Beyond Fitts' law: models for trajectory-based HCI tasks

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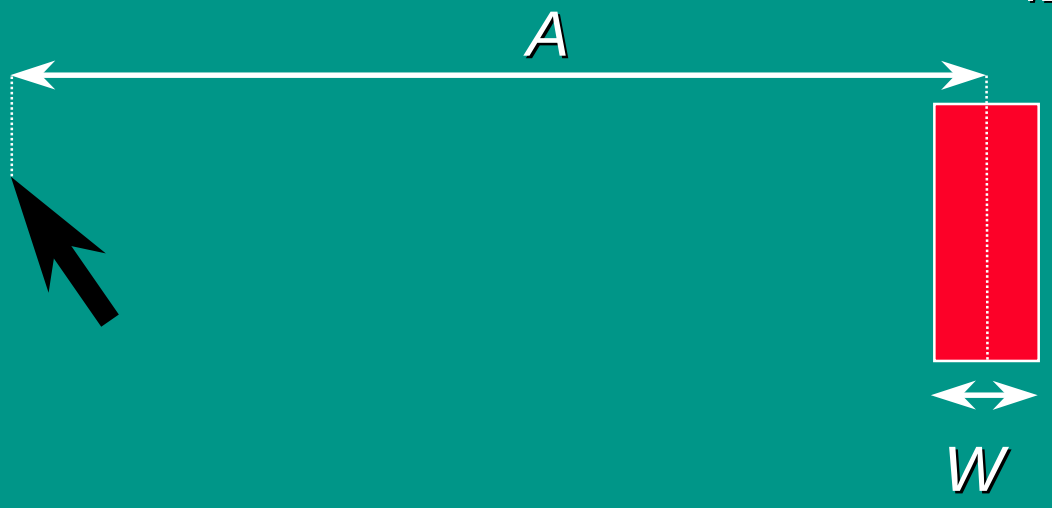
Modeling HCI

- *Hardening HCI* [Newell & Card, 1985]
- *Few models actually available*
- *One of the most common models: Fitts' law*

Fitts' law

- *"... the amplitude, the duration, and the variability of movements are interrelated ..."* *(Fitts, 1954)*
- *Target acquisition:* $MT = a + b \underbrace{\log_2\left(\frac{A}{W}+1\right)}_{ID}$



Applying Fitts' law: examples

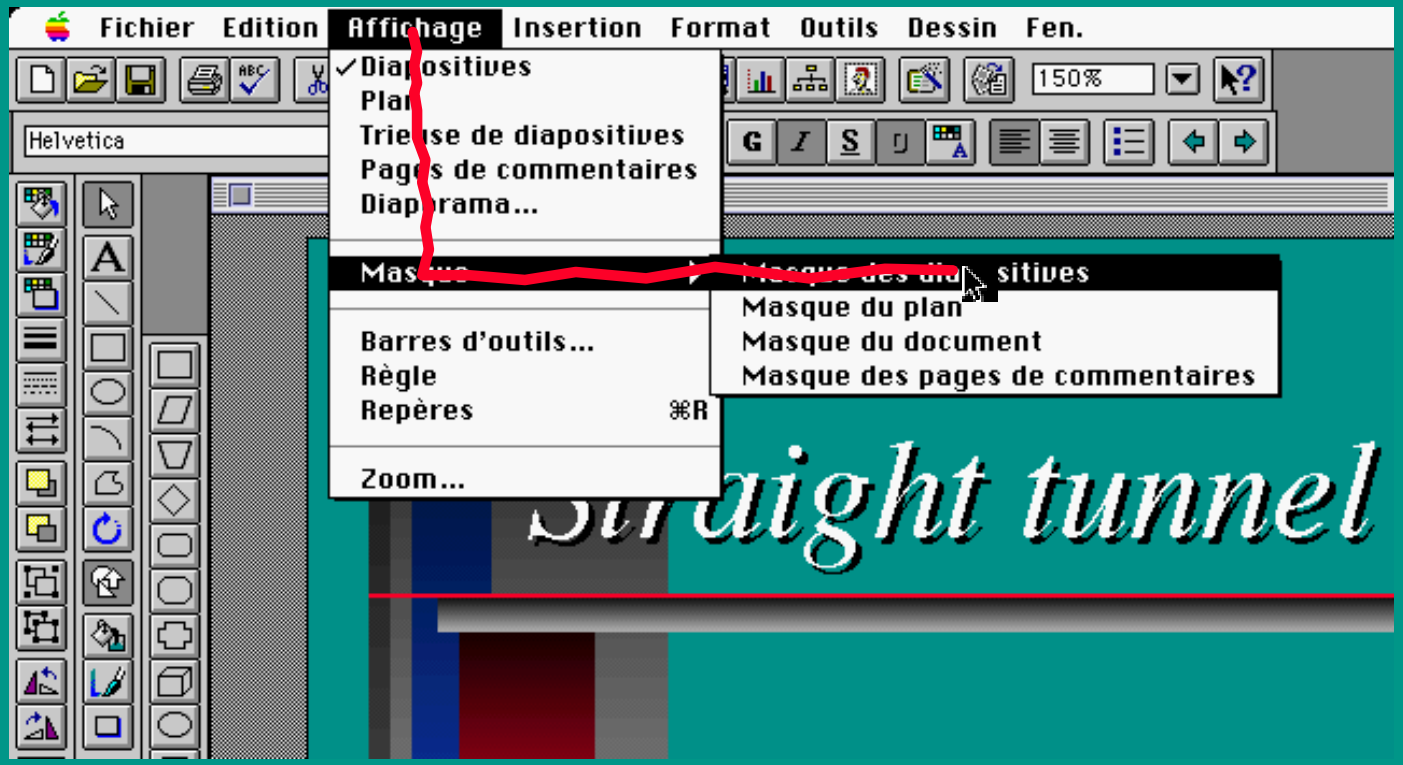
- *Devices comparison*
  - *Mouse, joystick* ..... [Card 1978, Epps 1986]
- *Limbs comparison*
  - *finger, wrist, arm* ..... [Langolf 1976, Balakrishnan 1997]
  - *right hand vs. left hand* ..... [Kabbash 1993]
- *Techniques comparison*
  - *dragging vs. pointing* ..... [Gillan 1990, MacKenzie 1993]
- *Influence of parameters*
  - *lag effect* ..... [Hoffmann 1992, MacKenzie 1993]
  - *control-display gain* ..... [Jagacinski 1978, Arnaut 1986]

Trajectory-based tasks (1)

- *Involves trajectory instead of targets*
- *In HCI:*
  - *moving in 3D worlds,*
  - *drawing curves,*
  - *writing,*
  - *navigating in hierarchical menus.*

Trajectory-based tasks (2)

- *Example: hierarchical menus*



Hints in the literature

- *Freeman (1914)*
  - *time to write is independent of script size*

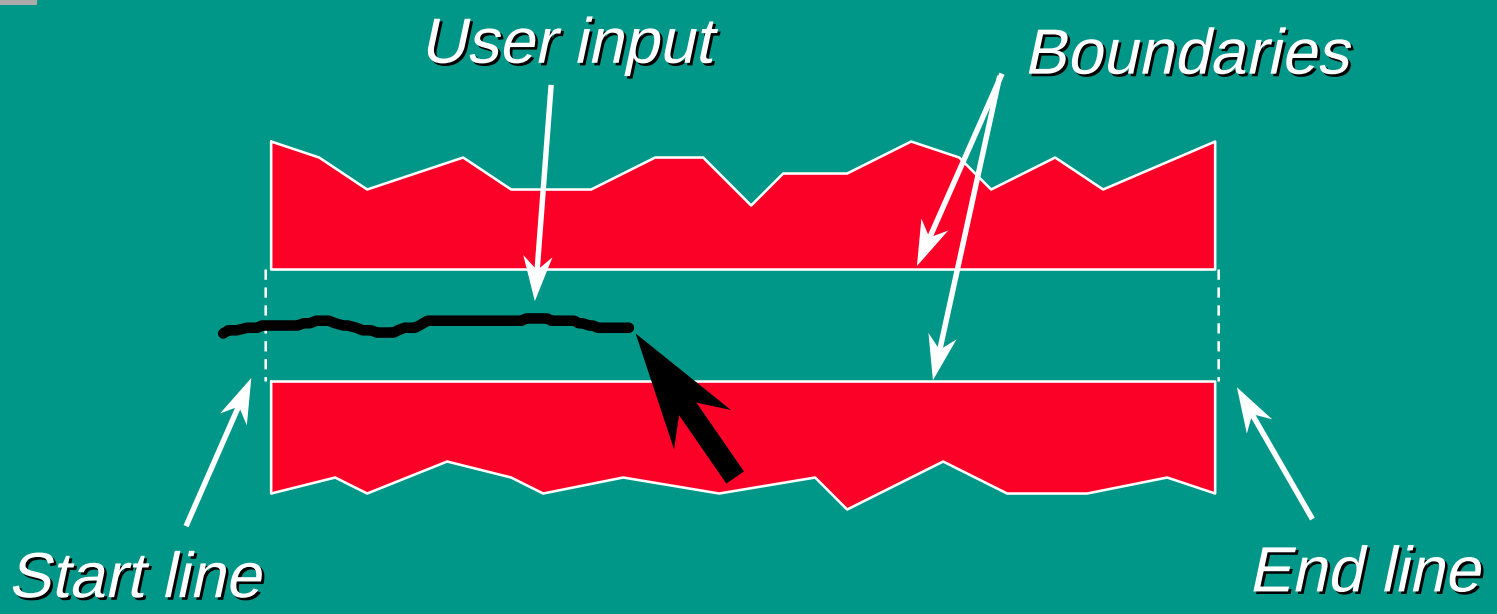
[Buxton, 1987]

- *speed/accuracy tradeoff in trajectory-based tasks?*

Steering paradigm

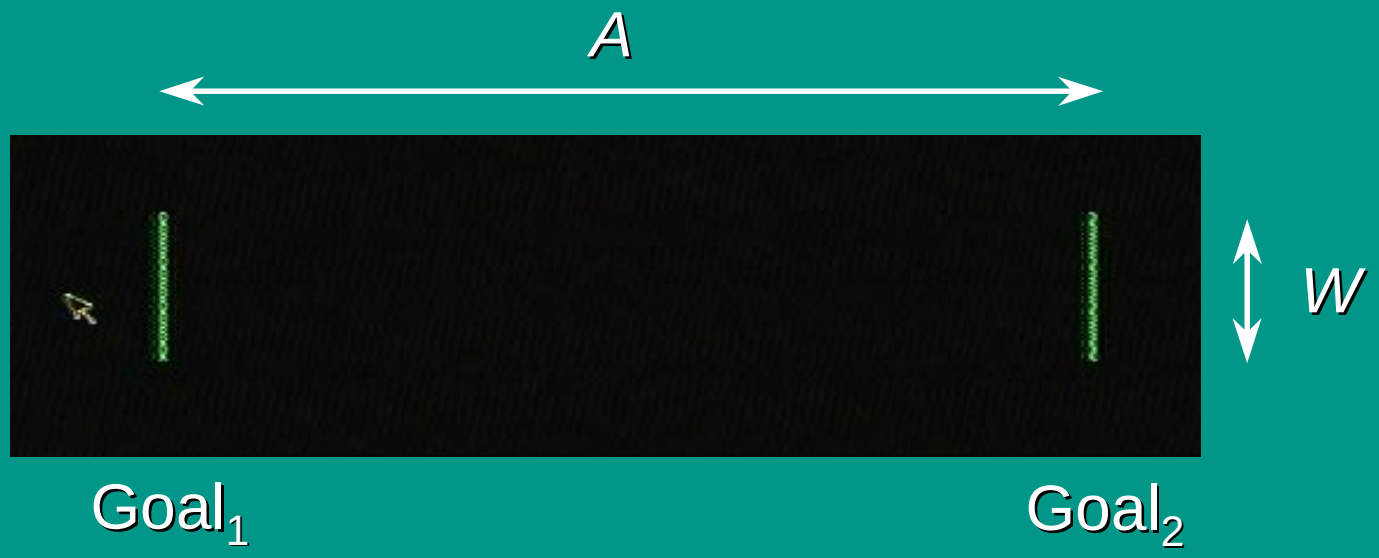
A new task paradigm: steering through tunnels

- *independent variables: amplitude and normal constraint,*
- *dependent variable: completion time*



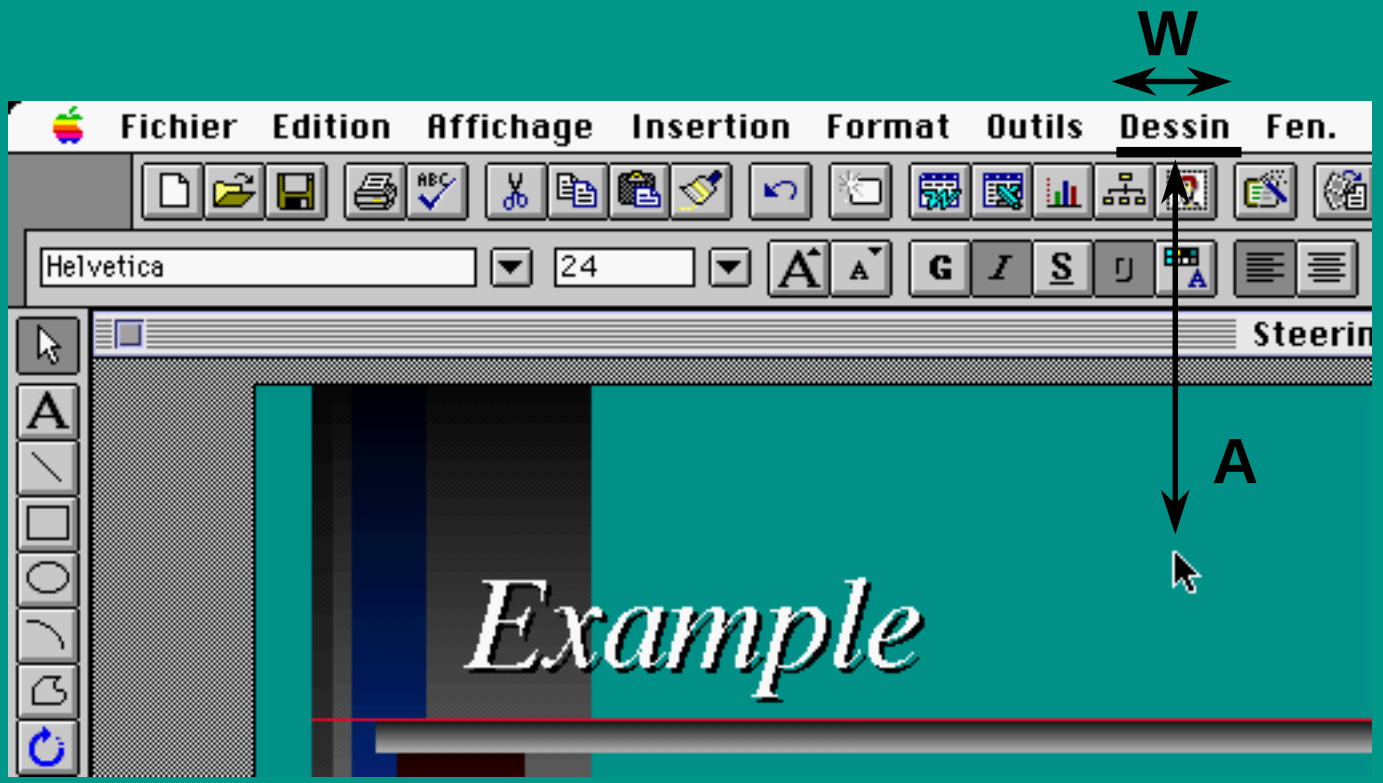
Goal passing (1)

- *<u>Procedure</u>: cross goal 1 and then goal 2*



Goal passing (2)

- *Example: menu of the Macintosh finder*

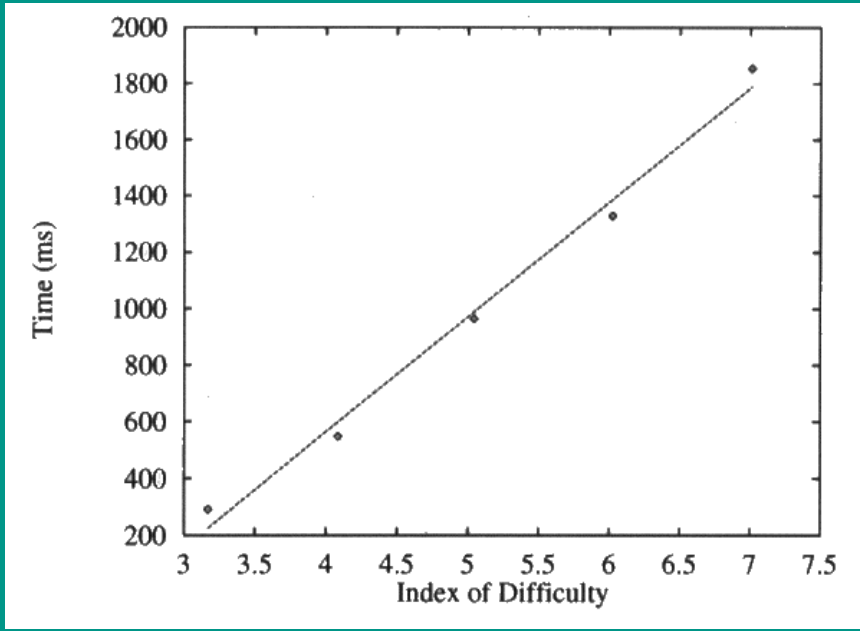


Goal passing (3)

- *Result:* $T = a + b \log_2 (\frac{A}{W} + 1)$ ✐ Still Fitts' law

Ten subjects:

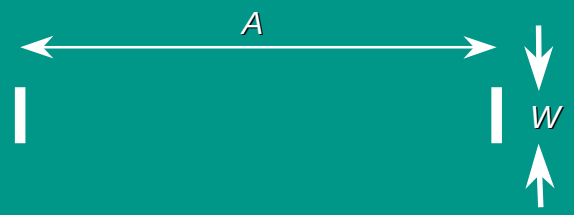
- *a = -1347 ms*
- *b = 391 ms*
- $r^2 = 0.987$



Defining a recursion...

- *2 goals passing*

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



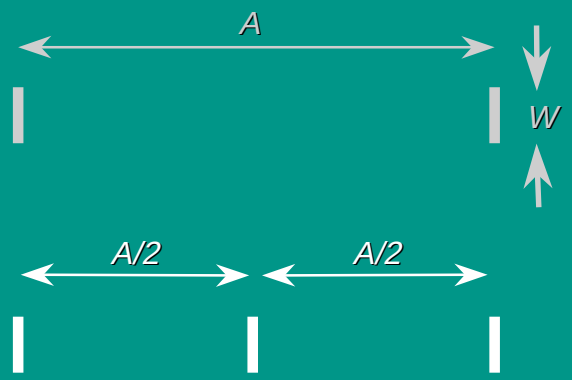
Defining a recursion...

- *2 goals passing*

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

- *3 goals passing*

$$ID = 2 \log_2 \left(\frac{A}{2W} + 1 \right)$$



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- *2 goals passing*

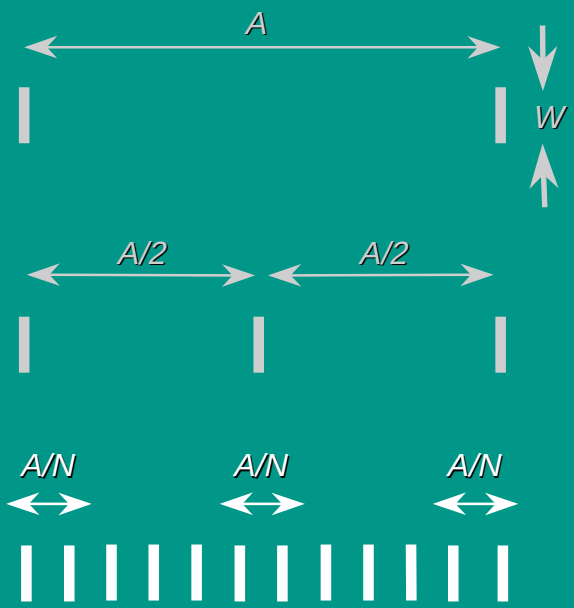
$$ID = \log_2 \left(\frac{A}{W} + 1 \right)$$

- *3 goals passing*

$$ID = 2 \log_2 \left(\frac{A}{2W} + 1 \right)$$

- *N+1 goals passing*

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



Defining a recursion...

- 2 goals passing

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

- 3 goals passing

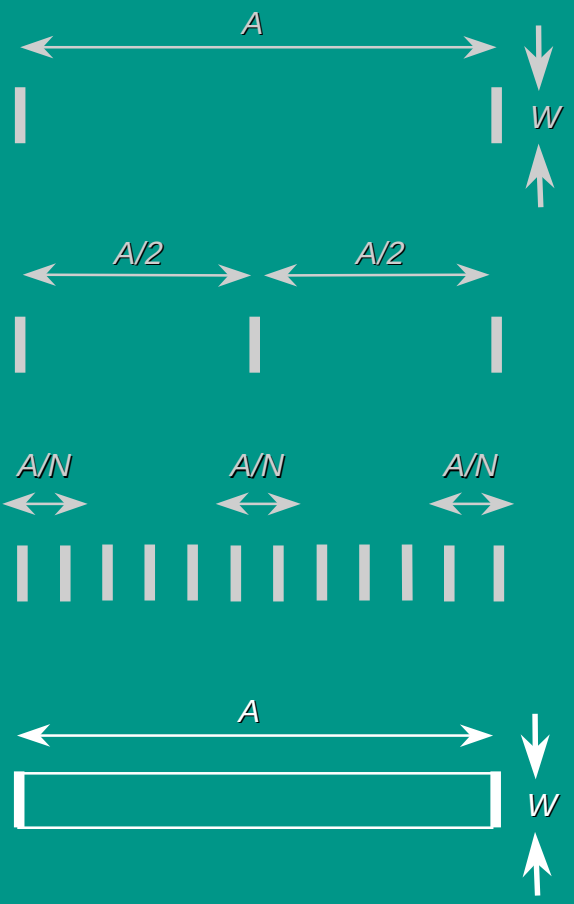
$$ID = 2 \log_2 \left(\frac{A}{2W} + 1 \right)$$

- N+1 goals passing

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

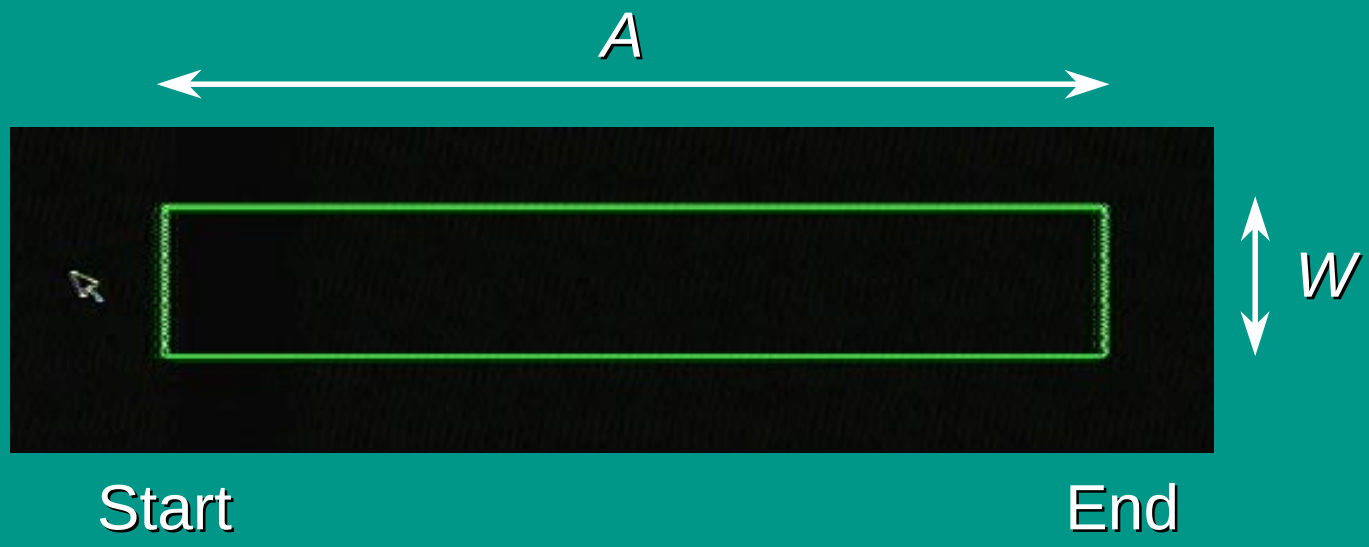
- ∞ goals passing

$$ID = \frac{A}{W} ?$$



Straight tunnel steering (1)

- *<u>Procedure</u>: cross start line, steer through the path, cross end line*

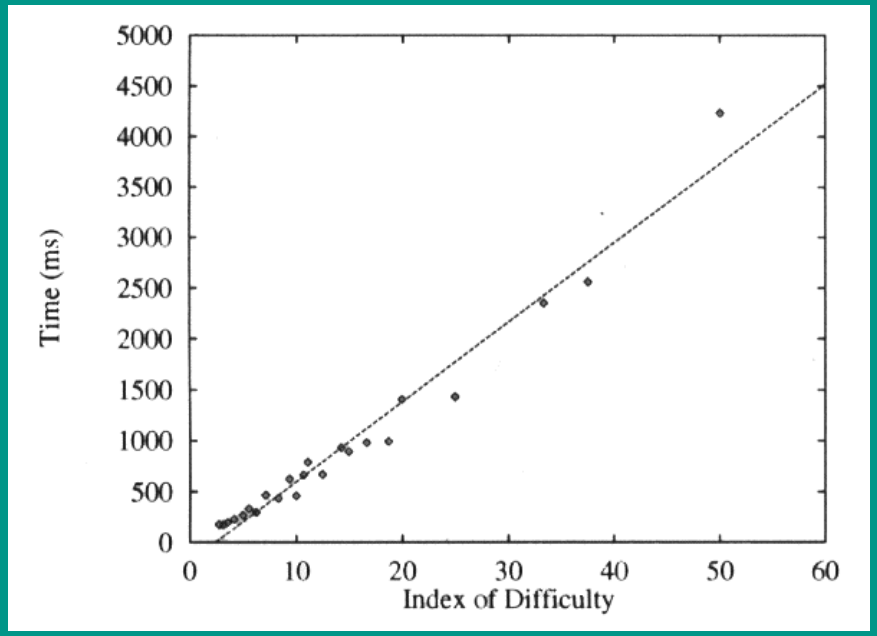


Straight tunnel steering (2)

- *Result:* $T = a + b\frac{A}{W}$

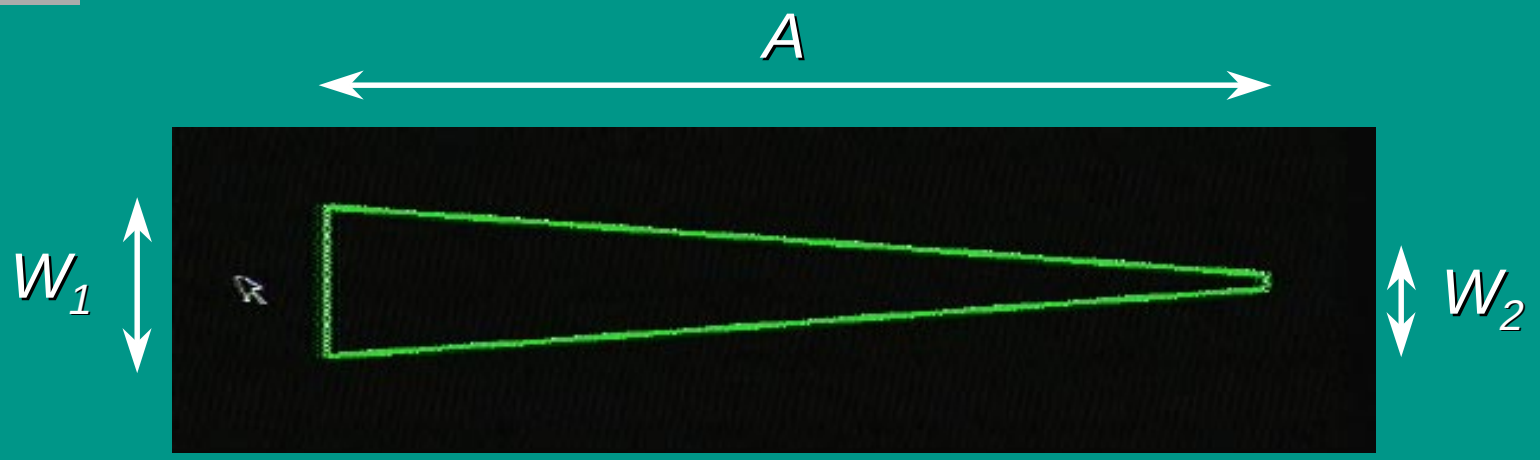
Thirteen subjects:

- *a = -188 ms*
- *b = 78 ms*
- $r^2 = 0.968$



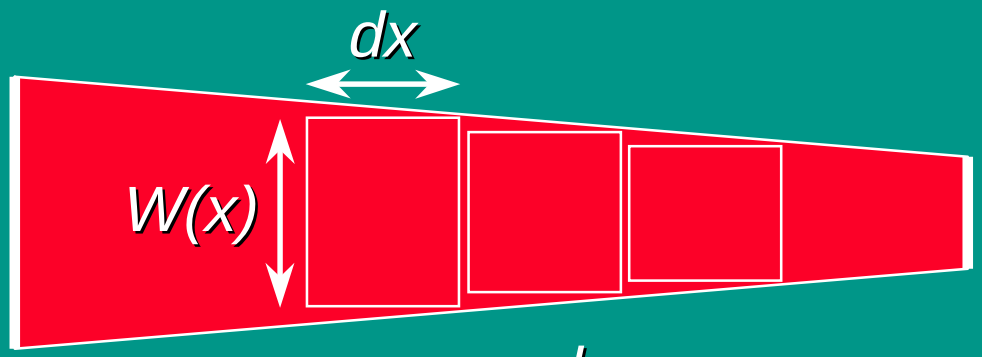
Narrowing tunnel steering (1)

- *<u>Procedure</u>: cross start line, steer through the path, cross end line*



Second decomposition

- *Decomposition of a steering task into a set of elementary straight tunnel steering tasks*



$$dID_x = \frac{dx}{W(x)}$$

$$T_C = a + b\, ID_C$$

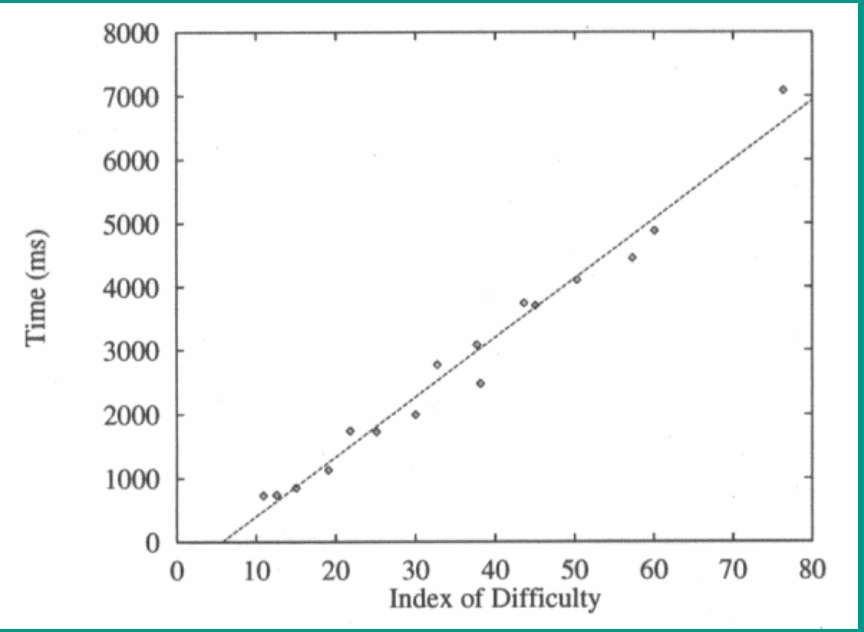
$$ID_C = \int_C \frac{dx}{W(x)}$$

Narrowing tunnel steering (2)

- *Result:* $T = a + b \frac{A}{W_2 - W_1} \ln \frac{W_2}{W_1}$

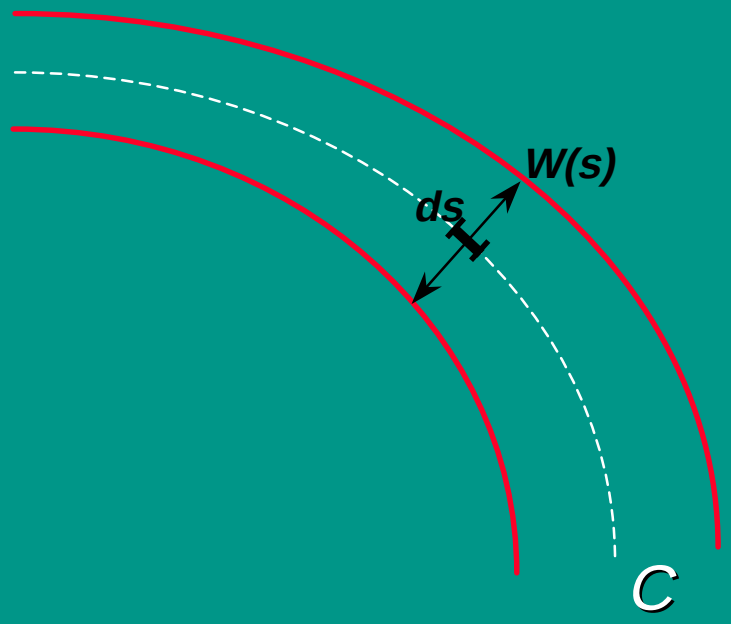
Ten subjects:

- *a = -532 ms*
- *b = 93 ms*
- $r^2 = 0.978$



Generic method

- Generalizes the method applied for narrowing tunnels: integration along the path



$$T_C = a + b\, ID_C$$

$$ID_C = \int_C \frac{ds}{W(s)}$$

Spiral tunnel steering (1)

- *<u>Procedure</u>: cross inner segment, steer through the spiral, cross outer segment*

$S_{n,w}$

n: influences the length
w: influences the width increase rate

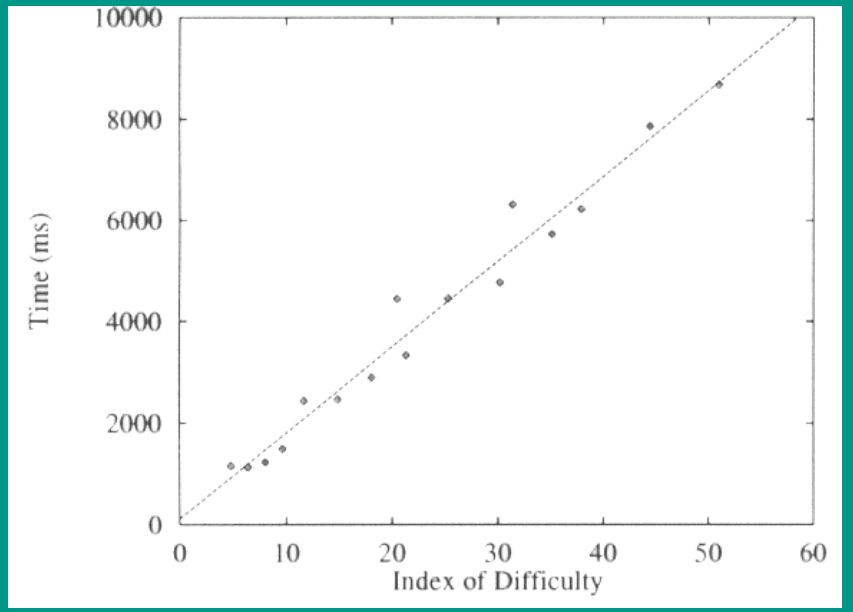
Spiral tunnel steering (2)

- *Result:* $T = a + b\ ID$

$$ID_{S_{n,w}} = \int_{2\pi}^{2\pi(n+1)} \frac{\sqrt{(\theta+w)^6 + 9(\theta+w)^4}}{(\theta+2\pi+w)^3 - (\theta+w)^3}\, d\theta$$

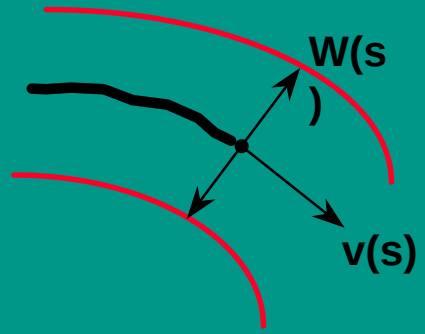
Eleven subjects:

- *a = -115 ms*
- *b = 169 ms*
- $r^2 = 0.971$



Local form

- *Integral form:* $T_C = a + b\, ID_C, \quad ID_C = \int_C \frac{ds}{W(s)}$
- *Local form:* $v(s) = \frac{W(s)}{\tau}$



v: velocity

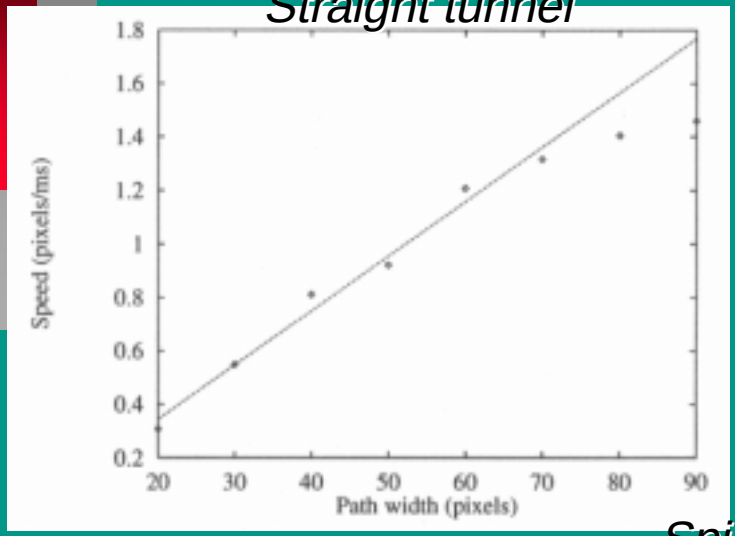
W: path width

τ: time constant

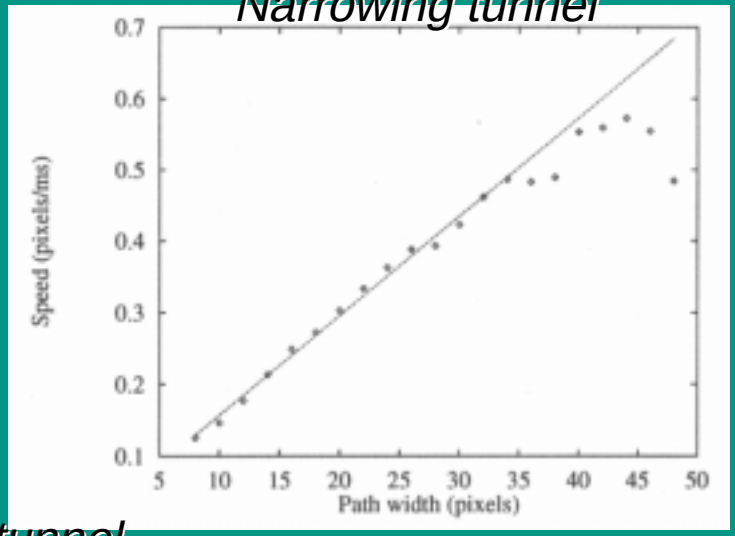
➔ *Speed is proportionnal to normal constraint*

Experimental verification

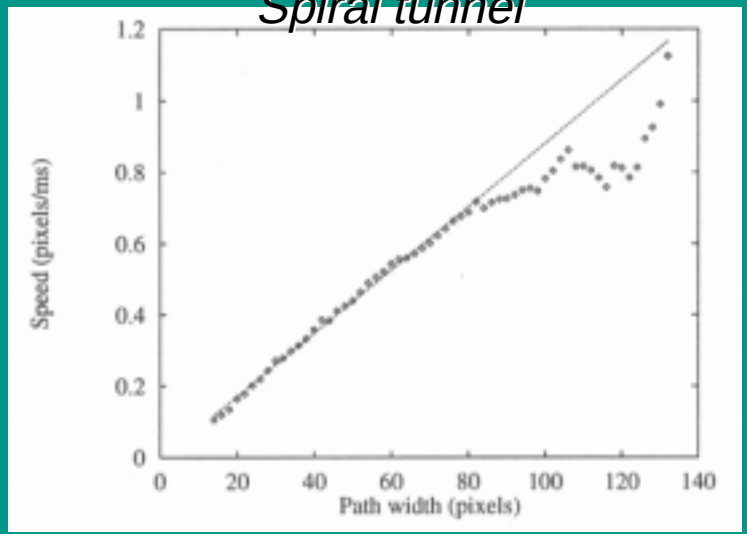
Straight tunnel



Narrowing tunnel



Spiral tunnel



Applications & future work

- *Performance comparisons*
  - *Devices*
  - *Limbs*
  - *Control/display gain*
  - *Transfer functions*
- *Theoretical evaluation of input techniques*
- *Extending the model (curvature, 3D)*

Conclusion

- Models for trajectory-based tasks do exist!
  - Integral form: $T_C = a + b \int_C \frac{ds}{W(s)}$
  - Local form: $v(s) = \frac{W(s)}{\tau}$
- Bridge between steering laws and Fitts' law: mathematical recursion
- Numerous applications of steering laws exist