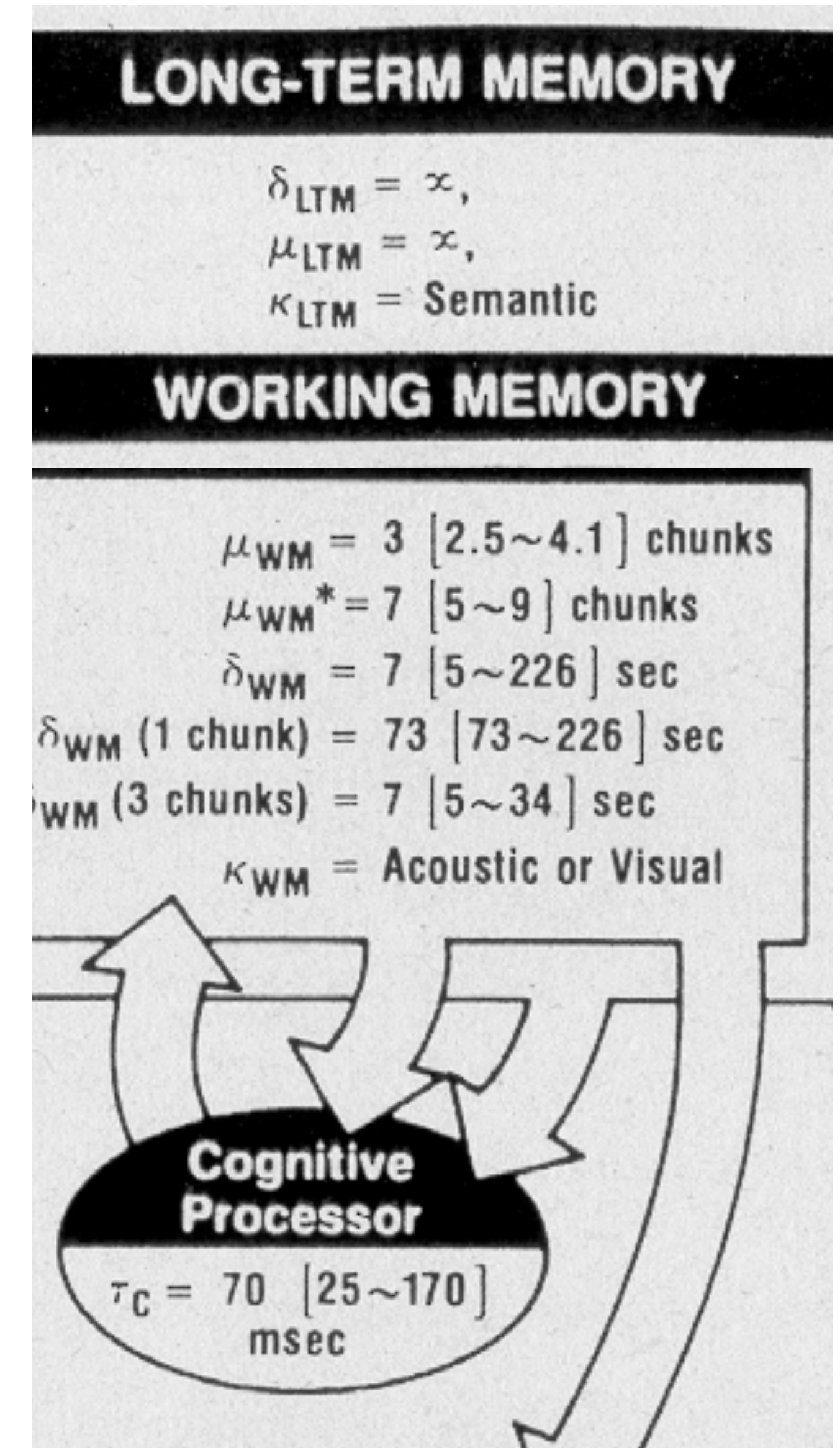
In-Class Experiment 3: Cognitive System



- 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.

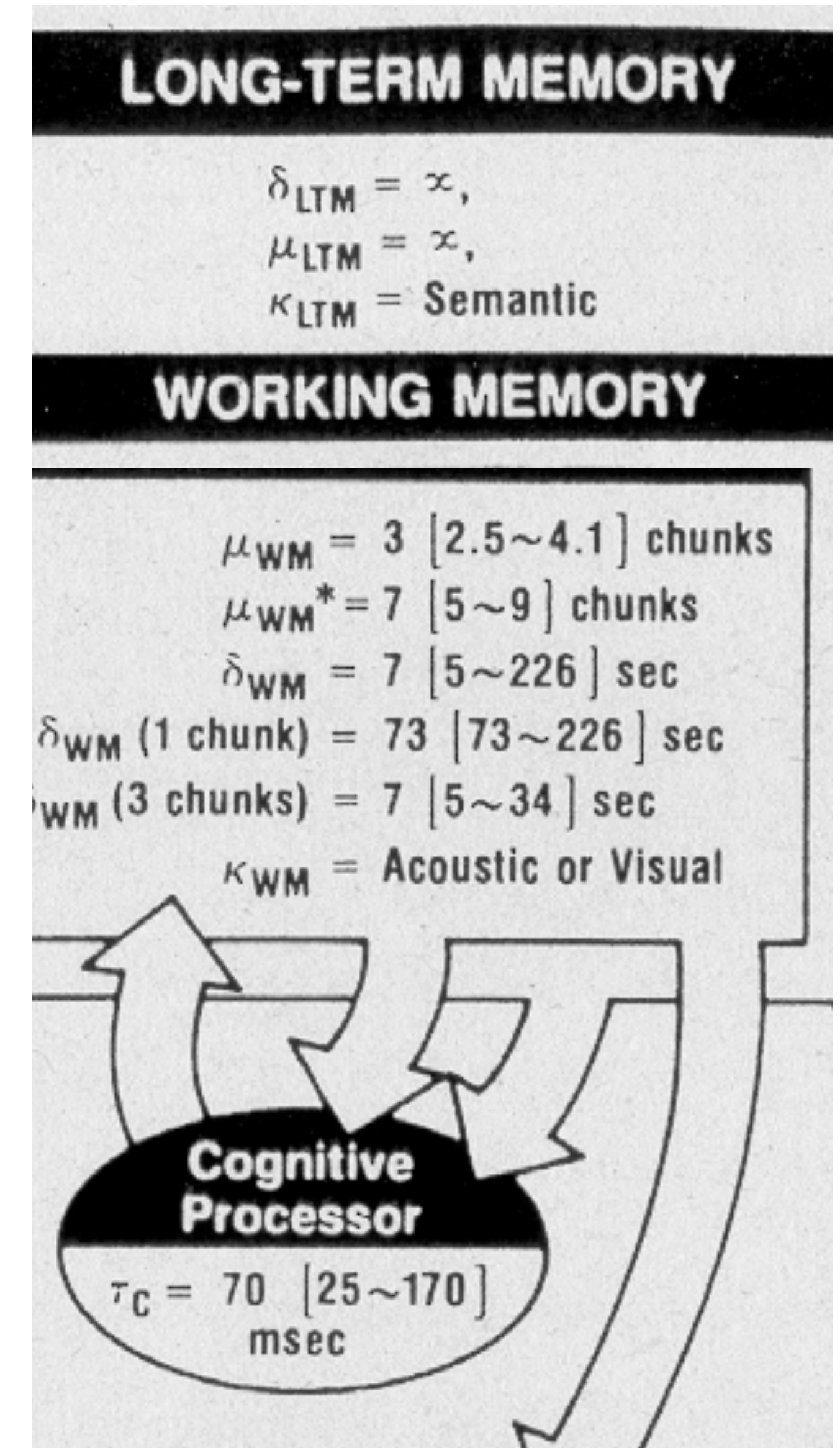
Cognitive System

- Chunks depend on user & task
- Working memory:
 - Capacity: $\mu_{WM} = 7 \pm 2$ 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.

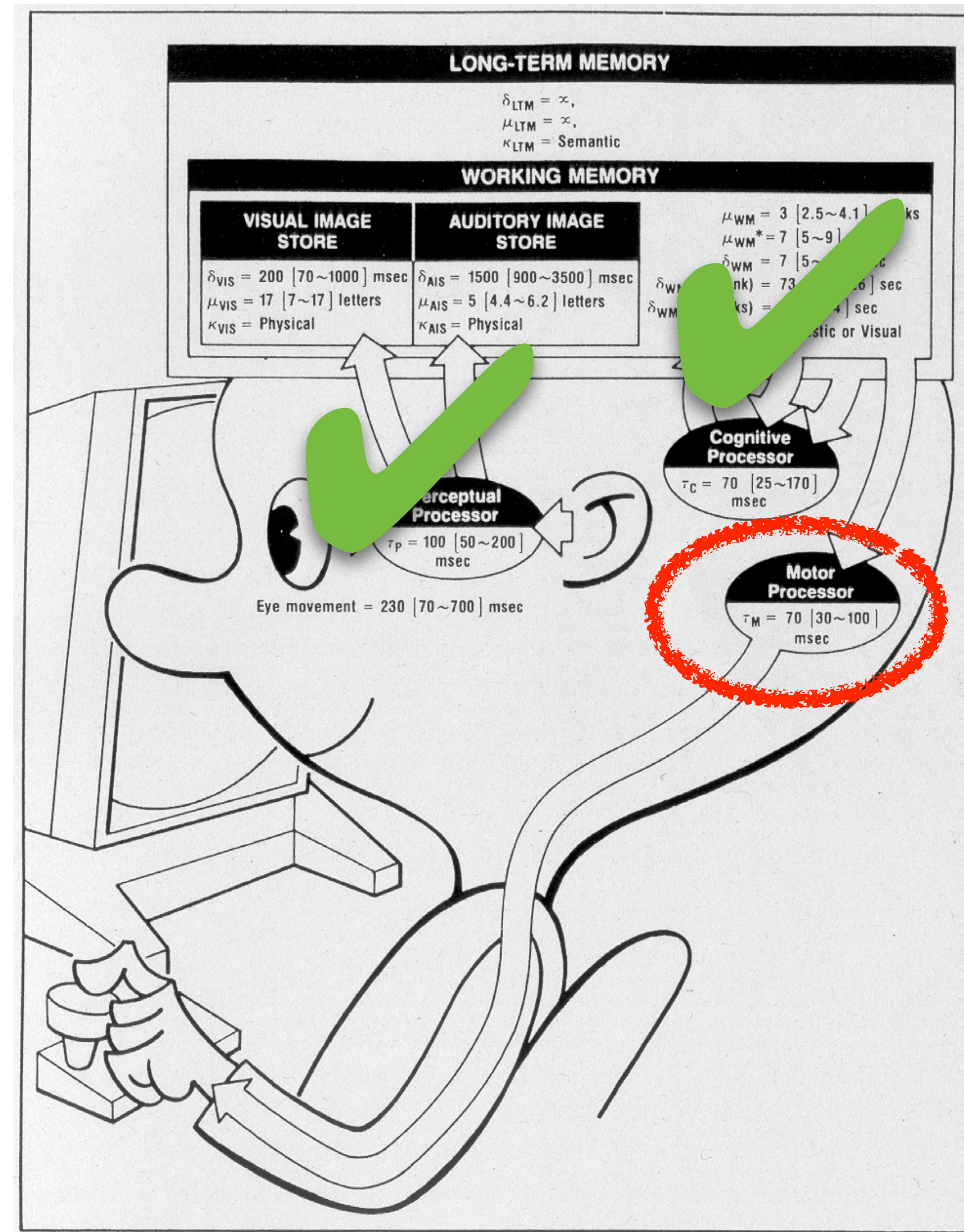


Cognitive System

- Cognitive processor:
 - Processing time $\tau_C = 70 \text{ ms}$
 - 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)



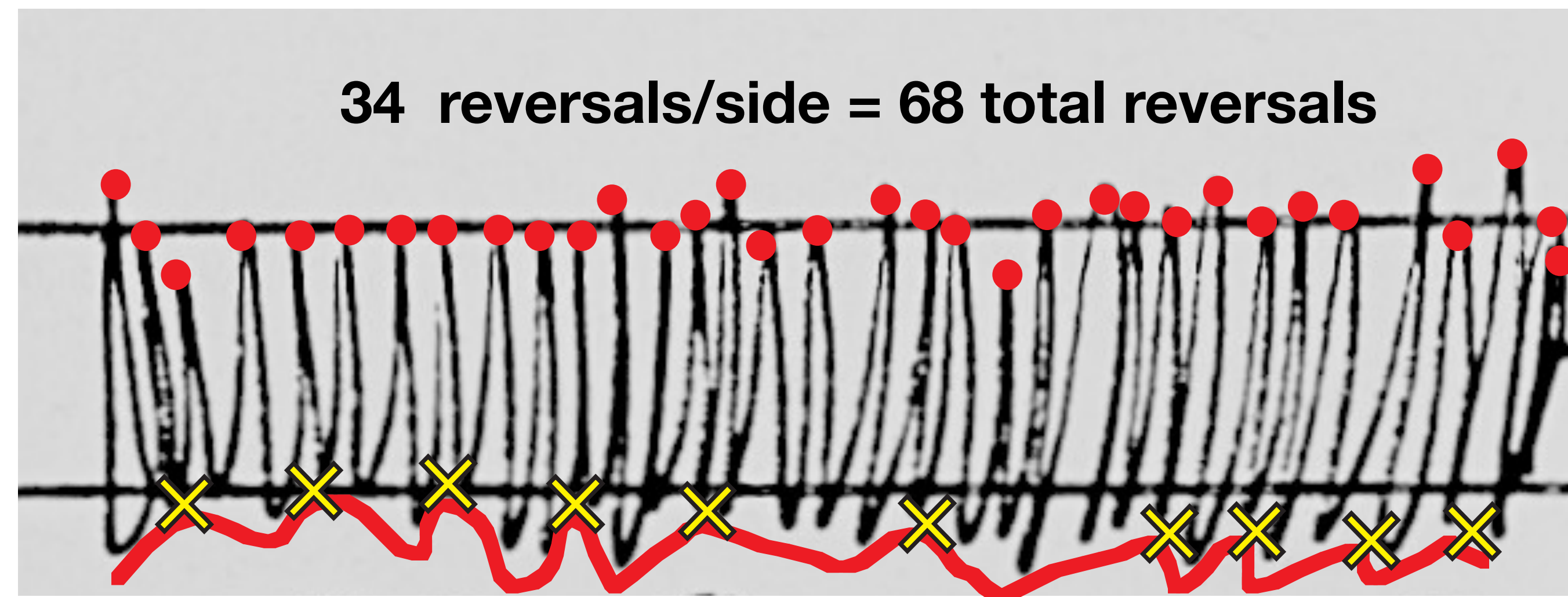
Model Human Processor



In-Class Experiment 4: Motor System

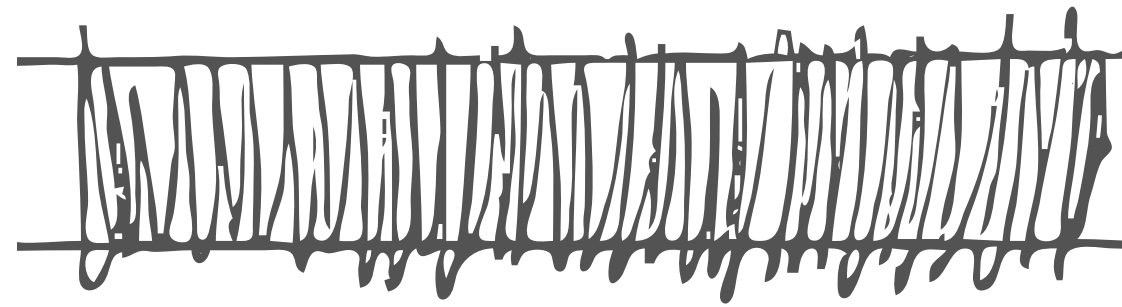


- Experiment: draw strokes between lines for 5s. Try to reach both lines.
- Count number of reversals
 - How many milliseconds per reversal?
- Create a contour of stroke bottoms, count number of corrections
 - How many milliseconds per correction?



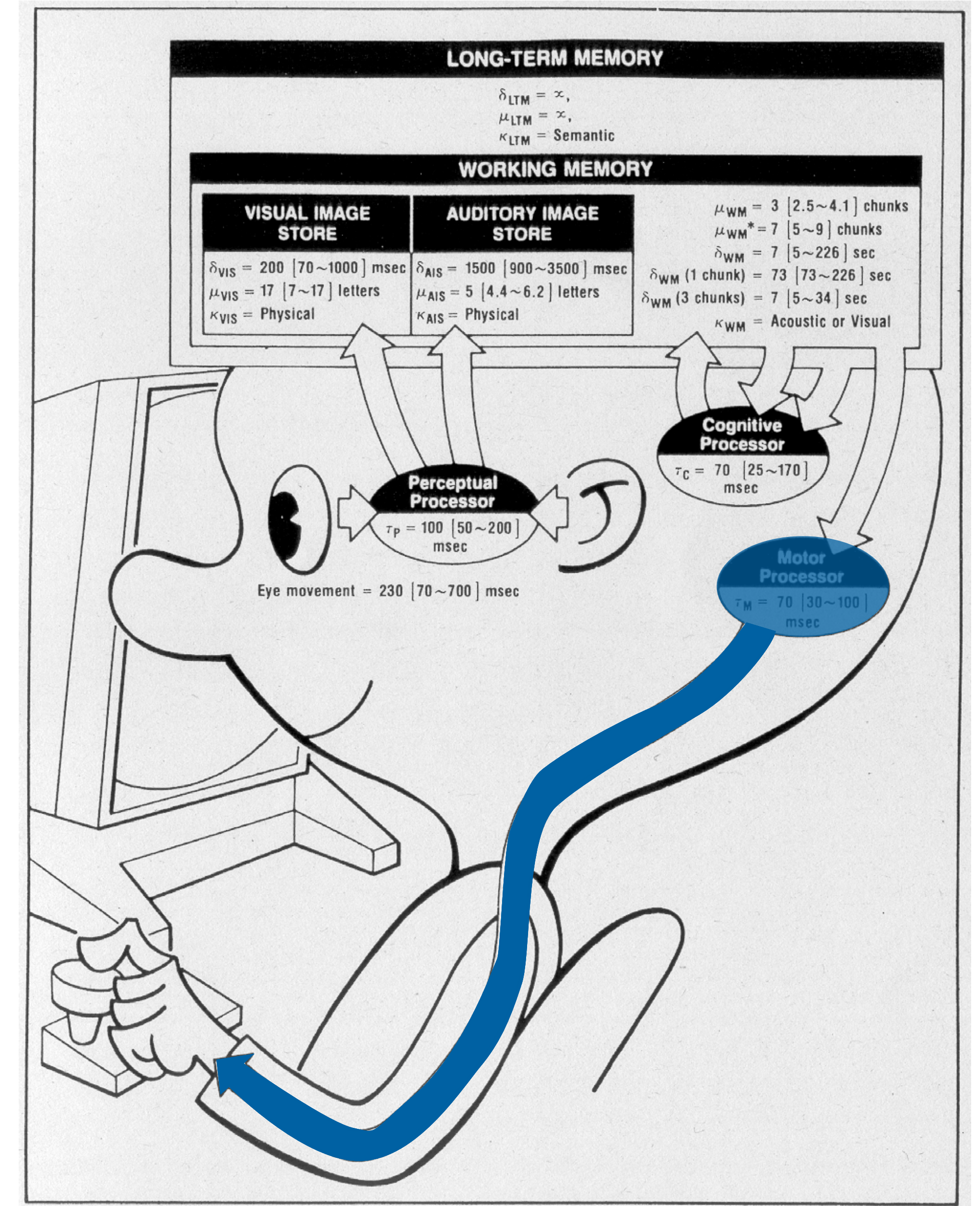
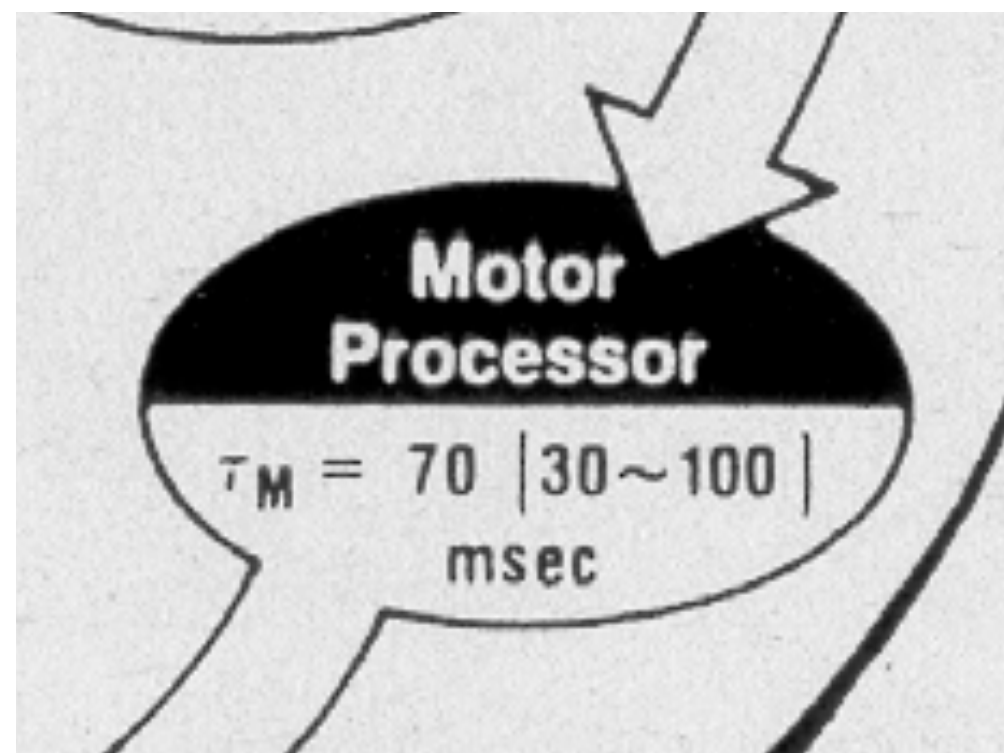
10 corrections/side = 20 total corrections

Motor System



74 ms/reversal
250 ms/correction

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

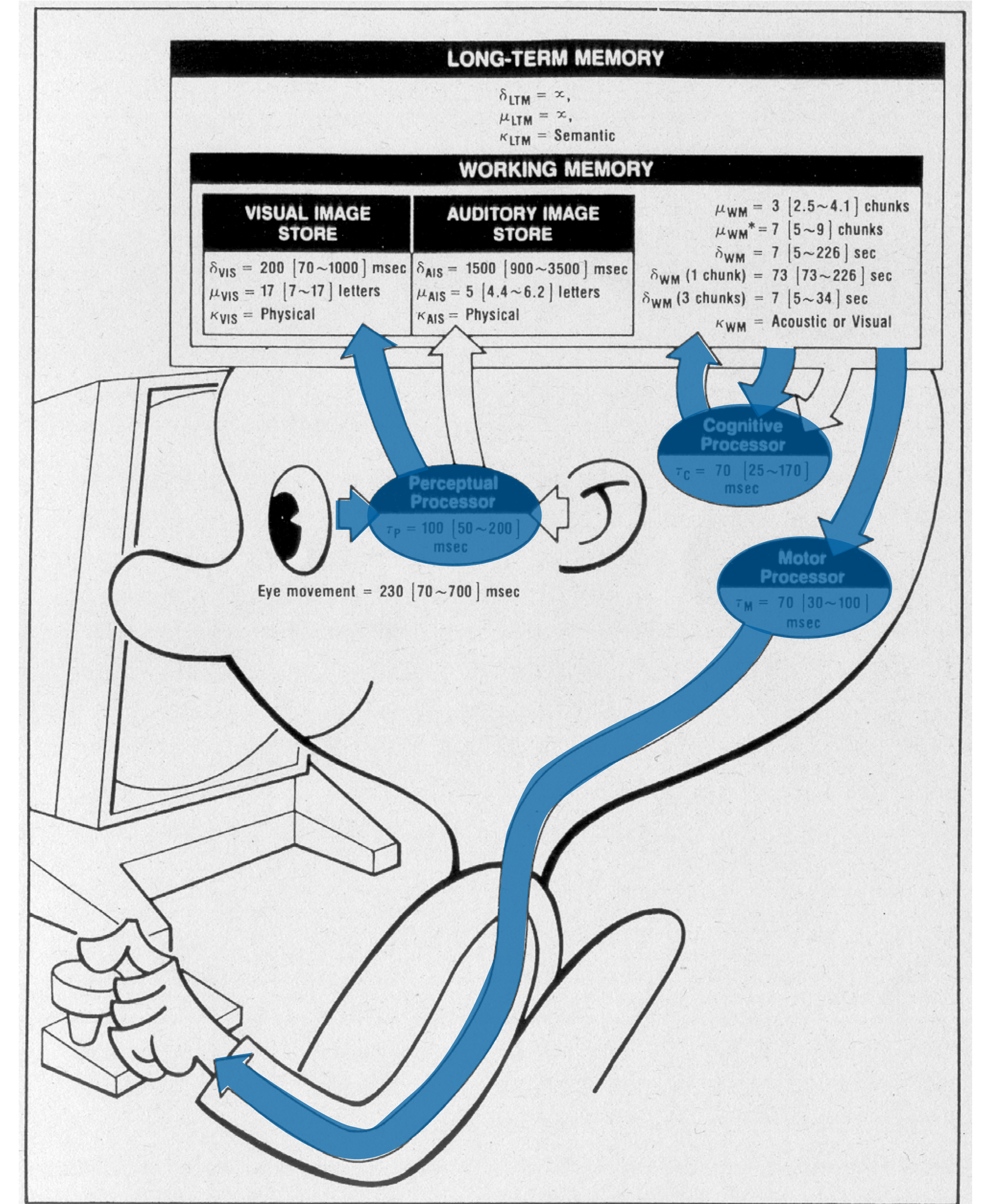


Motor System



74 ms/reversal
250 ms/correction

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

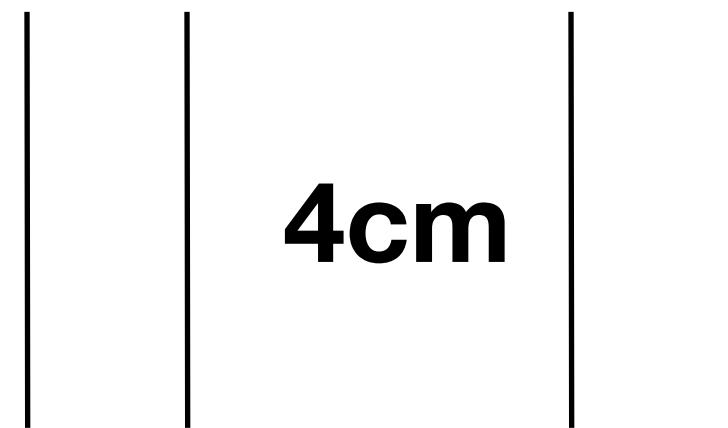


Fitts' Law

In-Class Experiment 5: Tapping Task

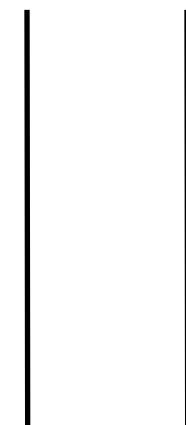


1cm

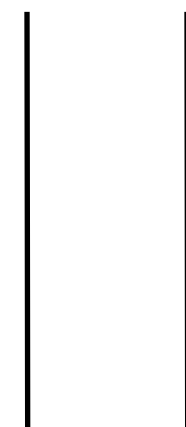


4cm

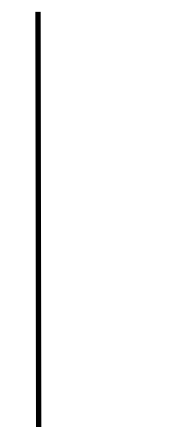
Same for 0.5 cm and 2 cm wide strips
Tap for 10 s, count taps afterwards



8cm

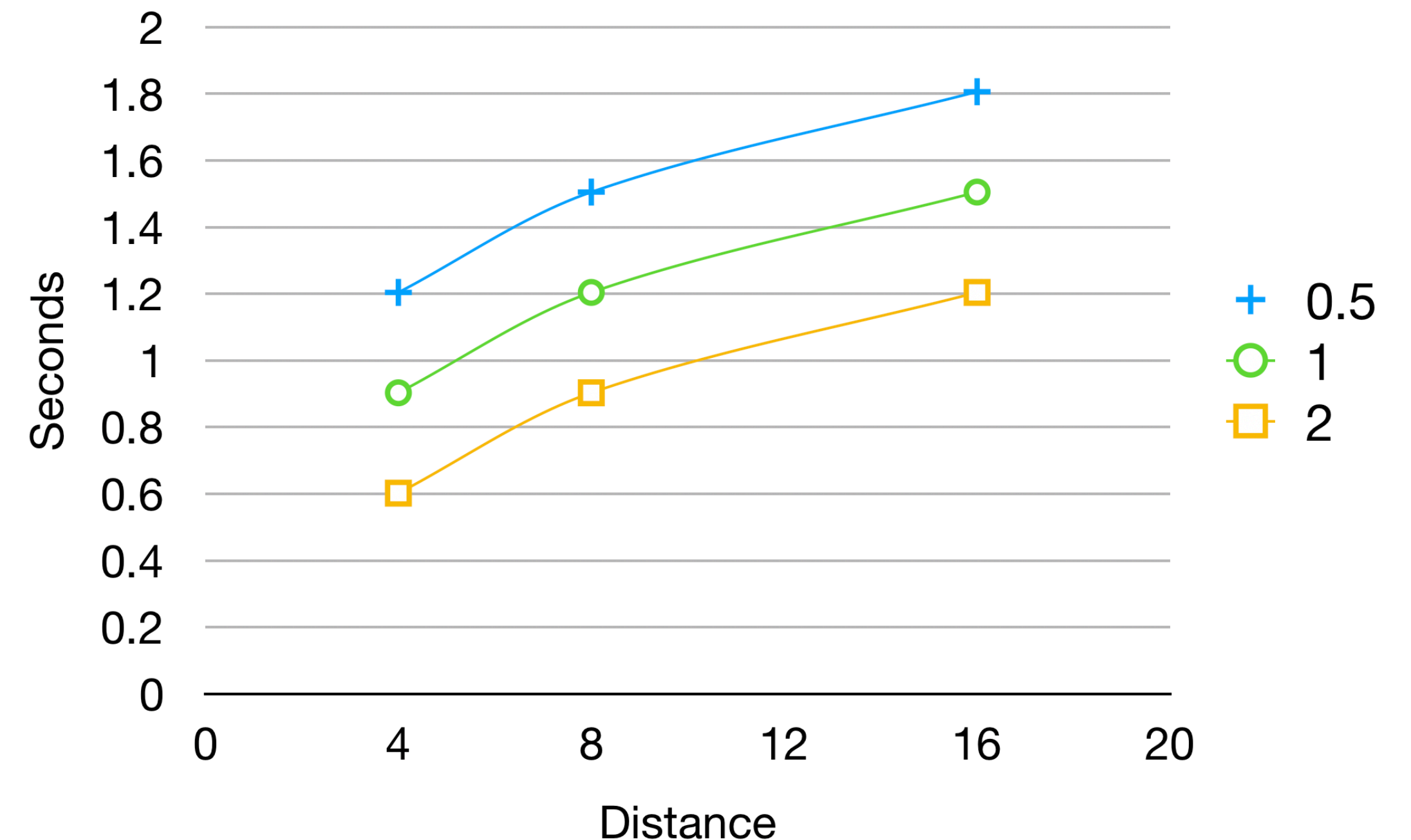


16cm



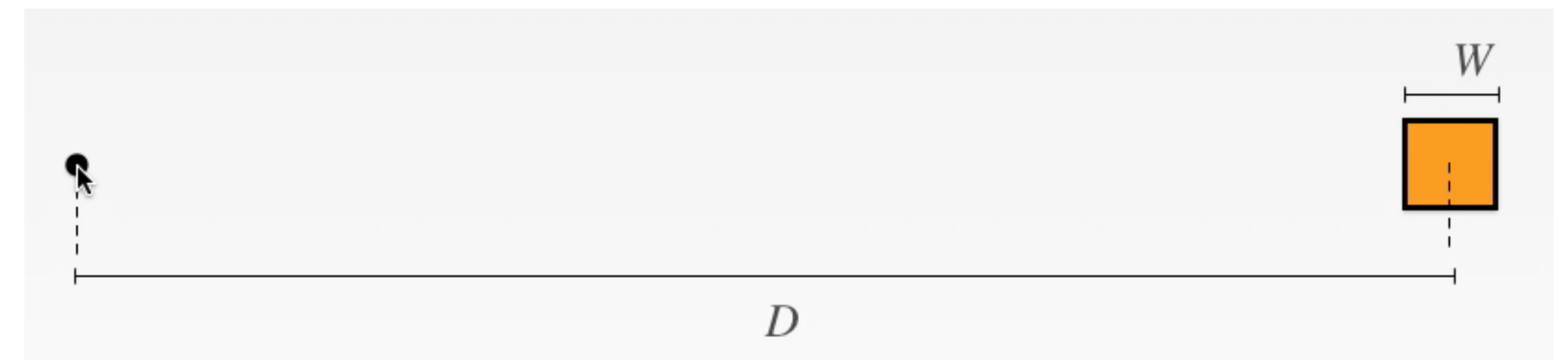
Tapping Task Results

- 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



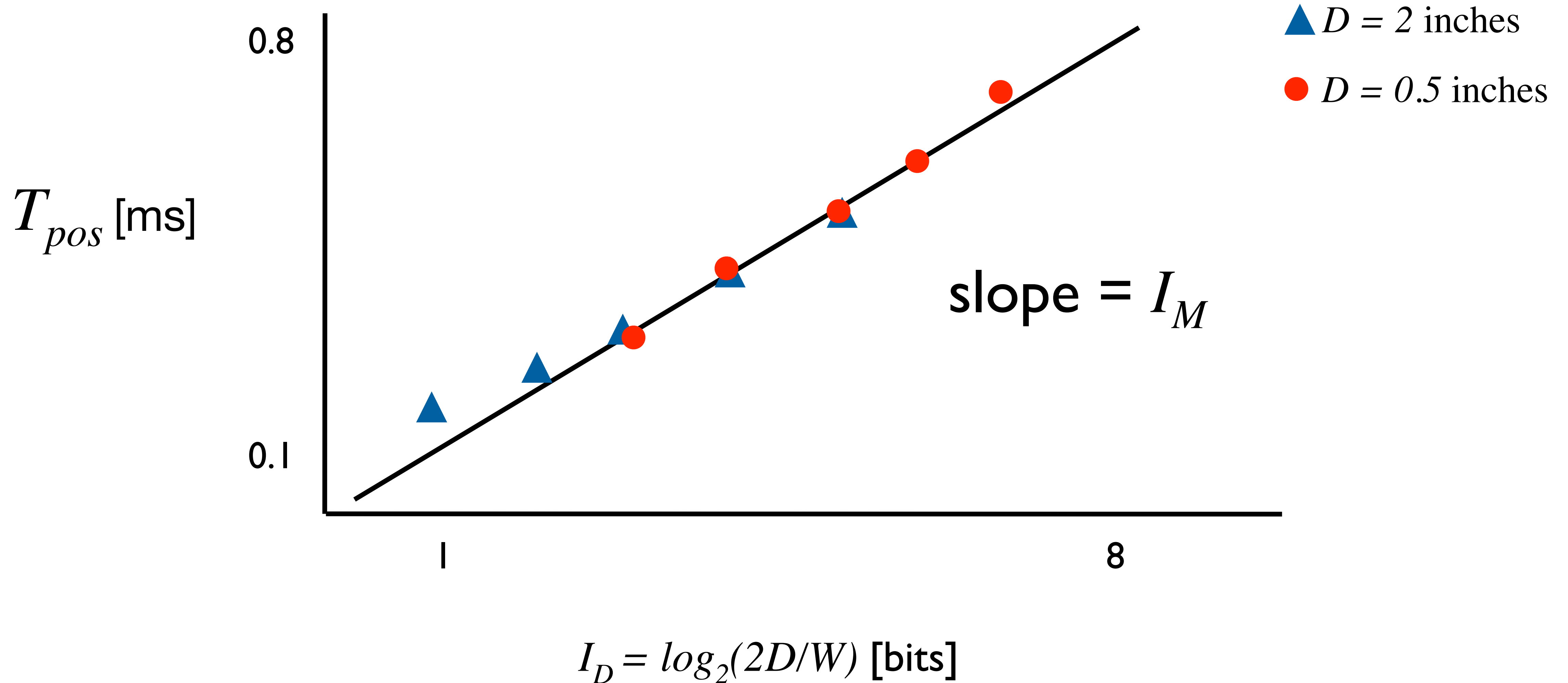
Motor System: Fitts' Law

- 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

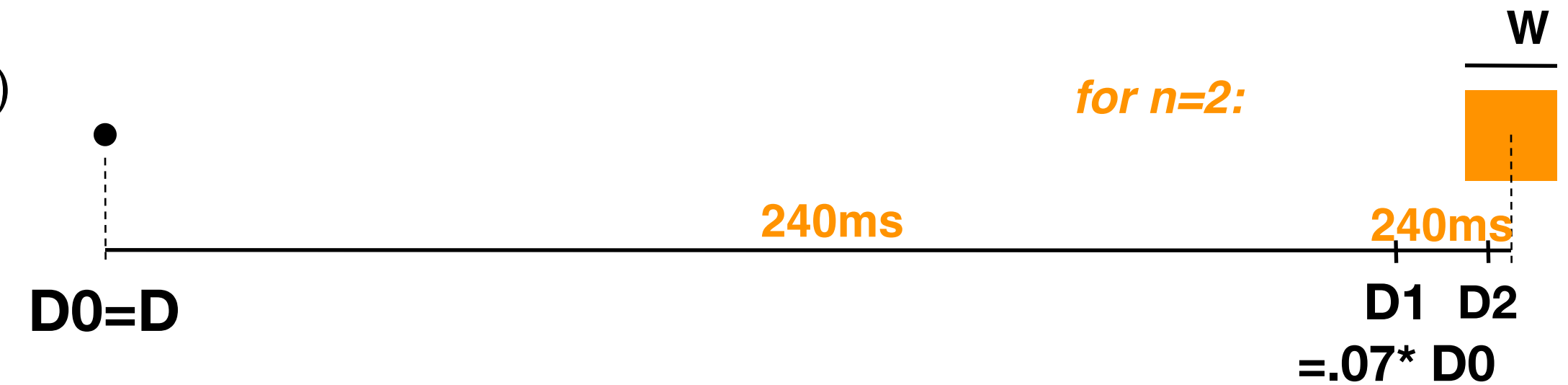
Experiment: fixed distance D , varying width W



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)

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



$$\begin{aligned}
 \epsilon^n &\leq \frac{W}{2D} \\
 \Leftrightarrow n &\geq \log_{\epsilon} \left(\frac{W}{2D} \right) \quad (\text{log for base } < 1 \text{ turns inequality sign}) \\
 \Leftrightarrow n &\geq \frac{\log_2 \left(\frac{W}{2D} \right)}{\log_2 \epsilon} \\
 \Leftrightarrow n &\geq -\frac{\log_2 \left(\frac{2D}{W} \right)}{\log_2 \epsilon}
 \end{aligned}$$

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:

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

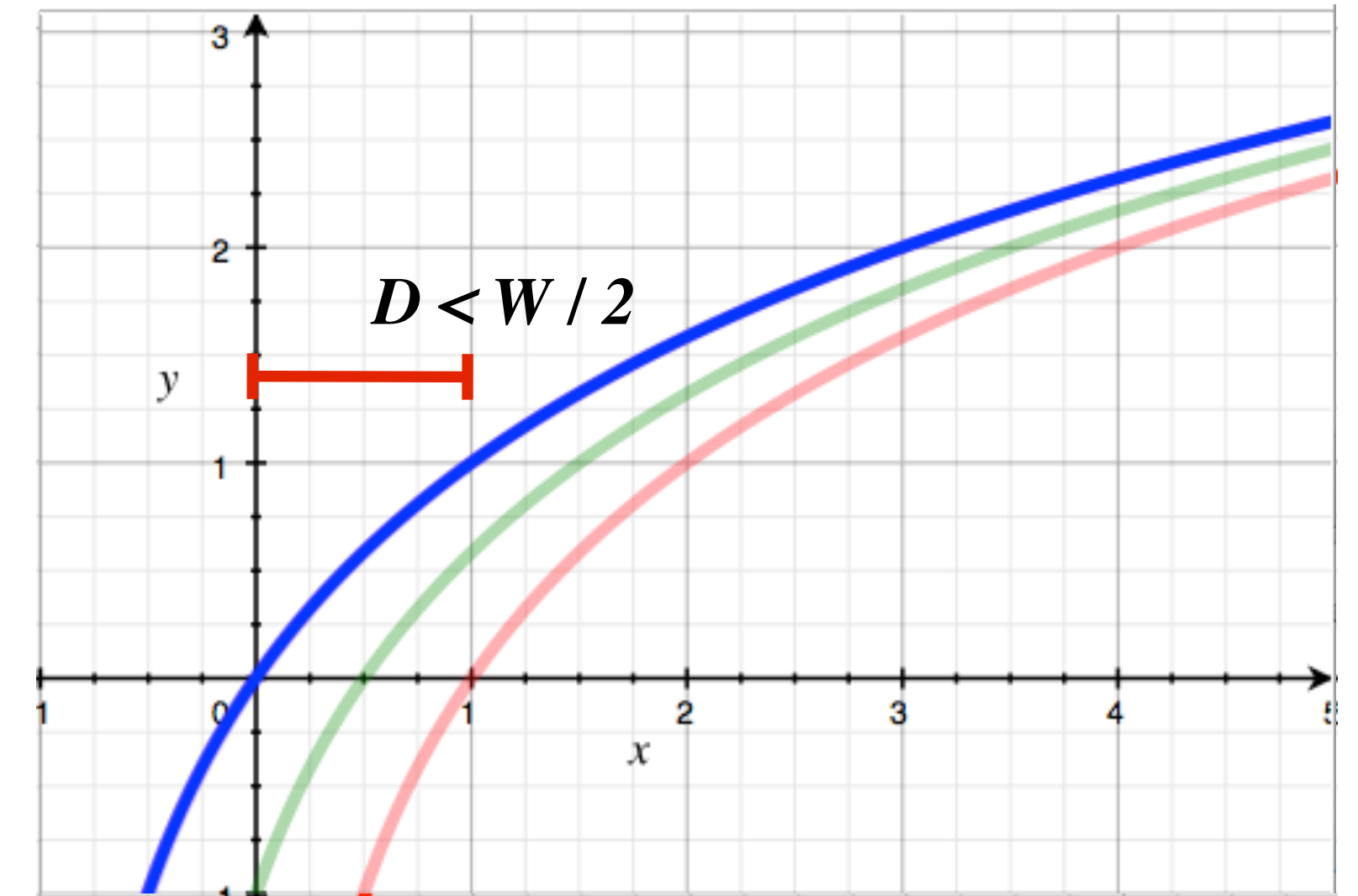
- Shannon's Formulation, ISO, 80's:

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

- 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

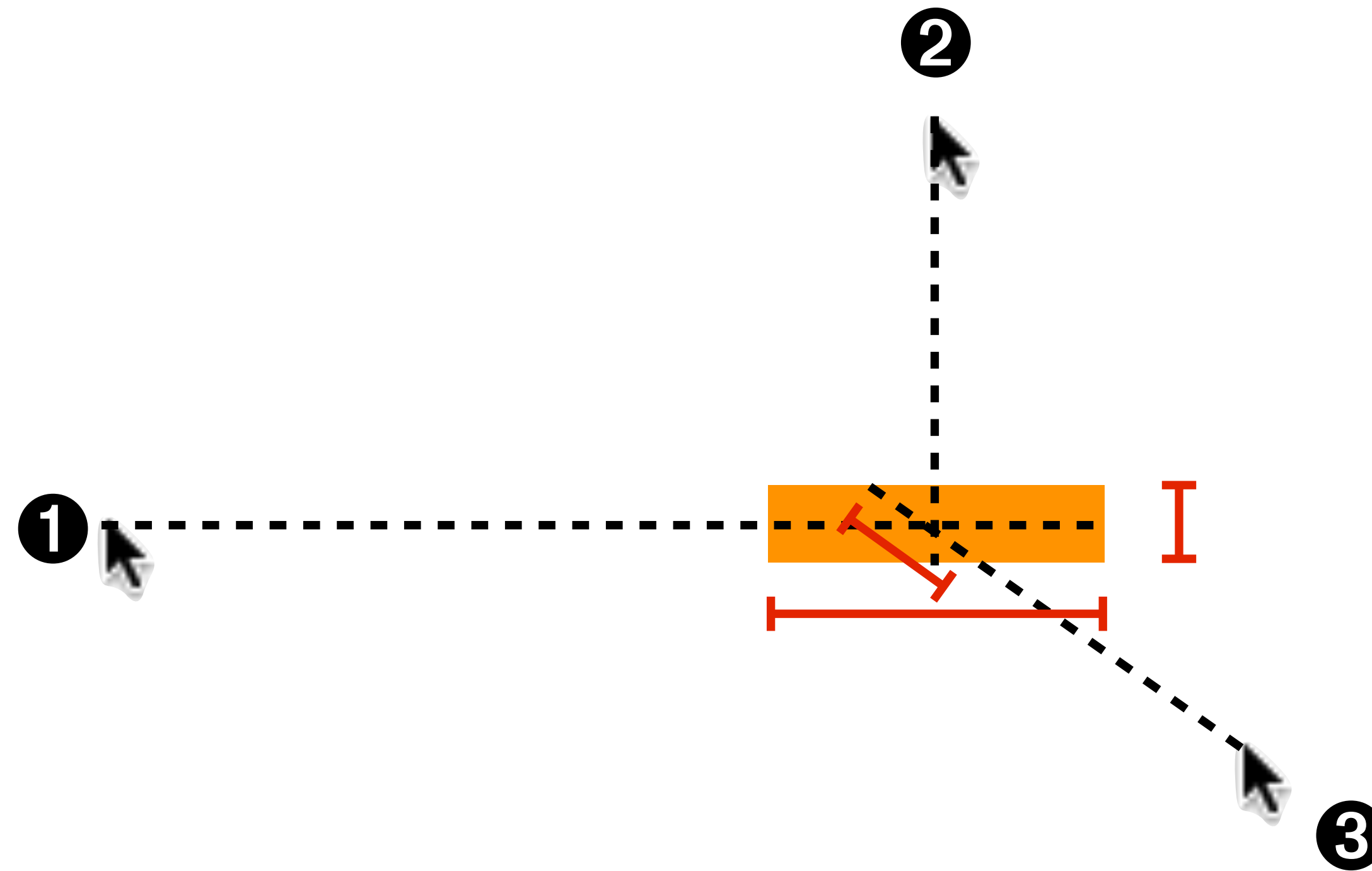


— $T_{pos} = I_M \cdot \log_2 \left(\frac{2D}{W} \right)$

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

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

Target Width

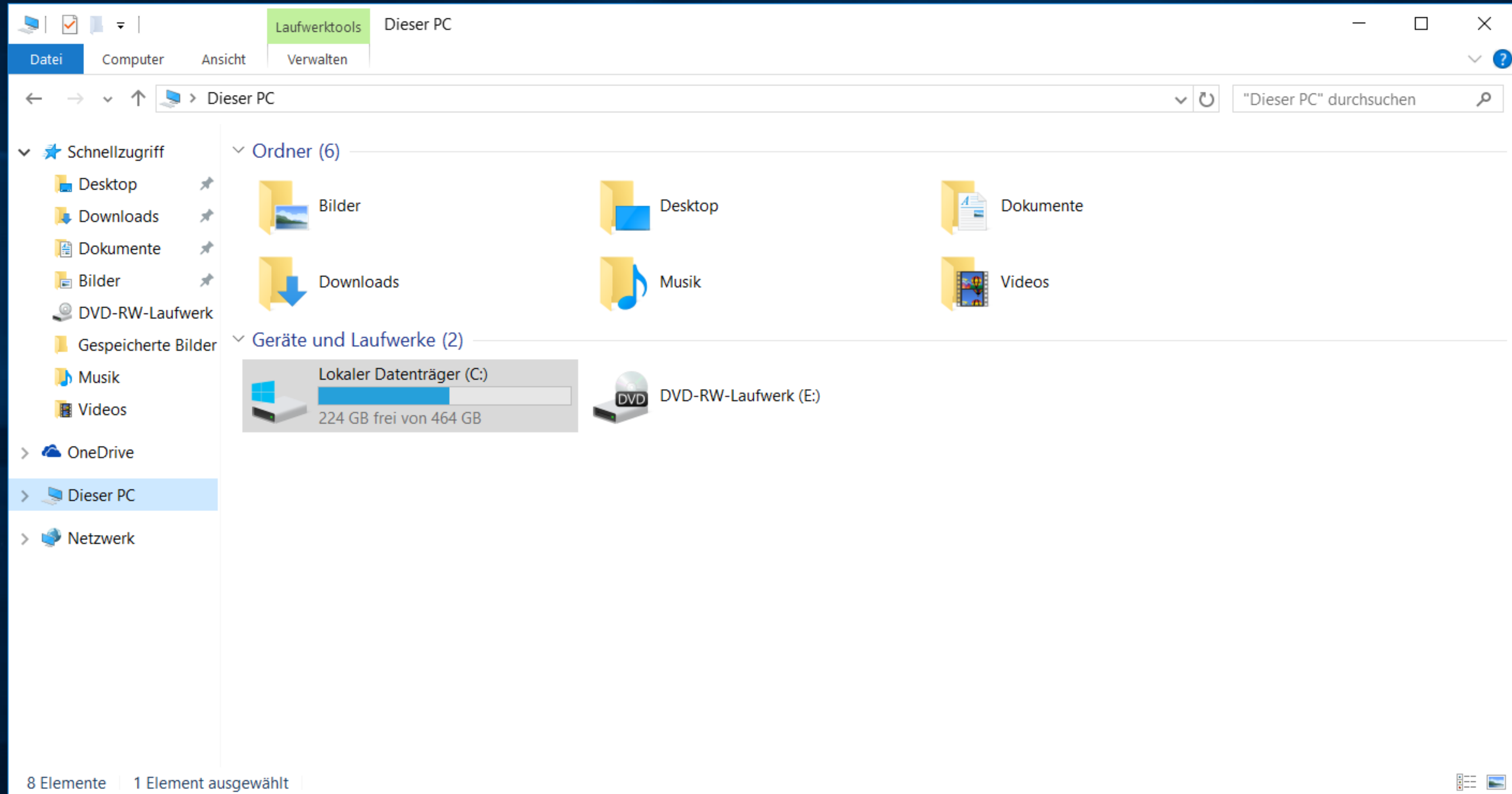


[MacKenzie & Buxton, CHI'92]

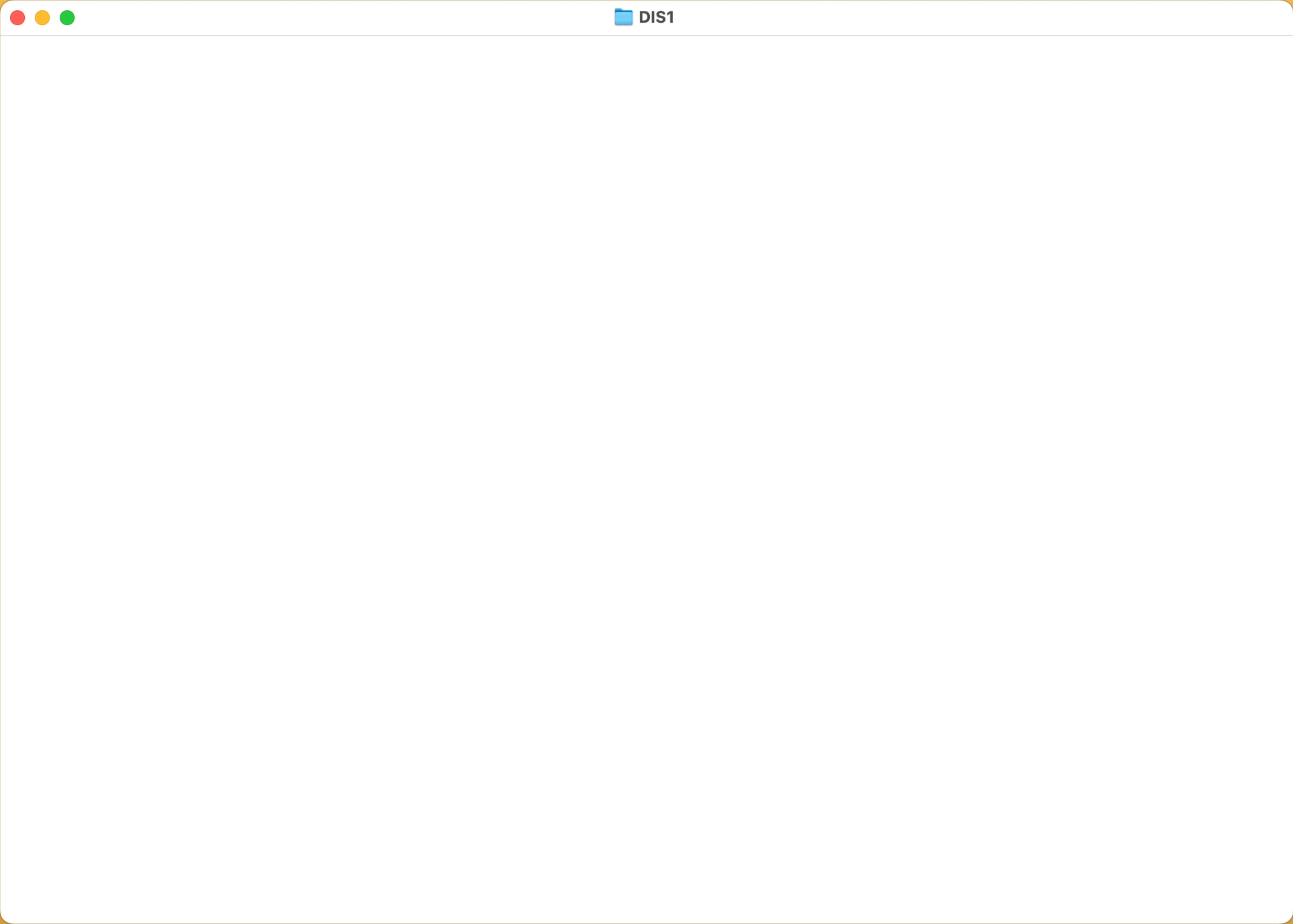


Papierkorb

Windows 10



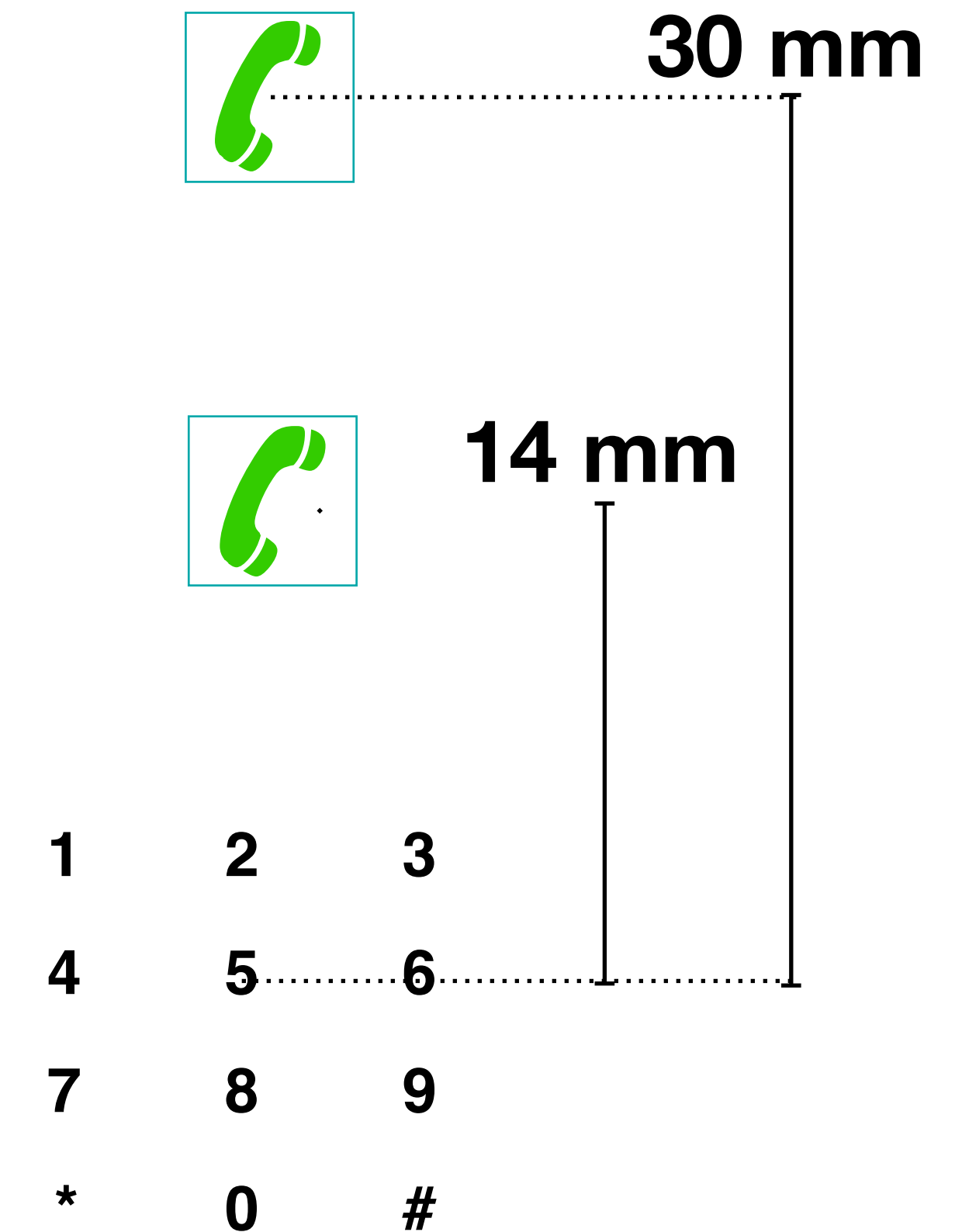
macOS Monterey



In-Class Exercise 6: 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

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

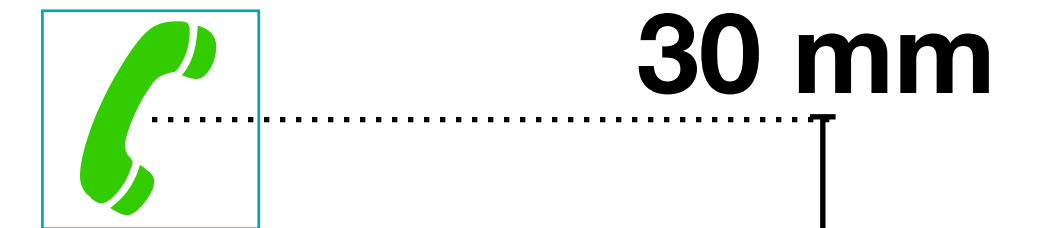
$$T_{Diff} = T_{pos1} - T_{pos2} = a + b \cdot \log_2\left(\frac{D_1}{W} + 1\right) - (a + b \cdot \log_2\left(\frac{D_2}{W} + 1\right))$$

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

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

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

⇒ 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)