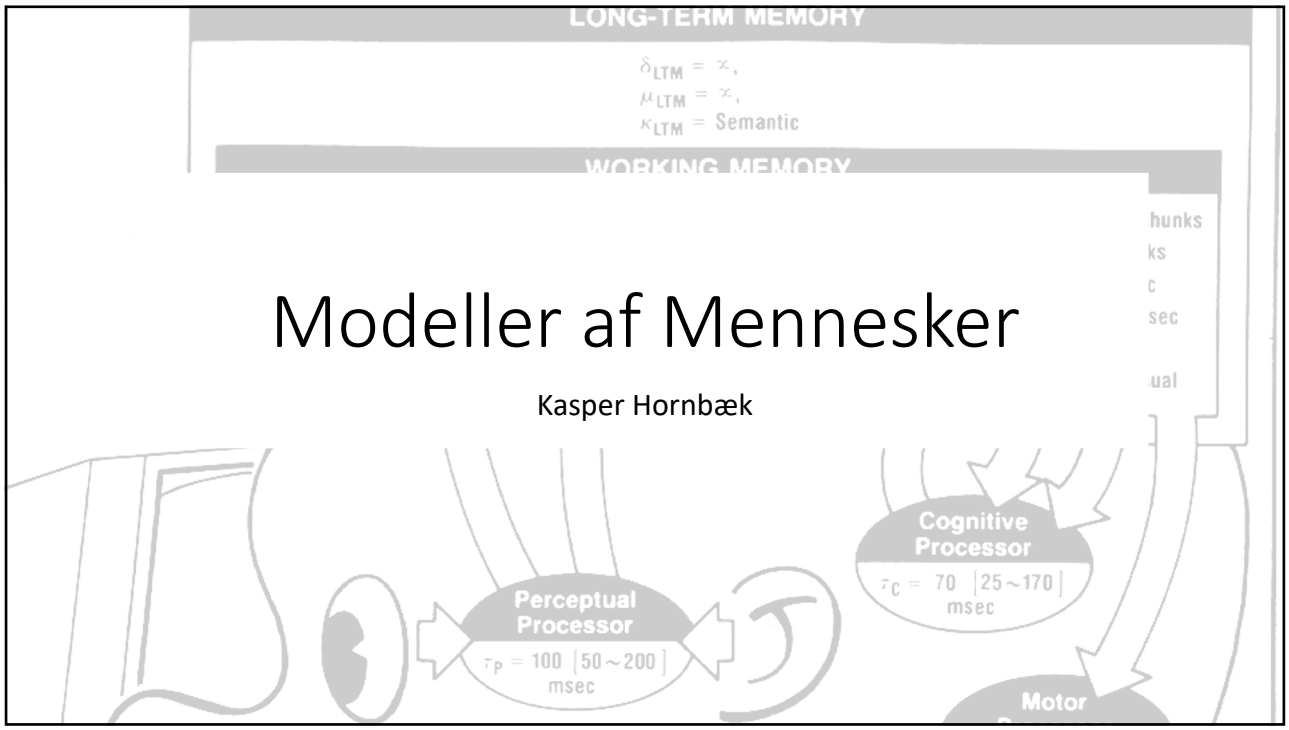


Modeller af Mennesker

Kasper Hornbæk

1

Praktisk

- Afleveringsopgave 2
  - Referencer og litteraturliste, hvorfor?
  - Andre spørgsmål
- Næste uges forelæsninger
  - Mandag online (https://ucph-ku.zoom.us/j/62129806514), onsdag på HCØ

2

Det får I med i dag

1. Modeller om mennesker som kan bruges på brugergrænseflader
2. Hvad er hurtigst: grænseflade A eller B?

3

Viden om mennesker

- Principper og retningslinier er nyttige
  - CRAP, gestalt love, PACT, Shneidermans otte gyldne regler, genkendelse over genkald, gulf-of-execution vs gulf-of-evaluatiom
- Viden om psykologi hjælper til at forstå reglerne (Johnson 2021)
- Men svære at bruge
  - Hvordan anvender man dem på en konkret grænseflade?
  - Hvad hvis de er i konflikt?

4

Modeller

- Modeller er en vigtig del af videnskab
- Modeller simplificerer

5

Modeller, beskrivende

- Modeller kan beskrive fænomener eller faktorer (e.g., taksonomier)
- Identificerer konstrukter og sammenhængen mellem dem
- Eksempler?

6

Modeller, beskrivende

	Same Time	Different Times
Same Place	Copy boards PC Projectors Facilitation Services Group Decision Room Polling Systems	Shared Files Shift Work Kiosks Team Rooms Group Displays
Different Places	Conference Calls Graphics and Audio Screen Sharing Video Teleconferencing Spontaneous Meetings	Group Writing Computer Conferencing Conversational Structuring Forms Management Group Voice Mail

7

Modeller, beskrivende

Hand	Role and Action
Non-preferred	• Leads the preferred hand • Sets the spatial frame of reference for the preferred hand • Performs coarse movements
Preferred	• Follows the non-preferred hand • Works within established frame of reference set by the non-preferred hand • Performs fine movements

Guiard's model af bimanual control

8

Modeller

- Men vi er interesserede i modeller som kan forudsige
  - Hvor hurtigt mennesker bevæger sig (Fitts)
  - Hvordan og hvor hurtigt en opgave løses (GOMS)
  - Hvor hurtigt en opgave gennemføres (KLM)
  - Hvor hurtigt mennesker beslutter sig (Hick-Hyman)
  - Hvor hurtigt mennesker lærer (power law of practice)
- Hvad kan de bruges til?

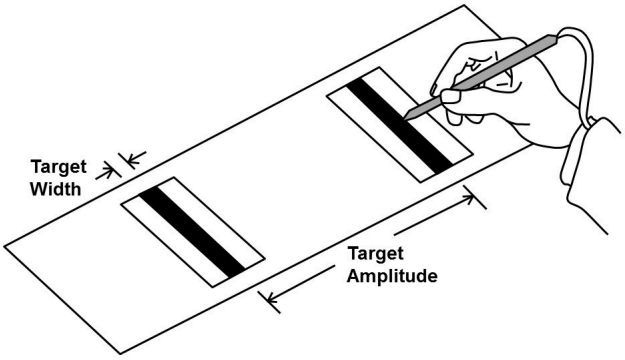
9

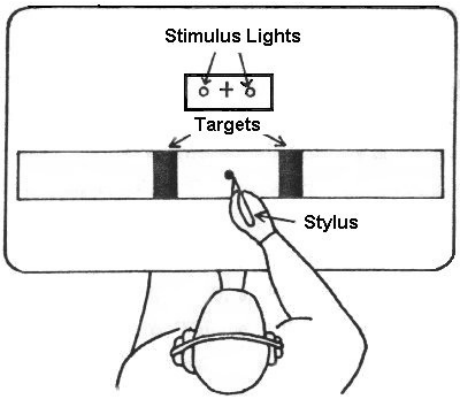
Fitts's law

- Modellerer bevægelser mod et mål (fx et ikon, en menupunkt)
- Kan bruges til
  - At modellere den tid det tager at ramme et mål
  - At komme på designs som mindsker tiden det tager at ramme et mål
- Stammer fra Paul Fitts's arbejde
  - 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.
  - Fitts, P. M., & Peterson, J. R. (1964). Information capacity of discrete motor responses. Journal of Experimental Psychology, 67, 103-112.

10

Typiske forsøgsopstillinger

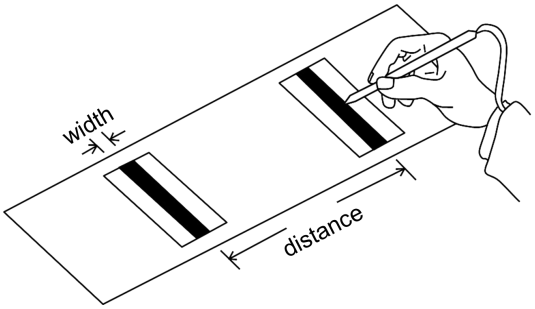




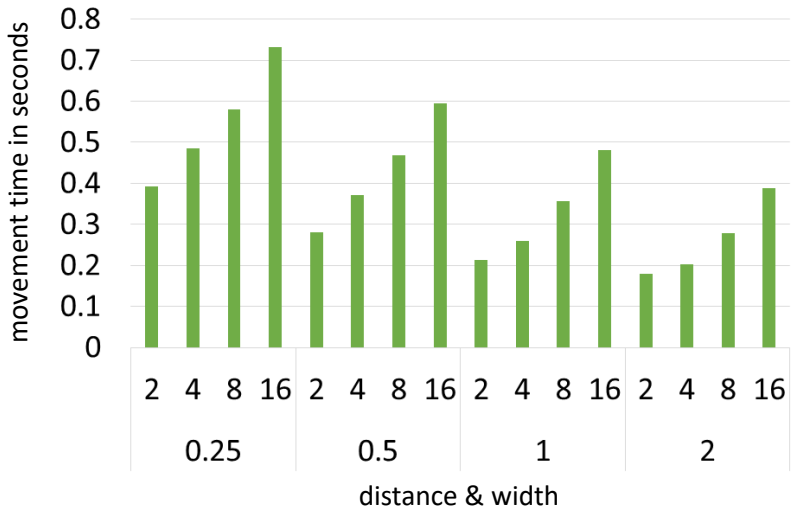
11

Fitts's eksperiment

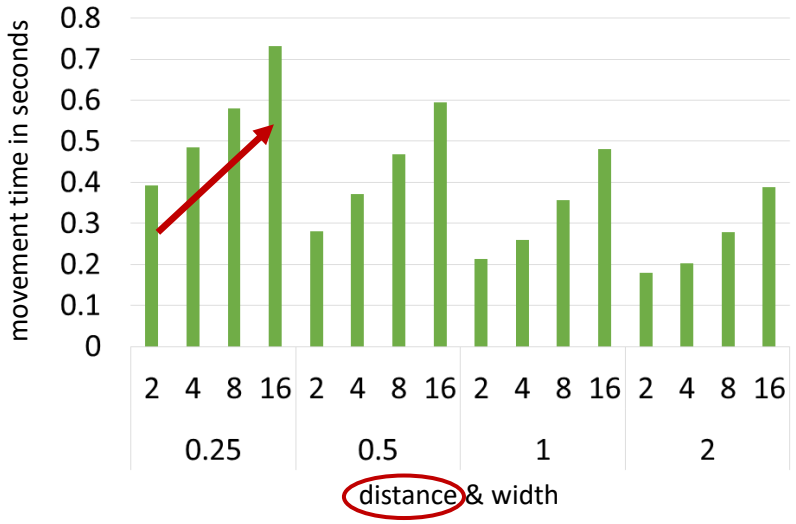
- Fire afstande 2, 4, 8, 16 tommer
- Fire bredde 0.25, 0.5, 1 2 tommer



12


movement time in seconds
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
2 4 8 16 2 4 8 16 2 4 8 16 2 4 8 16
0.25
0.5
1
2
distance & width

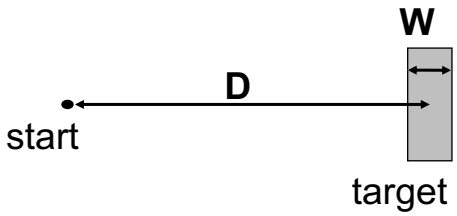
13


movement time in seconds
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
2 4 8 16 2 4 8 16 2 4 8 16 2 4 8 16
0.25
0.5
1
2
distance & width

14

15

Tiden er en funktion af afstand og bredde



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

Index of difficulty (ID)

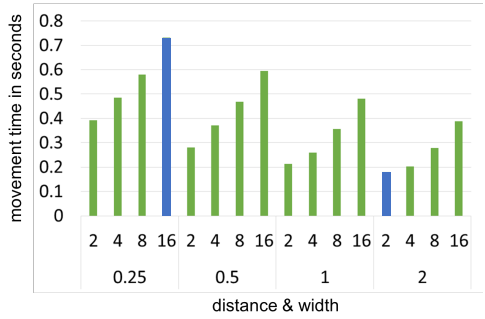
MT: movement time

a & b: input device-dependent constants

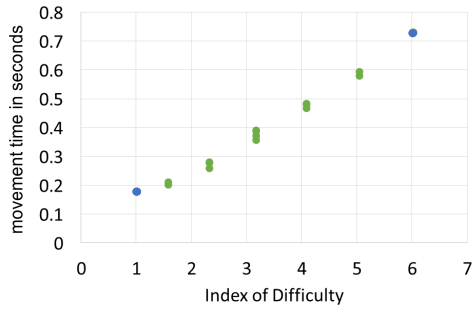
D: distance to the target

W: width of the target

16

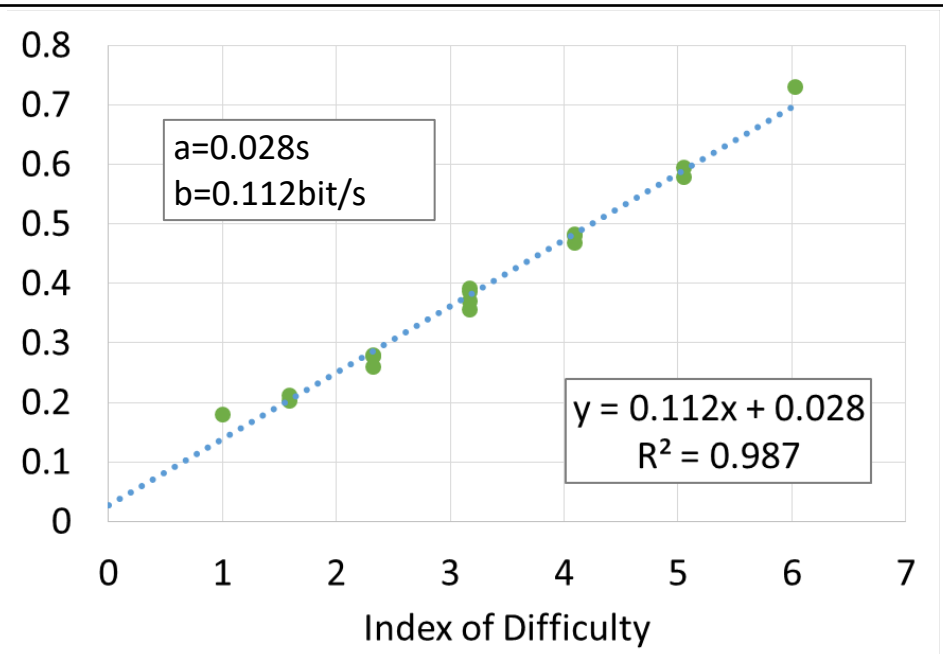


$$ID = \log_2\left(1+\frac{D}{W}\right)$$



- D=16, W=0.25
- $ID=\log_2(1+64)=6.02$

17



18

Konklusion

- Fitts's lov holder på tværs af mange område
- Bevægelsestiden er givet ved denne formel

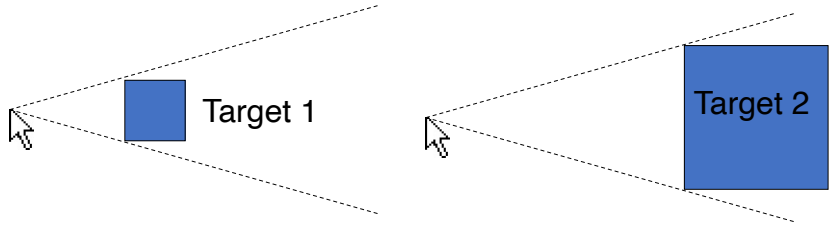
$$MT = a + b\log_2\left(1 + \frac{D}{W}\right)$$

19

Hvad kan vi bruge det til?

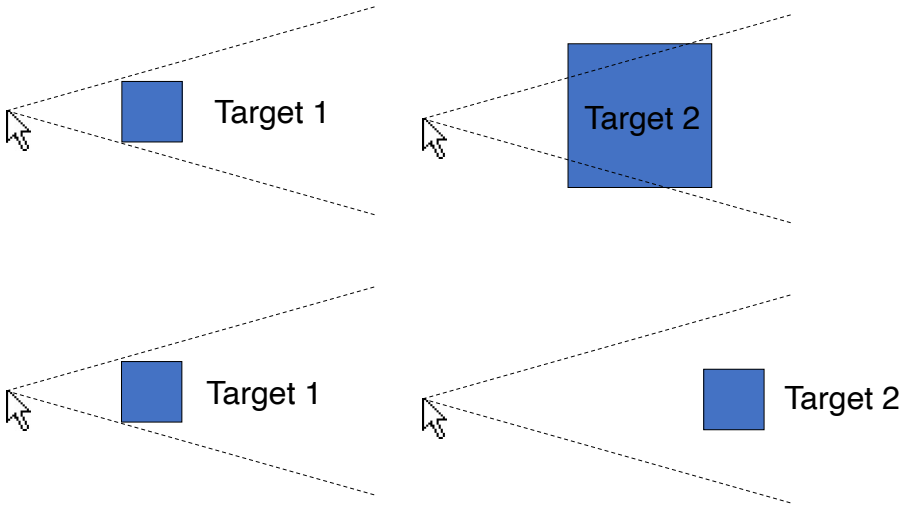
20

Hvad kan vi bruge det til?



21

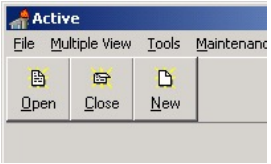
Hvad kan vi bruge det til?

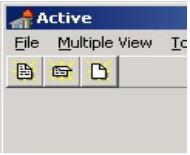


22

Hvad kan vi så bruge det til?

- Microsoft tool bars kunne på et tidspunkt have tekst under ikoner. Hvad er bedst?





23

Hvad kan vi så bruge det til?

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

a=0.028s

b=0.112s/bit

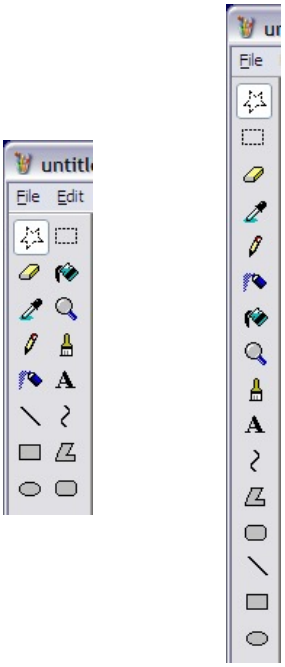
- How long does it take to select a target that is 21 inch away and 3 inch wide?
- MT = $0.028+0.112*\log_2(1+7)$
- = $0.028+0.112*\log_2(8)$
- = $0.028+0.112*3$
- = 0.364ms

24

Hvad kan vi så bruge det til?

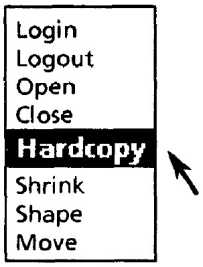
You have a toolbar with 16 icons, each with dimensions of 16x16

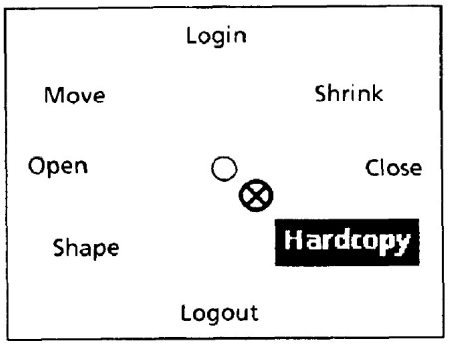
Without moving the array from the left edge of the screen, or changing the size of the icons, how can you make this more efficient?



25

Hvad kan vi så bruge det til?





https://doi.org/10.1145/57167.57182

26

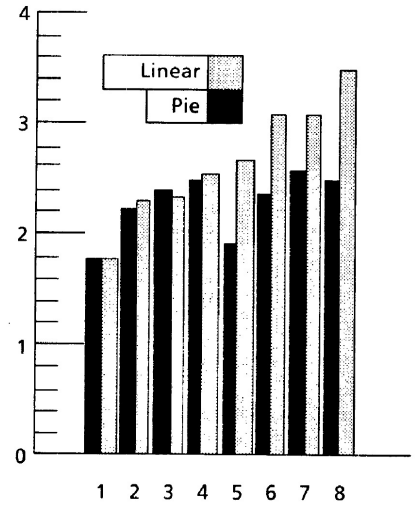
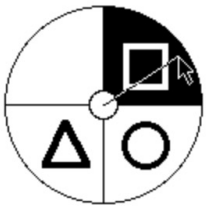
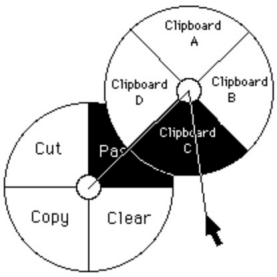


Figure 4: Target location (x) vs. seek time (y) in seconds





27

Hvad kan vi så bruge det til?

- “Beating” Fitts’s law (Balakrishnan 2004)

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

28

The Bubble Cursor:
Enhancing Target Acquisition by
Dynamic Resizing of the
Cursor's Activation Area

Tovi Grossman

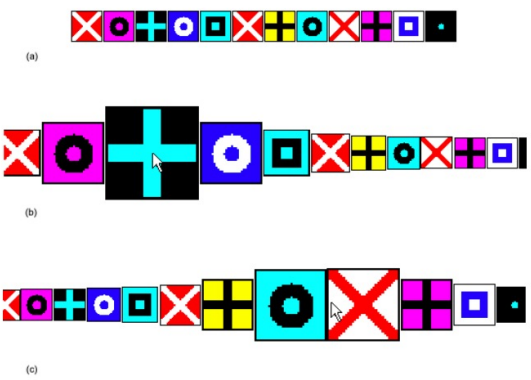
Ravin Balakrishnan

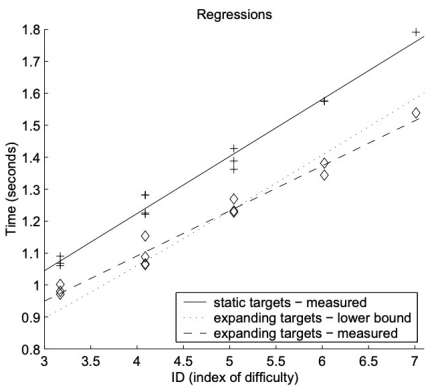
Dynamic Graphics Project Lab
Department of Computer Science
University of Toronto
www.dgp.toronto.edu

29

Expandable menus

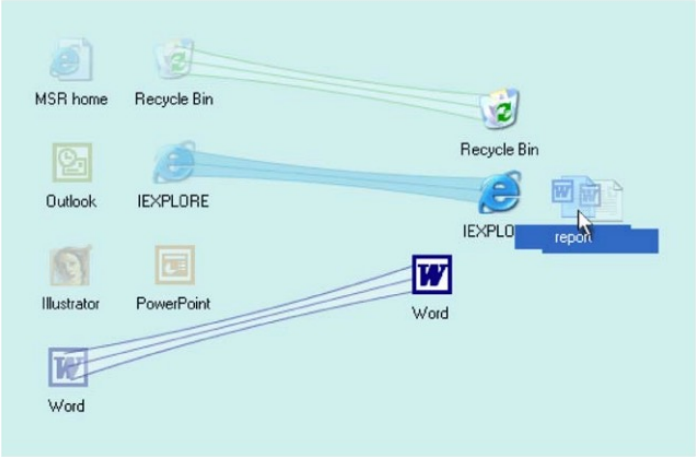
- McGuffin & Balakrishnan (2002)



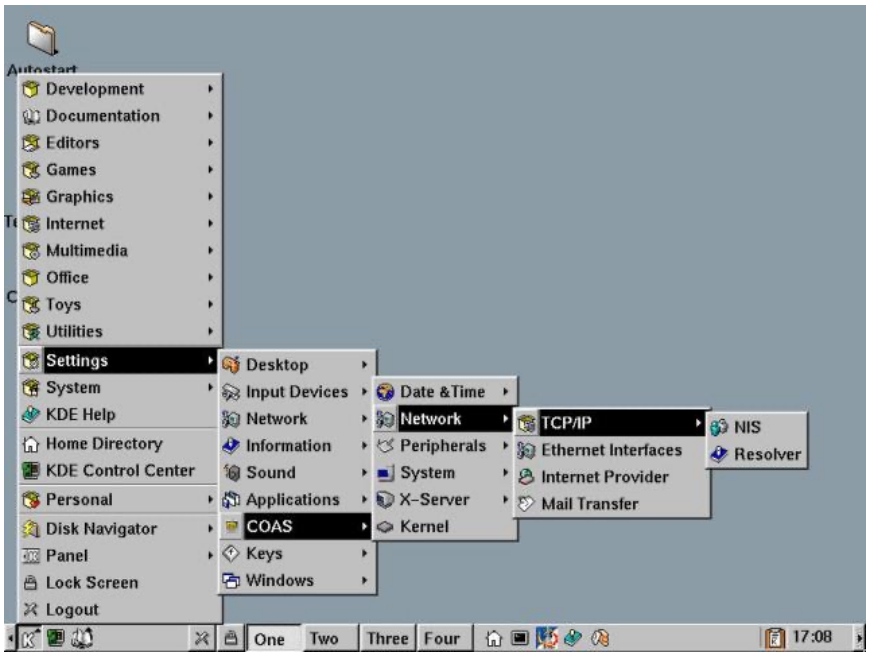


30

Drag'n'pop (Baudisch et al. 2003)



31



32

Steering law (Accot & Zhai 1997)

- Samme ide som Fitts's lov men når vi skal holde os inden for rammer, ikke kun ramme målet
- Fitts's lov bruges til at pege, Steering law fx til at tegne

33

Steering law

$T_{msec} = a + b\ (d/s)$

a, b = empirically-derived constants

d = distance, s = width of tunnel

ID (Index of Difficulty) = (d/s)

Index of Difficulty now *linear*, not logarithmic

(i.e. steering is more difficult then pointing)

34

Spørgsmål?

35

Keystroke Level Model

- KLM er en simplificering af GOMS
- Har operatorerne
  - **K**eypress
  - **H**ome (move hands between devices)
  - **P**oint (with mouse, no keypress)
  - **B**utton press/release (often same as keypress)
  - **M**entally prepare (think)
  - **R**esponse time (system response time)

36

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) Good typist (90 wpm) Average skilled typist (55 wpm) Average non-secretary typist (40 wpm) Typing random letters Typing complex codes Worst typist (unfamiliar with keyboard)	 0.08 0.12 0.20 0.28 0.50 0.75 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

B/BB Klik med mus 0.1s//0.2s

37

KLM Heuristic Rules (Raskin)

0: Insert M
- in front of all K
- in front of all P's selecting a command (not in front of P's ending a command)

1: Remove M between fully anticipated operators
- MPK → PK // MPBB → PK

2: if a string of MKs belong to a cognitive unit, delete all M's except the first
- 4564.23: MKMKMKMKMKMKMK → MKKKKKKK

3: if K is a redundant terminator, then delete M in front of it
- [enter] [enter]: MKMK → MKK

4a: if K terminates a constant string (command name) delete the M in front of it
- cd [enter]: MKKMK → MKKK

4b: if K terminates a variable string (parameter) keep the M in front of it
- cd class [enter]: MKKKMKKKKMK → MKKKMKKKKKMK

38

Andre forbedringer hos MacKenzie (2015)

- Erstat P med Fitts's lov (side 262)

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

- Brug P[A,W] (side 263)

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

- Gør M operatoren bedre (side 272)

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		$498 + 41\ N$

39

KLM workflow

- 1. define the task
- 2. break it down into operations
- 3. apply mental operators
- 4. add up

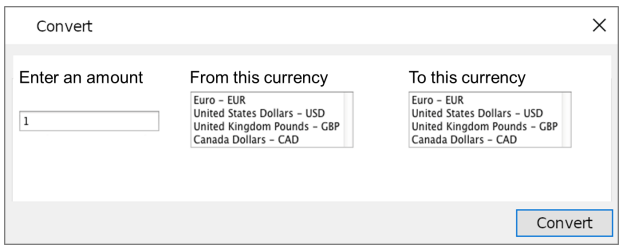
40

Worked example of KLM

- We need to enter our birthday

41

- Task: Convert 12 Euro in US Dollar
- One hand on the mouse, nothing selected



select text field	P, BB
delete value	H, K
enter value	M, K, K
select Euro	H, M, P, BB
select Dollar	M, P, BB
select Convert	P, BB

42

select text field	P, BB
delete value	H, K
enter value	M, K, K
select Euro	H, M, P, BB
select Dollar	M, P, BB
select Convert	P, BB

Operator Times:

P ≈ 1.1s B = 0.1s H = 0.4s

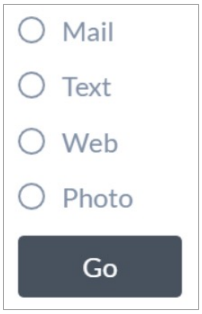
M = 1.35s K = 0.28s

4*P =	4.40s
8*B =	0.80s
2*H =	0.80s
3*M =	4.05s
3*K =	0.84s
Total =	**10,89s**

43

MPBB-PBB

Version 1



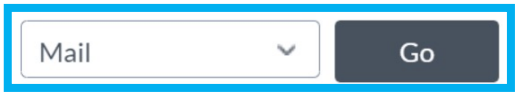
MPBB

Version 2

Hand on mouse, nothing selected, go to photo:

- Which is the fastest interface?
- Which is the slowest?

Version 3



MPBB-MPBB-PBB

Version 4

PBB-HMKKKK-HPBB

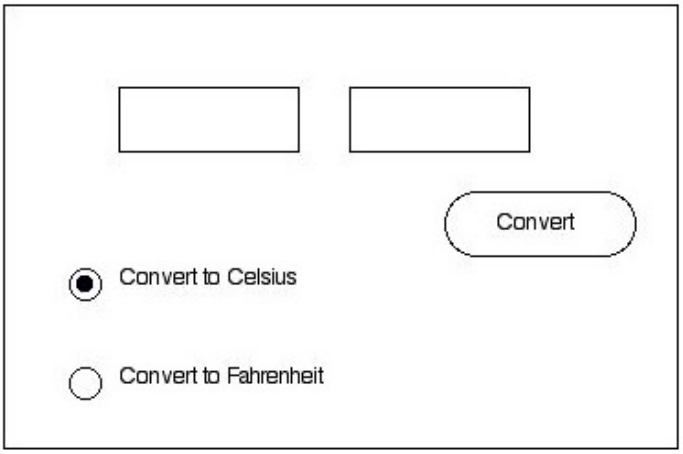
44

Another worked example

- Imagine we want to make an interface that converts a temperature in Celsius to Fahrenheit, and vice versa. Input with a keyboard and a mouse

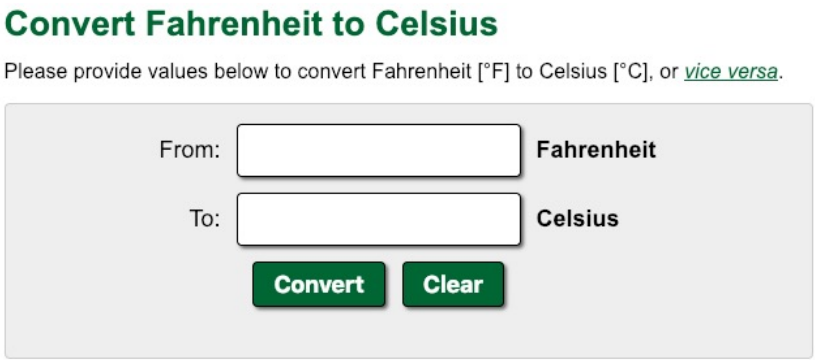
45

Case, cont'd



46

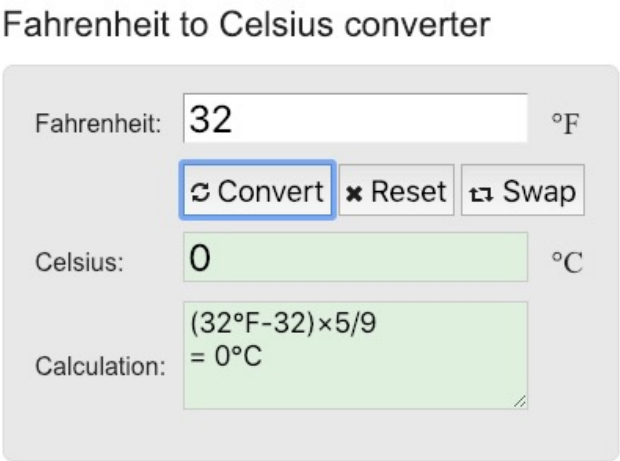
Case, cont'd



https://www.unitconverters.net/temperature/fahrenheit-to-celsius.htm

47

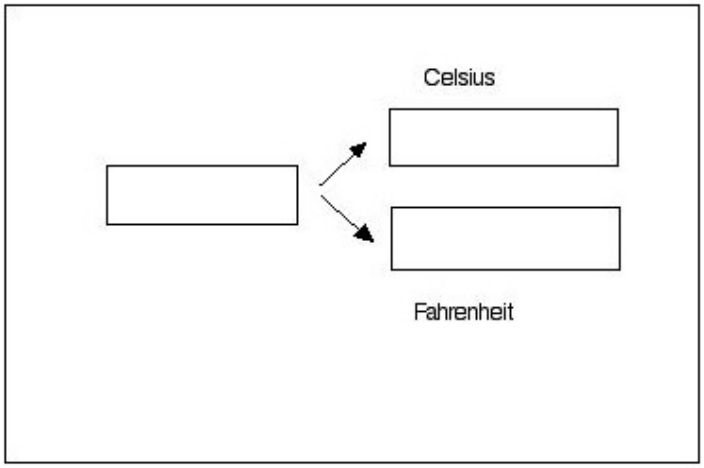
Case, cont'd



https://www.rapidtables.com/convert/temperature/fahrenheit-to-celsius.html

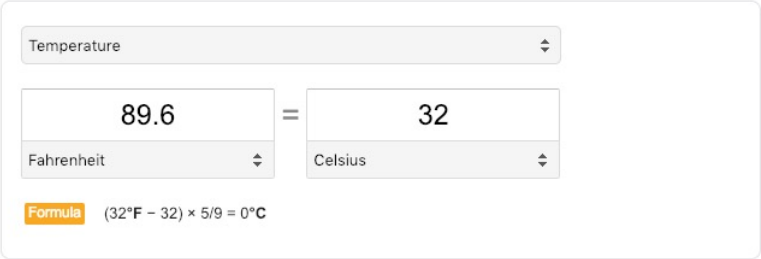
48

Case, cont'd



49

Case, cont'd



www.google.com

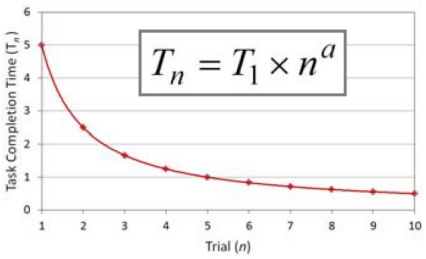
50

51

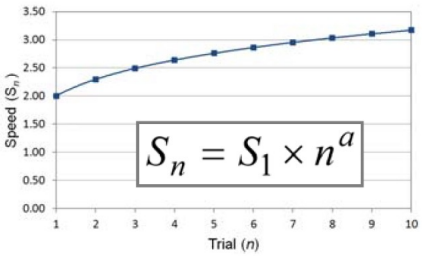
Power law of practice

- Beskriver transition fra novice til ekspert

Predicting time



Predicting speed



52

Hvilket tastatur er bedst?

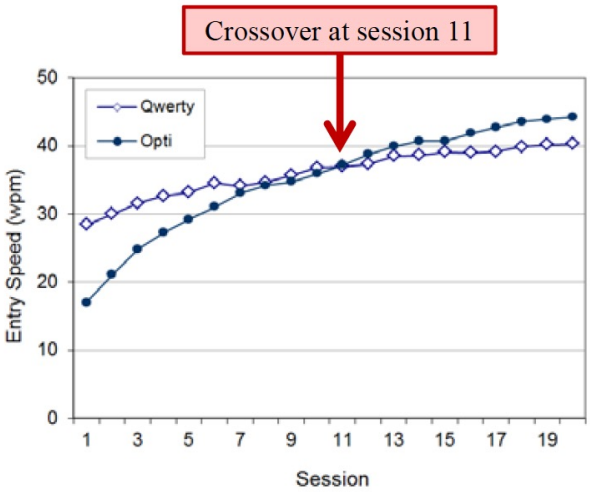
[1] MacKenzie, I. S., & Zhang, S. X. (1999). The design and evaluation of a high-performance soft keyboard. *Proc CHI '99*, 25-31, New York: ACM.

53

Resultater

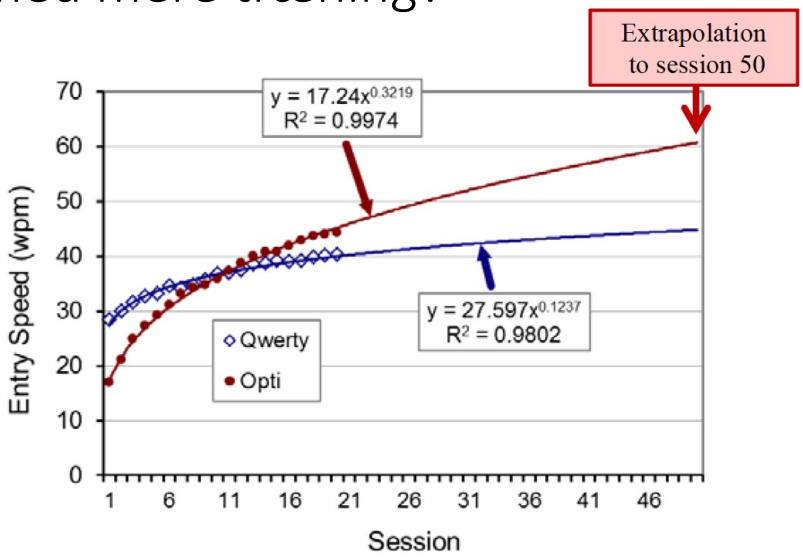
Entry Speed (wpm)

Session	Qwerty	Opti
1	28.44	16.98
2	29.98	21.06
3	31.56	24.80
4	32.62	27.26
5	33.20	29.18
6	34.52	31.04
7	34.14	33.08
8	34.68	34.16
9	35.66	34.72
10	36.77	35.89
11	36.95	37.22
12	37.36	38.75
13	38.50	39.95
14	38.65	40.73
15	39.12	40.68
16	39.00	41.85
17	39.20	42.74
18	39.85	43.55
19	40.16	43.91
20	40.30	44.29



54

Hvad med mere træning?



55

Hicks-Hyman Lov

- Kan anvendes for beslutninger mellem lige sandsynlige alternativer
- Beslutningstiden er givet som
  - $T = a + b \log2(n + 1)$
- Konstanterne kan for eksempel være a = 200ms og b = 150ms

56

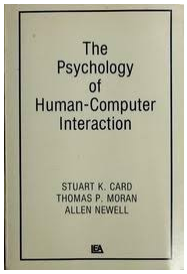
Implications

- Menuer skal være brede snarere end dybe

57

Model Human Processor

- Ambition om at modellere menneskers tænkemåder simpelt så vi kan bruge dem i grænsefladedesign
- Model Human Processor er en ide fra Card, Moran og Newell (1983)'s bog



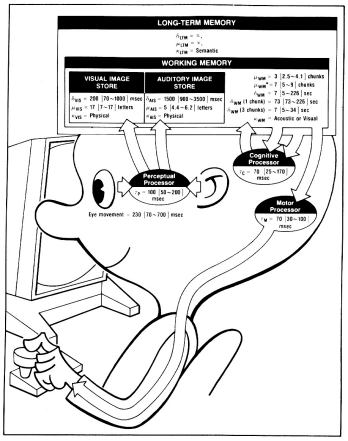
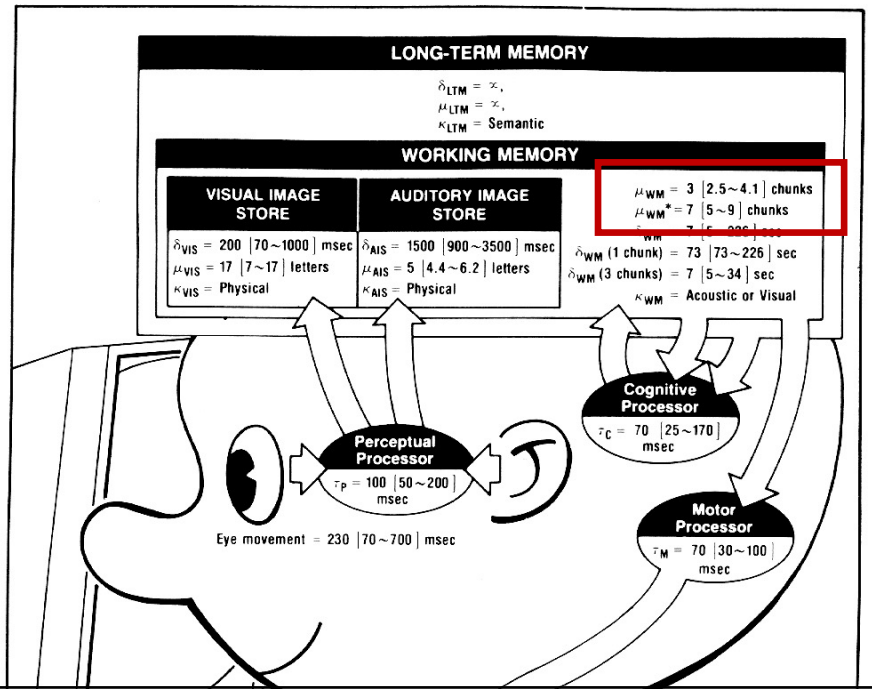


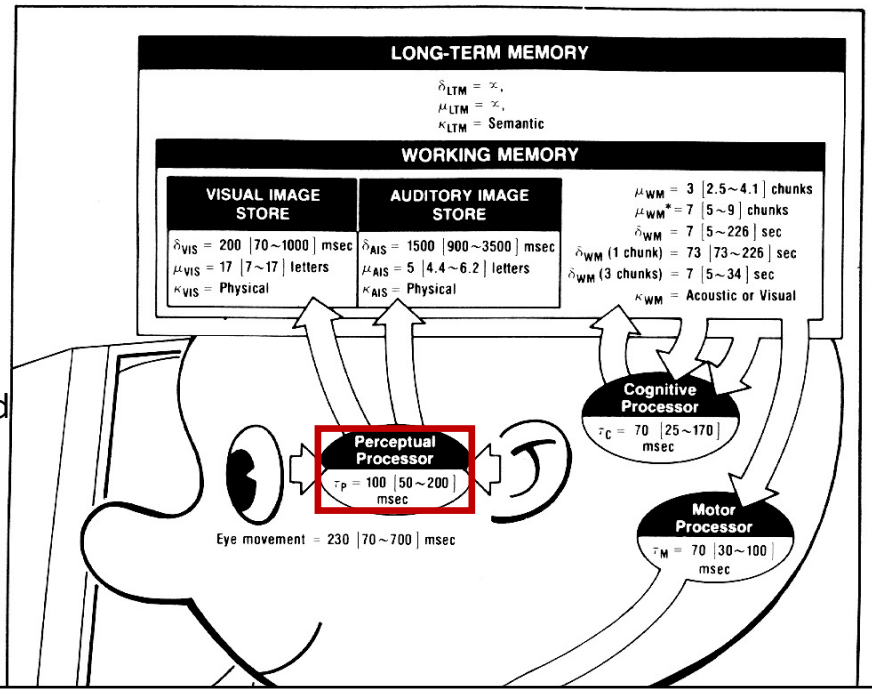
Figure 2.1. The Model Human Processor—memories and processors.

58



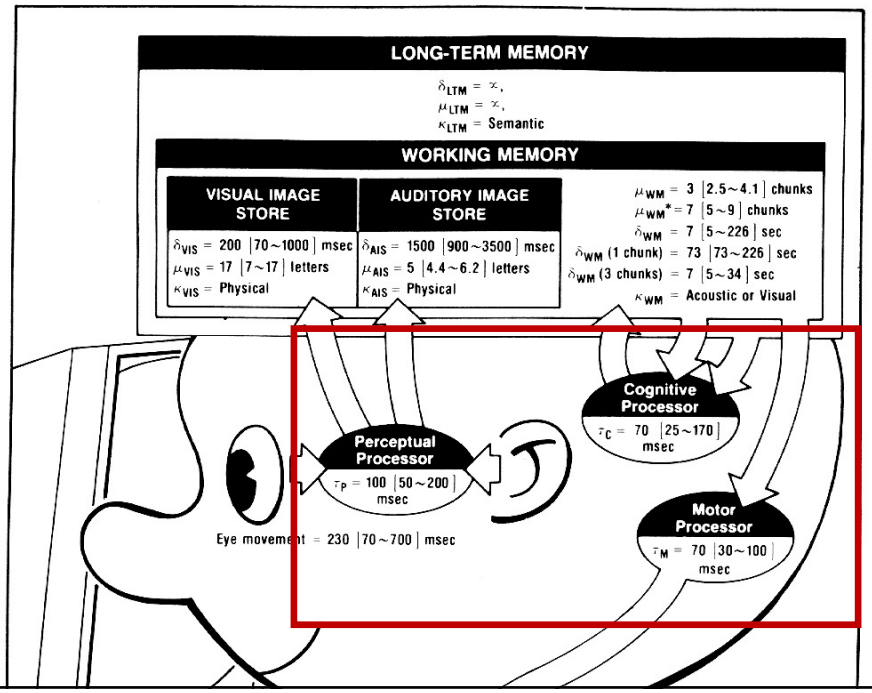
Chunking

59



Responstid skal være under 100ms

60



Recognize-act cycle

61

Hvad kan vi bruge det til?

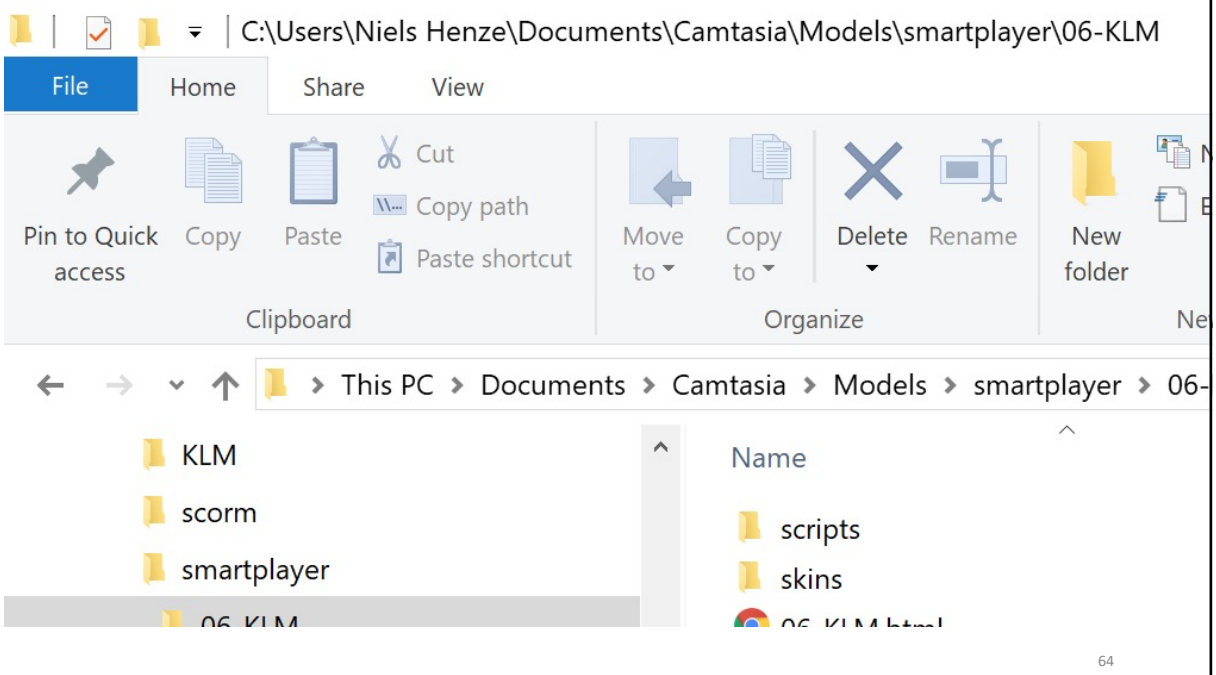
- Reaktionstider
  - Klik på en knap når du ser et symbol
    - Perceive (~100ms)
    - Decide (~70ms)
    - Move (~70ms)
  - Burde tage circa 240ms (fra 105ms til 470ms)
  - Hvis du kører 60km/t er det 4 meter

62

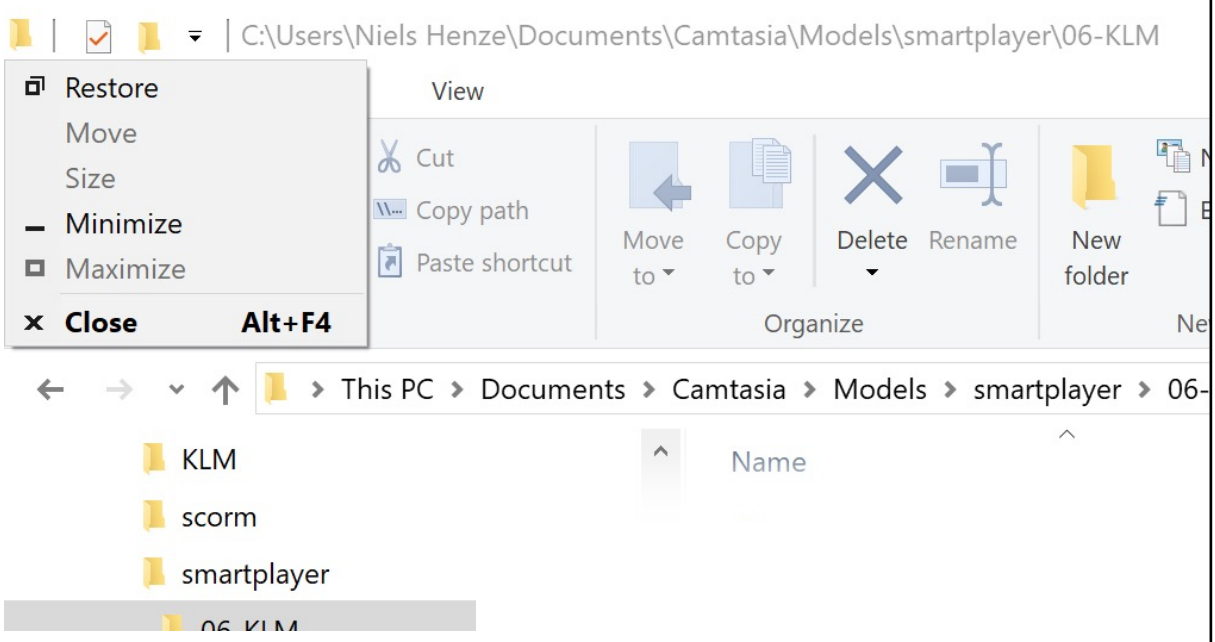
Modellere mere kompliceret aktivitet

- GOMS
  - Goals---hvad er det mennesker vil gøre ved kendte opgaver
  - Operators---simple handlemåder som mennesker kan gøre
  - Methods---delmål til at løse et bestemt mål
  - Selection rules---regler til at vælge mellem bestemte mål
- Handler ikke om problemløsning men om kendte opgaver

63



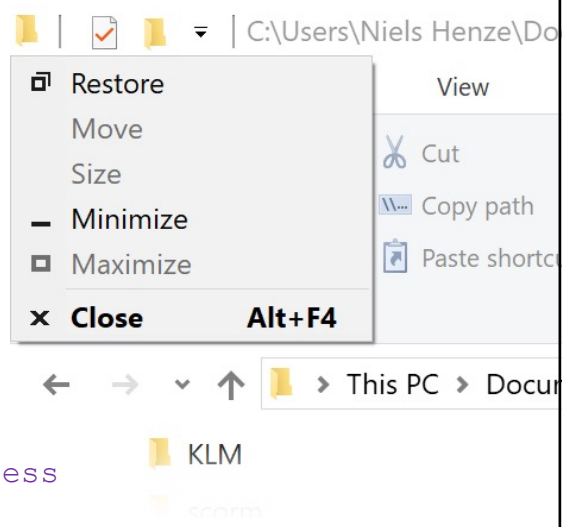
64



65

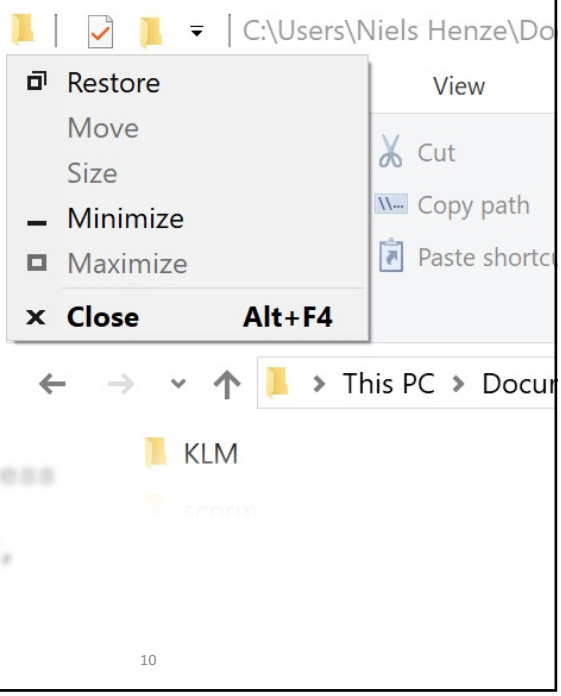
```
GOAL: CLOSE-WINDOW
  [select
    GOAL: USE-MENU-METHOD
      MOVE-MOUSE-TO-FILE-MENU
      PULL-DOWN-FILE-MENU
      CLICK-OVER-CLOSE-OPTION
    GOAL: USE-ALT-F4-METHOD
      HOLD-ALT-KEY
      PRESS-F4-KEY]
  VERIFY-CLOSE

For a particular user:
Rule 1: Select USE-MENU-METHOD unless
        another rule applies
Rule 2: If the application is GAME,
        select CTRL-F4-METHOD
```



66

```
GOAL: CLOSE-WINDOW
  [select
    GOAL: USE-MENU-METHOD
      MOVE-MOUSE-TO-FILE-MENU
      PULL-DOWN-FILE-MENU
      CLICK-OVER-CLOSE-OPTION
    GOAL: USE-ALT-F4-METHOD
      HOLD-ALT-KEY
      PRESS-F4-KEY]
  VERIFY-CLOSE
```



For a particular user:

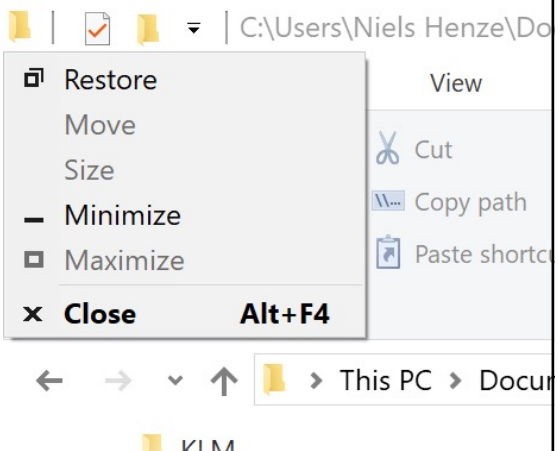
Rule 1: Select USE-MENU-METHOD unless another rule applies

Rule 2: If the application is GAME, select CTRL-F4-METHOD

10

67


```
GOAL: CLOSE-WINDOW
  [select
    GOAL: USE-MENU-METHOD
      MOVE-MOUSE-TO-FILE-MENU
      PULL-DOWN-FILE-MENU
      CLICK-OVER-CLOSE-OPTION
    GOAL: USE-ALT-F4-METHOD
      HOLD-ALT-KEY
      PRESS-F4-KEY]
  VERIFY-CLOSE
```

For a particular user:

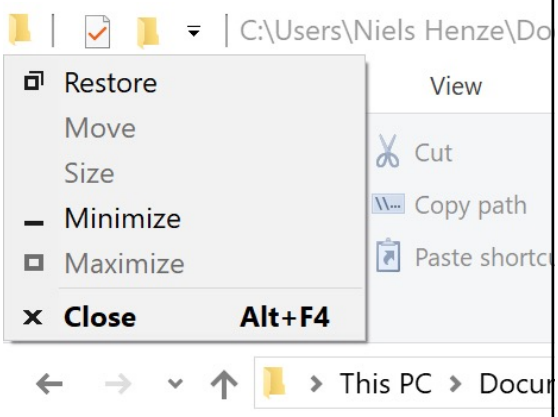
Rule 1: Select USE-MENU-METHOD unless another rule applies

Rule 2: If the application is GAME, select CTRL-F4-METHOD

11

68

```
GOAL: CLOSE-WINDOW
  [select
    GOAL: USE-MENU-METHOD
      MOVE-MOUSE-TO-FILE-MENU
      PULL-DOWN-FILE-MENU
      CLICK-OVER-CLOSE-OPTION
    GOAL: USE-ALT-F4-METHOD
      HOLD-ALT-KEY
      PRESS-F4-KEY]
  VERIFY-CLOSE
```

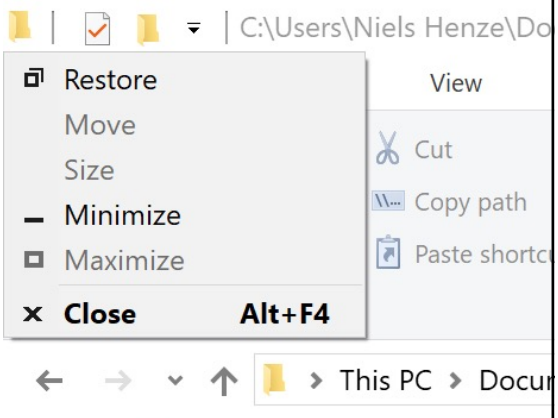



```
For a particular user:
Rule 1: Select USE-MENU-METHOD unless
        another rule applies
Rule 2: If the application is GAME,
        select CTRL-F4-METHOD
```

12

69

```
GOAL: CLOSE-WINDOW
  [select
    GOAL: USE-MENU-METHOD
      MOVE-MOUSE-TO-FILE-MENU
      PULL-DOWN-FILE-MENU
      CLICK-OVER-CLOSE-OPTION
    GOAL: USE-ALT-F4-METHOD
      HOLD-ALT-KEY
      PRESS-F4-KEY]
  VERIFY-CLOSE
```




```
For a particular user:
Rule 1: Select USE-MENU-METHOD unless
        another rule applies
Rule 2: If the application is GAME,
        select CTRL-F4-METHOD
```

13

70

Oprindelig anvendelse af GOMS

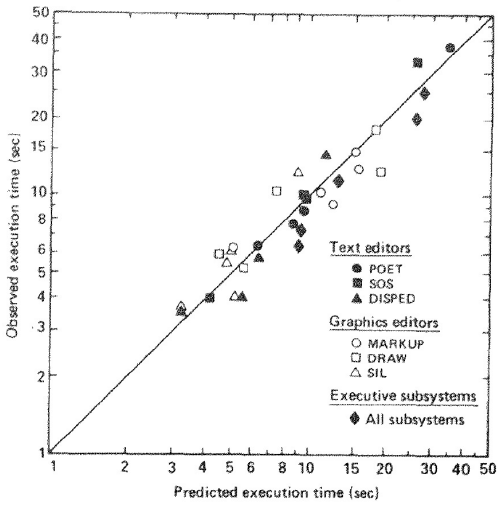
Model K2:

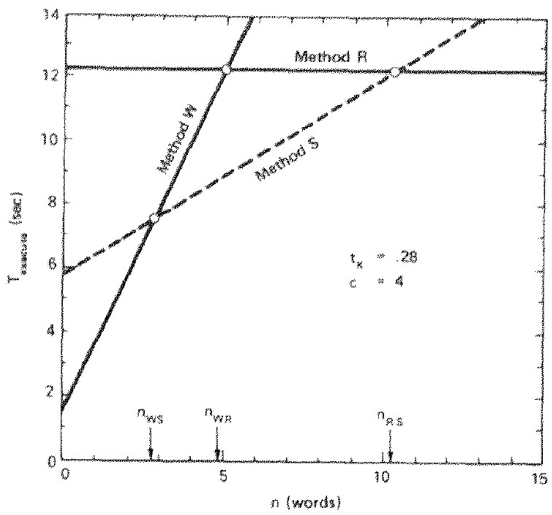
```
GOAL: EDIT-MANUSCRIPT
. GOAL: EDIT-UNIT-TASK                                  . repeat until no more unit tasks
. . GOAL: ACQUIRE-UNIT-TASK                             . . if task not remembered
. . . GOAL: TURN-PAGE* (see below)                      . . . if at end of manuscript page
. . GOAL: GET-FROM-MANUSCRIPT*
. . GOAL: EXECUTE-UNIT-TASK                             . . if an edit task was found
. . . GOAL: LOCATE-LINE                                 . . . if task not on current line
. . . . CHOOSE-COMMAND
. . . . [select GOAL: USE-QS-METHOD
. . . . . GOAL: SPECIFY-COMMAND*
. . . . . GOAL: SPECIFY-ARG*
. . . . GOAL: USE-LF-METHOD
. . . . . GOAL: SPECIFY-COMMAND*]                       . . . . . repeat until at line
. . . . GOAL: VERIFY-LOC*
. . . GOAL: MODIFY-TEXT
. . . . CHOOSE-COMMAND
. . . . [select GOAL: USE-S-COMMAND
. . . . . GOAL: SPECIFY-COMMAND*
. . . . . GOAL: SPECIFY-ARG*
. . . . . GOAL: SPECIFY-ARG*
. . . . GOAL: USE-M-COMMAND
. . . . . GOAL: SPECIFY-COMMAND*
. . . . . GOAL: SPECIFY-COMMAND*                        . . . . . repeat until at text
. . . . . GOAL: SPECIFY-ARG*
. . . . . GOAL: SPECIFY-COMMAND*]
. . . . GOAL: VERIFY-EDIT*
```

```
GOAL: TURN-PAGE
. LOOK-AT-MANUSCRIPT                                    . repeat twice
. ACTION
. MOVE-HAND                                             . repeat twice
. TURN-PAGE
GOAL: GET-FROM-MANUSCRIPT
. LOOK-AT-MANUSCRIPT
. SEARCH-FOR
. LOOK-AT-DISPLAY                                       . optional
GOAL: SPECIFY-COMMAND
. GOAL: GET-FROM-MANUSCRIPT*                            . if not already selected
. CHOOSE-COMMAND                                        . if not already selected
. GOAL: TYPE-STRING*
GOAL: SPECIFY-ARG
. GOAL: GET-FROM-MANUSCRIPT*                            . optional
. CHOOSE-ARG
. GOAL: TYPE-STRING*
GOAL: VERIFY
. LOOK-AT-DISPLAY
. GOAL: GET-FROM-MANUSCRIPT*                            . optional
. COMPARE
GOAL: TYPE-STRING
. HOME                                                  . optional
. LOOK-AT-KEYBOARD                                      . optional
. LOOK-AT-DISPLAY                                       . optional
. TYPE-STRING
```

71

GOMS forudsiger tidsforbrug





72

Niels Henze 73

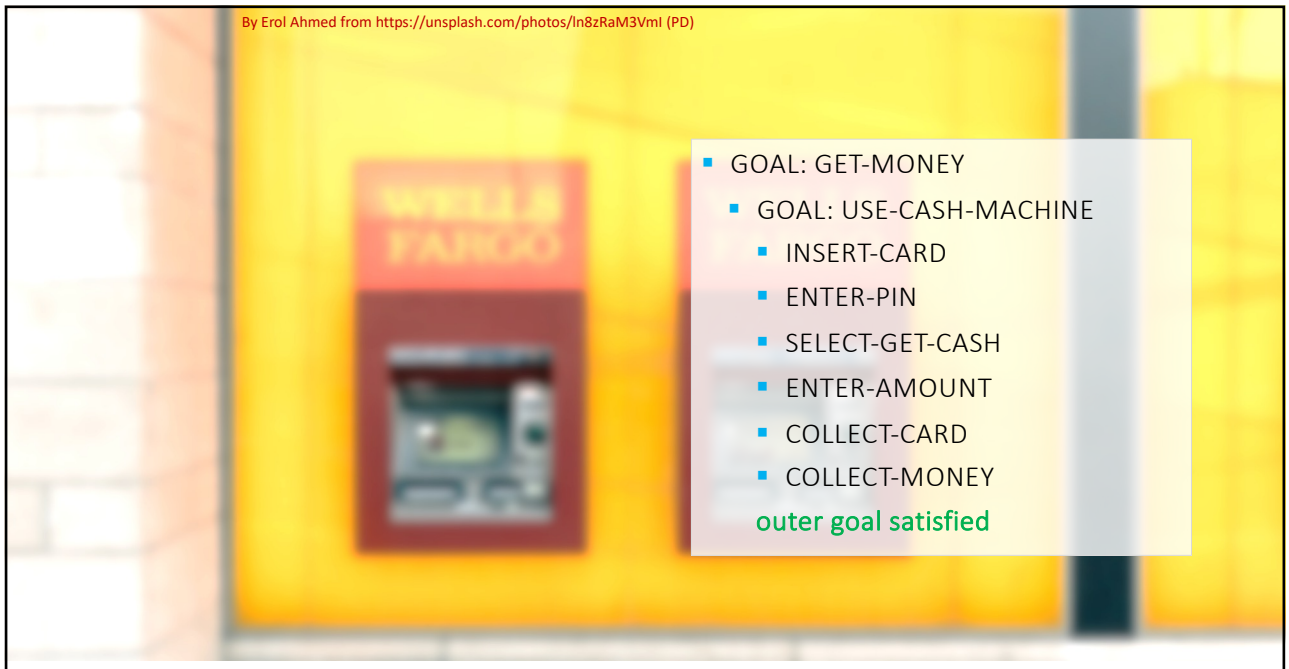
73

- GOAL: GET-MONEY
  - GOAL: USE-CASH-MACHINE
    - INSERT-CARD
    - ENTER-PIN
    - SELECT-GET-CASH
    - ENTER-AMOUNT
    - COLLECT-MONEY

    outer goal satisfied

Niels Henze 74

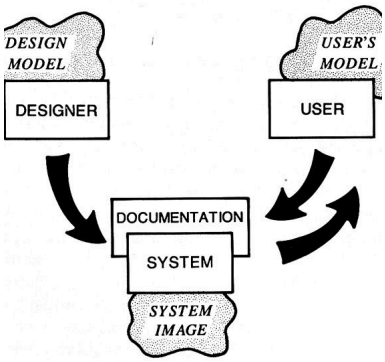
74



75

Mentale Modeller

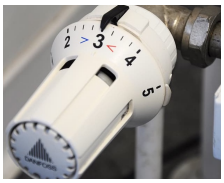
- Folk bygger mentale modelle af de ting de omgiver sig med
- Disse modeller kan delvist designes (gennem *system image)*
- Generelt er mentale modeller:
  - Upræcise
  - Præget af overtro og antagelser

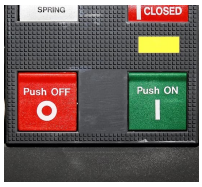


76

Termostater

- You came back and it is only 15°C in your room. You want a room temperature of 21°C. What do you do?
  1. You put the thermostat to 21°C and wait
  2. You put the thermostat to max (=35°) and switch it back to 21° once it is warm?
- What different mental models do people have who chose strategy 1 or 2?





77

Spørgsmål

78

Det har I fået med

- Modeller til at analysere hvordan mennesker handler og tænker
  - Fitts's lov og KLM

80