

INTERACTION DESIGN. SESSION 1

Dept. Computer Science – UPC

MOTIVATION

- **Usability & Design Principles**
- **Perception Laws**

DIRECT MANIPULATION INTERFACES (Pointing, choice selection)

- **Interaction Design and Evaluation:**
 - Design User Interfaces
 - Measure/Predict performance
 - Design interaction

OUTLINE

Session 1:

- Understanding the fundamentals of basic interaction in UI
 - Background (Information Theory)
 - Hick-Hyman Law: *Measuring Choice-Reaction Time*
 - Fitts' Law: *Measuring Pointing Time*
 - Crossing and Steering Laws: *Continuous Gestures*
- Fitts' Law in UI Design
 - Applications in UI Design
 - Accelerating Target Acquisition
- Exercises

Session 2:

- Typing & Keyboards
- Pointing Devices
- Mobile Interaction Design
- Exercises

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BACKGROUND. BASICS

- **Information Theory:**

- Due to Claude E. Shannon

- *A Mathematical Theory of Communication* (1948)

- Based on previous works by Nyquist and Hartley

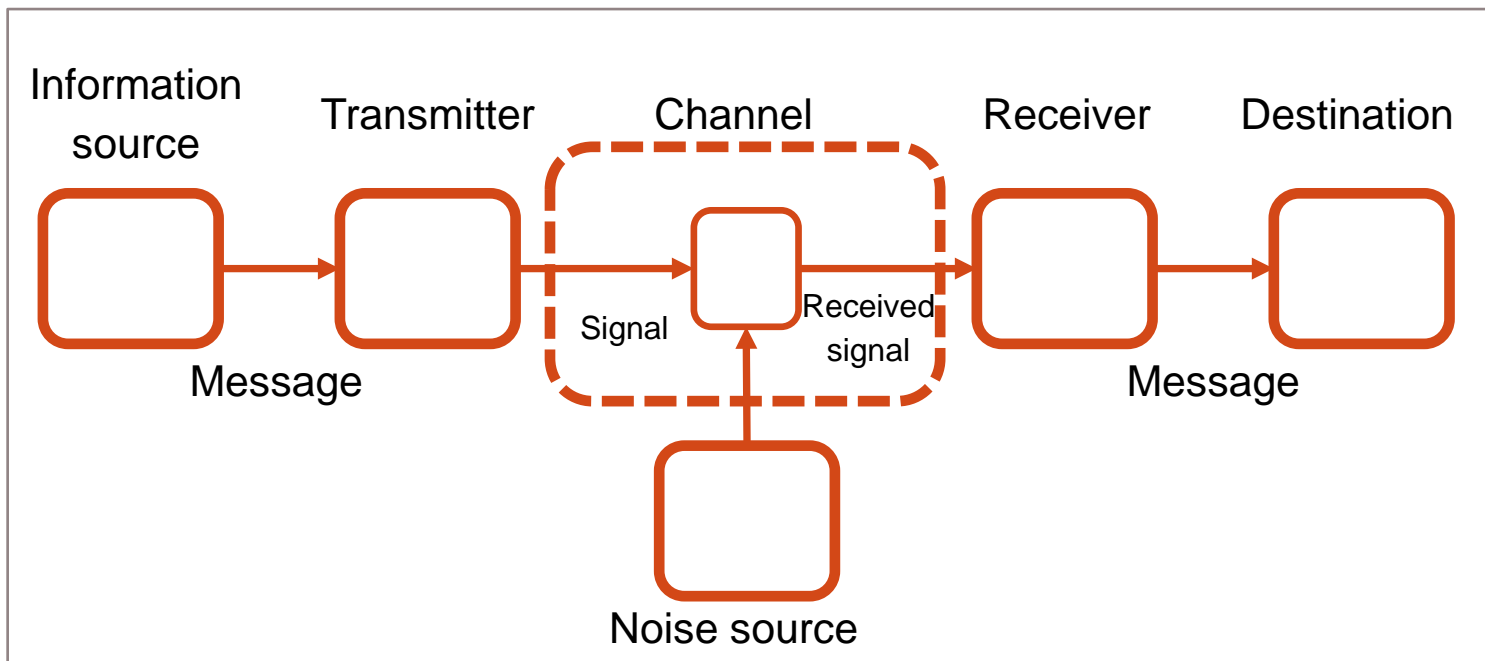
- Analysis of transmission of electrical signals for telegraphic communication

- Shannon Entropy measures:

- The amount of information to be transmitted by a message*

BACKGROUND. BASICS

- Information Theory. Elements (telegraph):



BACKGROUND. BASICS

- Information Theory. Elements (telegraph):
 - **Information source:** The element that produces a message or sequences of message.
 - **Transmitter:** Operates on the message to make it transmissible through a medium.
 - **Channel:** The medium that transmits the message.
 - **Receiver:** The element that reconstruct the message to the destination.

BACKGROUND. INFORMATION MEASURES

- Let d be a device that produces symbols A, B, C and D with the same probability
 - $M = 4$ is the total number of symbols
 - Each time a symbol is produced we are uncertain on which symbol is going to be generated
 - This uncertainty is not so big, since there are only four possibilities
 - The probability of a symbol to appear is $1/M : 1/4$
- The **uncertainty** is measured by **$\log_2(M)$** → here $\log_2(4)=2\text{bits}$
- Logarithms are commonly taken in base 2, and the units are bits.

BACKGROUND. INFORMATION MEASURES

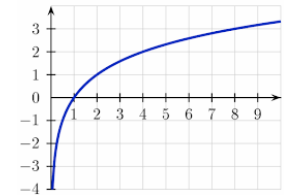
- **Example 1:** Let d be a device that produces one single symbol: C
 - $M = 1$ is the total number of symbols
 - We have **no uncertainty** and $\log_2(1) = 0$
 - The probability of getting the symbol C is 1
 - We previously know which symbol will appear!
- **Example 2:** Let d and e be two devices, one with outputs A, B, C, and the second with outputs 1, 2.
 - We combine *words* by concatenating one symbol of device d and one with device e .
 - We will have 6 different words: A1, A2, B1, B2, C1, C2
 - 6 symbols \rightarrow uncertainty of $\log_2(6) \rightarrow \log_2(2) + \log_2(3) = \log_2(6)$.
- The uncertainty of combined the signals of a set of devices is the sum of their uncertainties.

BACKGROUND. INFORMATION MEASURES

- For M symbols with equal probability → each symbol has probability $P=1/M$

- Rewriting the uncertainty

$$\log_2(M) = \log_2\left(\left(\frac{1}{P}\right)^{-1}\right) = \log_2(P^{-1}) = -\log_2(P)$$



- $-\log_2(P)$ is called the **surprise** or *surprisal* of finding a certain symbol
 - We will use p_i from now on for the probability of a symbol i
- For M symbols that have different probabilities, we may have a different p_i for each, provided that

$$\sum_{i=1}^M p_i = 1$$

BACKGROUND. INFORMATION MEASURES

- **Information is the reduction of uncertainty or average surprise of a set of symbols**
 - Measuring the surprise for an *infinite* set of N symbols (produced by a device) → the frequency of each symbol transforms to the probability.
 - Shannon Entropy measures the amount of information:

$$H = \sum_{i=1}^N p_i \log_2 \left(\frac{1}{p_i} \right) = - \sum_{i=1}^N p_i \log_2 p_i$$

- N is the number of alternatives
- p_i is the probability of the i th alternative.
- **H is the entropy of the message that is to be transmitted,
→ the amount of information expected to be received (no noise).**

BACKGROUND. INFORMATION MEASURES

- **Example 1: Source with two equiprobable symbols: A and B**
- **$p(A)=0.5, p(B)=0.5$**
- **$H = -0.5 \log_2(0.5) - 0.5 \log_2(0.5) = -\log_2(0.5) = -\log_2(2^{-1}) = 1$**
- The source requires an average of 1 bit per symbol.

- **Example 2: Source with two symbols: A and B**
- **$p(A)=0.1, p(B)=0.9$**
- **$H = -0.1 \log_2(0.1) - 0.9 \log_2(0.9) = 0,332 + 0,137 = 0,47$**
- The source requires an average of 0,47 bit per symbol.

BACKGROUND. INFORMATION MEASURES

$$p(A)=0.1, p(B)=0.9$$

H=0,47 bits → Is it possible? We can achieve it using a smart codification of the information. For instance:

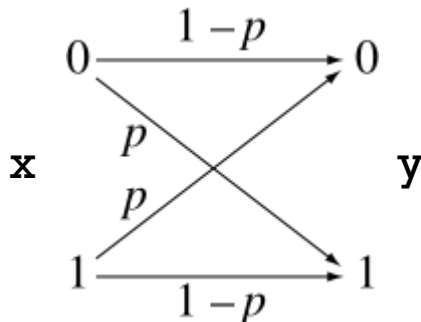
Symbols	Codification	Probability	Bits	Weighted bits
AA = 00	000	$0,1*0,1=0,01$	3	0,03
AB = 01	001	$0,1*0,9=0,09$	3	0,27
BA = 10	01	$0,1*0,9=0,09$	2	0,18
BB = 11	1	$0,9*0,9=0,81$	1	0,81
		1		1,29bits in average to send 2 symbols
				0,645 bits per symbol

BACKGROUND. INFORMATION MEASURES

- Information Theory. Shannon entropy:
 - There is interference: Not all information will reach the receiver
 - Average information faithfully transmitted (R):

$$R = H(x) - H_y(x)$$

- $H_y(x)$ is the **equivocation** or conditional entropy of x when y is known. Measures the information required to quantify the error.



p : error probability

$$H_y(x) = \sum_{i=0}^N \sum_{j=0}^N p(x_i, y_j) \cdot \log_2(p(x_i|y_j))$$

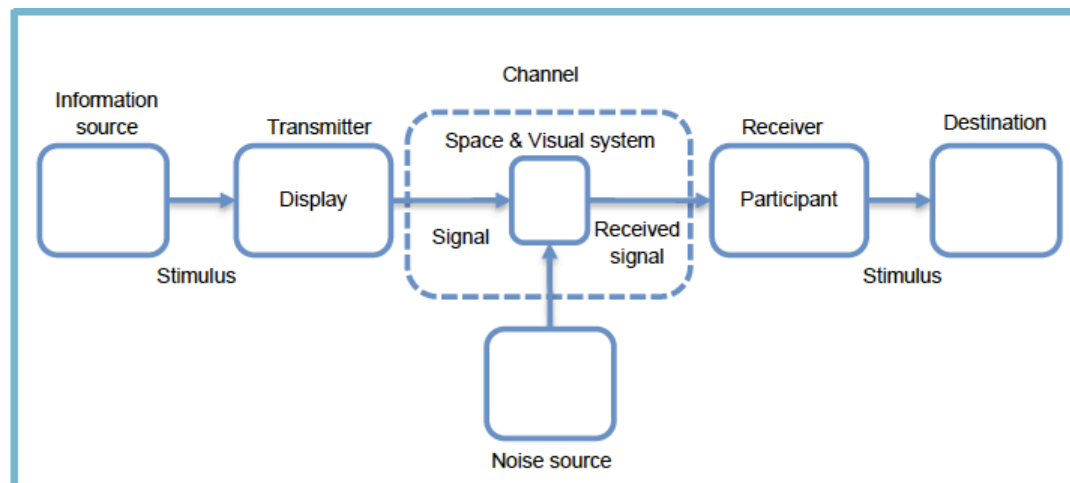
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HICK-HYMAN LAW

- Hick-Hyman Law:
 - Initially stated by William E. Hick (1951)
 - Describes human decision time as a function of the information content conveyed by a visual stimulus
 - It takes longer to respond to a stimulus when it belongs to a large set as opposed to a smaller set of stimuli
 - Extended by Ray Hyman (1952)



HICK-HYMAN LAW

- Time to make a decision (Reaction Time):

$$RT = a + bH_T$$

- a, b constants
- H_T transmitted information

HICK-HYMAN LAW

- Hick-Hyman Law:

- H_T : Transmitted information:

$$H_T = \log_2(n + 1)$$

- n are the equiprobable alternatives
 - original formulation did not have the “+1”
attends for the uncertainty whether to respond or not

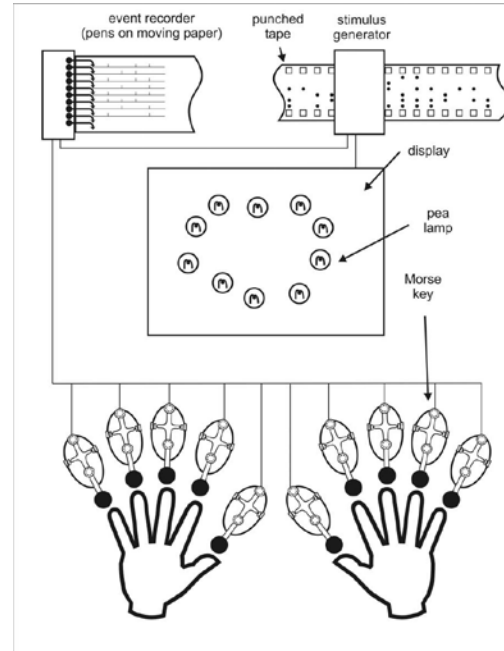
- Time to answer is the Reaction Time:

$$RT = a + b \log_2(n + 1)$$

HICK-HYMAN LAW

EXPERIMENTAL ASSESSMENT

- Hick's initial experiment:
 - 10 pea lamps are arranged in an irregular circle
 - One random lamp is lit every 5 seconds
 - User has to press the correct key corresponding to the lamp that is lit
 - Stimulus and response encoded in a moving paper in binary code



HICK-HYMAN LAW.

EXPERIMENTAL ASSESSMENT

- Time to answer. Reaction Time is a linear function of stimulus information

$$RT = a + b \log_2(n + 1)$$

- Hyman [Hyman53] found that it
also holds for not equiprobable alternatives
- Experiment:
 - 8 lights (whose names were *Bun*, *Boo*, *Bee*, *Bore*, *By*, *Bix*, *Bev*, and *Bate*)
 - The users had to name the one lit
 - A microphone attached to the throat detected the voice and stopped the timer
 - First with equal probabilities
 - Then, with varying probabilities

HICK-HYMAN LAW. EVIDENCES

■ **Evidences of Hick-Hyman Law**

- Performance *in hierarchical full-screen menu selections* is well described by Hick-Hyman [Landauer85]
- Selection times decay logarithmically with menu length for frequently selected items, but linearly with infrequent ones [Sears94].
 - Learnt locations (most frequent) fit Hick-Hyman decision times
 - Non-learnt locations fit a linear search
- Novice users search linearly while experts decide upon item location and fit a Hick-Hyman curve [Cockburn2008]

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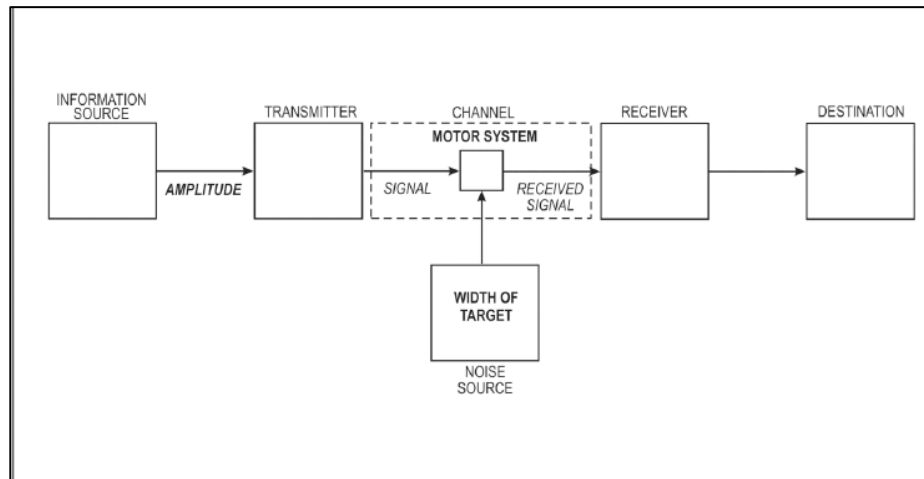
FITTS' LAW.

ORIGINAL FORMULATION

- States a **linear relationship between the movement time (MT) and task difficulty**

$$MT = a + b/D$$

- Formulation is also based on Information Theory
 - Amplitude of movement is the *signal*
 - Human motor system is the communication *channel*
 - Target width is the *noise*



FITTS' LAW.

ORIGINAL FORMULATION

- **Task difficulty:**

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

- *ID*: Index of difficulty
 - *A*: Amplitude of movement
 - *W*: Target width
-
- The larger the amplitude the higher the difficulty
 - The larger the target the lower the difficulty

FITTS' LAW.

ORIGINAL FORMULATION

- **Movement Time:** Time to point a certain objective (target)

$$MT = a + bID$$

- a start/stop times in seconds
- b inherent speed of the device

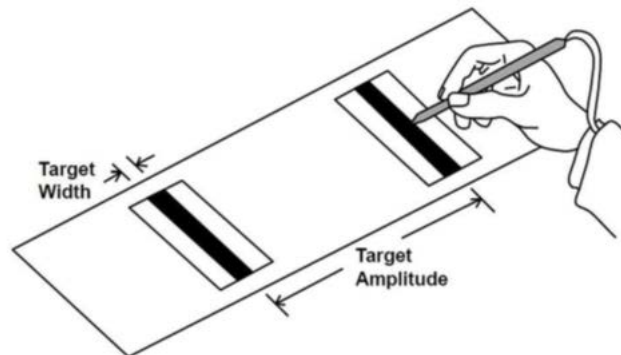
$$ID = \log_2 \left(\frac{2A}{W} \right)$$

- A : Amplitude of movement
- W : Target width

FITTS' LAW. EXPERIMENTAL EVIDENCES

Fitts' Law. Original experiments:

- Experiment 1: Reciprocal tapping:
 - Participants used a metal-tipped stylus:
 - Two experiments with two different stylus: ~ 28.35 and 453.6 gr
 - Tap two strips of metallic targets of width from ~ 0.635 to 5.08 cm
 - At distance 5.08 to 40.64 cm
 - Participants instructed to be accurate!



FITTS' LAW.

EXPERIMENTAL EVIDENCES

Fitts' Law. Original experiments:

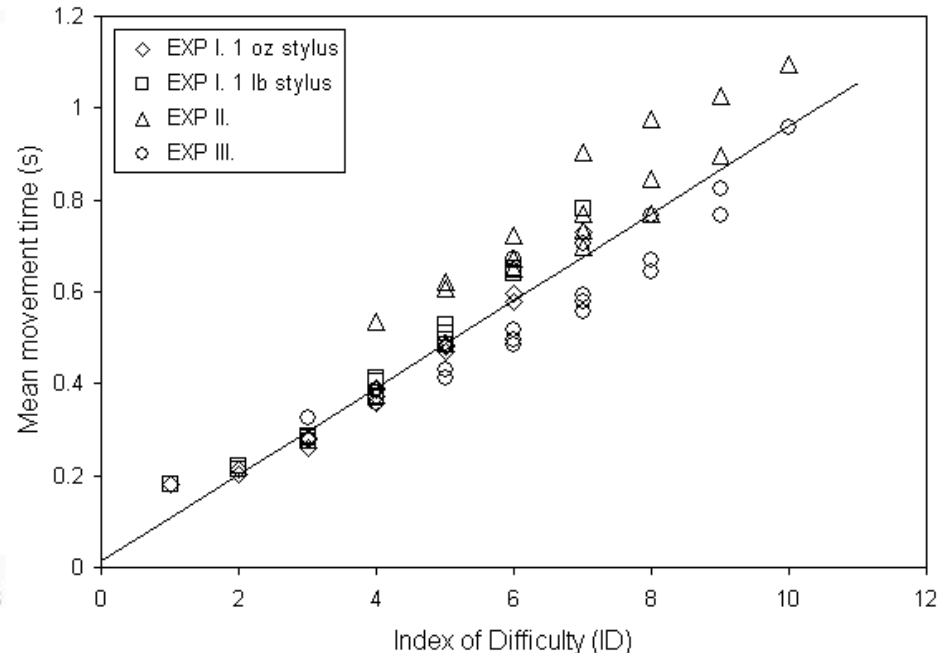
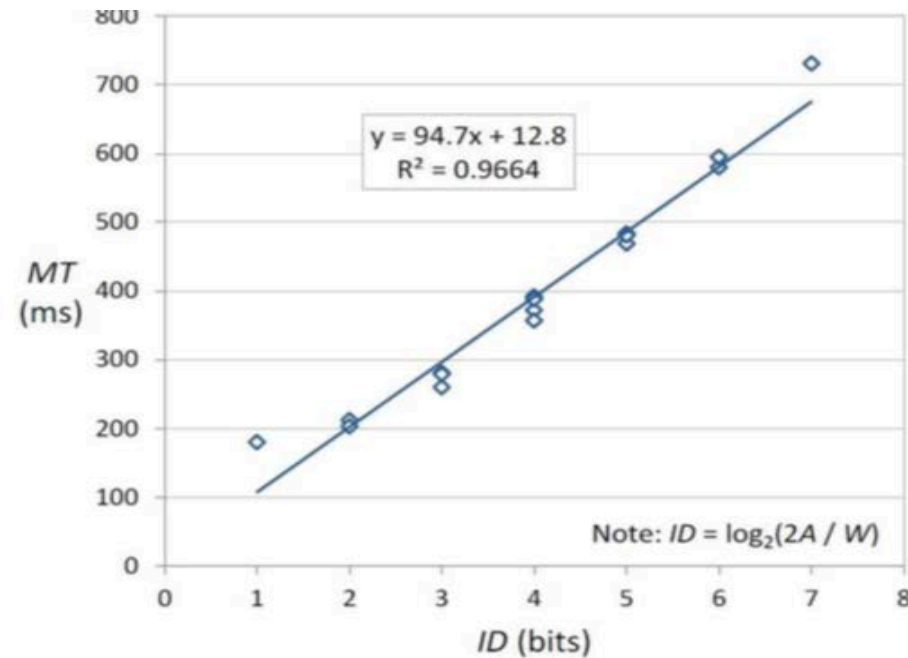
- Experiment 2: Disk transfer
 - Participants had to transfer stack round plastic disks (with holes drilled through the middle) from one pin to another
 - Holes of different sizes and pins of different diameters used
- Experiment 3: Pin transfer
 - Participants had to transfer pins of different diameters from a set of holes to another set of holes

FITTS' LAW. EXPERIMENTAL EVIDENCES

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

■ Fitts' Law. Results.

$$MT = 12.8 + 94.7 ID$$



- Results show that there is a linear relationship between MT and ID
- **Most difficult condition: Smaller W and largest A**
- Only valid for the experiments carried out
 - One curve per experiment fits better (different a and b values)

FITTS' LAW. VARIANTS

- Original formulation fits well to the original experiments
 - But it might fit better
- Other researchers have found different formulations that better model the experimental data
 - Including the experimental data by Fitts
- Welford [Welford68]:

$$MT = a + b \log_2 \left(\frac{D + 0.5W}{W} \right)$$

- D is the distance of movement
- W is the width of the target

FITTS' LAW. VARIANTS

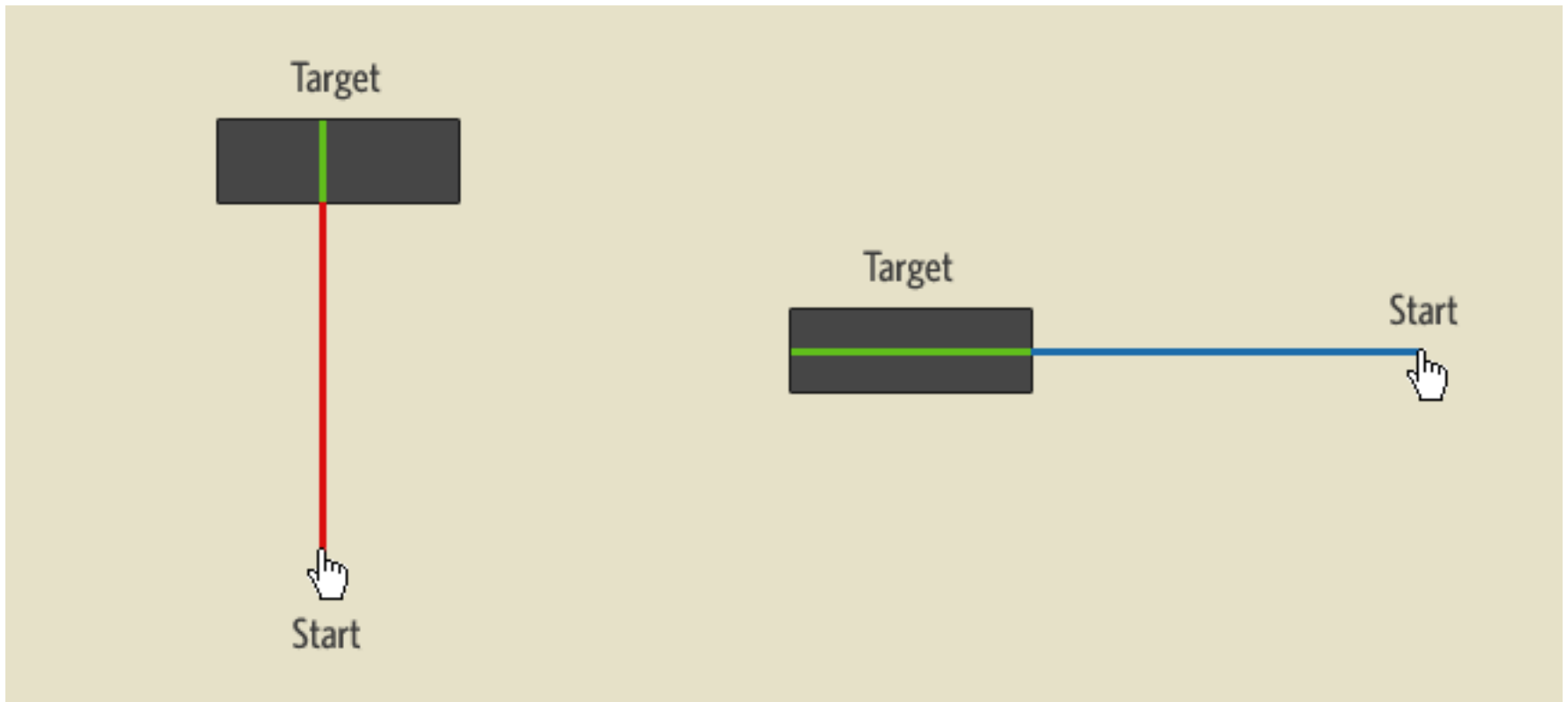
- **MacKenzie's** approach [MacKenzie92] is one of the most accepted:

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

- D is the distance of movement
- W is the width of the target

FITTS' LAW. VARIANTS

- Vertical and horizontal movements can be treated equally

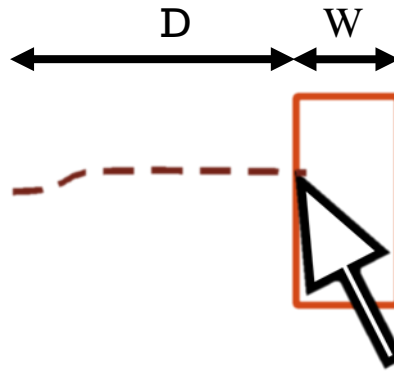


FITTS' LAW. EXTENSIONS

- Main application of Fitts in HCI is evaluation/design of UI and interaction
- Today's interfaces are much more complex
 - Variety of sizes
 - 2D movements
 - Use of fingers

FITTS' LAW. EXTENSIONS

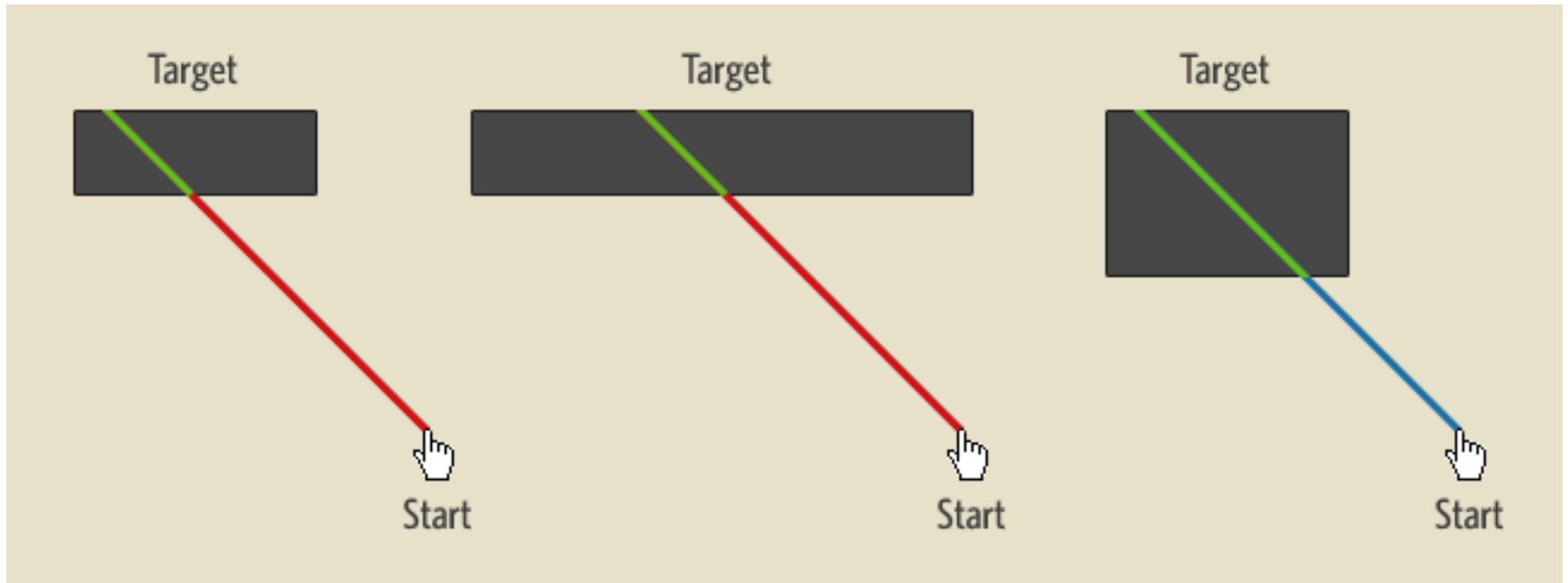
- Use in UI design or evaluation:



- D is the distance the pointer (mouse) covers to reach the target (button)
- W is the width of the target (button)

FITTS' LAW. EXTENSIONS 2D

- Fitts' Law is designed for 1D movements
BUT...most movements in a UI are 2D
- Vertical and horizontal movements can be treated equally... or not?



FITTS' LAW. EXTENSIONS 2D

- Several extensions deal with 2D movements
 - Mimicking Fitts' Law, but changing some of the parameters

- [Crossman83]:

$$MT = a + b \log_2 \left(\frac{2D}{W} \right) + c \log_2 \left(\frac{2D}{H} \right)$$

- [Accot97]:

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

FITTS' LAW. EXTENSIONS: PRECISION POINTING

- Fitts Law does not model properly very small targets:
 - Extra time devoted to fine adjustment
 - Increase of errors
 - ...
- Very small targets yield a lower fit of the regression curve of the MT function
- Touchscreens also modifies the timing we require to point targets.

FITTS' LAW. EXTENSIONS: PRECISION POINTING

Extension of Fitts' Law by analyzing the behavior both in tactile screens and small targets ([Sears91]):

- Named FFitts (**Finger Fitts**), also PPMT (Precision Pointing Movement Time) by some other authors :

$$FFits = a + bID + dID_2$$

$$FFitts = a + b \left[\log_2 \left(\frac{cD}{W} \right) \right] + d \left[\log_2 \left(\frac{e}{W} \right) \right]$$

- The higher number of freedom degrees, the easier to fit in a regression curve

FITTS' LAW. EXTENSIONS: PRECISION POINTING

- **FFitts:**

$$FFitts = a + b \left[\log_2 \left(\frac{cD}{W} \right) \right] + d \left[\log_2 \left(\frac{e}{W} \right) \right]$$

- the first logarithmic factor measures *the time to place the finger on the screen initially*
- the second factor measures *the time to position the cursor*
- D is the distance, measured in three dimensions, from the original hand location to the location of first contact
- If the task consists of iteratively clicking targets: D is the distance from one target to the next one
- W is some measurement of target size
- a, b, c, d , and e must be determined for each specific case

FITTS' LAW. ASSESSED RESULTS

- Validation of Fitts' Law may not extrapolate to outside the experiments carried out
 - ***Validity Fitts → Experimentation***
- Fitts' Law have been formulated in a number of ways, however its prediction is consistent:
 - "the ID to acquire a target is functions of the distance to and the size of the target"

FITTS' LAW. ASSESSED RESULTS

- Fitts' Law has shown its validity in multiple setups and devices:
 - Mouse, joystick, finger, stylus...
 - Different screen types of varying sizes...
 - **But the results cannot be extrapolate to data outside the experiment. *Validity Fitts* → *Experimentation***
- Fitts' law is a really good predictive model of human movement.
- Precued targets lead to more efficient and precise pointing movements than for non-precued targets [Hertzum2013].
 - Most common case: we know the buttons' positions in advance.
 - The benefit of precuing is larger for the mouse than the touchpad
 - Maybe movement preparation is more effective if the device is more demanding

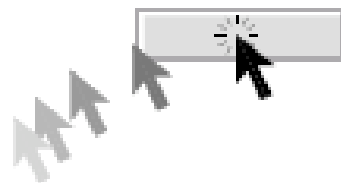
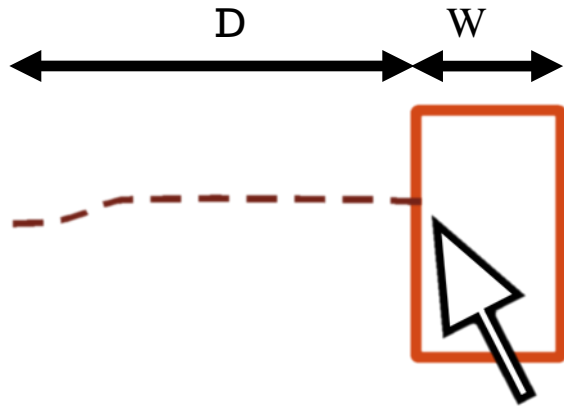
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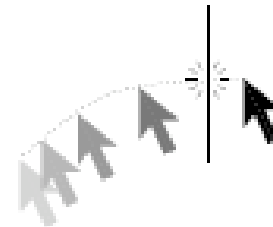
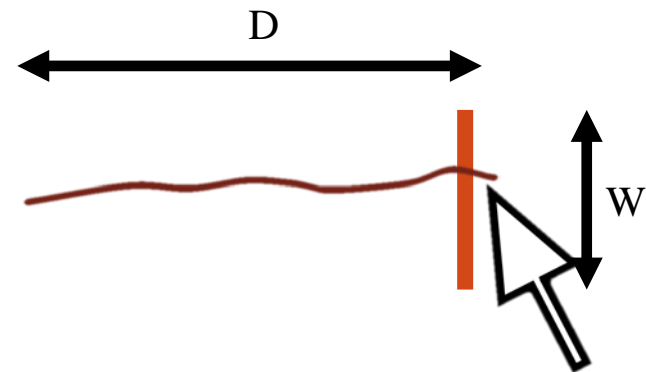
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LAW OF CROSSING

- Crossing movement as compared to pointing



(a) Pointing a target



(b) Crossing a goal

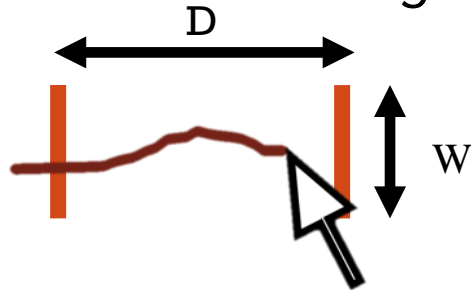
LAW OF CROSSING

- **Crossing configurations:**

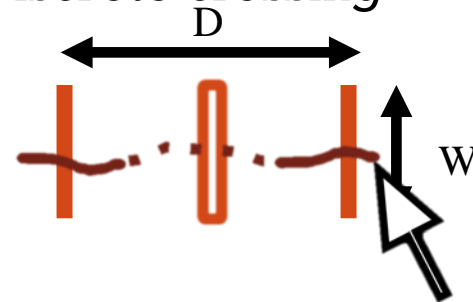
- Discreteness vs continuity of the movement:

- Landing and lifting off the stylus

Continuous crossing



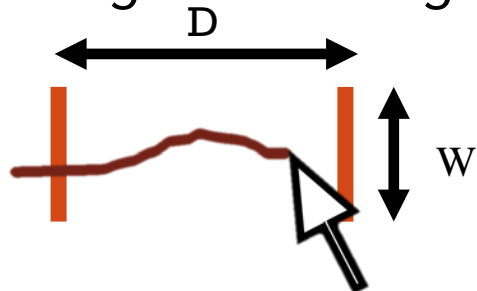
Discrete crossing



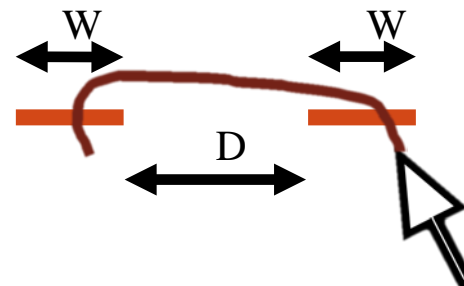
- Direction of the targets vs direction of the movement:

- If parallel, the trace will be larger

Orthogonal crossing



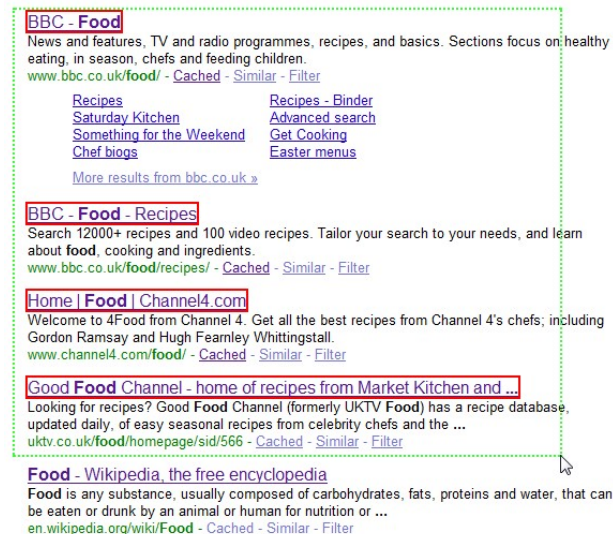
Collinear crossing



LAW OF CROSSING

- Stylus or fingers naturally lead to crossing gestures
 - Especially useful in tactile devices
 - Crossing an object is easier than double-clicking.
 - Drag & drop, multiple selections
 - Crossing can be a good alternative for users who have difficulties with clicking or double-clicking.
- Several objects can be crossed at the same time within the same gesture

Multi-links
extension for
Chrome
(LinkClump)



LAW OF CROSSING

- Crossing performance across two goals [Accot99, Zhai2002]:
 - Follows the same characterization than the Fitts' Law:

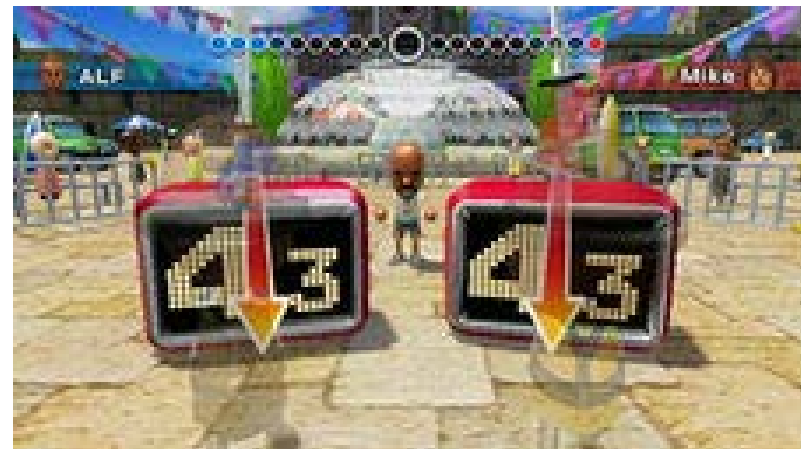
$$T = a + b \log_2 \left(\frac{D}{W} + 1 \right)$$

- T is the average moving time between passing the two goals.
- D is the distance between the two goals
- W is the width of each goal
- a and b are constants to be determined

LAW OF CROSSING

- **Results of the experiments:**
 - Crossing-based interfaces achieve similar (or faster) times than pointing.
 - The error rate in crossing is smaller than in pointing.
 - Discrete crossing becomes more difficult if the distance between the targets is small.

LAW OF CROSSING



<https://www.youtube.com/watch?v=C5L4vV3T2mU>

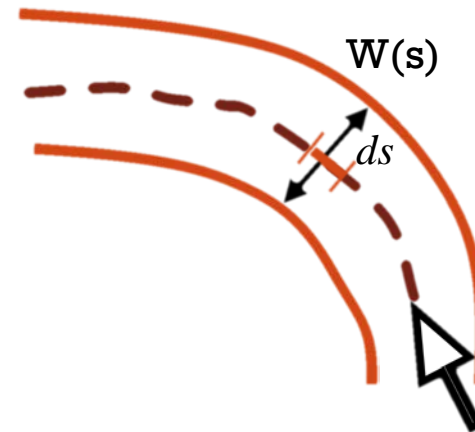
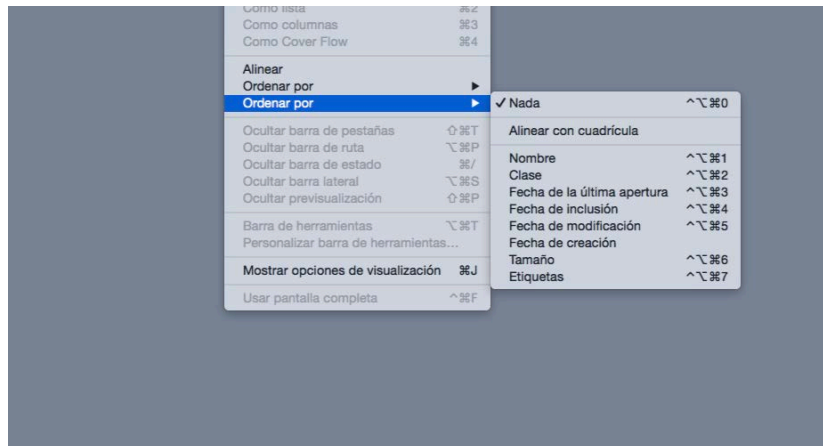
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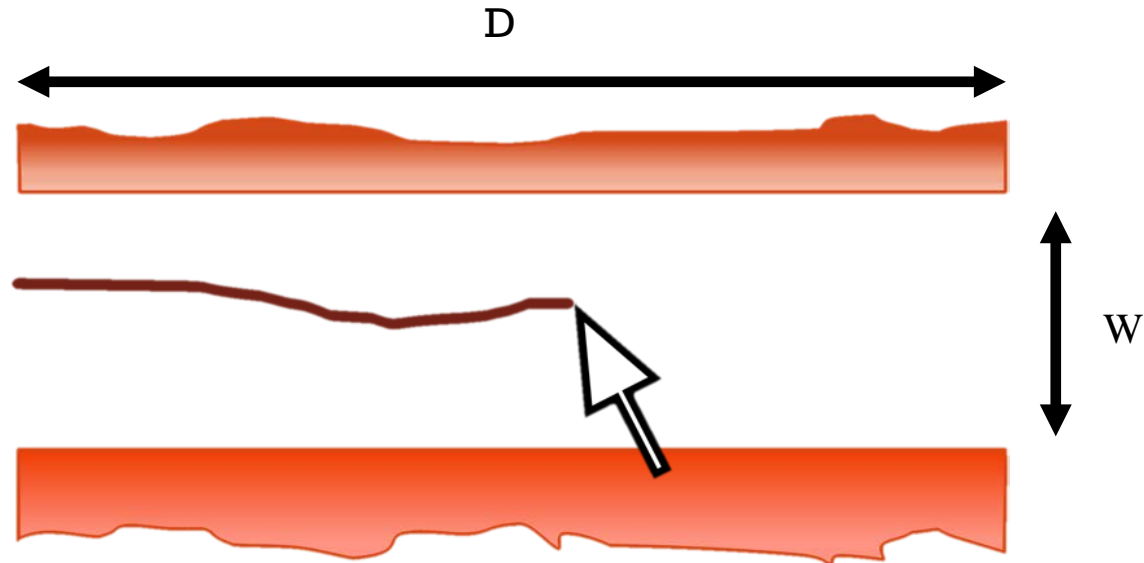
STEERING LAW

- Navigating through a constrained path is an useful operation in modern UIs
 - Navigating through nested menus
 - 3D navigation
 - Dragging elements
 - Free-hand Sketching/Drawing



STEERING LAW

- Steering through a **straight path**:

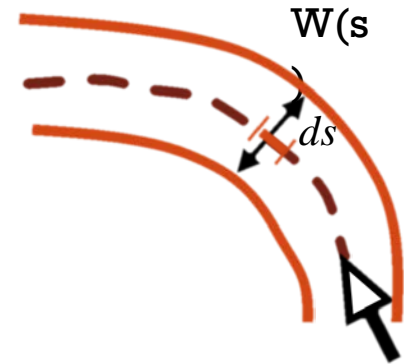


STEERING LAW

- Navigating through a **generalized path** can be expressed as infinite crossings [Accot97]
- Movement time across the path T_s :

$$T_s = a + b/D_s \quad T_s = a + b \int_c \frac{ds}{W(s)}$$

- C is the length of the path
- $W(s)$ is the path width at point s



STEERING LAW

- Time to navigate through a **straight path** (tunnel) T_p [Accot97]:

$$T_s = a + b \int_c \frac{ds}{W(s)} \qquad T_p = a + b \frac{D}{W}$$

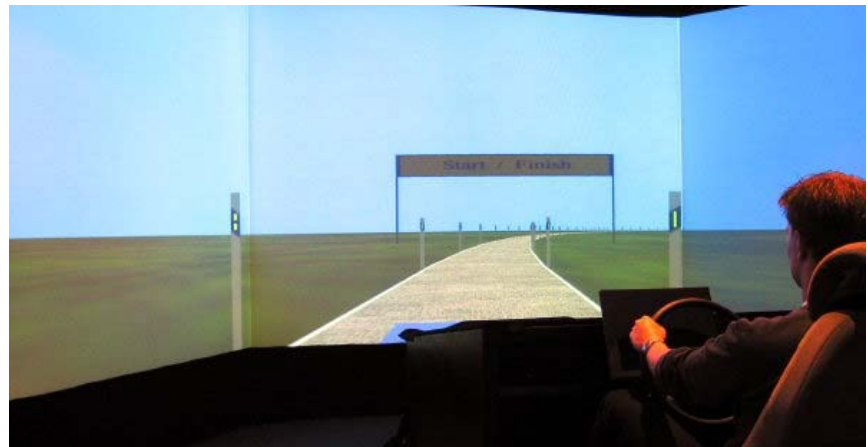
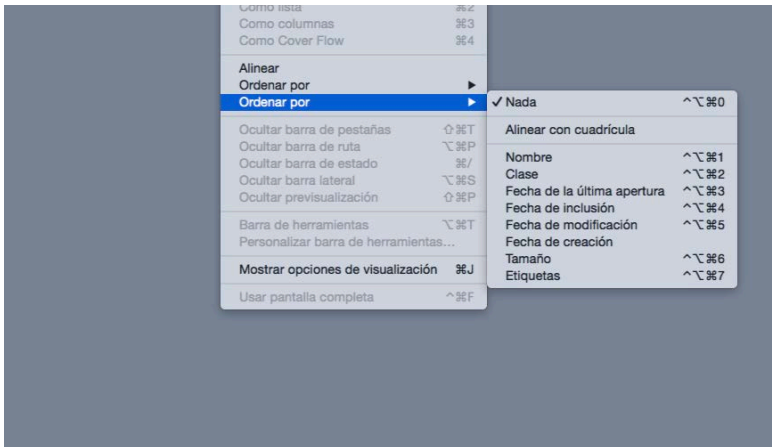
- D is the length of the path/tunnel
- W is the width of the path/tunnel
- Applying Fitts' formatting:

$$T_p = a + bID_p \qquad ID_p = \frac{D}{W}$$

- Which also applies to circular paths of constant width

STEERING LAW

- Results [Accot97, Zhai2004] show that the steering law is applicable to different configurations:
 - Different path shapes: cone, spiral, straight
 - Works with different devices, works in VR...
 - Can be used to analyse navigation through nested menus, compare menu designs...



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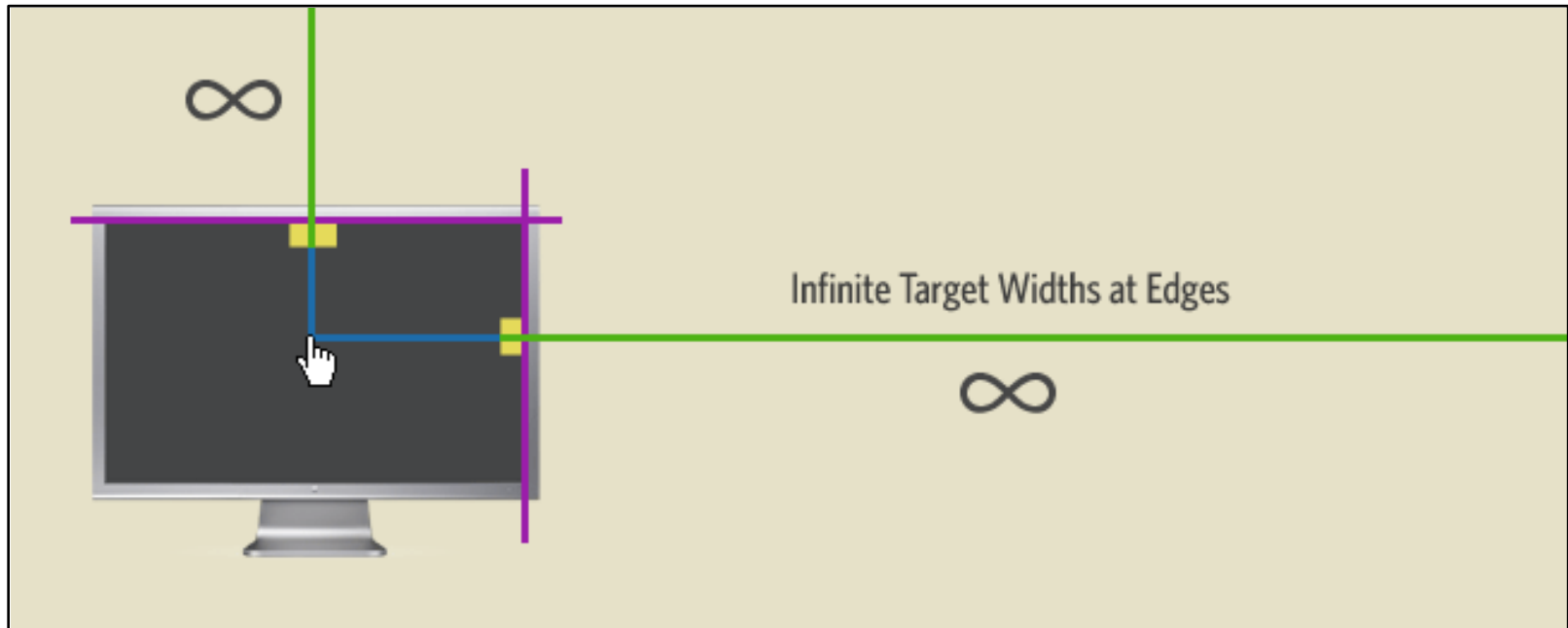
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FITTS' LAW IN UI DESIGN. IMPLICATIONS

- Fitts' Law accurately predicts **pointing** movement
 - Further distance → Harder to select
 - Larger target → Easier to select
- If improvement required, it can help us modify our UI
 - Change target width:
 - Increase size for faster reach
 - Change de “virtual distance” or pointer movement:
 - Increase speed, pop-up menus,....
- But visual stimuli must also be taking into account...

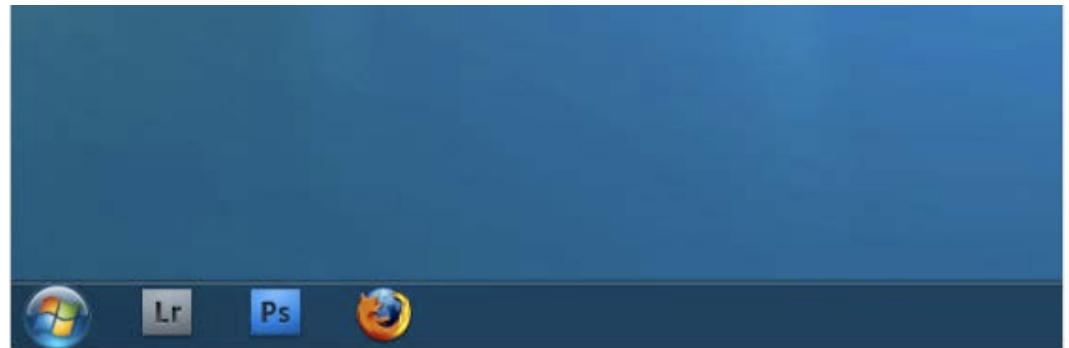
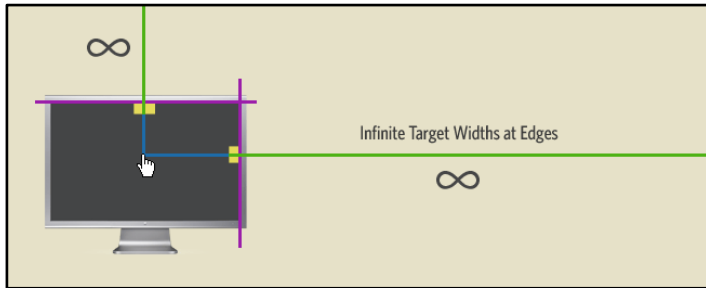
FITTS' LAW IN UI DESIGN. APPLICATIONS

The outer edges and corners

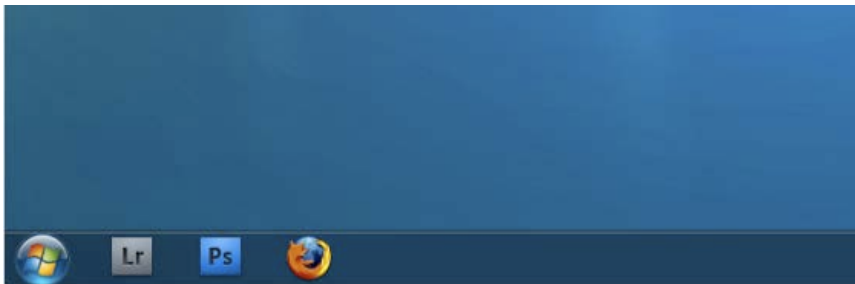
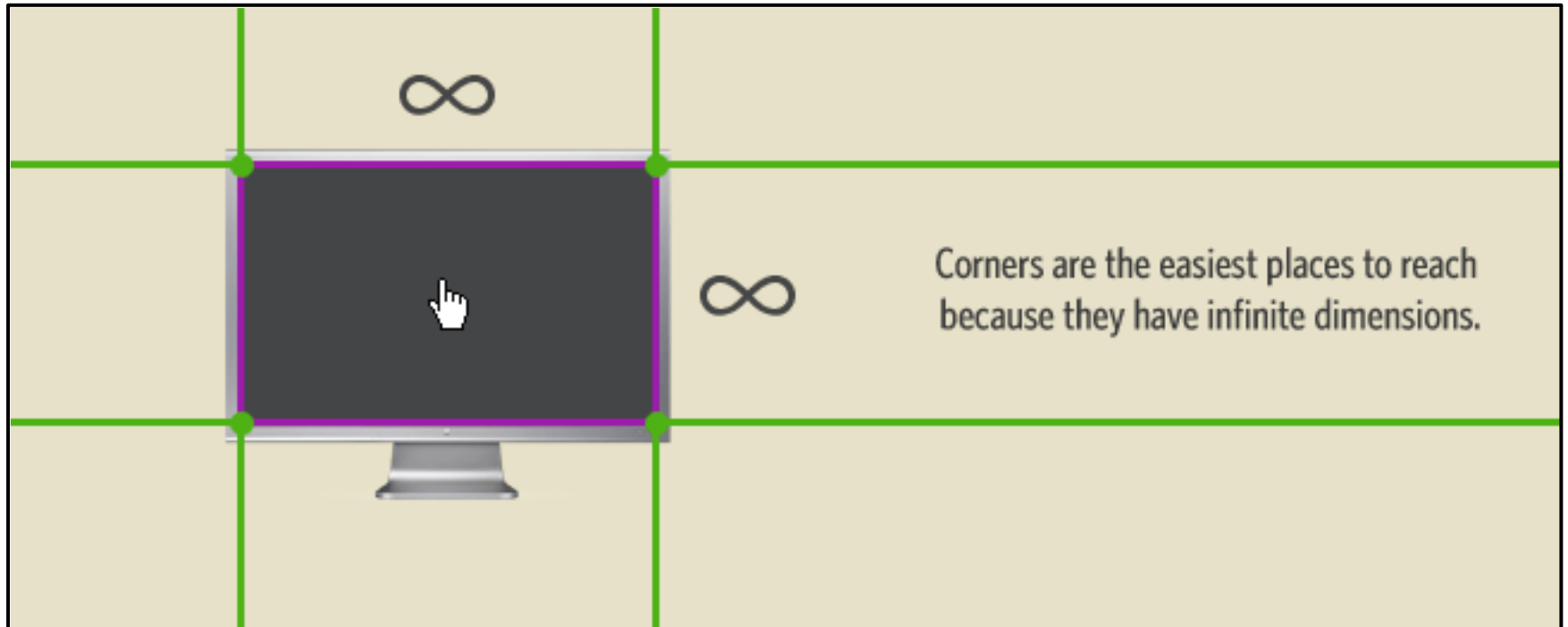


$$MT = a + b \log_2 \left(\frac{D}{W} + 1 \right)$$

FITTS' LAW IN UI DESIGN. APPLICATIONS



FITTS' LAW IN UI DESIGN. APPLICATIONS



FITTS' LAW IN UI DESIGN. APPLICATIONS

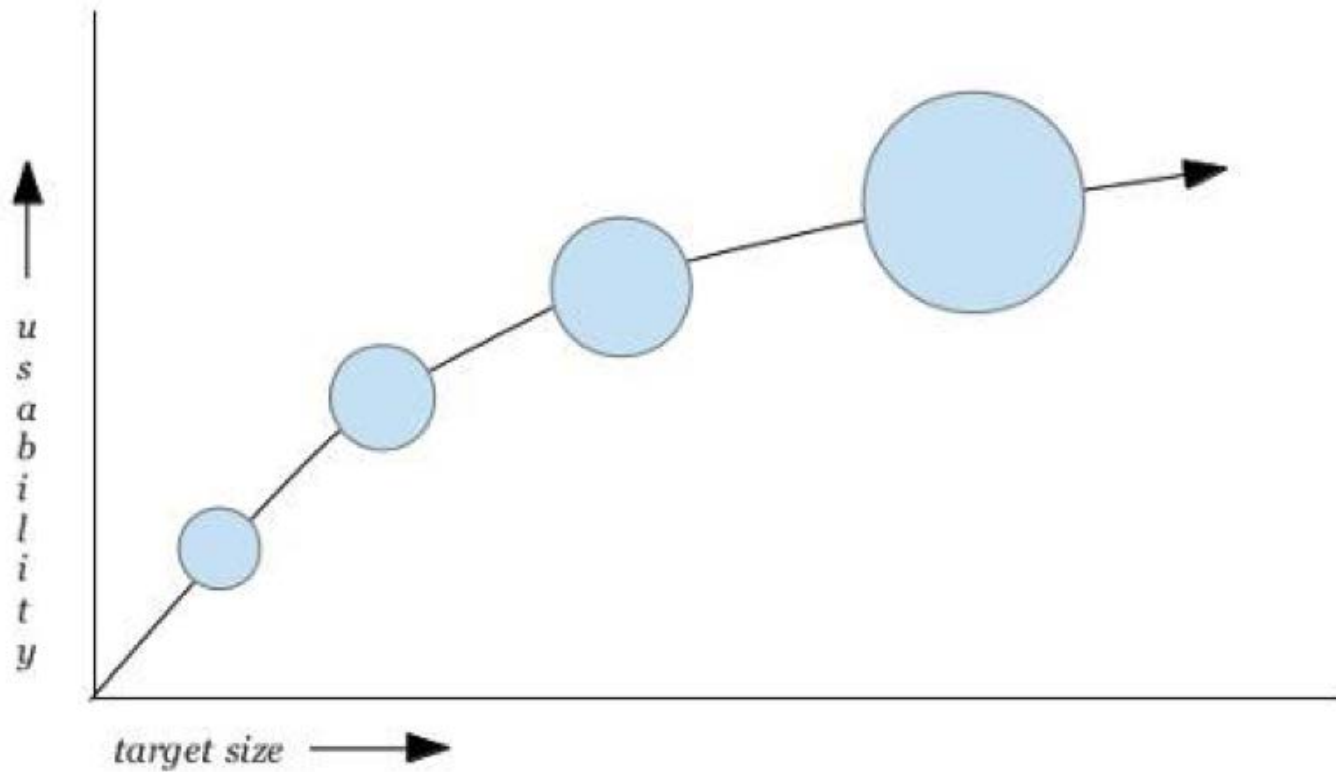


Web sites do not have edges or
corners of infinite width.

:(

FITTS' LAW IN UI DESIGN. APPLICATIONS

Create larger target size



FITTS' LAW IN UI DESIGN. APPLICATIONS

Keep related things close

- Filters should be placed close to the search field



FITTS' LAW IN UI DESIGN. APPLICATIONS

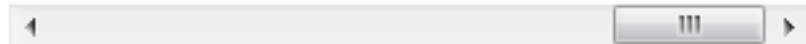
Keep related things close

- Mac OS scrolls are faster to navigate

OSX Snow Leopard



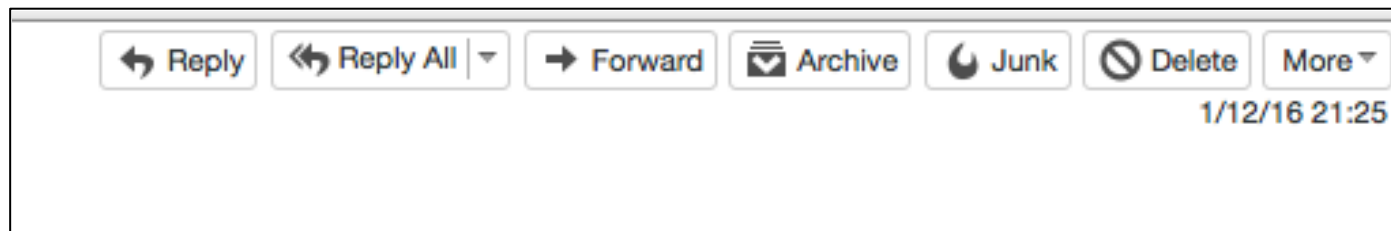
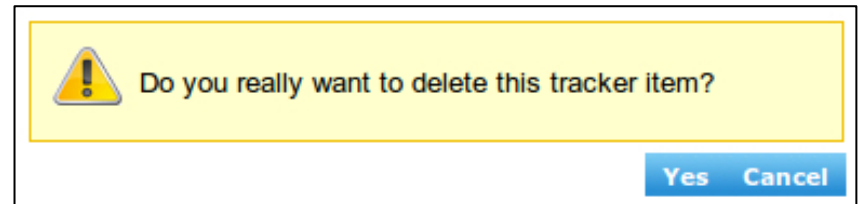
Windows



FITTS' LAW IN UI DESIGN. APPLICATIONS

Keep related things close and **Opposite Elements Far**

- These buttons should be placed far away from each other



But...don't forget the usability principles!!!

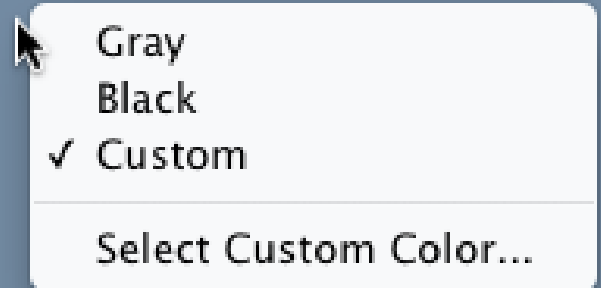
FITTS' LAW IN UI DESIGN. APPLICATIONS

Pop-up menus: Reduce travelling distance

- **Improve two aspects:**

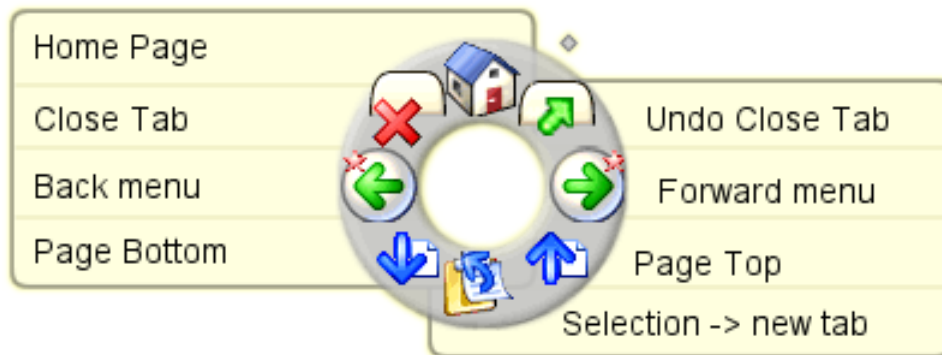
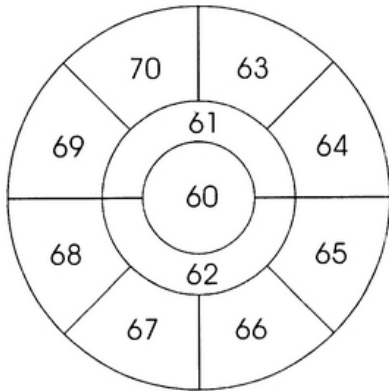
- Reduction of distance to travel (Fitts)
 - The option is close to the menu emerging place
- Frequency-enabled may improve the time to pick an option:
 - Based on Hick-Hyman:
Recall that users are able to point faster objects that are known

- Only used by experts!



FITTS' LAW IN UI DESIGN. APPLICATIONS

- *What about pie menus?*



FITTS' LAW IN UI DESIGN. APPLICATIONS

- *What about pie menus?*
 - Sort of contextual menu
 - Needs to be created on demand
 - **Needs some room!**
 - Should not have occlusions
 - On mobile half-pie menus better than fully circular



FITTS' LAW IN UI DESIGN. APPLICATIONS

Pie menus difficult to design!

- Second layer changes the size and distance
- Organizing by frequency may be a problem (learning)



FITTS' LAW IN UI DESIGN. APPLICATIONS

+ **Perception:** Grouping things may improve over distance



OUTLINE

Session 1:

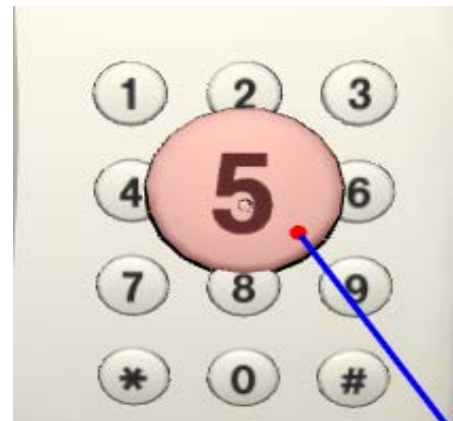
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 - **Accelerating Target Acquisition:**
 - Dynamic Expanding Targets
 - Target moving
- Exercises

ACCELERATING TARGET ACQUISITION: EXPANDING TARGETS

➤ Increase the size of targets close to the pointer

Two implementation approaches:

- Size-enlargement and position-changing icons
- Enlarged icons overlap over their neighbours

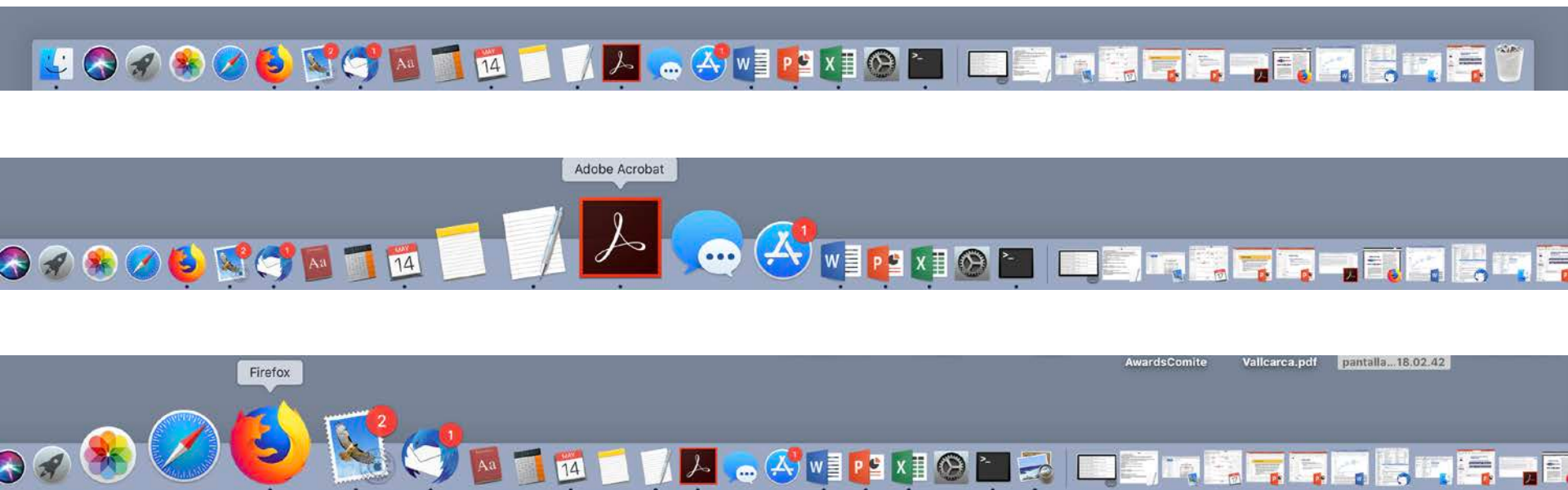


ACCELERATING TARGET ACQUISITION: EXPANDING TARGETS

Increase the size of targets close to the pointer

Exemple 1: Implemented in Mac OSX Dock:

- Mix of target size increase and moving target



ACCELERATING TARGET ACQUISITION: EXPANDING TARGETS

Enlarged icons overlap over their neighbours

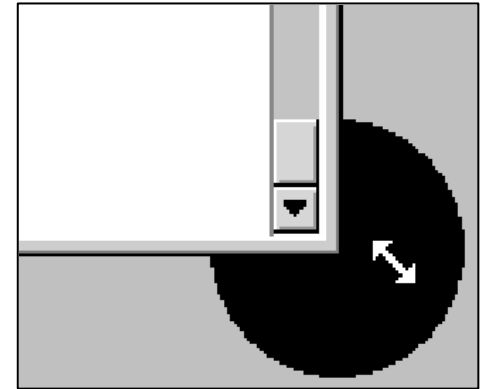
Dynamic Scaling (DS)

Objects near the selection ray are dynamically scaled

ACCELERATING TARGET ACQUISITION: EXPANDING TARG

➤ **Bubble targets:**

- Increase selectable region around target
 - Only when the mouse is close
 - Improves selection times
- Issues:
 - **Bubble appearing may distract users**
 - **Overlapping targets:**
 - Close selection points may generate several bubbles

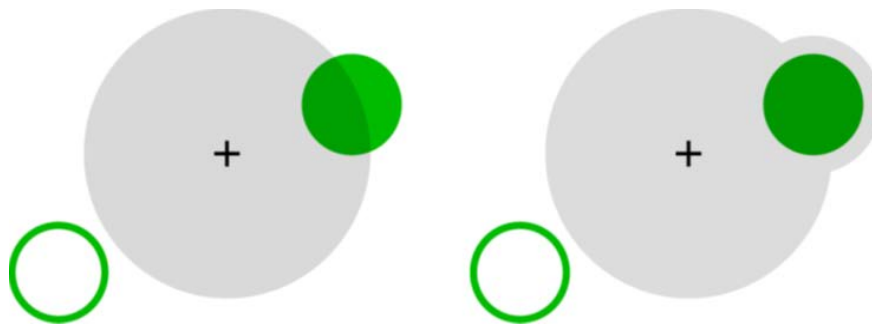


ACCELERATING TARGET ACQUISITION: EXPANDING TARGET

➤ **Bubble cursor** [Grossman2005] ➔

Reduction of amplitude movement

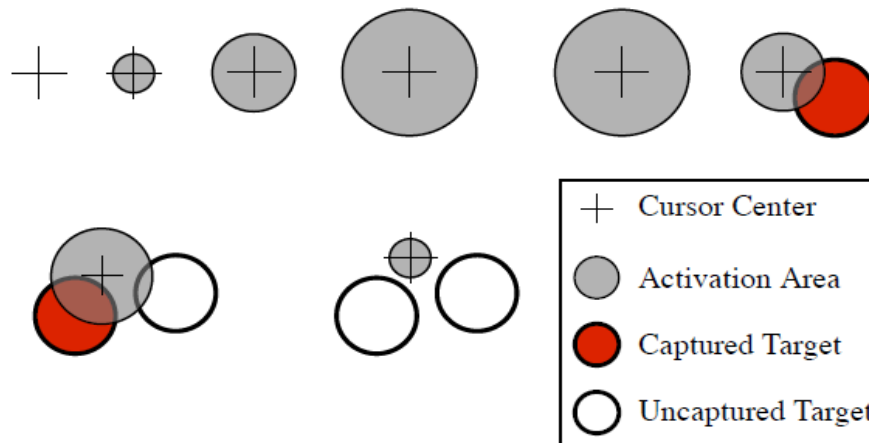
- Cursor size increases when it is close to objectives
- It may even grow to *absorb* the closer target when it is not completely inside the main cursor bubble.
 - Based on position, no speed
 - In experiments Control-Display ratio fixed to 1



ACCELERATING TARGET ACQUISITION: EXPANDING TARGET

➤ **Dynamic Bubble cursor** [Chapuis2009]:

- Based on the Bubble cursor idea
- It takes into account the speed of the mouse
 - Area increases according to speed and position
 - Visual cues to indicate the captured target: the target closer to the cursor center.



ACCELERATING TARGET ACQUISITION: TARGET MOVING

- **Move targets to the user:**



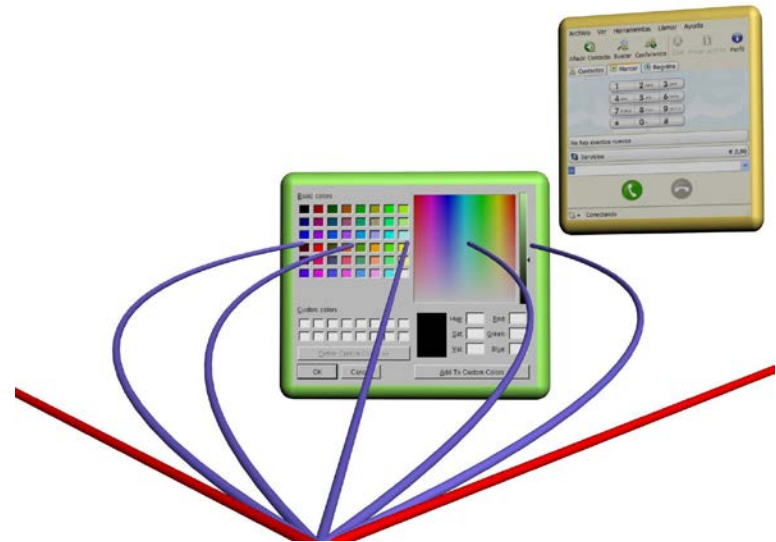
- **Generate targets next to the user: pop-up menus**



ACCELERATING TARGET ACQUISITION: TARGET MOVING

➤ Sticky targets:

- Attract pointer
 - When the pointer is close to a selectable area
 - May reduce selection time
 - Precision not required
 - Users adapt easily



ACCELERATING TARGET ACQUISITION: CONTROL-DISPLAY RATIO

- Relation between the amplitude of movements of the user's real hand and the amplitude of movements of the virtual cursor
- Moves in real world (physical move) mapped to moves in virtual desktop (cursor move)
- Different strategies:
 - Constant
 - Dependent on mouse speed
 - Dependent on cursor position
- Interpretation according to Fitts Law:
Dynamic C-D ratio adaptation can be interpreted as dynamic change of physical motor space

ACCELERATING TARGET ACQUISITION: CONTROL-DISPLAY RATIO

- Mac OSX and Windows both use mouse acceleration
 - When mouse moves fast, it is accelerated
 - Reducing the amplitude of movement to cover large distances
 - When mouse moves slow, it is decelerated
 - Magnifying amplitude of movement to improve precision
- No clear how the mapping affects perception and productivity
 - Some studies say it is not intuitive
 - Some studies say it improves some pointing tasks

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Donades les constants $a = 400$ ms, $b = 200$ ms/bit i un objectiu de mida 2.1 cm a una distància de 10.5 cm. Marca la resposta correcta assumint que fem els càlculs amb la versió de McKenzie de la llei de Fitts.

- a. $ID \approx 3.4$.
- b. $2 < ID < 3$.
- c. $ID \approx 4.3$.
- d. MT està entre 1100 i 1200 ms.

La llei de Hick-Hyman:

- a. Modela el temps de decisió com una funció de la informació transmesa.
- b. Modela el temps de selecció d'un element com a funció de la distància a recórrer i la mida de l'element.
- c. Modela el temps de decisió com una funció de la distància a recórrer i l'entropia dels elements a seleccionar.
- d. Utilitza l'entropia de Shannon per a mesurar la distància del recorregut mínim.

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

- Els *expanding targets*:
 - a. Es basen en la llei de Hick-Hyman.
 - b. Pretenen reduir el temps d'accés als elements basant-se en el fet que, segons la llei de Fitts, el temps d'accés es redueix si s'augmenta la longitud del desplaçament.
 - c. Si es combinen amb el moviment dels objectius poden causar confusió a l'usuari.
 - d. Cap de les anteriors.

Ens han encarregat fer un disseny d'una interfície per a un sistema tipus desktop en la qual hi haurà botons i menús drop-down.

- a. Podem predir la dificultat d'accedir als botons utilitzant la llei de Fitts i la dificultat de recórrer els menús amb la llei de crossing.
- b. Podem analitzar el nombre d'elements a posar en un menú utilitzant la llei de steering i en funció dels digrams.
- c. Podem analitzar el nombre d'elements a posar en un menú utilitzant la llei de Fitts.
- d. Podem analitzar la dificultat de recórrer els menús utilitzant la llei de steering.

■ **La llei de *steering*:**

- a. No es pot derivar a partir de la llei de *crossing*.
- b. Serveix per a modelar el temps necessari per a recórrer un camí de forma arbitrària.
- c. Diu que hi ha una relació logarítmica entre l'índex de dificultat de creuar un objectiu i el temps que requereix per a fer-ho.
- d. Diu que l'índex de dificultat de creuar un objectiu és D/W .

- Dos elements T1 i T2 a distàncies $D1 = 10$ cm i $D2 = 8$ cm en direcció horitzontal i d'amplades 5 cm i 2 cm, respectivament. Per a T1 fem un dispositiu amb $a1 = 200$ ms i $b1 = 200$ ms/bit. Per a T2 utilitzem un dispositiu amb $a2 = 200$ ms i $b2 = 100$ ms/bit. Assumint la formulació original de la llei de Fitts:
 - a. $ID1 > ID2$.
 - b. $ID1 = ID2$.
 - c. $MT1 = MT2$.
 - d. $MT2 < MT1$.

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