Modeling Interaction 2

CS6501: Human-Computer Interaction

Seongkook Heo

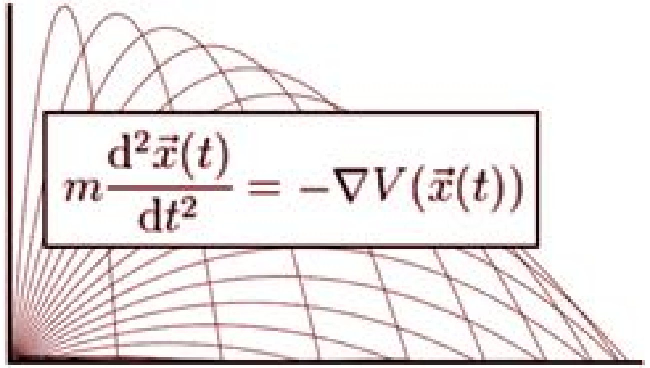
Fall 2020, Department of Computer Science

What is a model?

- A *model* is a simplification of reality

Architect's scale model of a building

Physicist's model for the trajectory of a tossed ball



description

→ provides insight into space usage, movement of people, light, etc.

prediction

→ gives the ball's position as a function of time

Fitts' Law

- One of the most widely used models in HCI
- Model for rapid aimed movements
- Three applications:
  1. Use a Fitts' law prediction equation to analyse and compare design alternatives
  2. Use Fitts' *index of performance* (now *throughput*) as a dependent variable in a comparative evaluation
  3. Determine if a device or technique "conforms to Fitts' law"
- Origins: Two papers in experimental psychology[1,2]

[1] Fitts, P. M. (1954). The information capacity of the human motor system in controlling the amplitude of movement. *Journal of Experimental Psychology, 47*, 381-391.

[2] Fitts, P. M., & Peterson, J. R. (1964). Information capacity of discrete motor responses. *Journal of Experimental Psychology, 67*, 103-112.

Fitts' Law

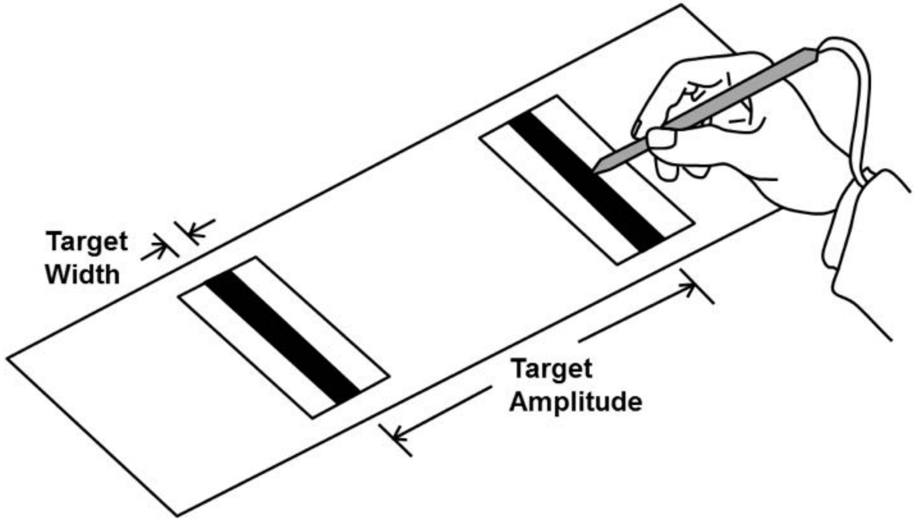
- One of the most widely used models in HCI
- Model for rapid aimed movements
- Three applications:
  1. Use a Fitts' law prediction equation to analyse and compare design alternatives

     Predictive model
  2. Use Fitts' *index of performance* (now *throughput*) as a dependent variable in a comparative evaluation
  3. Determine if a device or technique "conforms to Fitts' law"
- Origins: Two papers in experimental psychology[1,2]

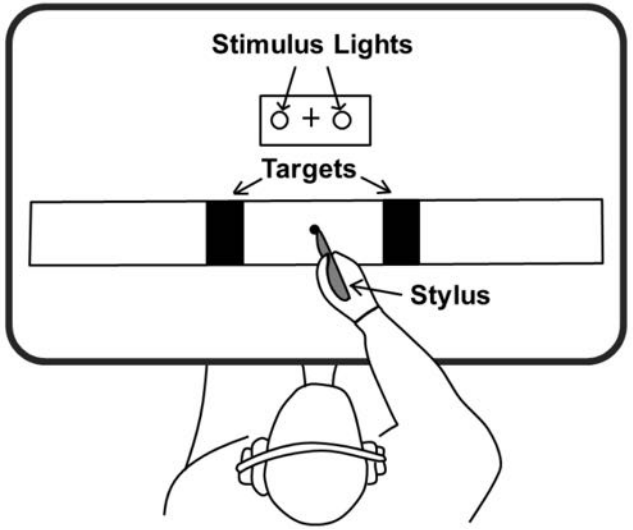
[1] Fitts, P. M. (1954). The information capacity of the human motor system in controlling the amplitude of movement. *Journal of Experimental Psychology, 47*, 381-391.

[2] Fitts, P. M., & Peterson, J. R. (1964). Information capacity of discrete motor responses. *Journal of Experimental Psychology, 67*, 103-112.

Fitts' Law – Task Paradigms



Serial task



Discrete task

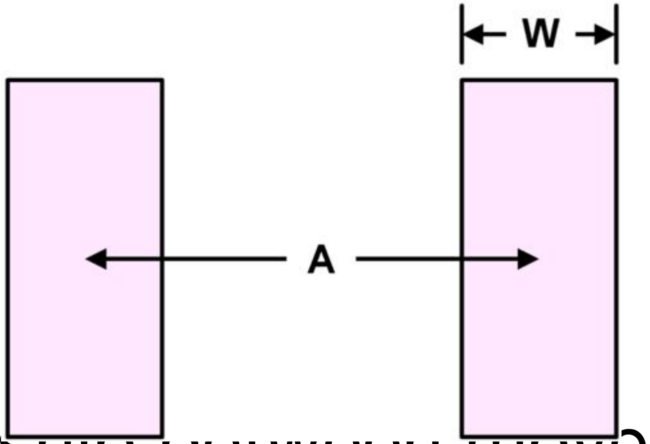
These sketches were adapted from Fitts' 1954 and 1964 papers.

Fitts' Index of Difficulty (*ID*)

- Fitts' index of difficulty (*ID*) is a measure of the difficulty of a target selection task:

$$ID = \log_2\left(\frac{A}{W} + 1\right)$$

Units: bits



- Fitts hypothesized that the relationship between movement time (*MT*) and *ID* is linear

Fitts' Law Models for Pointing Devices

- A research project compared four pointing devices, including two for remote pointing[1]
- Twelve participants performed the tasks using for devices, including:

Interlink *RemotePoint*

Microsoft *Mouse 2.0*

[1] MacKenzie, I. S., & Jusoh, S. (2001). An evaluation of two input devices for remote pointing. *Proceedings - EHCI 2000*, 235-249, Heidelberg, Germany: Springer-Verlag.

Experiment Conditions and Observations

Conditions

Mouse Observations

RemotePoint Observations

A (pixels)	*W* (pixels)	*ID* (bits)	Mouse				RemotePoint			
			W_e (pixels)	ID_e (bits)	*MT* (ms)	*TP* (bits/s)	W_e (pixels)	ID_e (bits)	*MT* (ms)	*TP* (bits/s)
40	10	2.32	11.23	2.19	665	3.29	13.59	1.98	1587	1.25
40	20	1.58	19.46	1.61	501	3.21	21.66	1.51	1293	1.17
40	40	1.00	40.20	1.00	361	2.76	37.92	1.04	1001	1.04
80	10	3.17	10.28	3.13	762	4.11	10.08	3.16	1874	1.69
80	20	2.32	18.72	2.40	604	3.97	25.21	2.06	1442	1.43
80	40	1.58	35.67	1.70	481	3.53	37.75	1.64	1175	1.40
160	10	4.09	10.71	3.99	979	4.08	10.33	4.04	2353	1.72
160	20	3.17	21.04	3.11	823	3.77	19.09	3.23	1788	1.81
160	40	2.32	41.96	2.27	615	3.69	35.97	2.45	1480	1.65
		Mean	23.25	2.38	644	3.60	23.51	2.35	1555	1.46

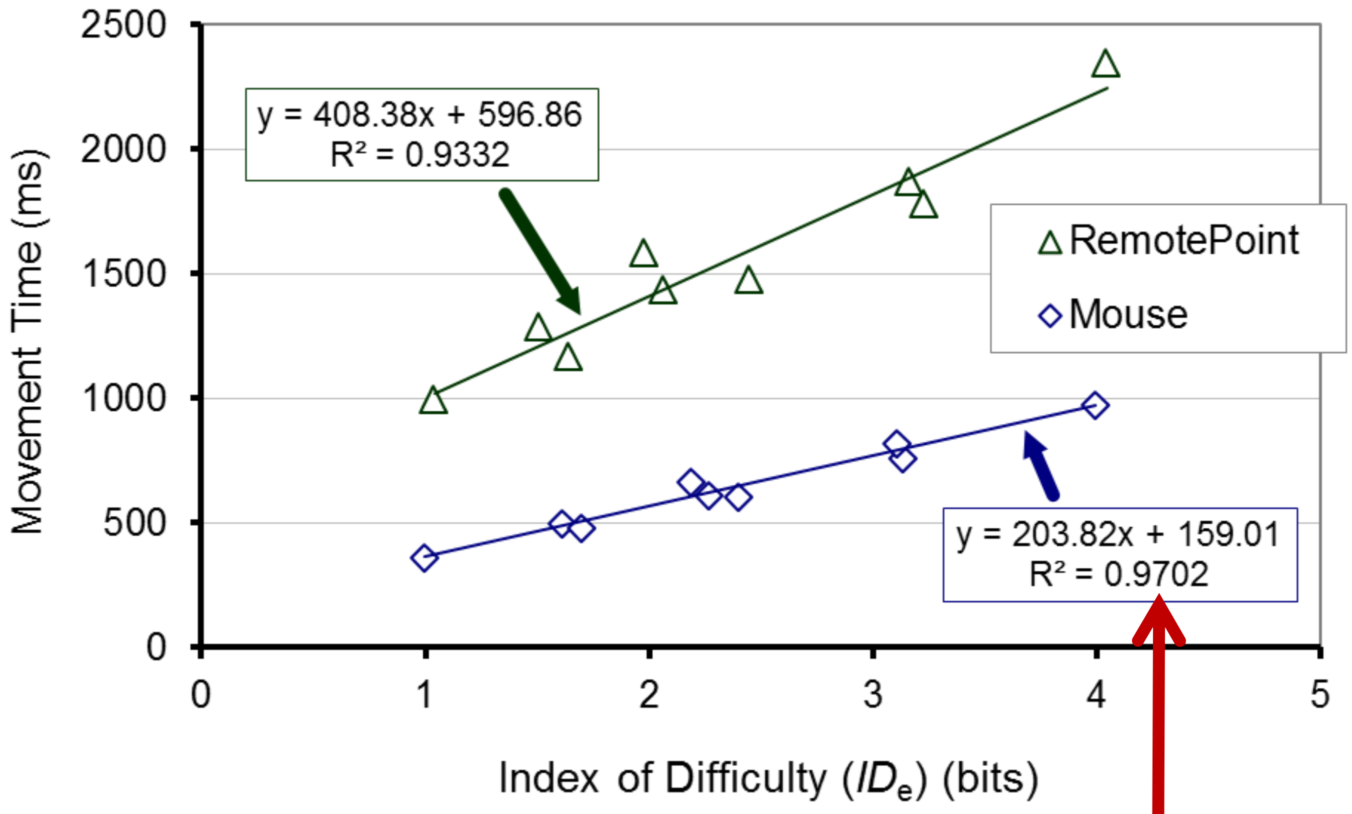
x sample points

y sample points

x sample points

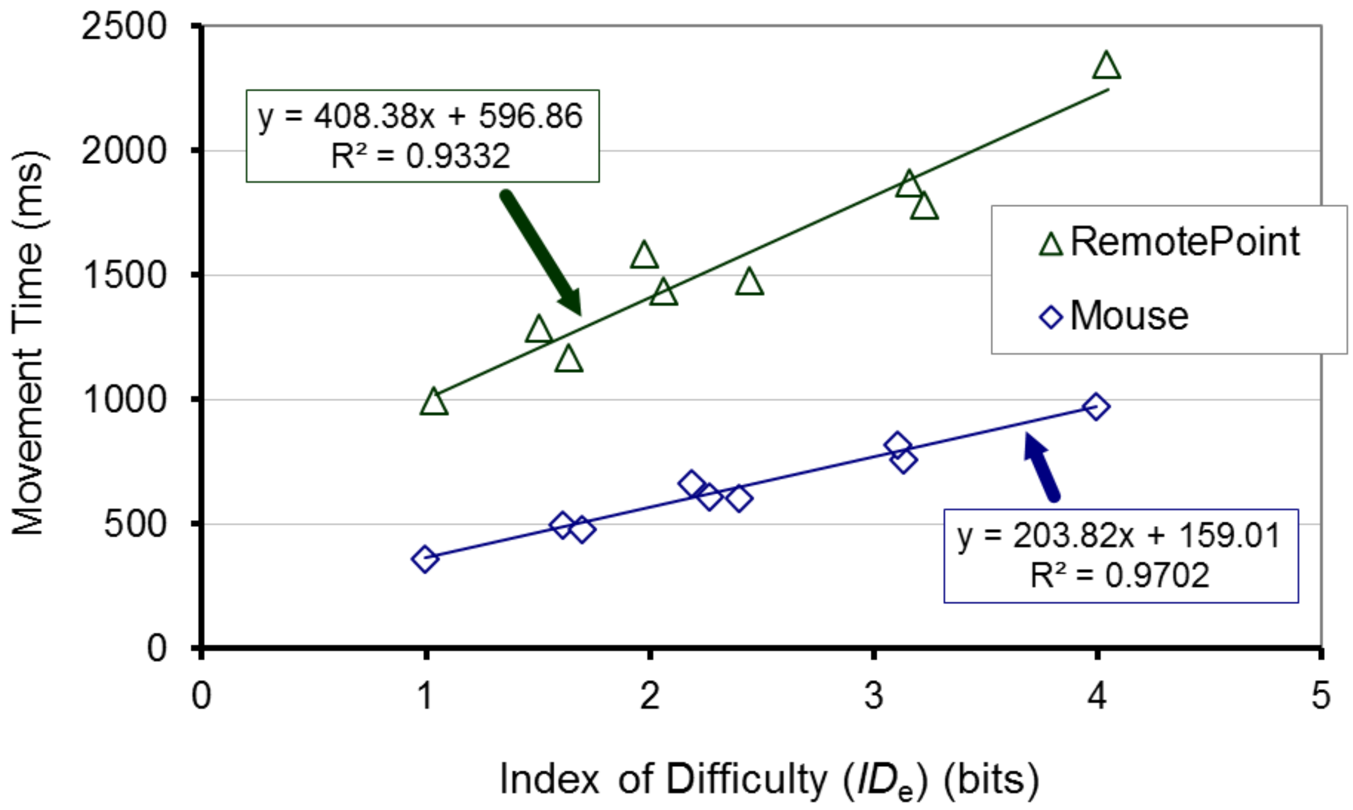
y sample points

Fitts' Law Prediction Equations



Squared correlations are very high.
Yes, the *MT-ID* relationship is linear!

Fitts' Law Prediction Equations



$$\mathrm{MT} = a + b \cdot \mathrm{ID}$$

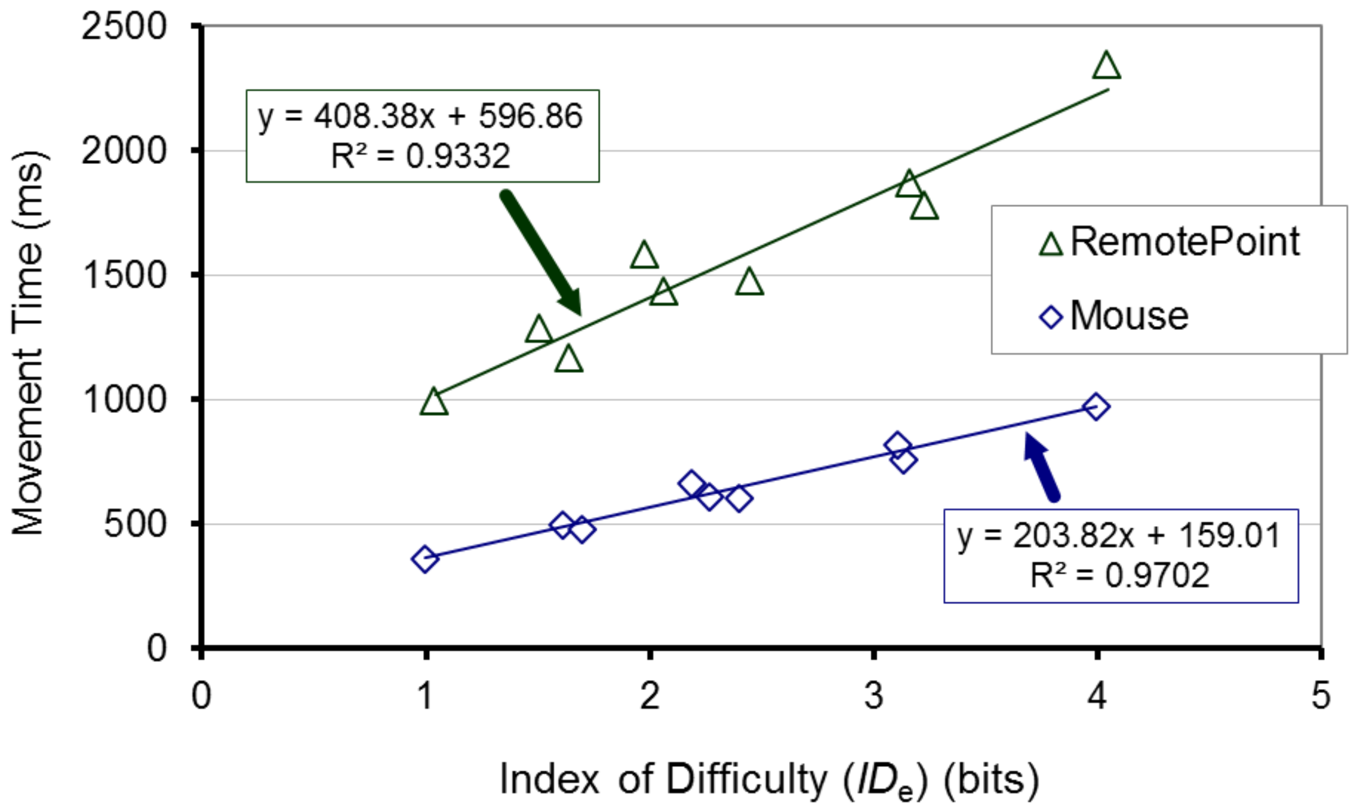
Mouse

MT = 159 + 204 x $\log_2$(A/W +1) ms

RemotePoint

MT = 597 + 408 x $\log_2$(A/W +1) ms

Fitts' Law Prediction Equations



$$MT = a + b \cdot ID$$

Mouse

MT = 159 + 204 x $\log_2$(A/W +1) ms

RemotePoint

MT = 597 + 408 x $\log_2$(A/W +1) ms

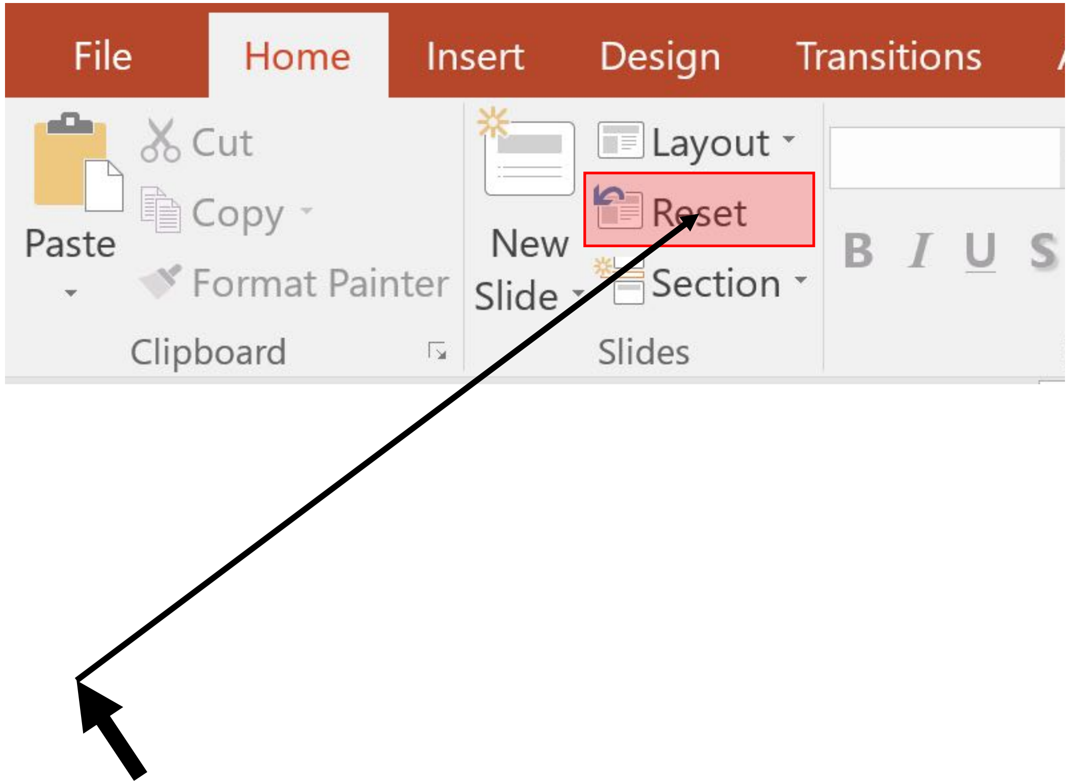
Throughput (Index of Performance) = *ID/MT (bits per second)* = *1/b*

60 Years of Data

Device	Study	*IP* (bits/s)
Hand	Fitts (1954)	10.6
Mouse	Card, English, & Burr (1978)	10.4
Joystick	Card, English, & Burr (1978)	5.0
Trackball	Epps (1986)	2.9
Touchpad	Epps (1986)	1.6
Eyetracker	Ware & Mikaelian (1987)	13.7

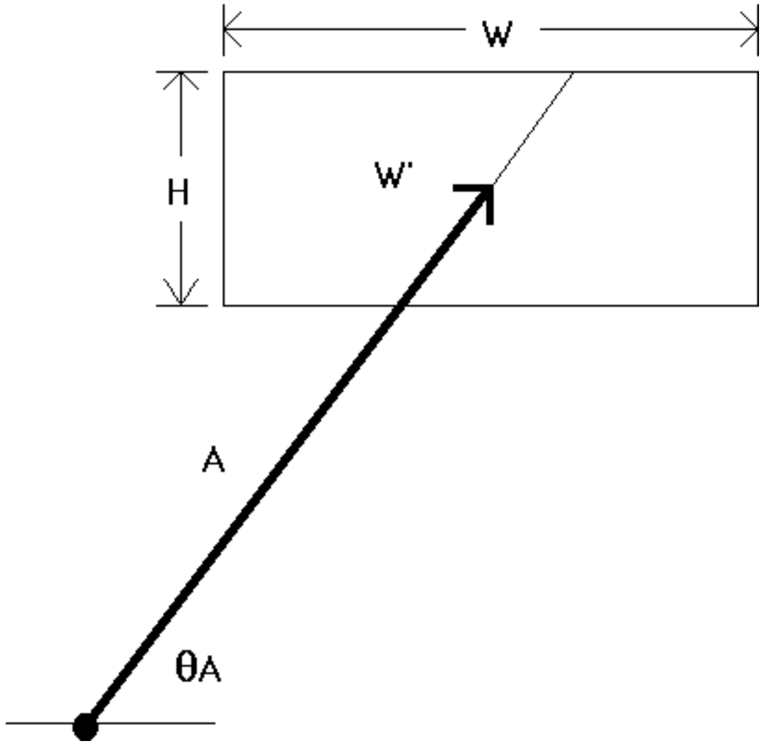
MacKenzie, I. Fitts' Law as a research and design tool in human computer interaction. *Human Computer Interaction, 1992, Vol. 7, pp. 91-139*

What About 2D Targets?



Fitts' Law in 2D

- What is the target width?

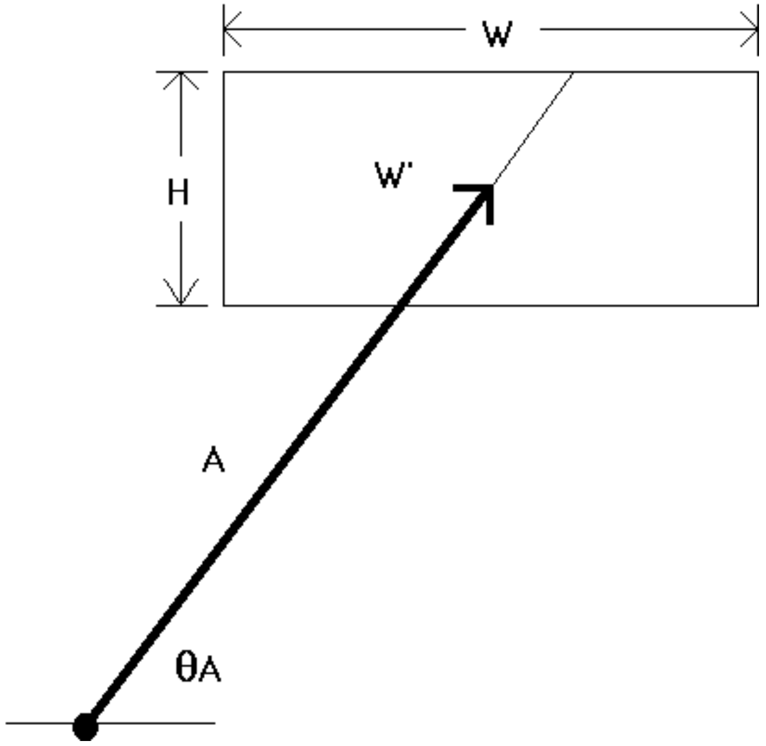


MacKenzie, I. S., & Buxton, W. (1992, June). Extending Fitts' law to two-dimensional tasks. In *Proceedings of the SIGCHI conference on Human factors in computing systems* (pp. 219-226). ACM.

Fitts’ Law in 2D

- What is the target width?
- Compare various interpretations of width
- See which has best fit

Model	Target Width
STATUS QUO	horizontal extent (*W*)
W+*H*	sum of width and height
W×*H*	area
SMALLER-OF	smaller of width or height
W'	width along line of approach

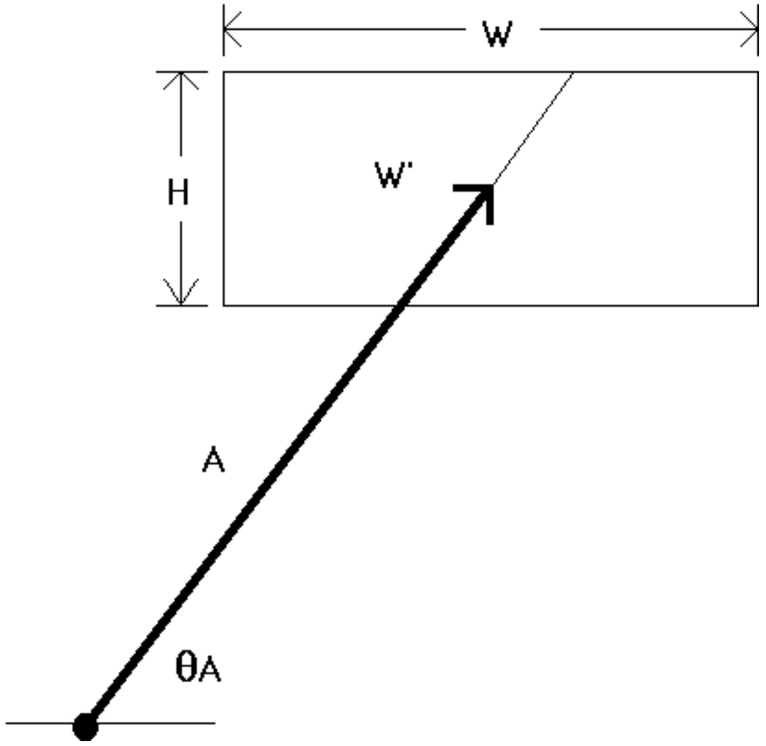


MacKenzie, I. S., & Buxton, W. (1992, June). Extending Fitts' law to two-dimensional tasks. In *Proceedings of the SIGCHI conference on Human factors in computing systems* (pp. 219-226). ACM.

Fitts' Law in 2D

- What is the target width?
- Compare various interpretations of width
- See which has best fit

Model for Target Width	ID Range (bits) Low	High	r^2
SMALLER-OF	1.58	5.04	.9501
W '	1.00	5.04	.9333
W+H	0.74	3.54	.8755
WxH	0.32	4.09	.8446
STATUS QUO	1.00	5.04	.8097



MacKenzie, I. S., & Buxton, W. (1992, June). Extending Fitts' law to two-dimensional tasks. In *Proceedings of the SIGCHI conference on Human factors in computing systems* (pp. 219-226). ACM.

Beating Fitts' Law

$$ID = \log_2\left(\frac{A}{W} + 1\right)$$

Increase the Width

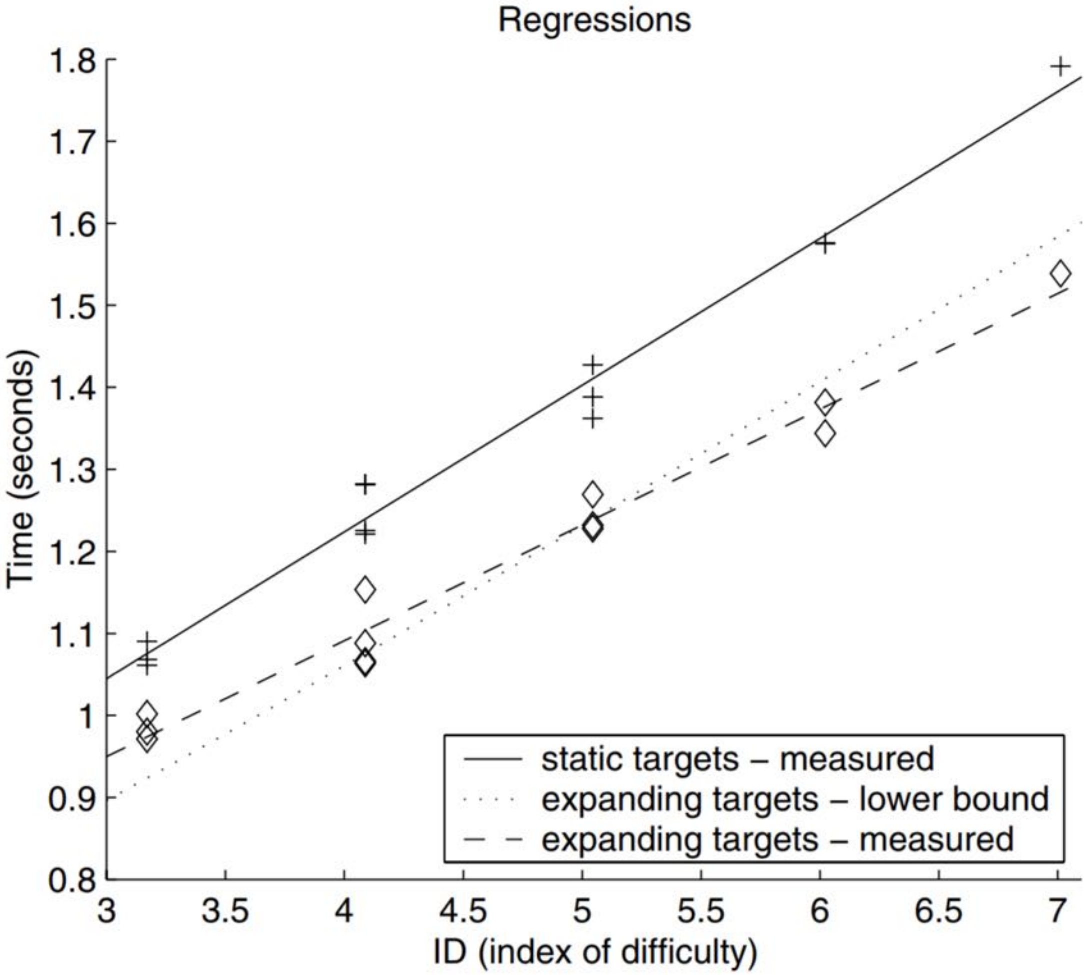
Decrease the Distance

Ravin Balakrishnan. 2004. "Beating" Fitts' law: virtual enhancements for pointing facilitation. Int. J. Hum.-Comput. Stud. 61, 6 (December 2004), 857-874.

Increasing the Width: Expanding Targets

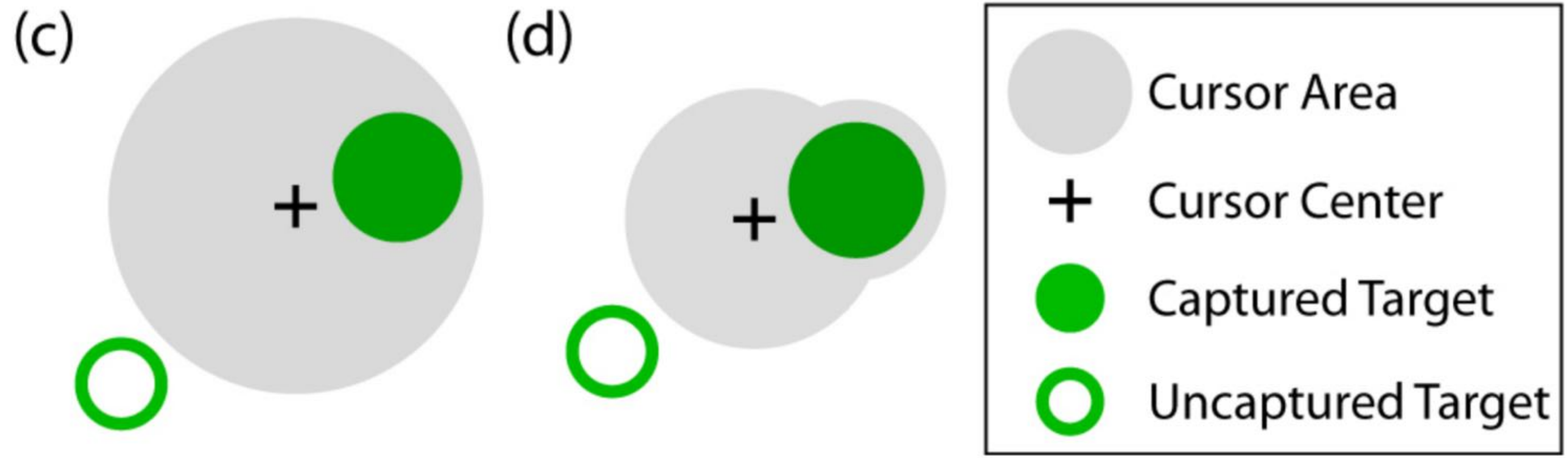
http://www.dgp.toronto.edu/people/ravin/papers/expandingTargets

Increasing the Width: Expanding Targets



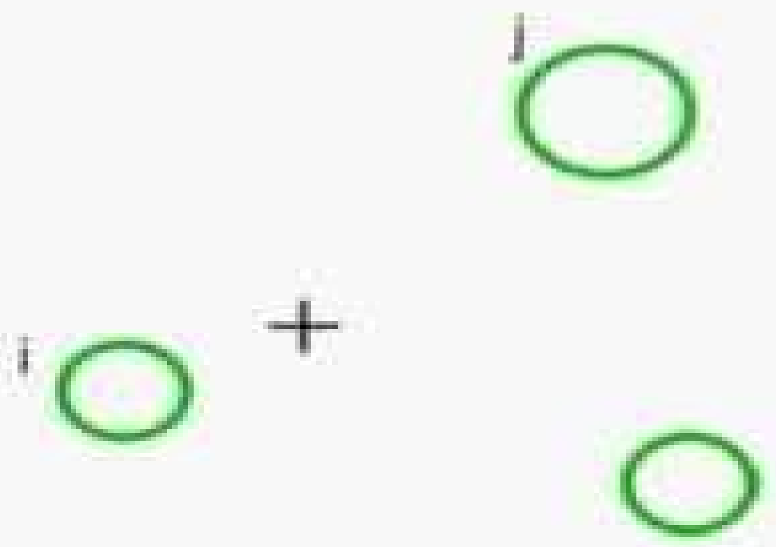
Michael McGuffin, Ravin Balakrishnan. (2002). Acquisition of expanding targets. Proceedings of CHI 2002 – the ACM Conference on Human Factors in Computing Systems. p. 57-64.

Increasing the Width: Bubble Cursor



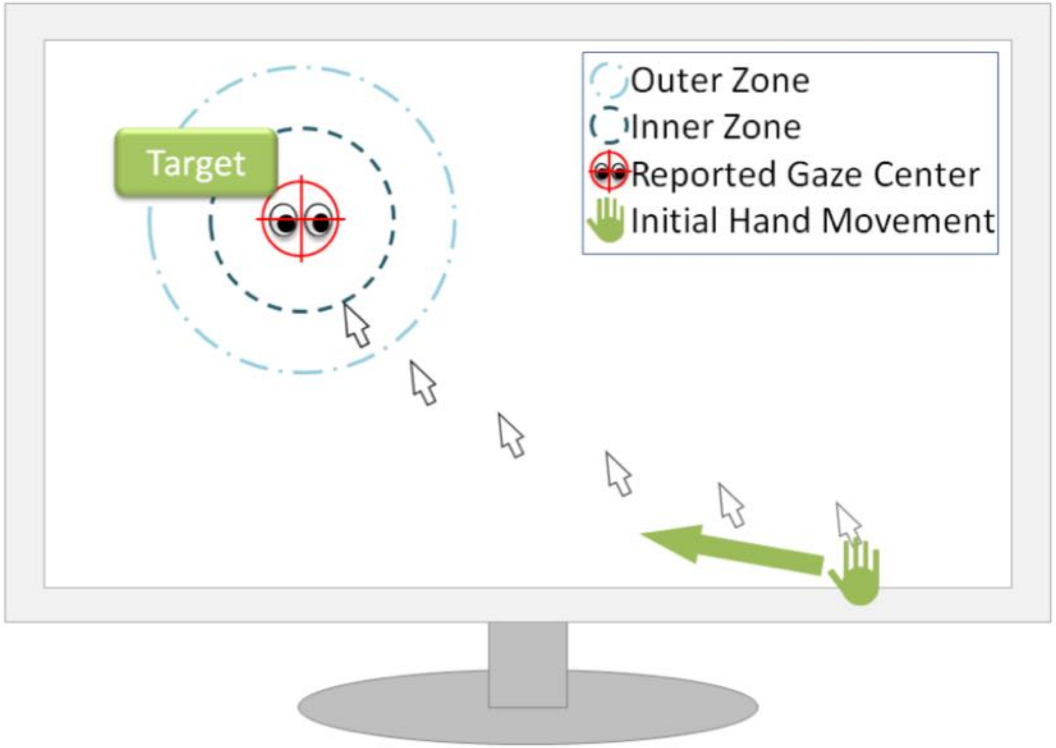
Tovi Grossman and Ravin Balakrishnan. 2005. The bubble cursor: enhancing target acquisition by dynamic resizing of the cursor's activation area. In *Proceedings of the SIGCHI conference on Human factors in computing systems* (CHI '05). ACM, New York, NY, USA, 281-290.

Calculating the Radius



Consider the two closest targets i and j

Decreasing the Distance: Gaze-Assisted Cursor



Ribel Fares, Shaomin Fang, and Oleg Komogortsev. 2013. Can we beat the mouse with MAGIC?. In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '13). ACM, New York, NY, USA, 1387-1390.

Can We Beat the Mouse with MAGIC?

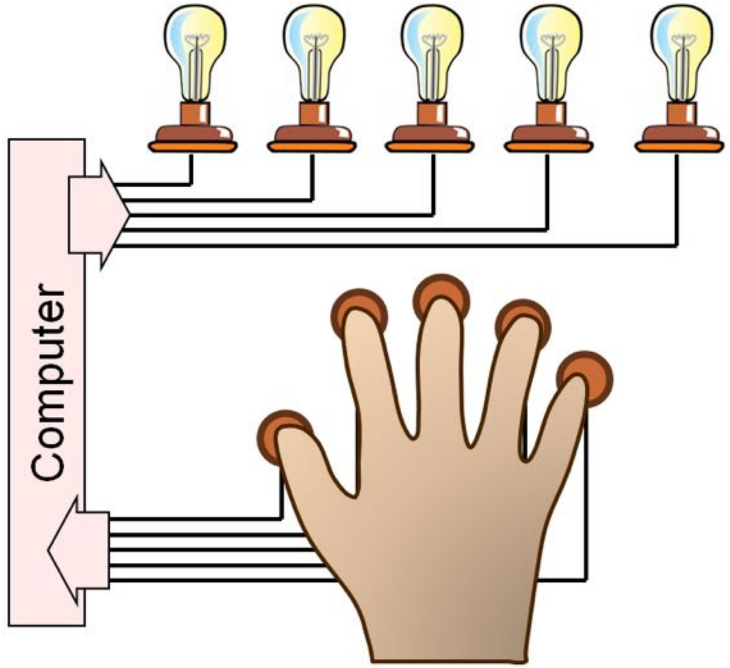
CHI 2013

Ribel Fares, Shaomin Fang, Oleg Komogortsev

Department of Computer Science
Texas State University–San Marcos

Hick's Law

- Reaction time = a + b $\log_2$ (C)
  - Where C is the number of choices
  - a and b are empirically determined
  - $\log_2$ (C) represents amount of information processed by human operator (Bits)



[1] Hick, W. E. (1952). On the rate of gain of information. *Quarterly J Exp Psychol, 4*, 11-36.
[2] Hyman, R. (1953).Stimulus information as a determinant of reaction time. *J Exp Psychol, 45*, 188-196.

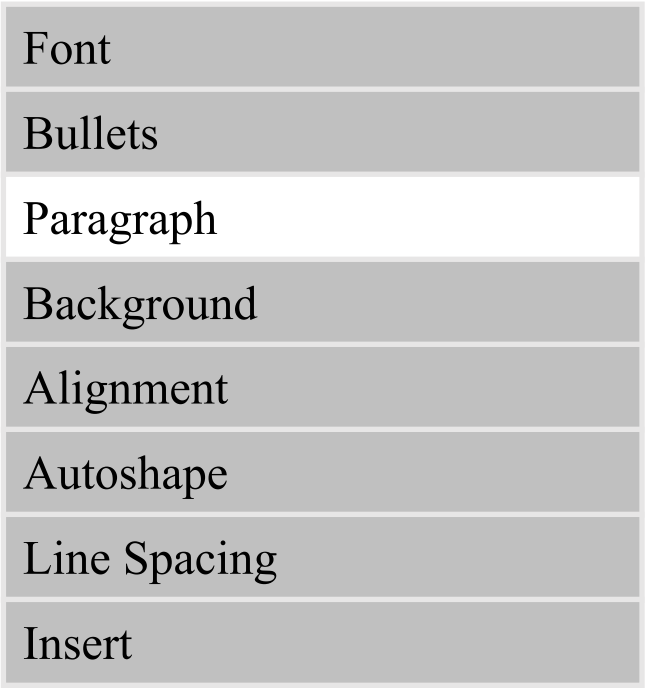
Hick’s Law

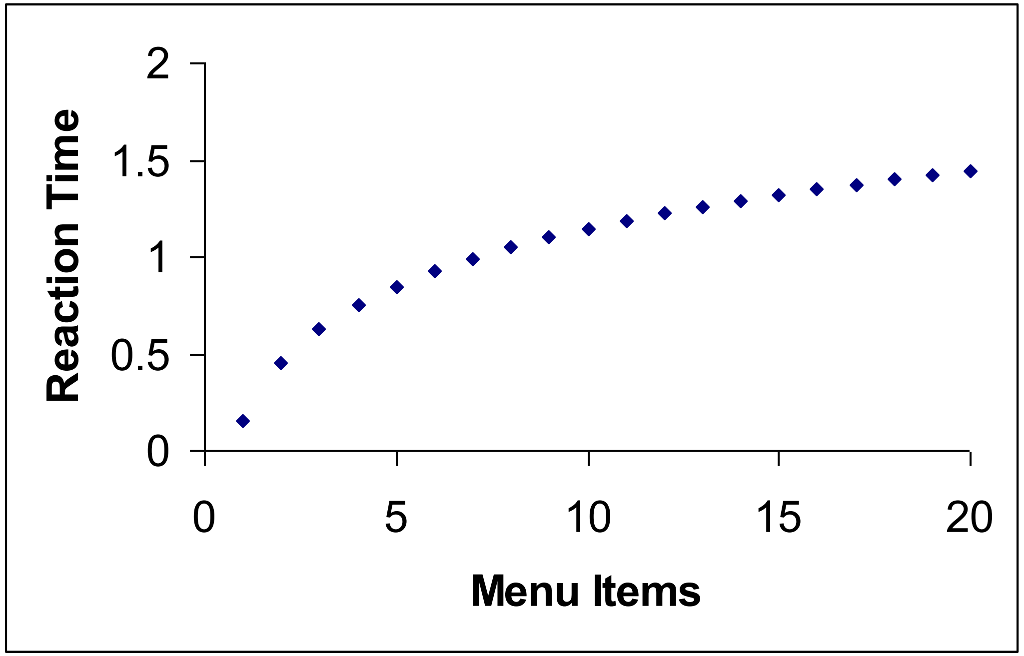
Font
Bullets
Paragraph
Background
Alignment
Autoshape
Line Spacing
Insert

Hick’s Law

- Font
- Bullets
- Paragraph
- Background
- Alignment
- Autoshape
- Line Spacing
- Insert

Hick’s Law


Font
Bullets
Paragraph
Background
Alignment
Autoshape
Line Spacing
Insert


Reaction Time
2
1.5
1
0.5
0
0
5
10
15
20
Menu Items

Keystroke-Level Model (KLM)

- Developed for predicting task performance using interactive computing systems
- Predicts **expert error-free** task completion times
- Elements of a KLM prediction
  - Task (or a series of tasks)
  - Method used
  - Command language of the system
  - Motor skill parameters of the user
  - Response time parameters of the system

Why Use the KLM?

- Consider a task such as “delete a file”
- Perhaps there are two ways to do the task:
    1. Mouse + menu selection
    2. Keyboard + command entry
- The KLM can predict the time for each method
- If used at the design stage, design alternatives may be considered and compared → design choices follow

KLM Operators

- Six operators
  - Keystroke
    - Average time determined by typing tests
  - Pointing
    - Varies from 0.8 – 1.5 seconds (Fitts' Law)
  - Homing
    - 0.4 seconds based on various studies
  - Drawing
    - Roughly defined as 0.9n + 0.16l
  - Mental
    - 1.35 seconds, experimentally determined
  - Response (system response)
    - Must be input to the model, varies widely

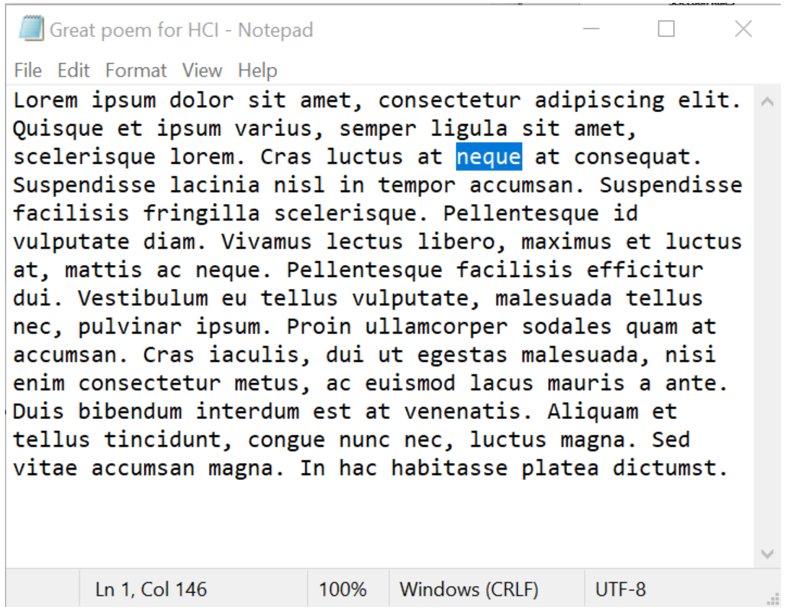
$$t_{\text{EXECUTE}} = t_K + t_P + t_H + t_D + t_M + t_R$$

Operator	Description	Time (s)
K	PRESS A KEY OR BUTTON Pressing a modifier key (e.g., shift) counts as a separate operation, Time varies with typing skill:	
	Best typist (135 wpm)	0.08
	Good typist (90 wpm)	0.12
	Average skilled typist (55 wpm)	0.20
	Average non-secretary typist (40 wpm)	0.28
	Typing random letters	0.50
	Typing complex codes	0.75
	Worst typist (unfamiliar with keyboard)	1.20
P	POINT WITH A MOUSE Empirical value based on Fitts' law. Range from 0.8 to 1.5 seconds. Operator does *not* include the button click at the end of a pointing operation	1.10
H	HOME HAND(S) ON KEYBOARD OR OTHER DEVICE	0.40
D(n_D.l_D)	DRAW n_D STRAIGHT-LINE SEGMENTS OF TOTAL LENGTH l_D. Drawing with the mouse constrained to a grid.	.9 n_D + .16 l_D
M	MENTALLY PREPARE	1.35
R(t)	RESPONSE BY SYSTEM Different commands require different response times. Counted only if the user must wait.	t

KLM Example

- Replace 5 letter word with another in a text editor

Reach for mouse	H_{mouse}
Point to word	P_{word}
Select word	K_{select}
Home on keyboard	$H_{keyboard}$
Call replace cmd	$K_{replace}$
Type new 5 letter word	$5K_{word}$



Keystroke
Pointing
Homing
Drawing
Mental
Response

$$T_{execute} = H_{mouse} + P_{word} + K_{select} + H_{keyboard} + K_{replace} + 5K_{word}$$

Original KLM Experiment

Keystroke
Pointing
Homing
Drawing
Mental
Response

- The KLM was validated in an experiment with fourteen tasks performed using various methods and systems

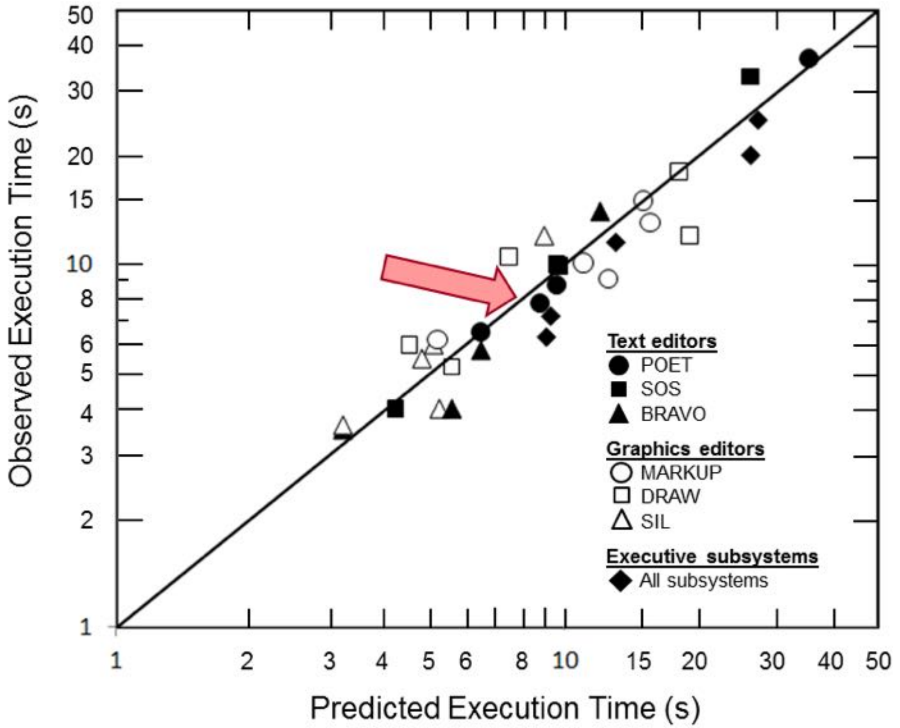
Command Line Editor (POET)	
Jump to next line	**M K**[LINEFEED]
Call Substitute command	**M K**[S]
Specify new 5-digit word	**5K**[word]
Terminate argument	**M K**[RETURN]
Specify old 5-digit word	**5K**[word]
Terminate argument	**M K**[RETURN]
Terminate command	**K**[RETURN]

$$\mathbf{T}_{execute} = 4 \times t_M + 15 \times t_K = 8.85 \text{ sec.}$$

Card, S. K., Moran, T. P., & Newell, A. (1983). *The psychology of human-computer interaction*. Hillsdale, NJ: Erlbaum.

Original KLM Experiment

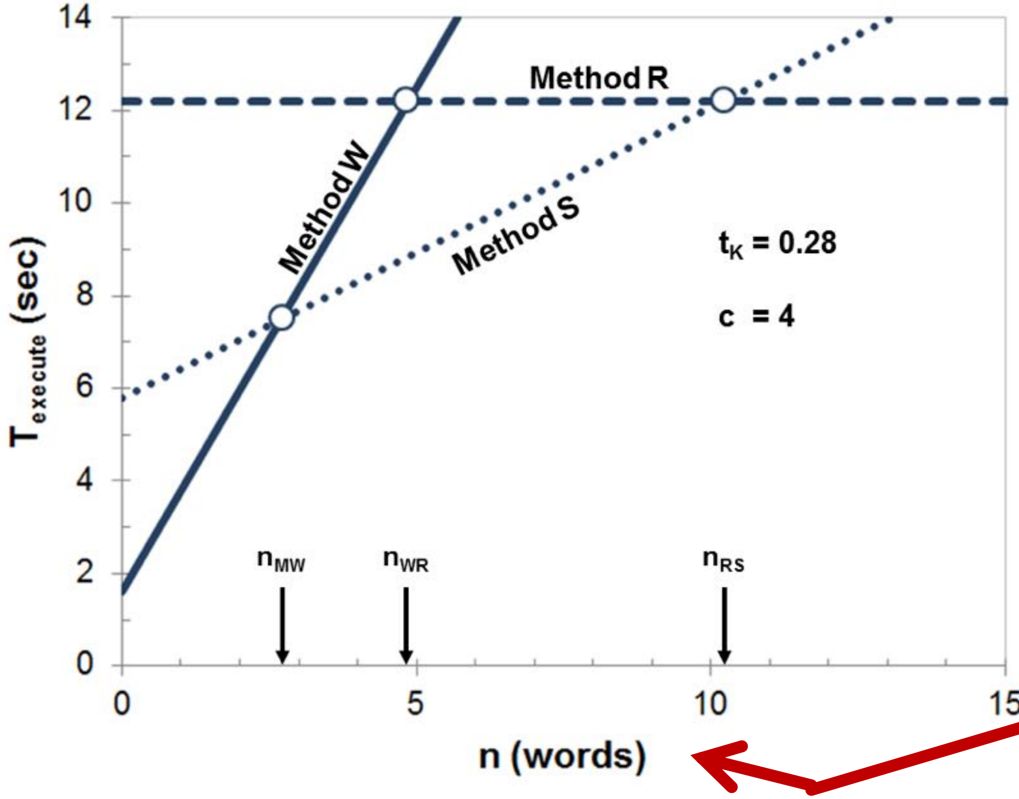
- The KLM was validated in an experiment with fourteen tasks performed using various methods and systems



Card, S. K., Moran, T. P., & Newell, A. (1983). *The psychology of human-computer interaction*. Hillsdale, NJ: Erlbaum.

Sensitivity Analysis

- If parameters are treated as variables, the sensitivity of predictions to changes in parameters can be assessed

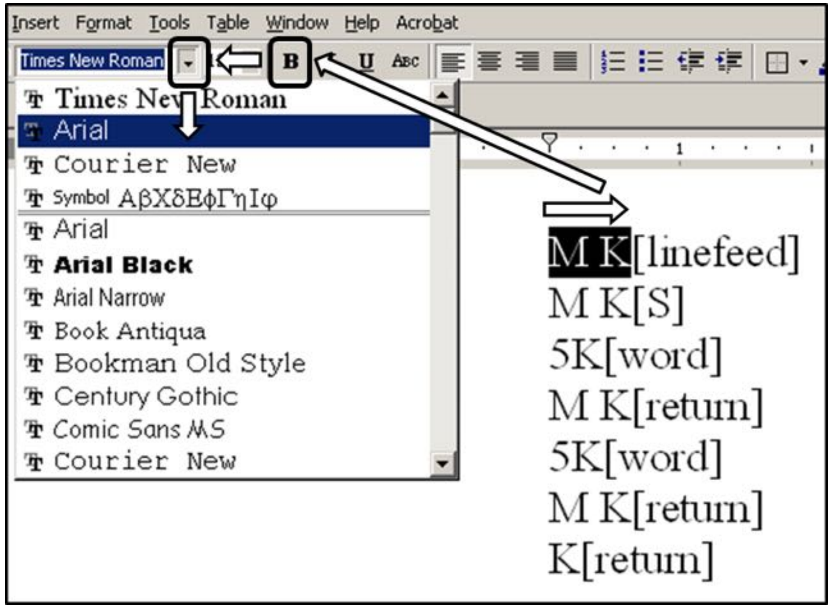


Implication: The preferred method changes with the distance to the misspelled word.

n is a parameter – the distance in words to the location of a misspelled word to correct.

Pointing Operator – Example

- Develop KLM mouse and keyboard predictions for the GUI screen below
- Task: Change the font and style for “M K” to bold, Arial



Keystroke
Pointing
Homing
Drawing
Mental
Response

Mouse Analysis

- Operations:

Mouse Subtasks	KLM Operators	t_P (s)
Drag across text to select "M K"	**M P**[2.5, 0.5]	0.686
Move pointer to Bold button and click	**M P**[13, 1]	0.936
Move pointer to Font drop-down button and click	**M P**[3.3, 1]	0.588
Move pointer down list to Arial and click	**M P**[2.2, 1]	0.501
	$\sum t_P =$	2.71

- Prediction:

$$t_{\mathrm{EXECUTE}} = 4 \times t_{\mathrm{M}} + \sum t_{\mathrm{P}} = 4 \times 1.35 + 2.71 = 8.11 \text{ seconds}$$

$$t_{\mathrm{P}} = 0.159 + 0.204 \times \log_2\left(\frac{A}{W} + 1\right)$$

Keystroke
Pointing
Homing
Drawing
Mental
Response

Keyboard Analysis

- Operations:

Keyboard Subtasks	KLM Operators
Select text	**M** **K**[shift] 3**K**[→]
Convert to boldface	**M** **K**[ctrl] **K**[b]
Activate Format menu and enter Font sub-menu	**M** **K**[alt] **K**[o] **K**[f]
Type *a* (“Arial” appears at top of list)	**M** **K**[a]
Select “Arial”	**K**[↓] **K**[enter]

- Prediction:

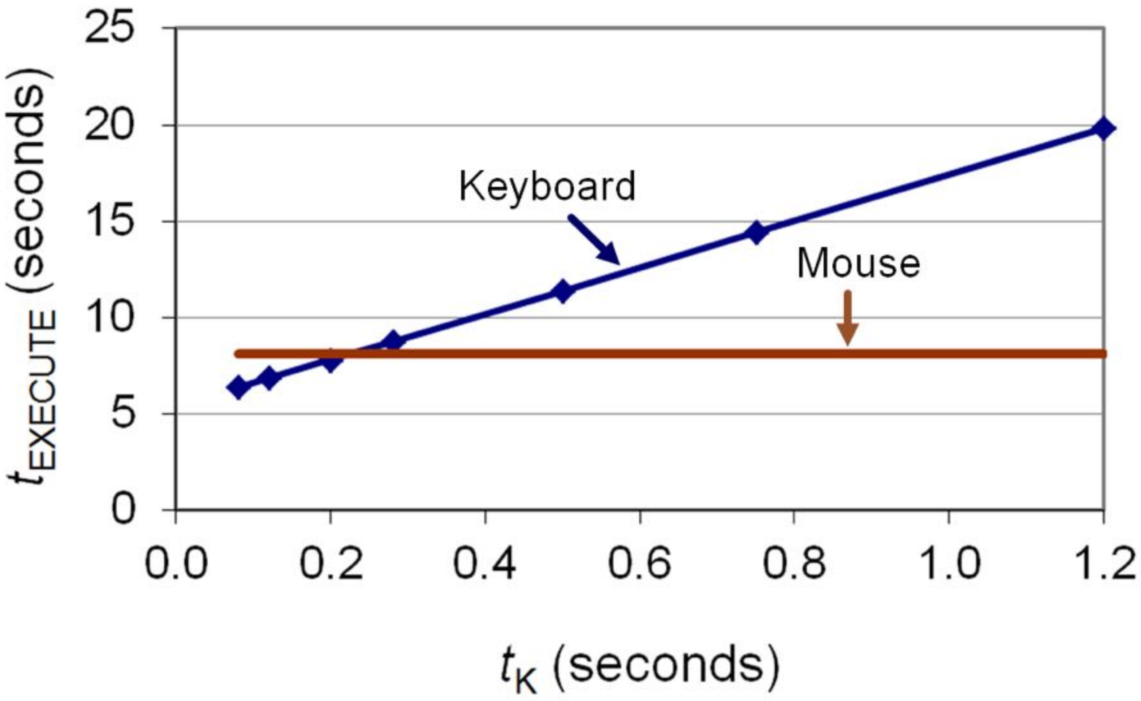
$$t_{\mathrm{EXECUTE}} = 4 \times t_{\mathrm{M}} + 12 \times t_{\mathrm{K}} = 4 \times 1.35 + 12 \times 0.75 = 14.40 \text{ seconds}$$

Use “typing complex codes” (t_{K} = 0.75 s)

Keystroke
Pointing
Homing
Drawing
Mental
Response

Sensitivity Analysis

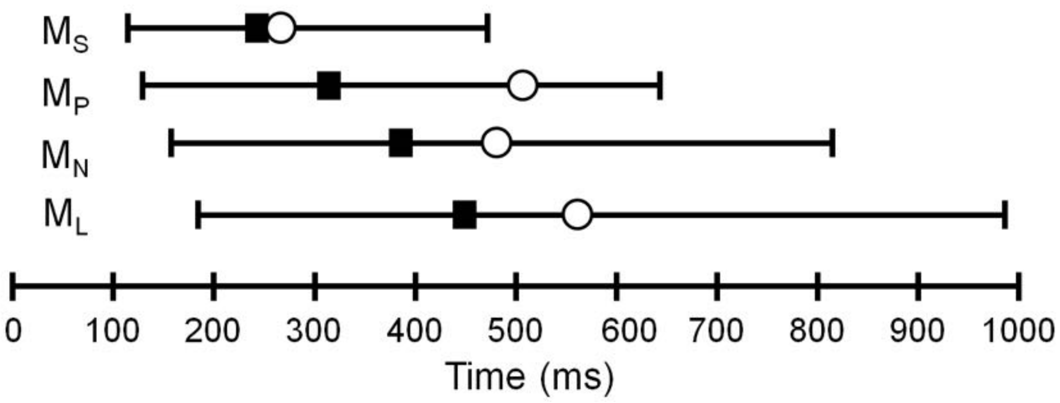
- The keyboard prediction is sensitive to the parameter t_K, the keystroking time
- If t_K is allowed to vary, what is the effect on the predictions?



Implication: The mouse is faster than the keyboard, except for $t_K \leq 0.2$ seconds (which is unlikely, given the nature of the keyboard actions).

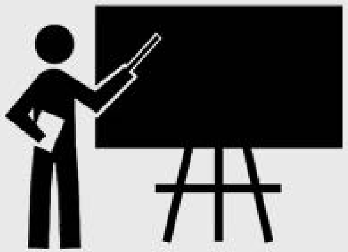
Updating the KLM's Mental Operator

Proposed Mnemonic	Task	Execution Time (ms)	
		Card et al.	Figure 2-28 & Figure 2-30
M_S	Simple Reaction	240 [105 – 470]	277 [±44]
M_P	Physical Matching	310 [130 – 640]	510 [±59]
M_N	Name Matching	380 [155 – 810]	485 [±52]
M_L	Class Matching	450 [180 – 980]	566 [±96]
M_C	Choice Reaction	$200 + 150 \log_2(N + 1)$	
M_V	Visual Search		$498 + 41\,N$



Contemporary Uses of the KLM

- The KLM continues to be widely used in HCI
- Examples:
  - Attention shifts with mobile phones
  - Stylus-based circling gestures
  - Managing folders and messages in e-mail applications
  - Predictive text entry on mobile phones
  - Task switching in multi-monitor systems
  - Mode switching on tablet PCs
  - Distractions in in-vehicle information systems (IVIS)



RIMES: Interactive Multimedia Exercises for Lecture Videos

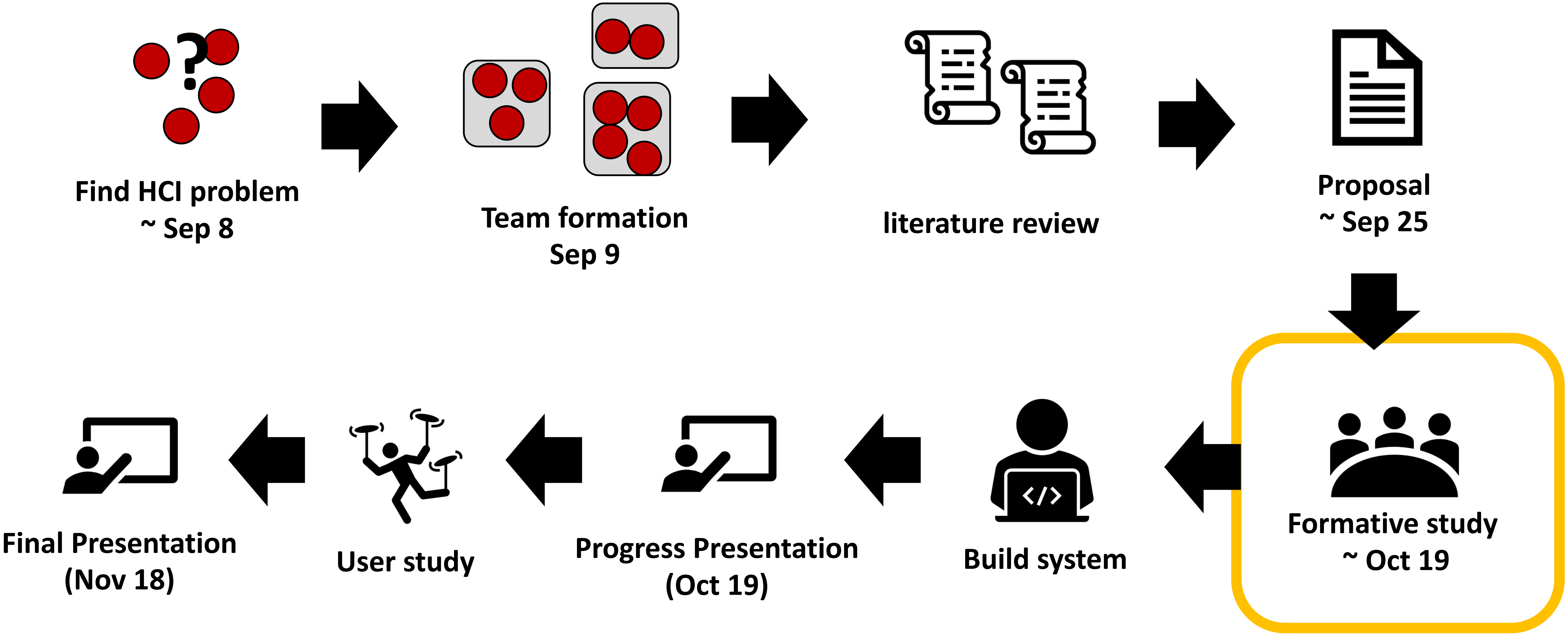
Juho Kim (Microsoft Research, MIT CSAIL)

Elena L. Glassman (Microsoft Research, MIT CSAIL)

Andrés Monroy-Hernández (Microsoft Research)

Meredith Ringel Morris (Microsoft Research)

Course Project: Timeline



Assignment #2: Formative Study

- Conduct an Interview or a Focus Group
- Find an interview topic that's related to your project.
- Team effort, team report
- 2+ interview sessions or a focus group
  with 4+ participants.
- Report should include:
  - Interview design
  - Interview results (summary and insights)
  - Your reflections on the interview

Due Oct 19 (Mon) 23:59 pm

Assignment instruction will be on the course webpage

Project Progress Report (Presentation + Document)

- Project Progress Report (Due Oct 23)
  - Similar to Method Section of a CHI paper
  - Three sections
    - Findings from Formative Study
    - Study Method
    - Research Plan

Project Progress Report (Presentation + Document)

- You will share
  - What you found during your formative study
  - How you will conduct your study
  - Your detailed timeline

Project Progress Report (Presentation + Document)

- Project Progress Report (Due Oct 23)
  - Similar to Method Section of a CHI paper
  - Three sections
    - Findings from Formative Study
    - Study Method
    - Research Plan

Project Progress Report (Presentation + Document)

- Project Progress Presentation (On Oct 19, 21)
  - Each team will present for 15 minutes
  - Each team will have 5 minutes Q&A and feedback session
  - Presentation order will be randomized

Topic Presentation – Preparation

- There are 12 topics to be presented (check the topic list on Collab)
  Topic sign-up is due today. You’ll be randomly assigned to a topic if you don’t do it.
- Each team will have two or three students.
- Each team will cover a topic, which has two papers.
- All team members should thoroughly read the papers.
- After reading the papers, team should discuss them.
  E.g., about the benefits/contributions, limitations, or future directions of the paper

Topic Presentation – Presentation

- Each team will present for 30-35 minutes and discuss for 10-15 minutes
- Presentation will have three components
    - **Topic introduction:** a brief description about the topic
    - **Paper summary:** explain what these papers are about, including their contributions, design, and study design and results.
    - **Discussion:** share your discussion and also lead discussions in the class
- Every member of the team should present.

Topic Presentation – Participation

- All students should read the papers before each class so that they can actively participate in the class
- You will choose a paper among the four papers to be presented in the class and write a reading response to it.
- You don't need to write a reading response for the day you're presenting
- Actively participate in the class, feel free to ask questions or talk about your thoughts – it will not be recorded.

Topic Presentation – Grading

- Grade breakdown (15 points)
  - Topic Introduction (2 points)
  - Understanding Paper 1 (5 points)
  - Understanding Paper 2 (5 points)
  - Effective Talk Delivery (1 points)
  - Discussion (2 points)
- First two teams will get 0.5 bonus points

Thank you!