# Human Performance Modeling - 3

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# Explanation of $R^2$

$$R^2 \equiv 1 - \frac{SS_{\text{res}}}{SS_{\text{tot}}}$$

$$SS_{\text{res}} = \sum_i (y_i - f_i)^2 = \sum_i e_i^2$$

$$SS_{\text{tot}} = \sum_i (y_i - \bar{y})^2,$$

# How to carry out your research?

1. Choose your research topic

2. Literature review.

3. Planning.

4. Execution.

5. Evaluation.

6. Write report.

# Choosing Research Topic

1. Novelty.

The research should be novel, and advance the status quo.

2. Usefulness.

The expected outcome should be better than the status quo at least in some scenarios.

3. Appropriate Scope

- Make sure your team is able to finish it in one semester.
- Have enough time to write up the report, and prepare the final presentation.

# How to carry out your research?

1. Choose your research topic

2. Literature review.

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# Literature Review

- Search in ACM Digital library to see if your idea has been explored
- Think about the potential contributions of your research in light of the exiting work
- Write down some notes. You may use them in the “Related Work” section of your final report.

# How to carry out your research?

1. Choose your research topic

2. Literature review.

3. Planning.

4. Execution.

5. Evaluation.

6. Write report.

# Planning

- Have some self-imposed internal deadlines
- Remember to allocate enough time for writing report
- Be flexible

Plans are worthless, but planning is everything

Dwight D. Eisenhower

# How to carry out your research?

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# Points breakdown (35%):

execution (15%) + final report (15%) + presentation (5%)

# Example Project Ideas

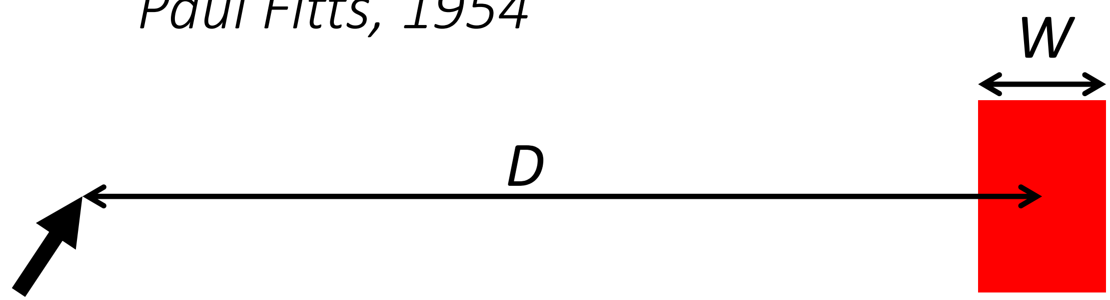
# Idea #1. Mobile Learning Game

**ToneWars: Connecting Language Learners and Native Speakers through Collaborative Mobile Games**

By Andrew Head, Yi Xu, Jingtao Wang

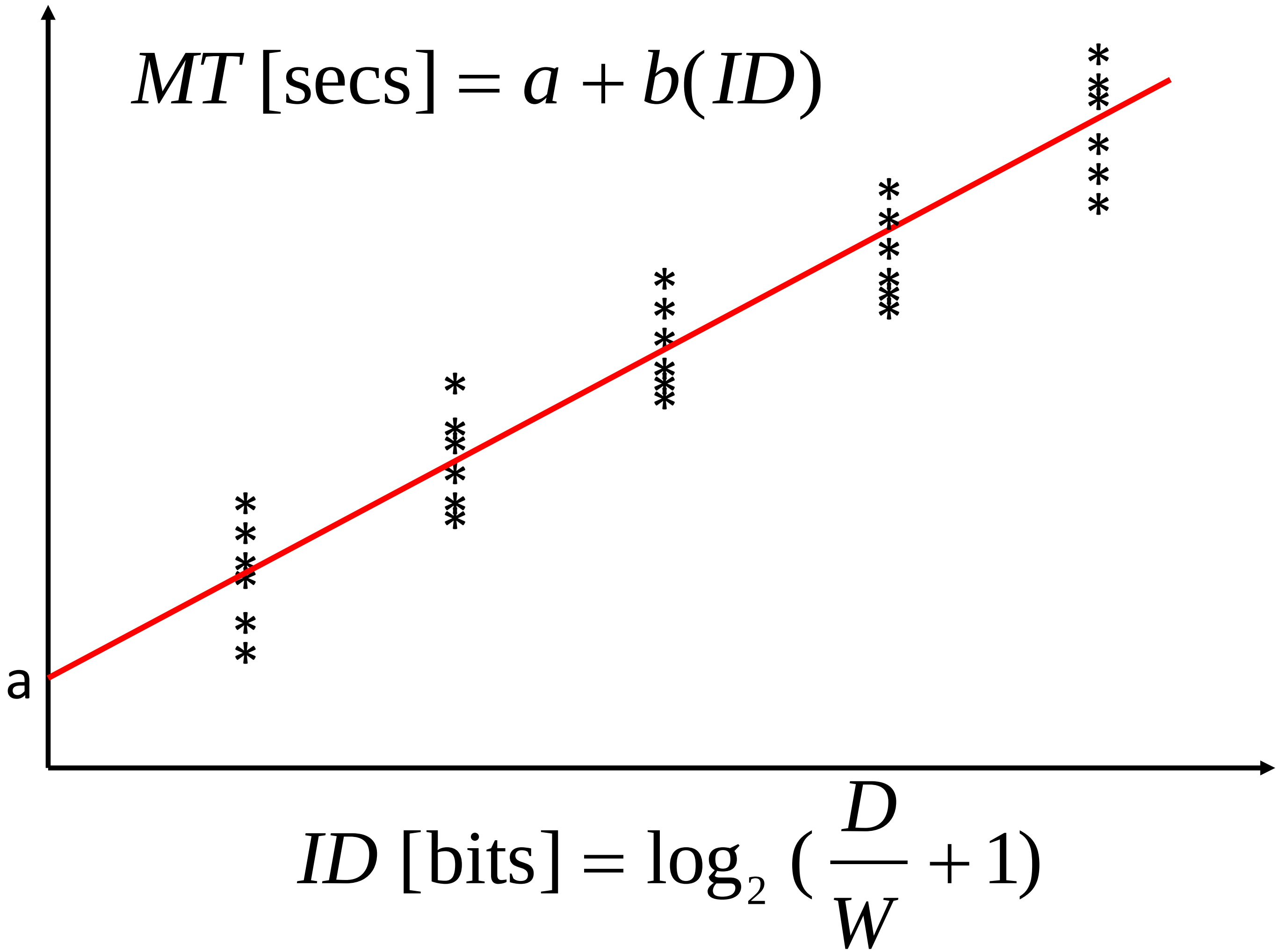
# Fitts' Law

*Paul Fitts, 1954*




$$\underbrace{MT}_{\textbf{Movement Time}} = a + b\,\underbrace{\log_2\left(\frac{D}{W} + 1\right)}_{\textbf{Index of Difficulty}\ (\textit{ID [bits]})}$$

# Fitts' Law



# Extending Fitts' law to Two-Dimensional Tasks

- Experiment Result

**Empirically, this is the best**

| Model for Target Width | *ID* Range (bits) Low | High | $r^a$ | $SE^b$ (ms) | Regression Coefficients Intercept, $a$ (ms) | Slope, $b$ (ms/bit) | $IP$ (bits/s) |
|---|---|---|---|---|---|---|---|
| SMALLER-OF | 1.58 | 5.04 | .9501 | 64 | 230 | 166 | 6.0 |
| $W'$ | 1.00 | 5.04 | .9333 | 74 | 337 | 160 | 6.3 |
| $W+H$ | 0.74 | 3.54 | .8755 | 99 | 402 | 218 | 4.6 |
| $W \times H$ | 0.32 | 4.09 | .8446 | 110 | 481 | 173 | 5.8 |
| STATUS QUO | 1.00 | 5.04 | .8097 | 121 | 409 | 135 | 7.4 |

$^a n = 78, p < .001$

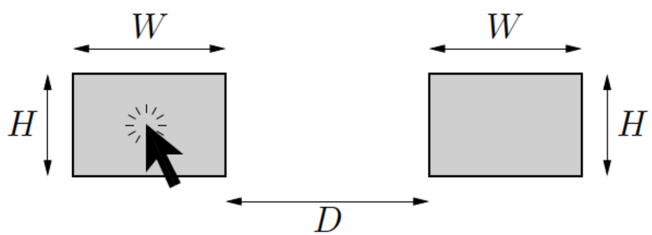
$^b$standard error of estimate

**Theoretically, this is similar to Fitts' Law**

**Figure 6.** Correlations and regression coefficients for five models for target width.

# Refining Fitts' law models for bivariate pointing

- Conclusion




$$T = a + b \log_2 \left( \sqrt{\left(\frac{D}{W}\right)^2 + \eta \left(\frac{D}{H}\right)^2} + 1 \right)$$

η: [1/7, 1/3]

# Agenda

- Application of Fitts' law

- Crossing Law
  - More than dotting the i's – Foundations for crossing-based interfaces

- Steering Law
  - Beyond Fitts' Law: Models for Trajectory-Based HCI Tasks

# Application of Fitts’ Law in UI Design

## Keyboard Layout Optimization

# Qwerty Layout

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Q | W | E | R | T | Y | U | I | O | P |
| A | S | D | F | G | H | J | K | L | |
| | Z | X | C | V | B | N | M | | |

Qwerty is inefficient for one finger typing.

# Optimization Objective Function

- Fitts' Law (Fitts 1954):

$$MT_{ij} = a + b\log_2\left(\frac{D_{ij}}{W} + 1\right)$$

$MT_{ij}$: Movement Time from Key *i* to Key *j*
$D_{ij}$ : Distance from Key *i* to Key *j*
$W$ *:* Key Width

# Optimization Objective Function

- Fitts' Law (Fitts 1954):

$$MT_{ij} = a + b\log_2\left(\frac{D_{ij}}{W} + 1\right)$$

$MT_{ij}$: Movement Time from Key *i* to Key *j*
$D_{ij}$ : Distance from Key *i* to Key *j*
$W$ *:* Key Width

- Average time of typing a letter:

$$t = a + b\sum_{i}^{26}\sum_{j}^{26} P_{ij}\log_2\left(\frac{D_{ij}}{W} + 1\right)$$

$P_{ij}$: Frequency of an ordered letter pair *i, j*

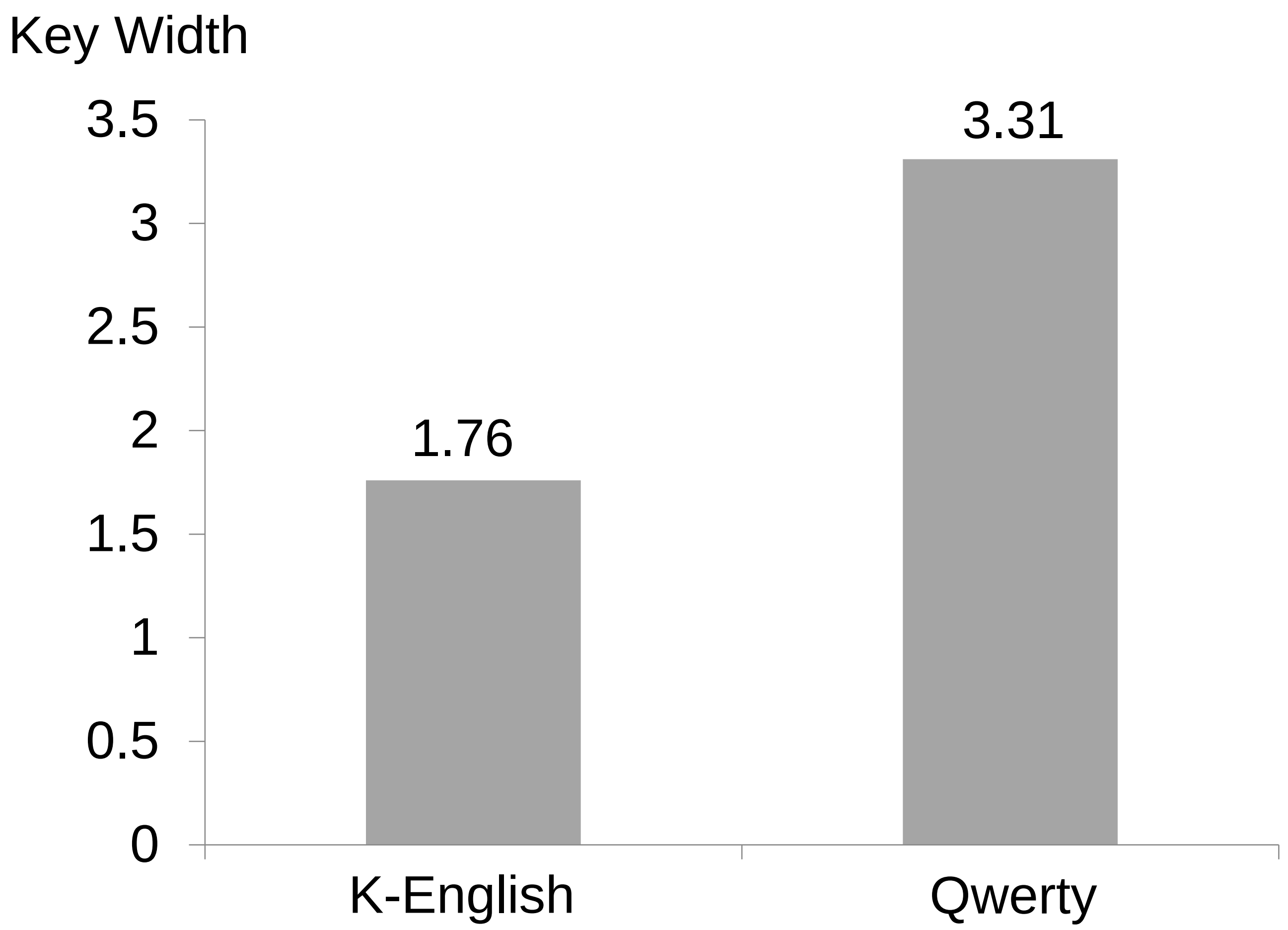
# Layout Optimized for English

K-English

| | | | | | |
|---|---|---|---|---|---|
| Z | J | D | G | K | |
| Y | L | N | I | C | |
| F | O | A | T | H | W |
| B | U | R | E | S | |
| Q | P | M | V | X | |

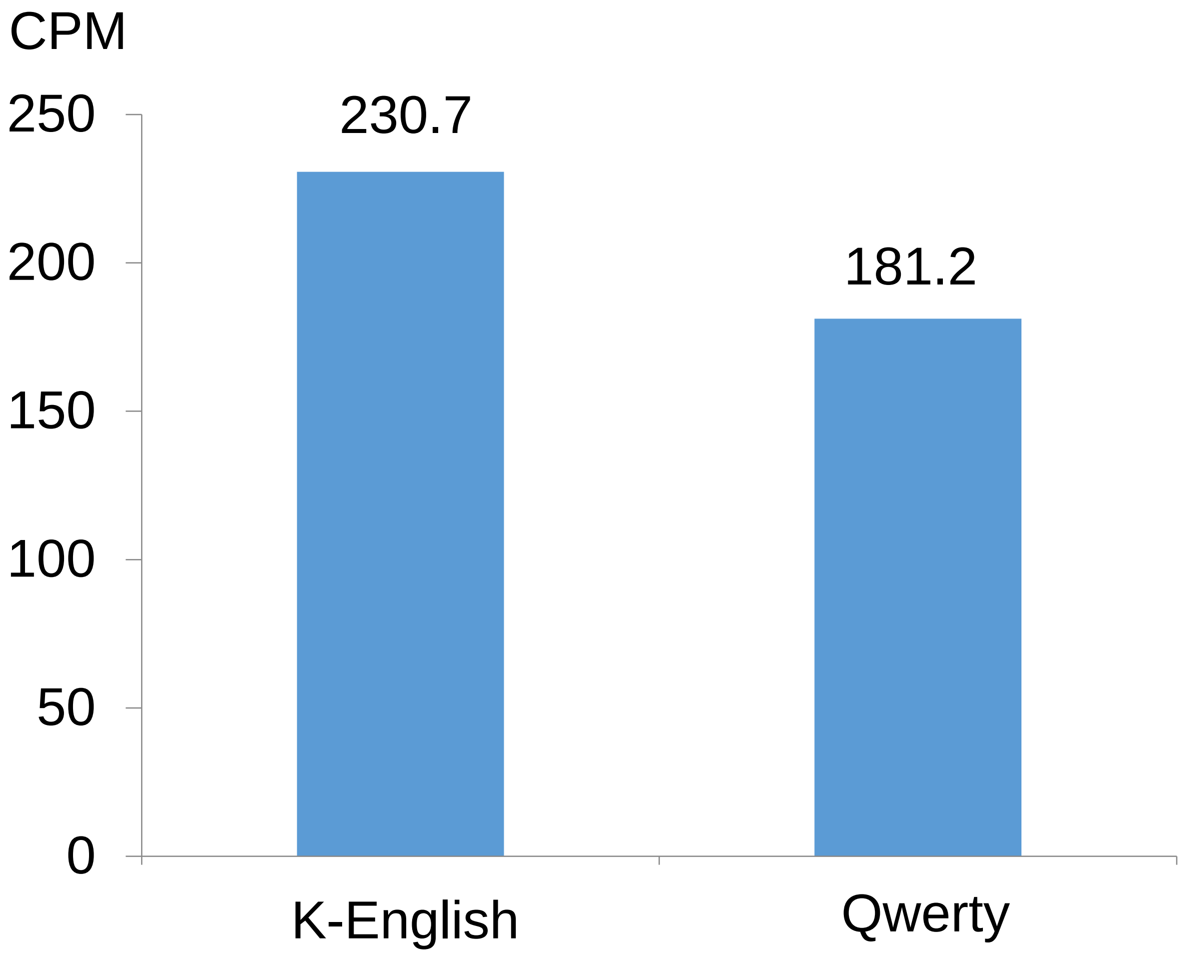
[**Bi,** Smith, Zhai. *Multilingual Touchscreen Keyboard Design and Optimization* Human-Computer Interaction 2012]

# Average Finger Travel Distance




[**Bi,** Smith, Zhai. *Multilingual Touchscreen Keyboard Design and Optimization* Human-Computer Interaction 2012]

# Typing Speed




[**Bi,** Smith, Zhai. *Multilingual Touchscreen Keyboard Design and Optimization* Human-Computer Interaction 2012]

# Quasi-Qwerty Layout

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Q | W | D | R | T | U | Y | L | K | P |
| Z | A | S | E | H | N | I | O | M | |
| | X | F | V | C | G | B | J | | |

[**Bi,** Smith, Zhai. *Quasi-Qwerty Soft Keyboard Optimization.* ACM CHI2010]

# Quasi-Qwerty Layout

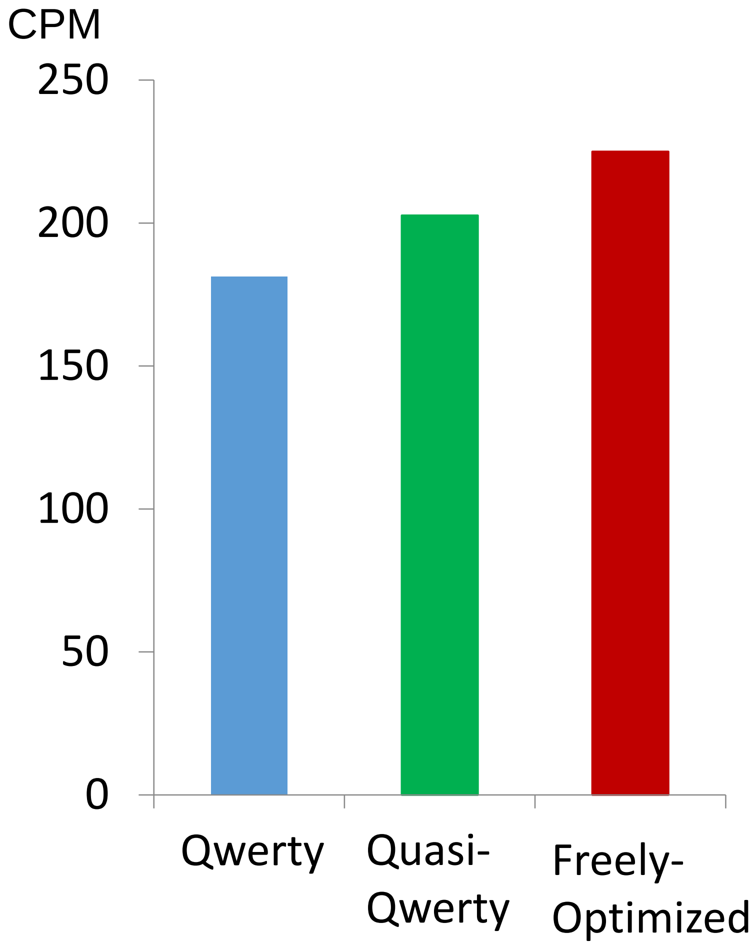
| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Q | W | D | R | T | U | Y | L | K | P |
| Z | A | S | E | H | N | I | O | M | |
| | X | F | V | C | G | B | J | | |

Qwerty

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Q | W | E | R | T | Y | U | I | O | P |
| A | S | D | F | G | H | J | K | L | |
| | Z | X | C | V | B | N | M | | |

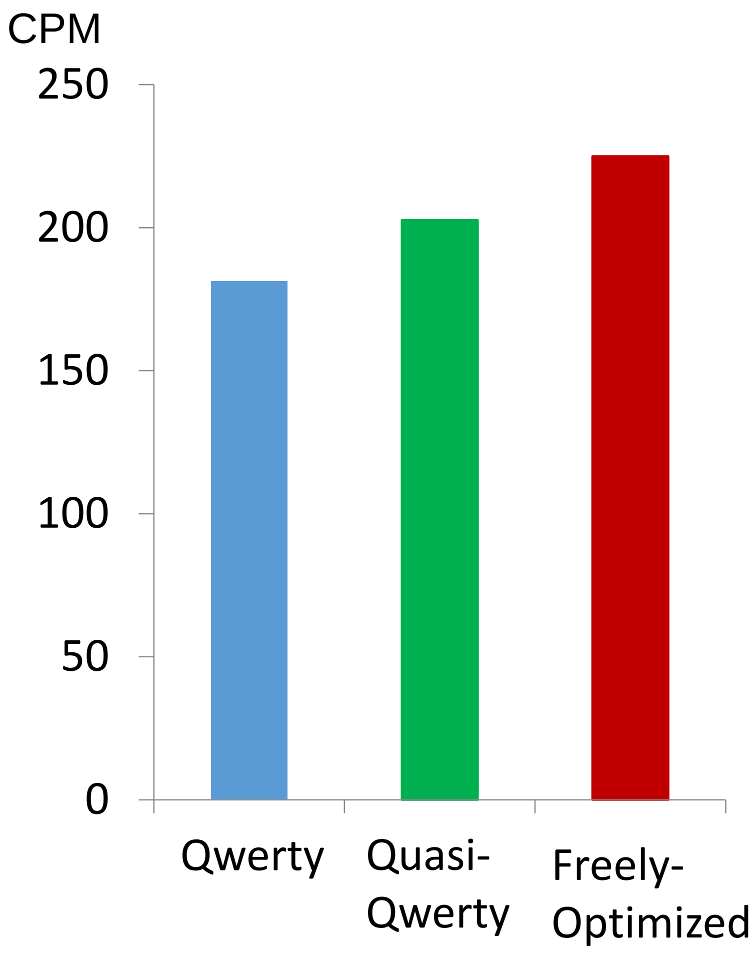
[**Bi,** Smith, Zhai. *Quasi-Qwerty Soft Keyboard Optimization.* ACM CHI2010]

# Expert Typing Speed

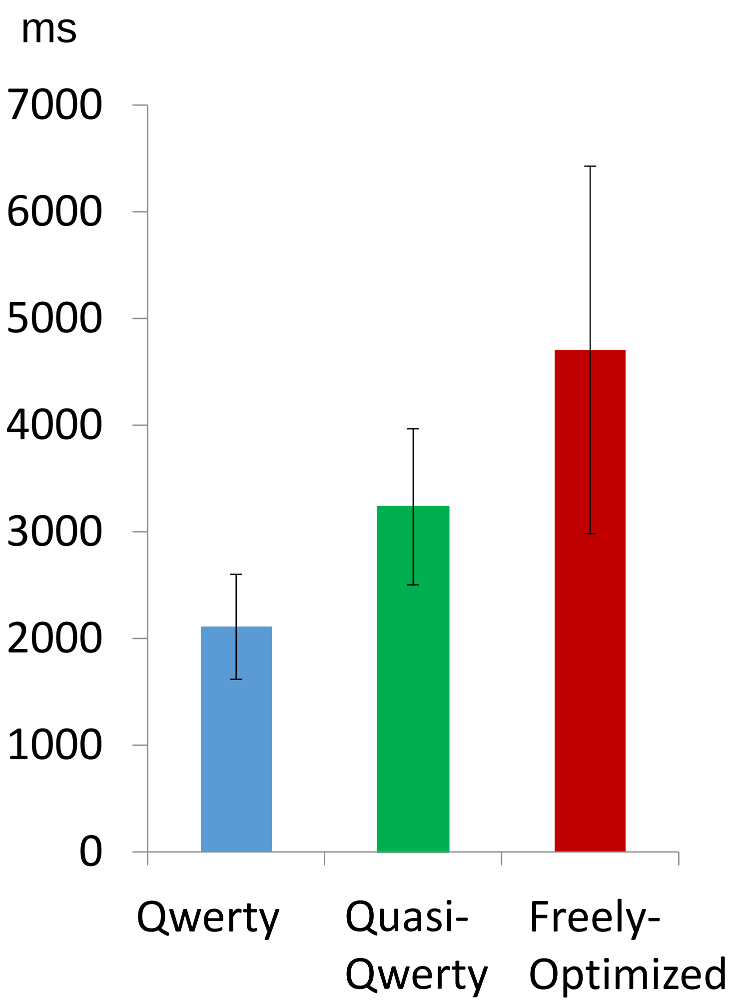



[**Bi,** Smith, Zhai. *Quasi-Qwerty Soft Keyboard Optimization.* ACM CHI2010]

## Expert Typing Speed




## Initial Text Entry Time



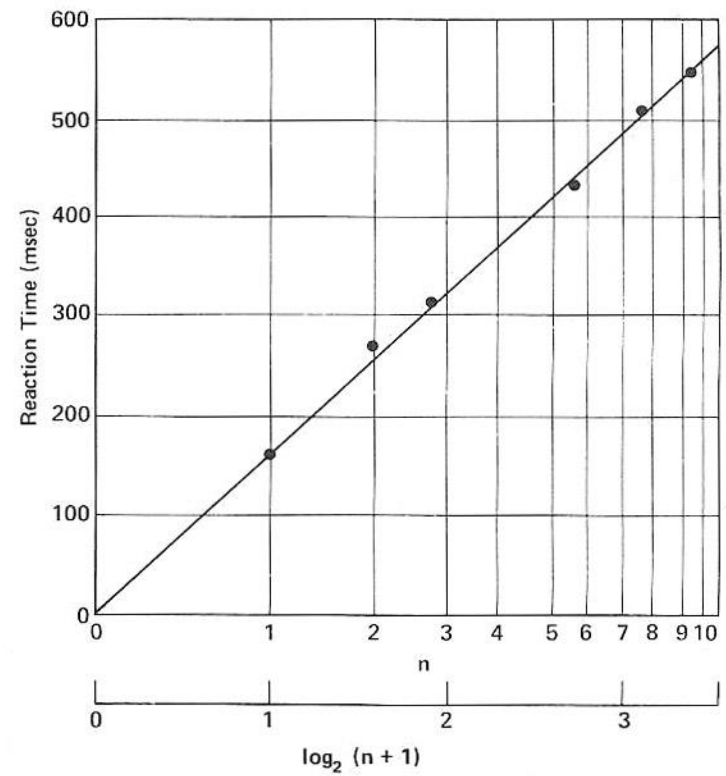

[**Bi,** Smith, Zhai. *Quasi-Qwerty Soft Keyboard Optimization.* ACM CHI2010]

# Choice Reaction Time

# Hick's Law

The time it takes for a person to make a decision as a result of the possible choices he or she has: increasing the number of choices will increase the decision time logarithmically.

$$T = b \cdot \log_2(n+1)$$




At the onset of one of *n* lights, arranged in a row, the subject is to press the key located Below the light (After Welford, 1968, p62)

# Hick's Law

**Uncertainty Principle.** Decision time $T$ increases with uncertainty about the judgment or decision to be made:

$$T = I_C H,$$

where $H$ is the information-theoretic entropy of the decision and $I_C$ = 150 [0–157] ms/bit. For $n$ equally probable alternatives (called Hick's Law),

$$H = \log_2 (n + 1).$$

For $n$ alternatives with different probabilities $p_i$ of occurrence,

$$H = \Sigma_i p_i \log_2 (1/p_i + 1).$$

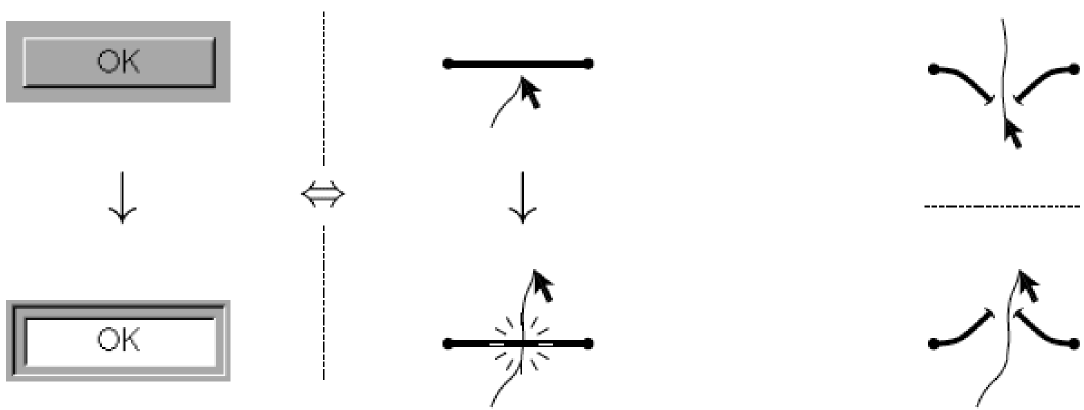
# Crossing Law

- Not just pointing, how about crossing a boundary?


Johnny Accot and Shumin Zhai. 2002. More than dotting the i's --- foundations for crossing-based interfaces. CHI '02. ACM, New York, NY, USA, 73-80.

# More than dotting the i’s – Foundations for crossing-based interfaces

- Pointing
  - may be time-consuming if the object to be pointed is small, or
  - widgets might occupy more spaces
- Use crossing as interface



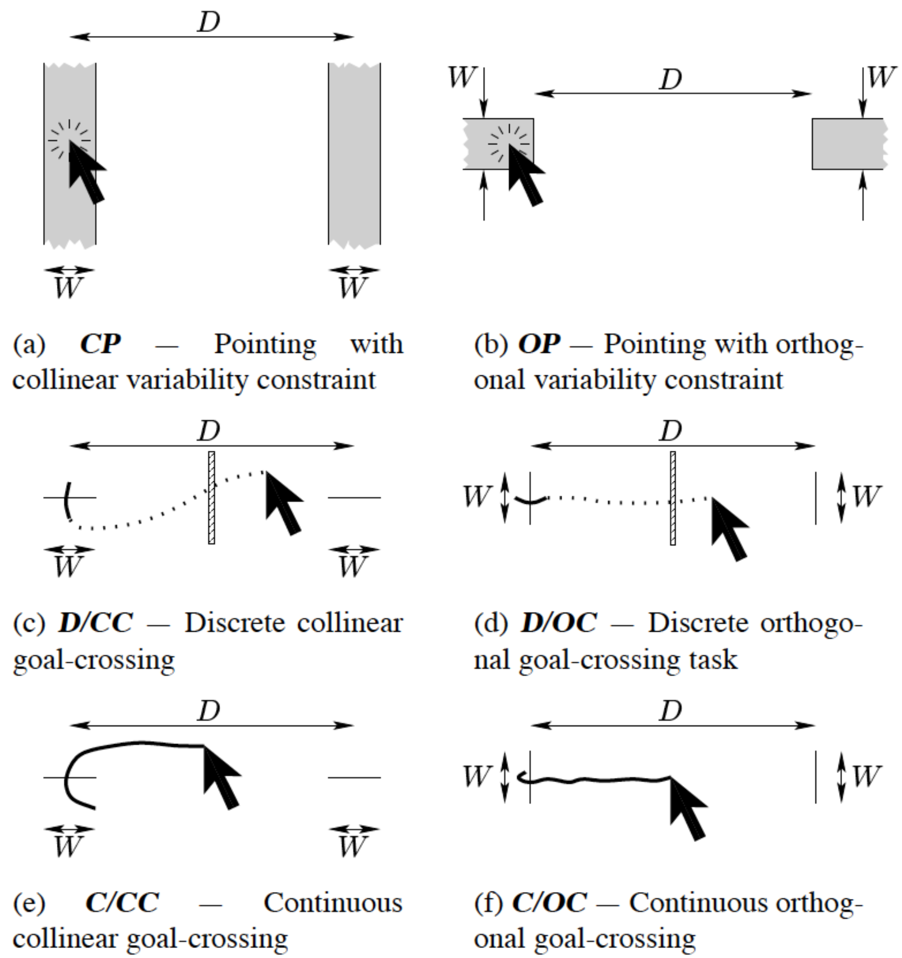

(a) To trigger an action: on the left we push the button; on the right we cross the goal.

(b) Unlike a traditional check box, a goal can “store” two visual states depending on the crossing direction.

# More than dotting the i’s – Foundations for crossing-based interfaces

- Possible actions
  - Orthogonal / collinear
  - Discrete / continue

- Compare with pointing, Accot and Zhai propose 6 test conditions
  - 2 pointing tasks
  - 4 crossing tasks




(a) ***CP*** — Pointing with collinear variability constraint

(b) ***OP*** — Pointing with orthogonal variability constraint

(c) ***D/CC*** — Discrete collinear goal-crossing

(d) ***D/OC*** — Discrete orthogonal goal-crossing task

(e) ***C/CC*** — Continuous collinear goal-crossing

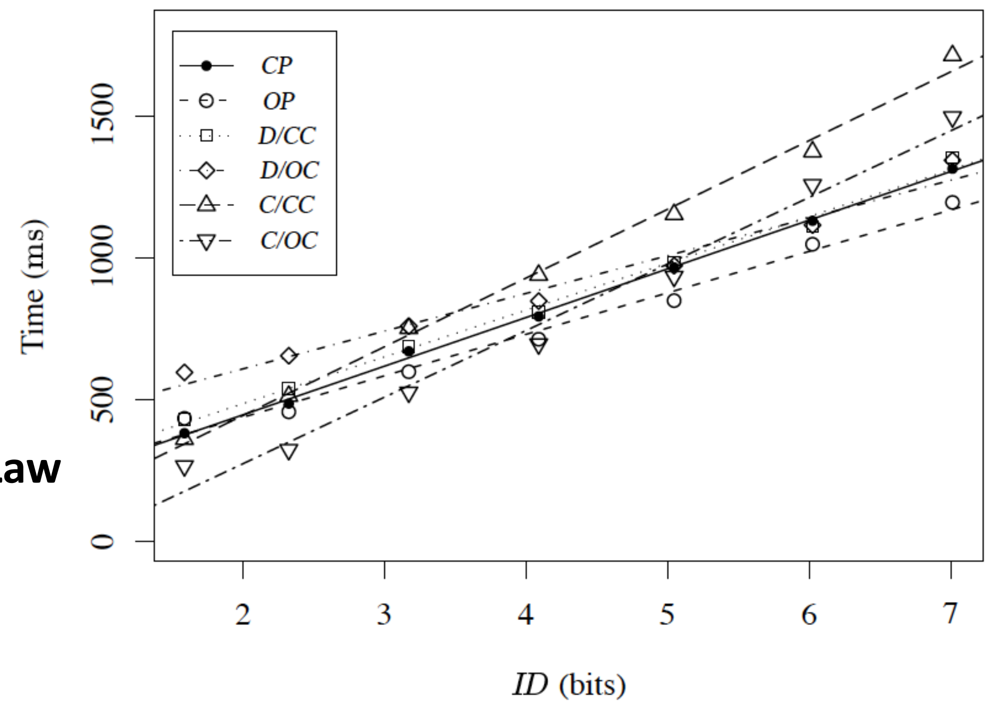
(f) ***C/OC*** — Continuous orthogonal goal-crossing

Figure 4: The six tested conditions. All tasks were reciprocal.

# More than dotting the i's – Foundations for crossing-based interfaces

- Experiment result

$$\begin{aligned}
&CP: && T = 103 + 172 \times ID && r^2 = 0.998 && (4)\\
&OP: && T = 145 + 146 \times ID && r^2 = 0.986 && (5)\\
&D/CC: && T = 155 + 165 \times ID && r^2 = 0.994 && (6)\\
&D/OC: && T = 342 + 133 \times ID && r^2 = 0.975 && (7)\\
&C/CC: && T = -41 + 242 \times ID && r^2 = 0.995 && (8)\\
&C/OC: && T = -196 + 235 \times ID && r^2 = 0.984 && (9)
\end{aligned}$$




Conclusion:

**Pointing tasks can be modeled by Fitts' Law**

# More than dotting the i's – Foundations for crossing-based interfaces

- Application in crossing interface

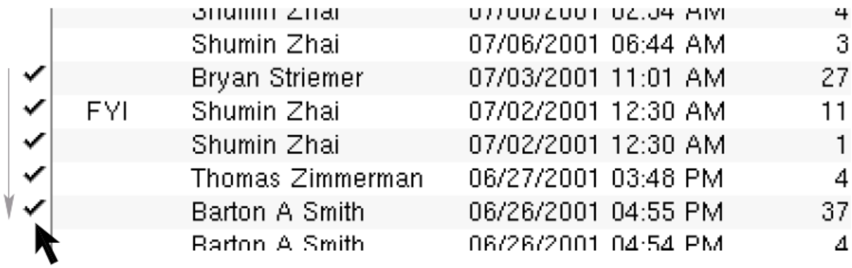



Figure 13: Selection of multiple messages by a continuous goal-crossing action in Lotus Notes

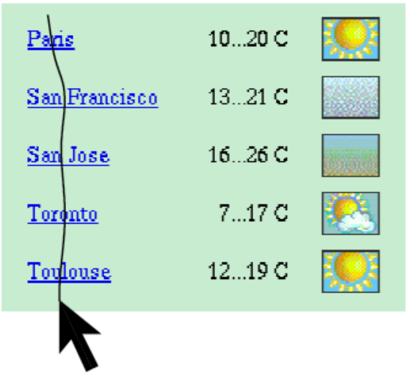


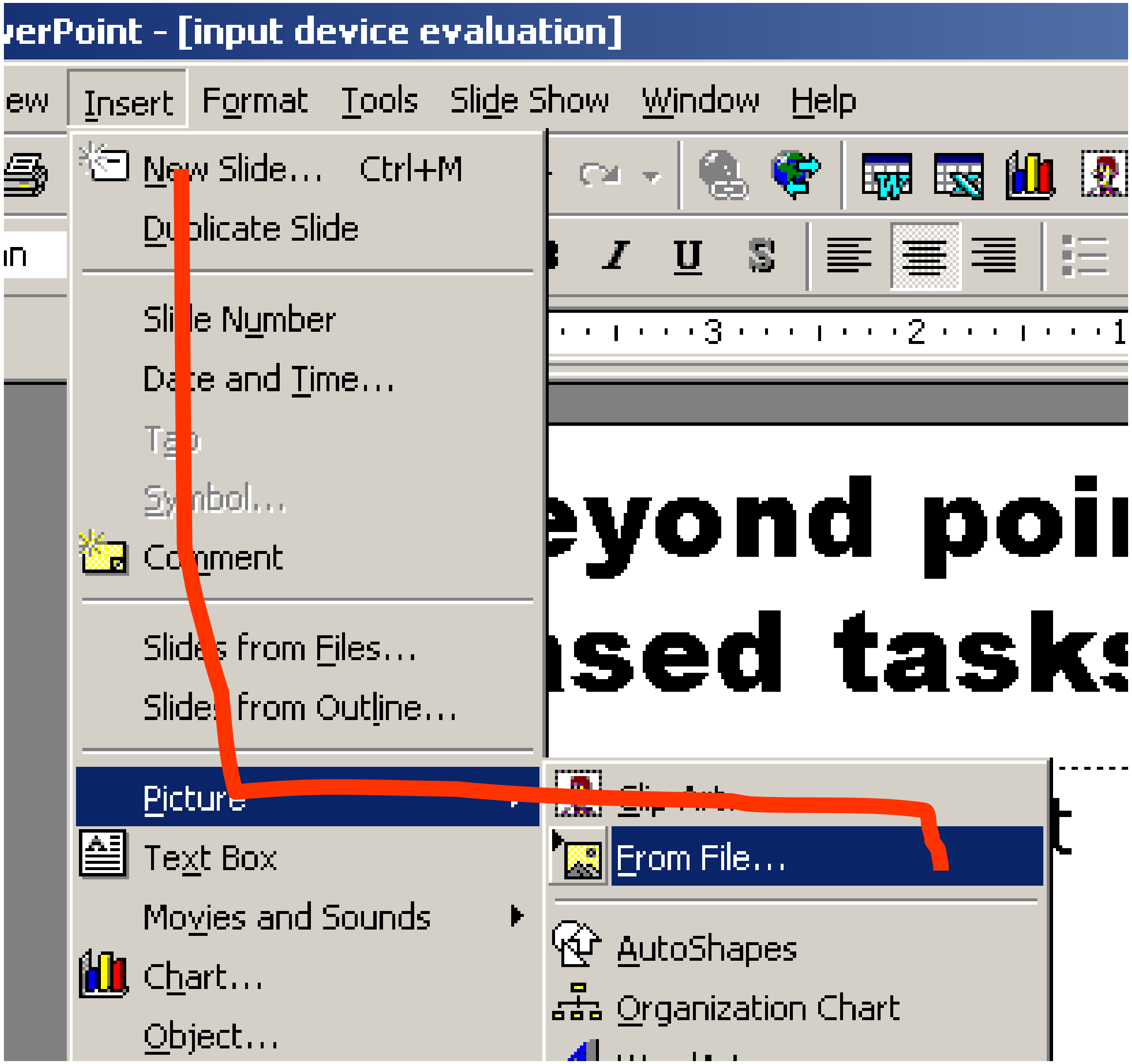

Figure 16: Crossing multiple city names to get their detailed weather forecast

# Steering Law (a.k.a Accot-Zhai Law)

Johnny Accot and Shumin Zhai. 1997. Beyond Fitts' law: models for trajectory-based HCI tasks. In *CHI '97*. ACM, New York, NY, USA, 295-302.


Google
22
23
24
25
EXIT
9
0

# Beyond Pointing: Trajectory-based Tasks



# From Targets to Tunnels…

- 1 goal to pass through:

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

- 2 goals to pass through:

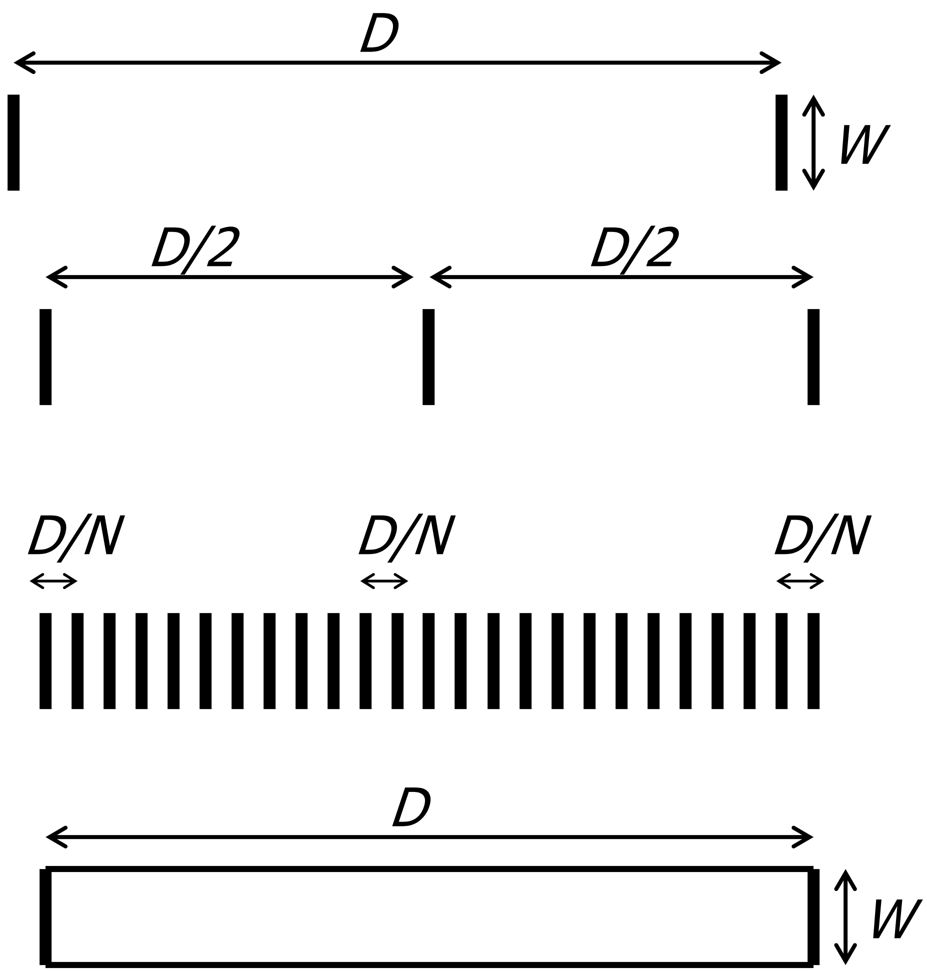
$$ID = 2\log_2\left(\frac{D}{2W} + 1\right)$$

- N goals to pass through:

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

- ∞ goals to pass through:

$$ID_\infty = \frac{D}{W \ln 2}$$

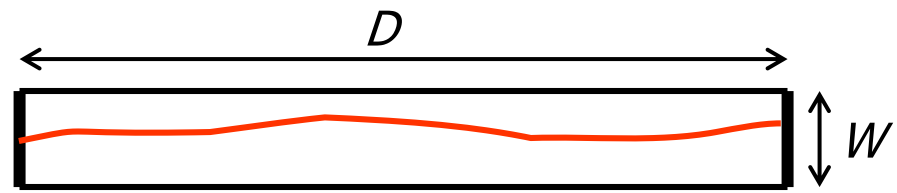


# Steering Law *(Accot and Zhai, 1997)*

"Beyond Fitts' Law: Models for trajectory based HCI tasks."
Proceedings of ACM CHI 1997 Conference

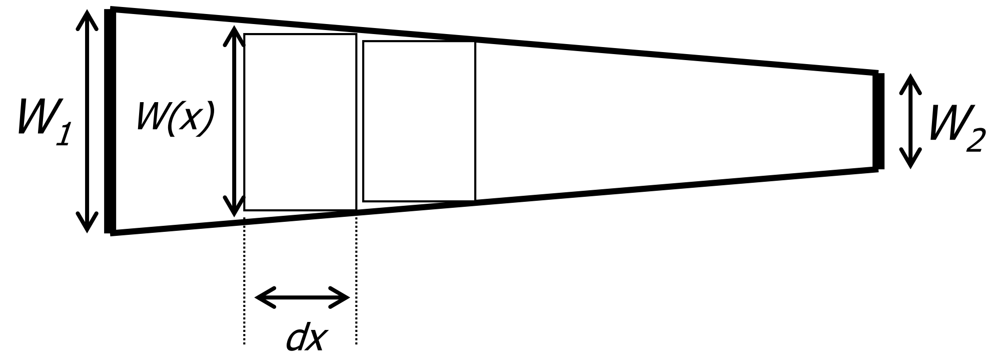
## fixed width tunnel:

$$ID = \frac{D}{W}, \quad MT = a + b\frac{D}{W}$$



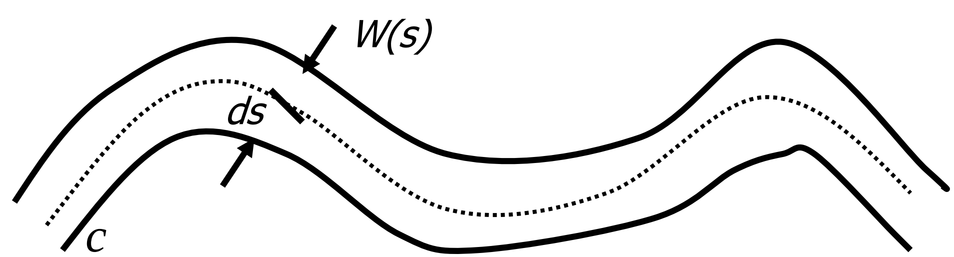

## narrowing tunnel:

$$ID = \int_0^D \frac{dx}{W(x)}$$




## general Steering Law:

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



# Some Results (from Accot, 1997)