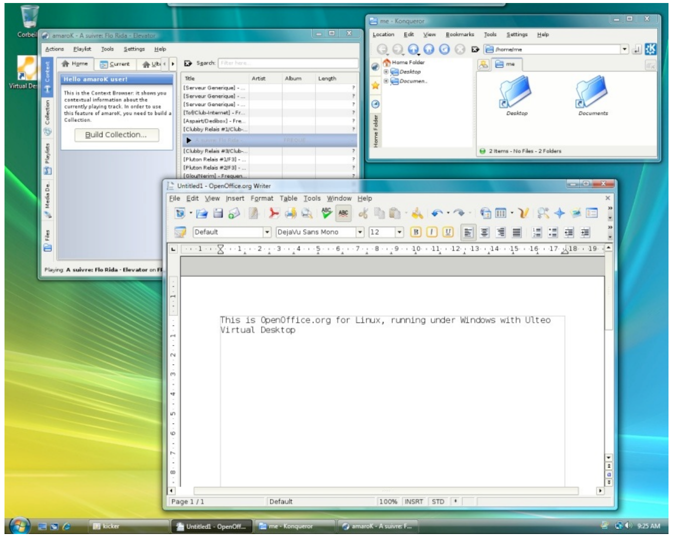
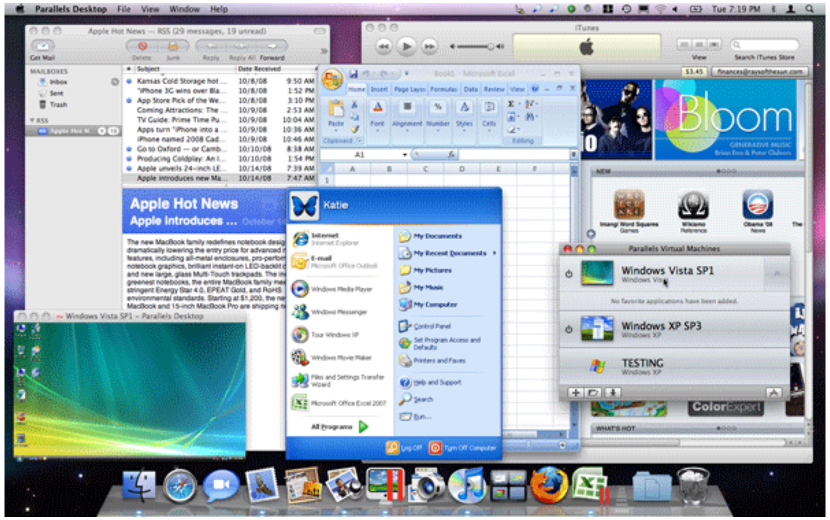
Perception / Action
Colors
Ergonomic criteria

Eric Lecolinet - Télécom ParisTech

www.telecom-paris.fr/~elc

Pointing

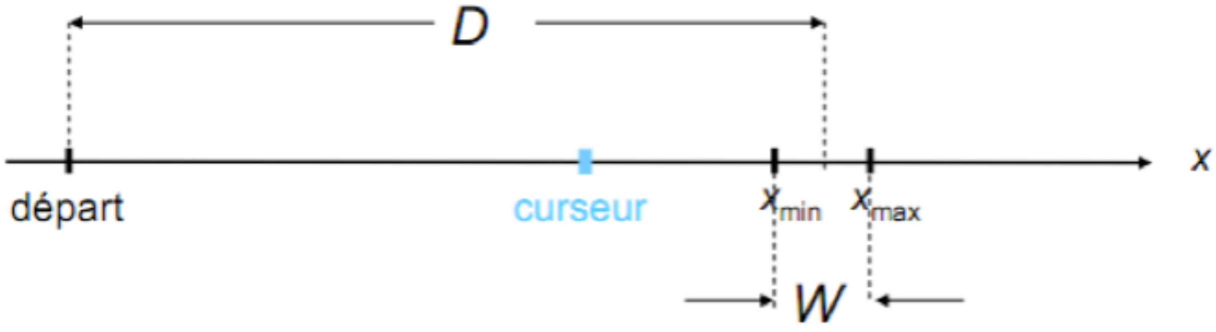


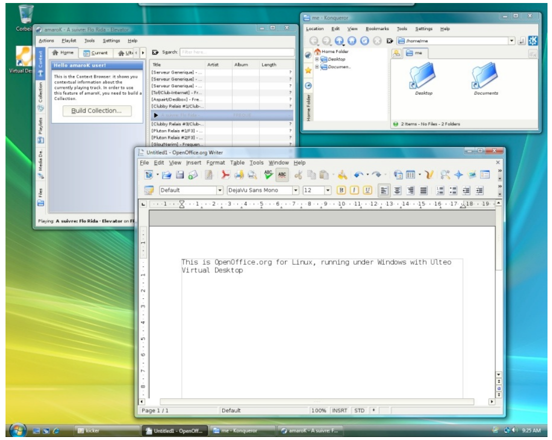


Ubiquitous in GUIs

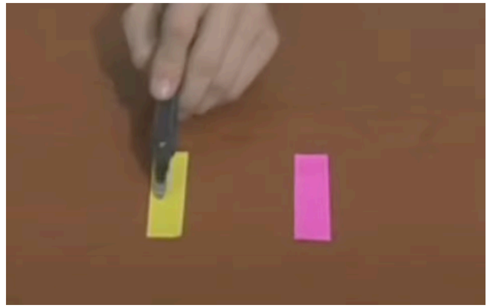
- Significant impact on **time** and **error** performance
- How can we:
    - **Estimate** pointing time?
    - **Facilitate** pointing?
    - **Avoid** pointing?

Fitts' law



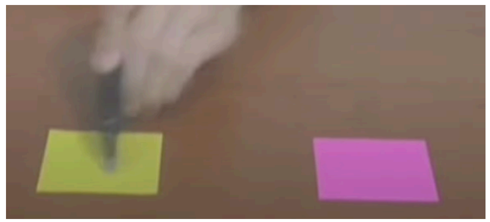


$$TM = a + b\,\underbrace{\log_2 (D/W + 1)}_{ID}$$

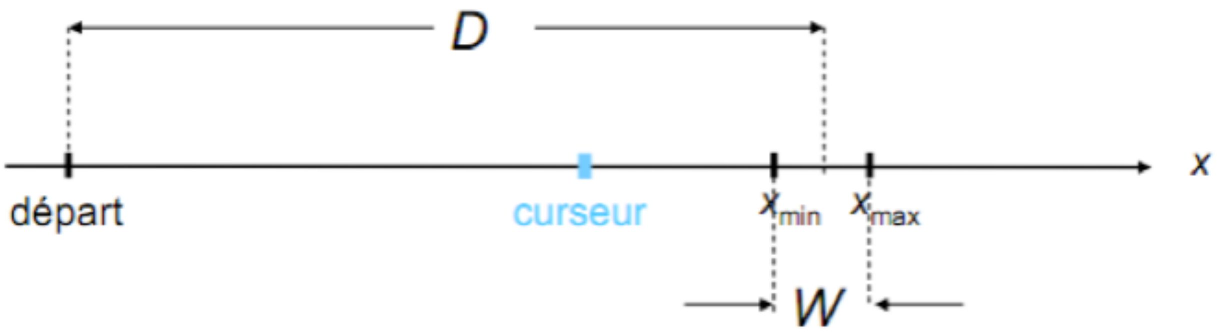


Experimental law predicting pointing time

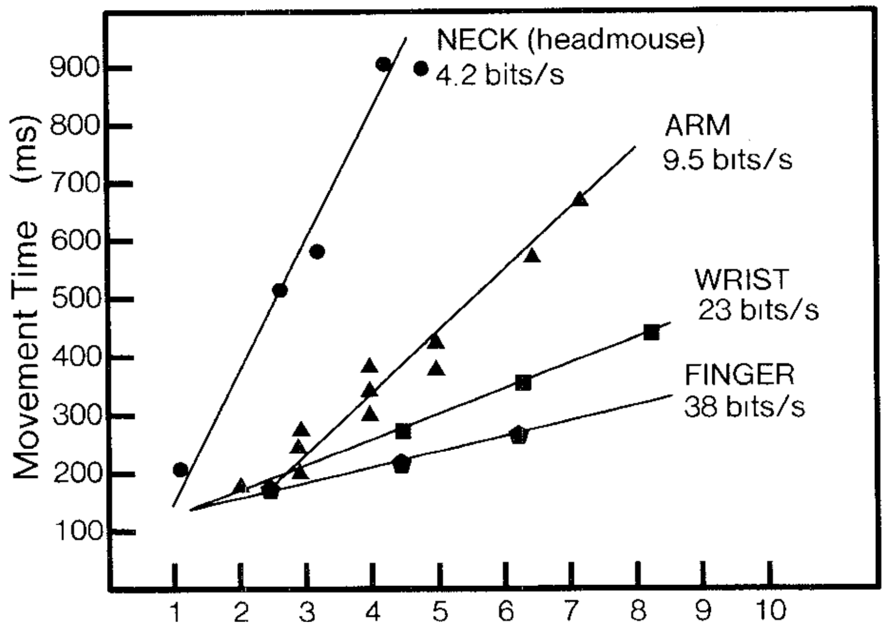
- **Speed accuracy tradeoff**
- exemple (@ 0.33)



Fitts' law



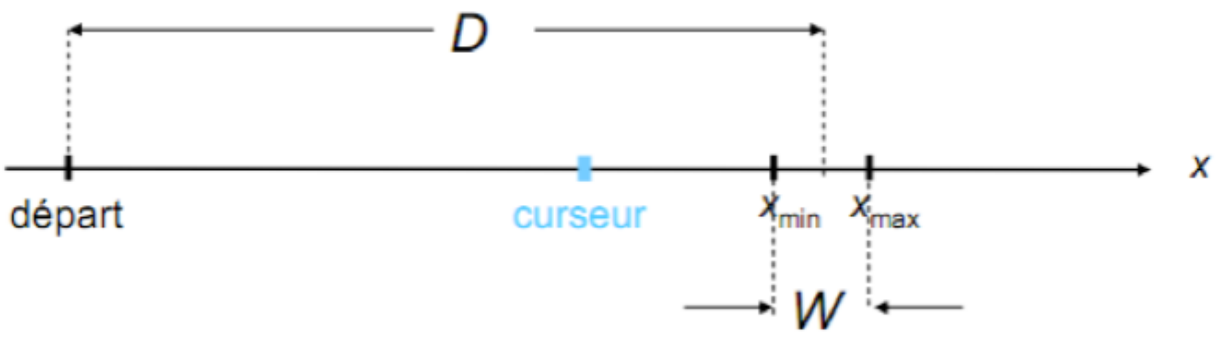
$$TM = a + b \underbrace{\log_2 (D/W + 1)}_{ID}$$



- **a, b** = **empirical constants** that depend on:
  - the device
  - the member
  - the type of population (age, etc.)

- **ID** = **index of difficulty**: depends only on **D/W ratio**
  - similarity with Shannon's entropy

Facilitating pointing

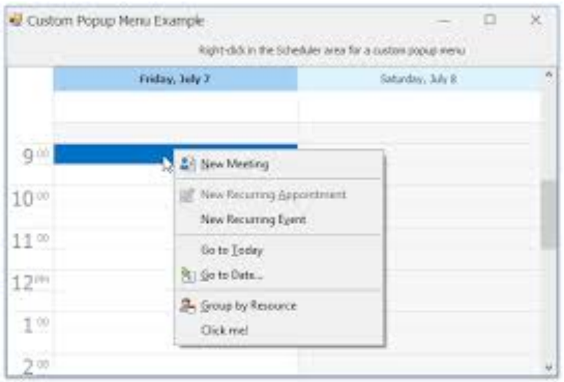


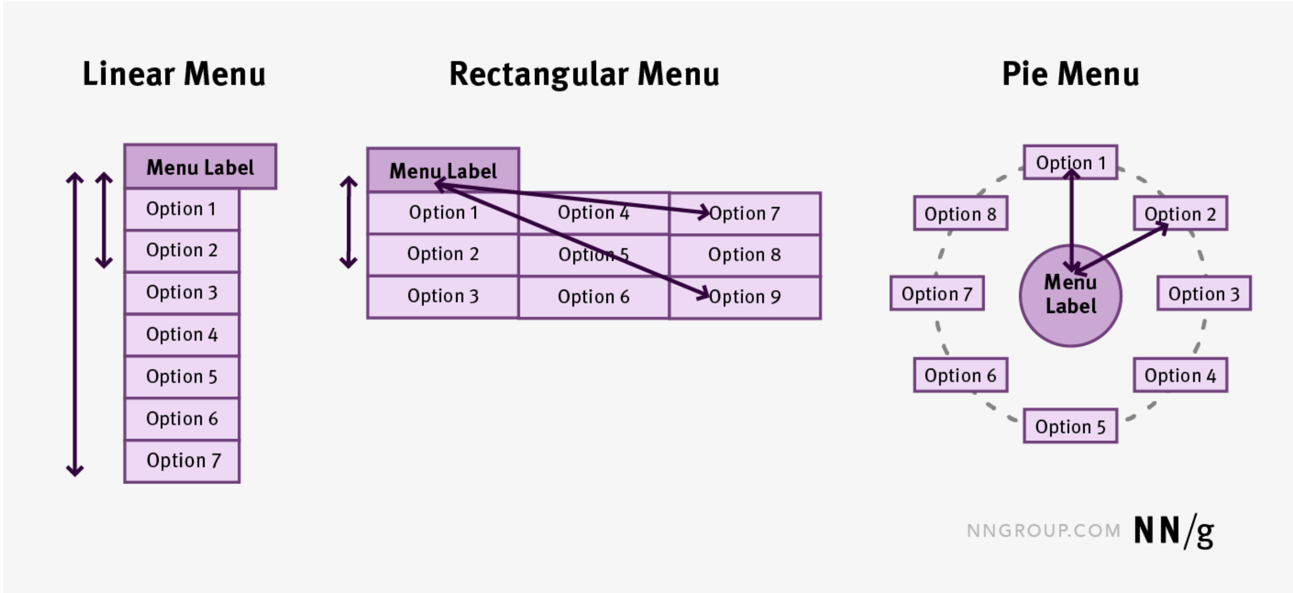
$$TM = a + b \underbrace{\log_2 (D/W + 1)}_{ID}$$

Approaches

- 1) Reduce **distance** (D)
- 2) Increase **size** (W) of target
- 3) Modulate **mouse gain**
- 4) **Semantic** techniques
- 5) **Avoid** pointing

1. Reduce distance





Spatial organization of buttons

Popup menus reduce distance between target and command

- Most used items at the **top**
  (or at the very bottom: helps visual search)

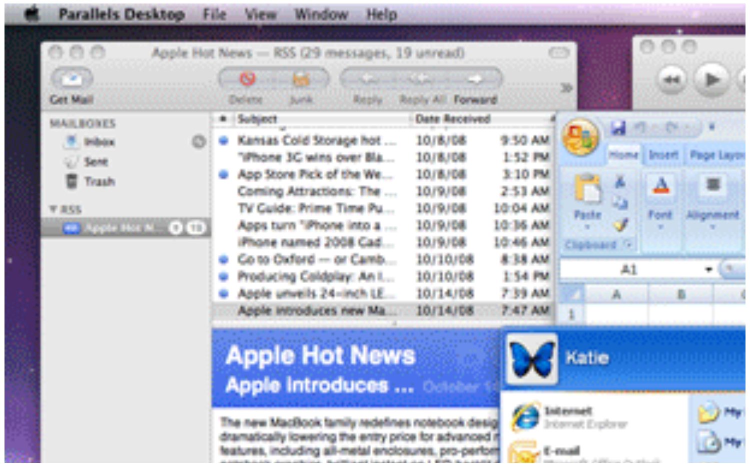
2. Increase size

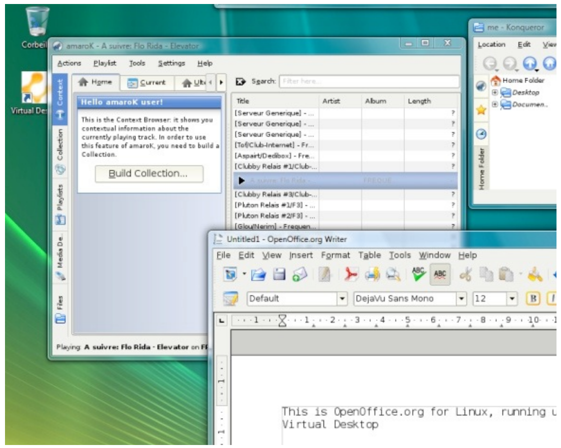
Button size

- Most used => **larger**
- Small buttons for **unfrequent** or **dangerous** actions

MacOS menu bar

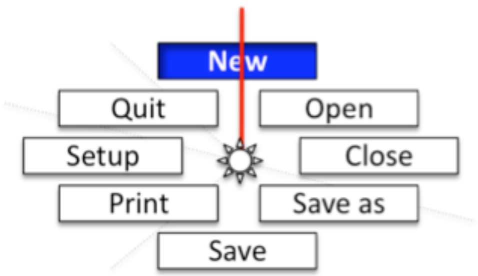
- Larger distance
- But infinite size!

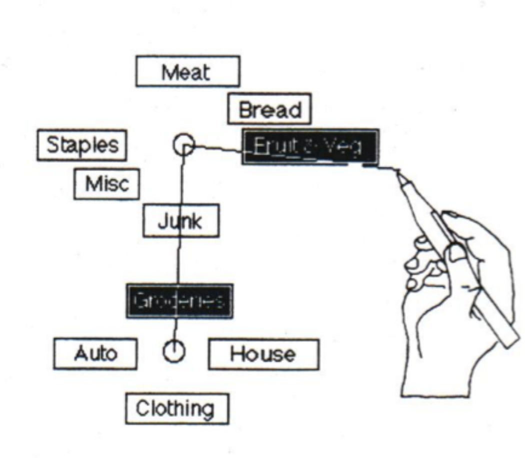




$$TM = a + b\ \underbrace{\log_2(D/W+1)}_{ID}$$

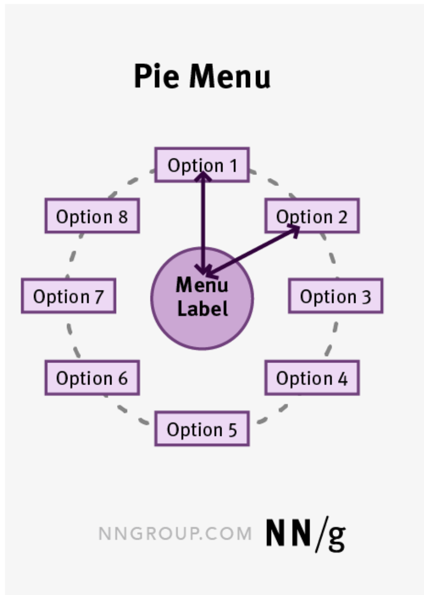
2. Increase size



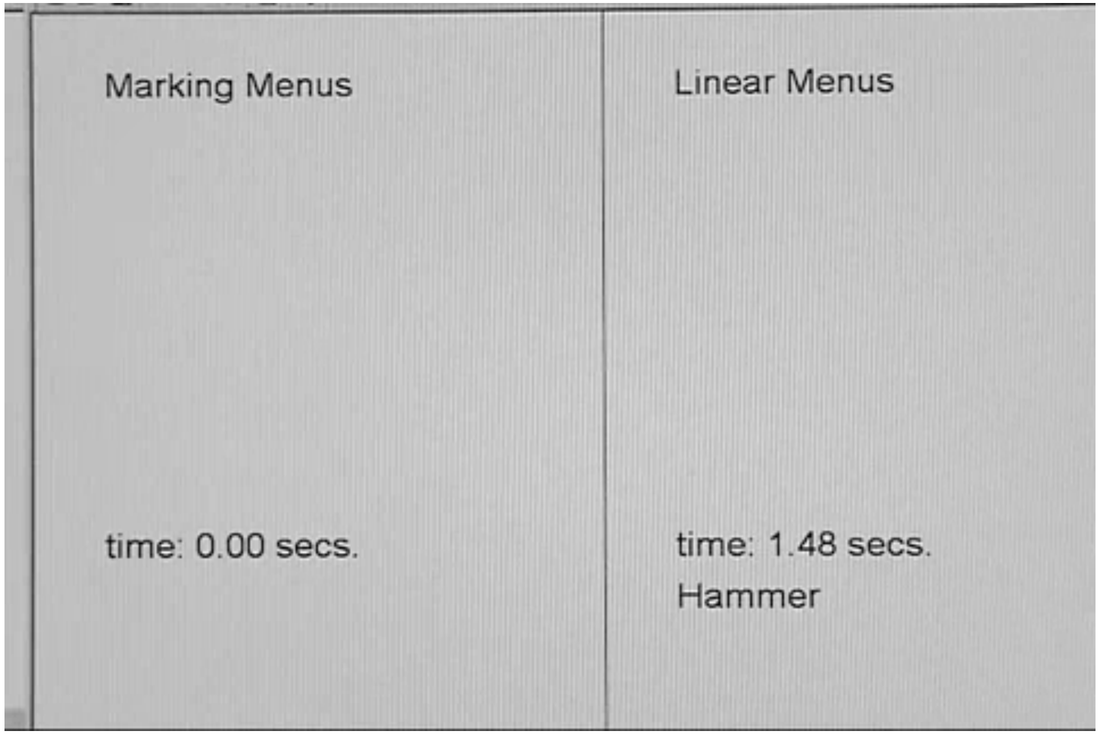


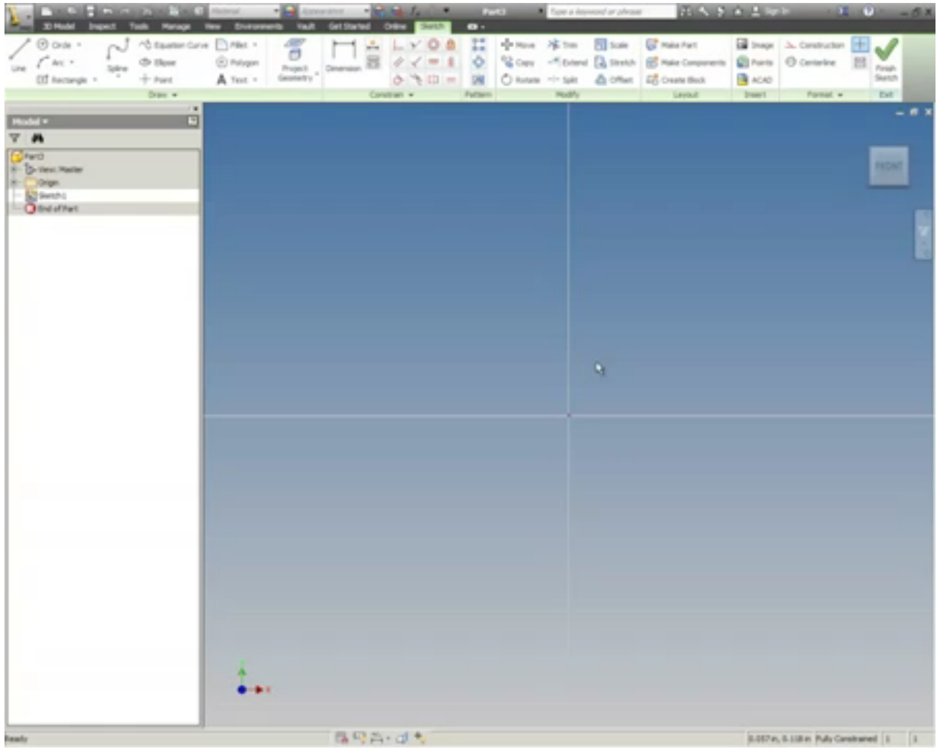
Marking menus

- **Novice mode**: circular menu
- **Expert mode**: gestural interaction with infinite size



2. Increase size





Marking menus

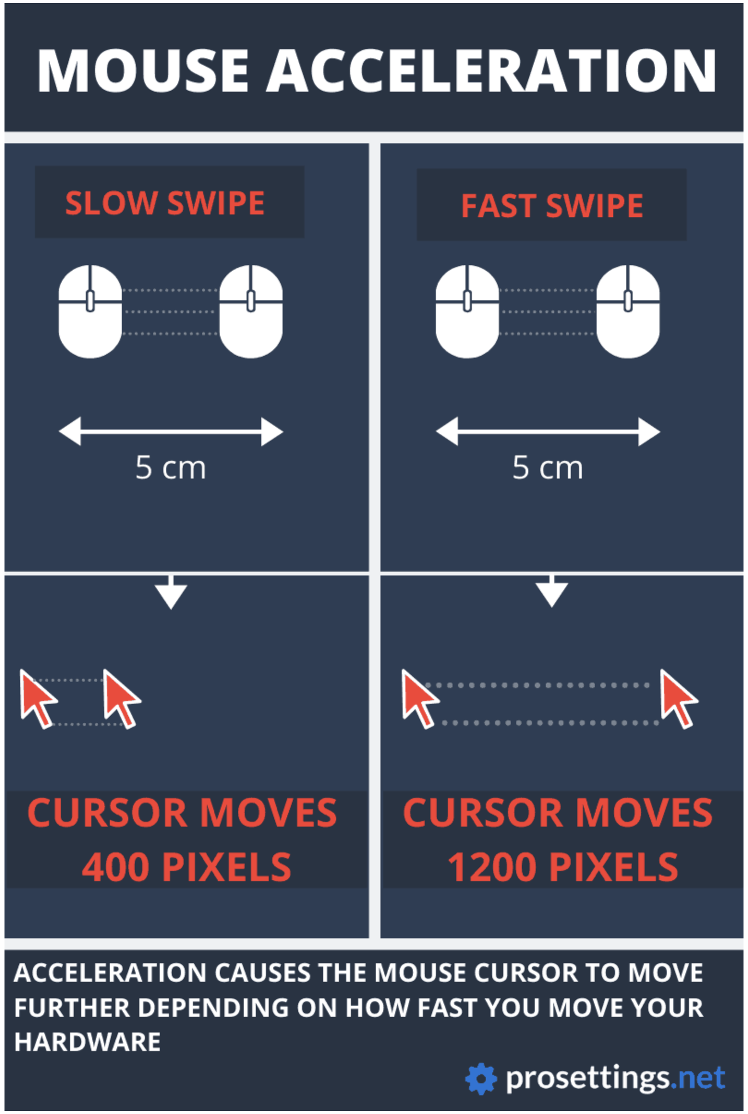
Expert mode: gestural interaction

- Infinite size (only angle matters)

Learning by repetition

- same gestures in expert and novice modes

3. Mouse gain



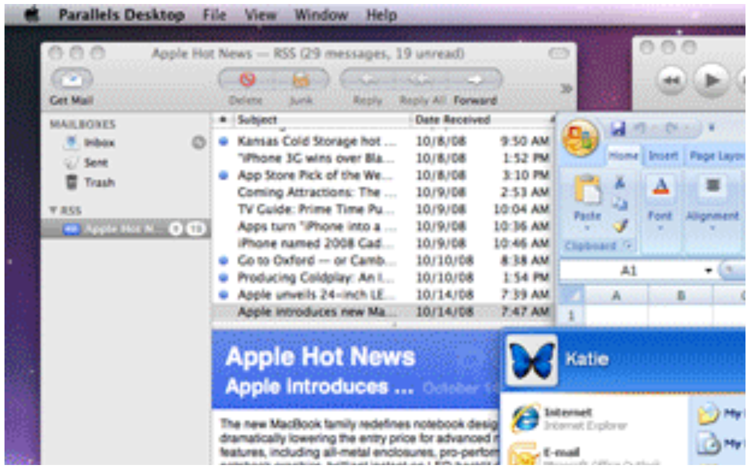
https://prosettings.net/

Mouse gain (pointer acceleration)

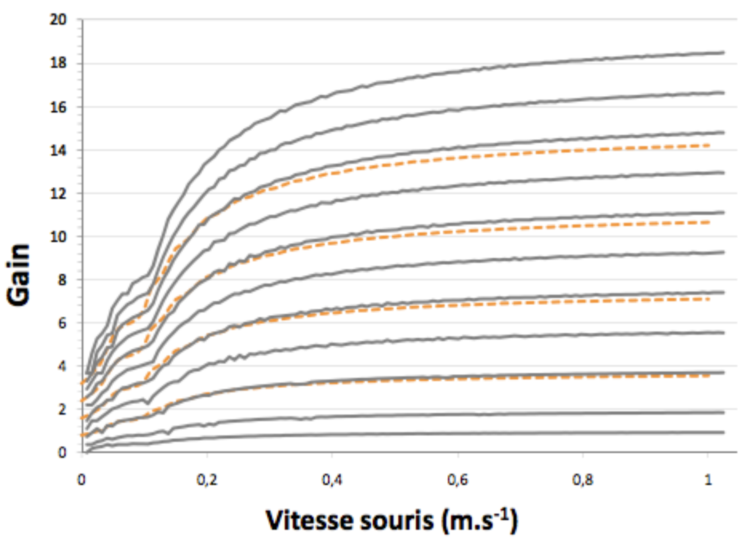
= cursor speed / mouse speed

(visual space / motor space)

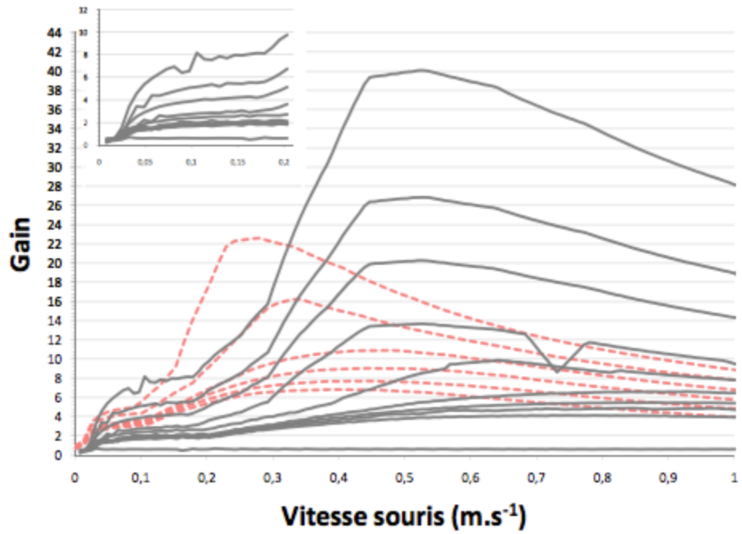
- Depends on **mouse speed**



3. Mouse gain



Windows XP

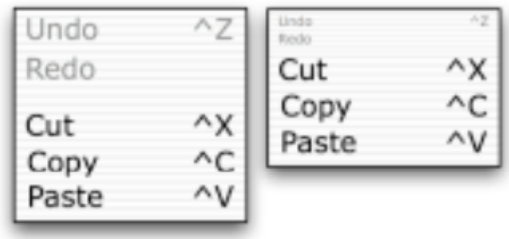


src: Casiez et al.

Mac OS X

- Slow speed => **small gain** **:** cursor move **slowly** (accurate pointing)
- Fast speed => **high gain** **:** cursor moves **quickly**
- So *"natural"* that people don't even realize!

4. Semantic pointing



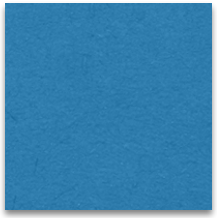
visual space

motor space

src: Blanch et al.

- Gain depends on objects' **semantics**
- **Motor** space != **visual** space
  - **Empty space** => high gain : **cursor moves quickly**
  - **Common** actions => low gain : **easier to reach**
  - **Dangerous** actions => high gain : avoids clicking by **mistake**

4. Magnetic grids



"Magnetic" grids

- common in drawing software

"Attracting" objects

- relies on object semantics

5. Avoid pointing

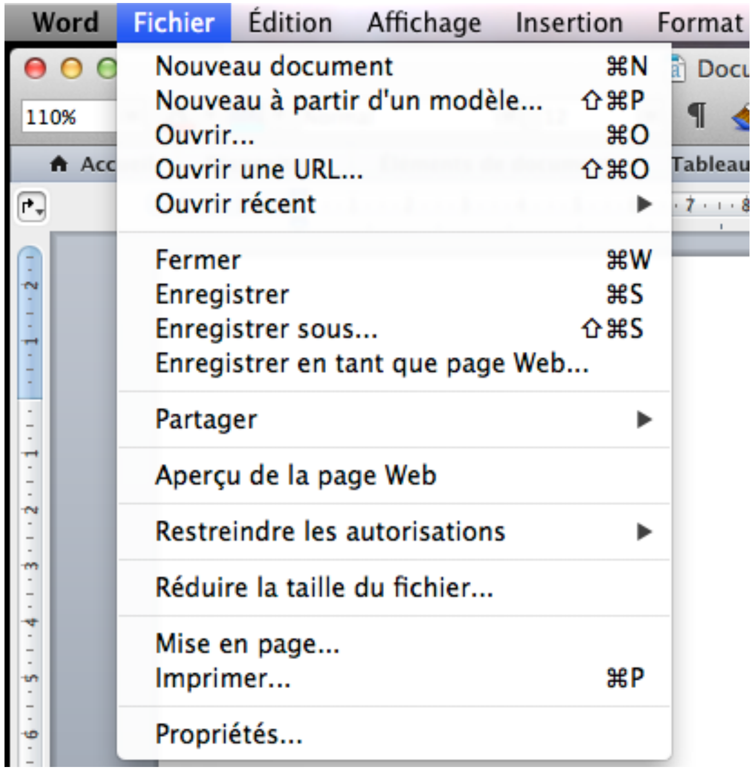
Hotkeys

Drawbacks

- Not the same **modality** as pointing
- Require **explicit learning**

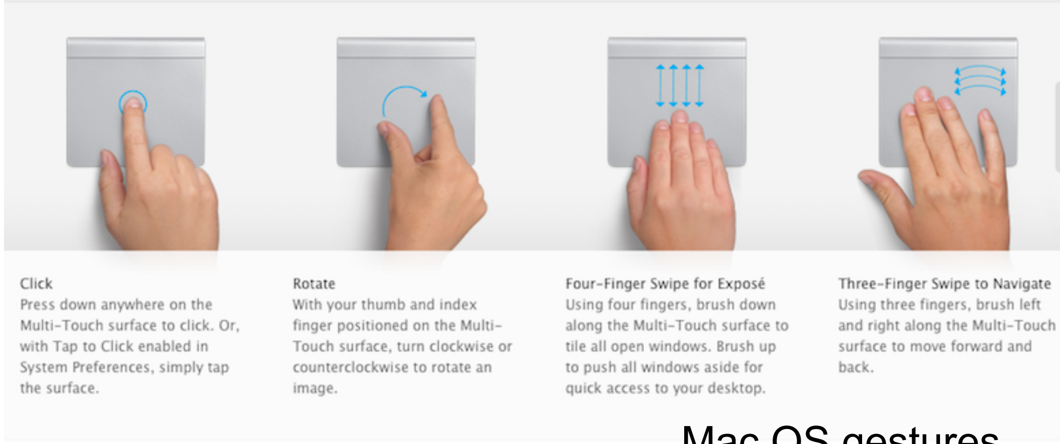
Usability?

- How many of them do you use?

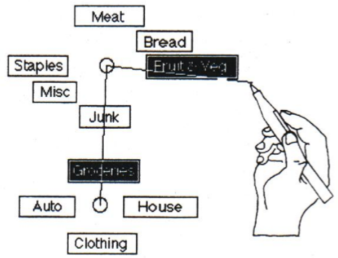


5. Gestures

- Finger gestures
- Marking menus
- Tapping gestures, etc.



Mac OS gestures



JerkTilts: Using Accelerometers for Eight-Choice Selection on Mobile Devices

5. Gestures on a large display

Complements

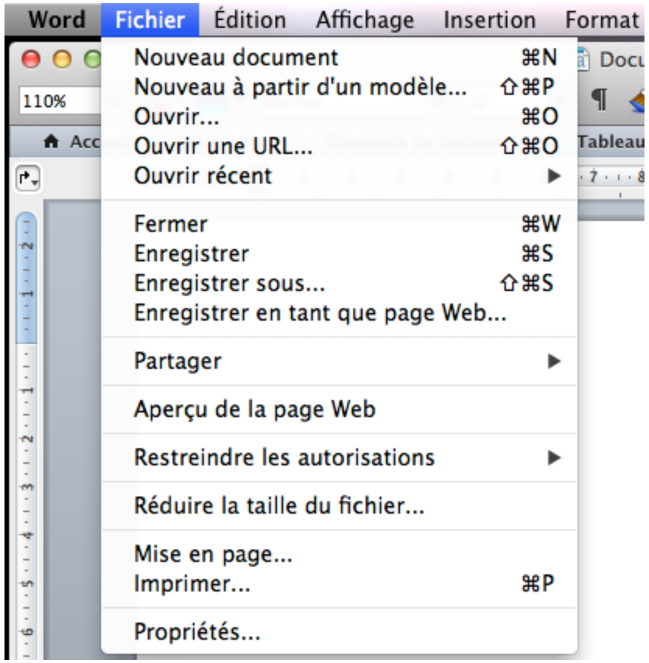
On Fitts' law

- Yves Guiard « Méthodes et Modèles de la Psychologie Expérimentale »
  http://www.telecom-paristech.fr/~elc/ihm

GOMS and Keystroke

- **GOMS**: Behavior description model
- **Keystroke**: Relies on **GOMS** to predict **execution time**
  - *See James Eagan's course*

Hick law



Time for chosing an item in a set

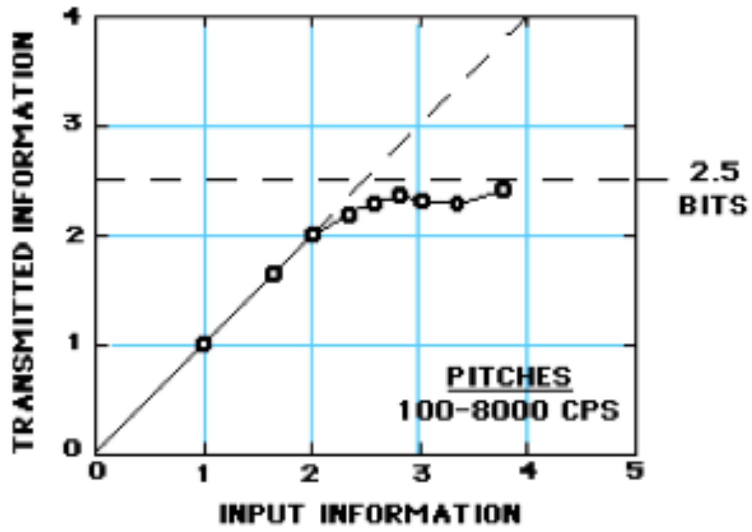
$$\mathbf{TR = a + b \log_2(n + 1)}$$

a, b = empirical constants

n = number of elements

Magical number seven (G. A. Miller)

- **Channel capacity**
  How many values can be **distinguished**
  in an **absolute** way for a given modality?



- **About 7 (+/- 2)** (2 to 3 bits)
  - **sound**: ~ 6 frequencies, ~5 intensities
  - **light** : ~8 shades, ~5 intensities
  - **salty taste** : ~4 intensities
  - **pointing** in an interval: ~10 (short time) to ~15 (long time), etc.

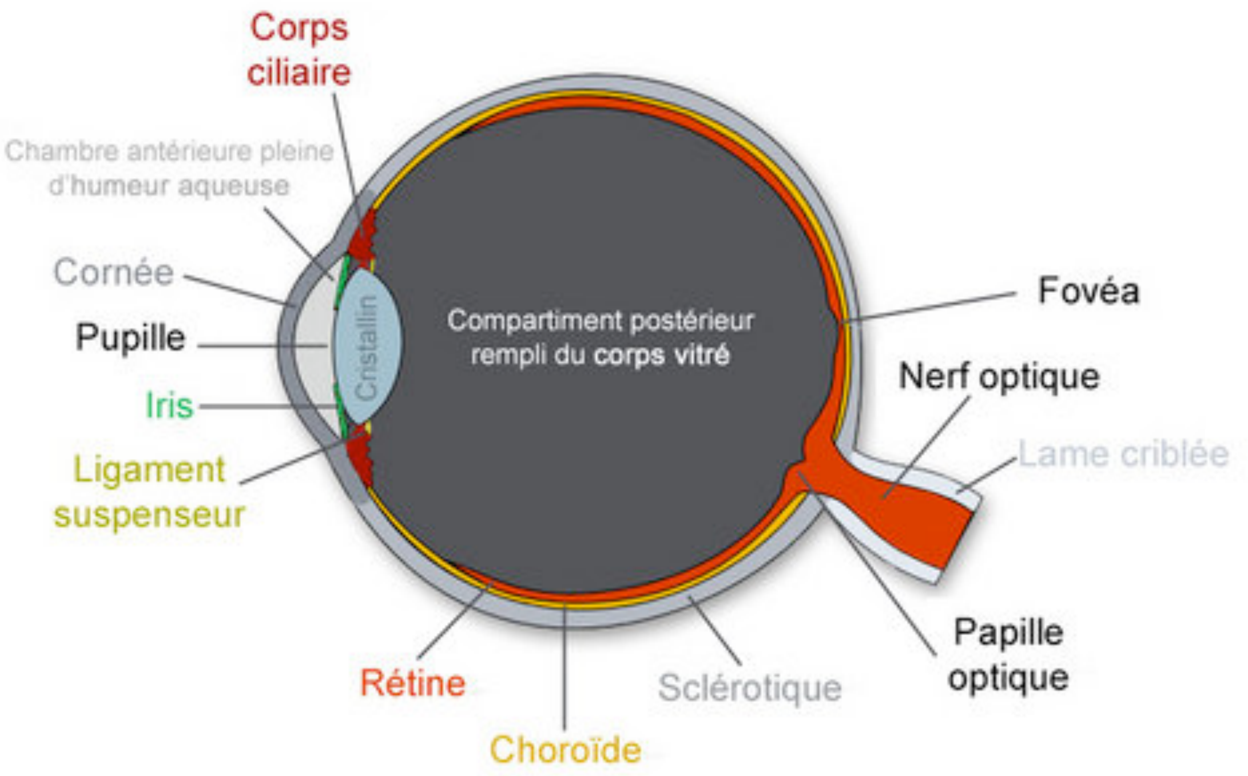
- **Related to chunking**
  - **immediate memory**: less than 7 chunks (about 5)
  - little depends on the **level of abstraction**

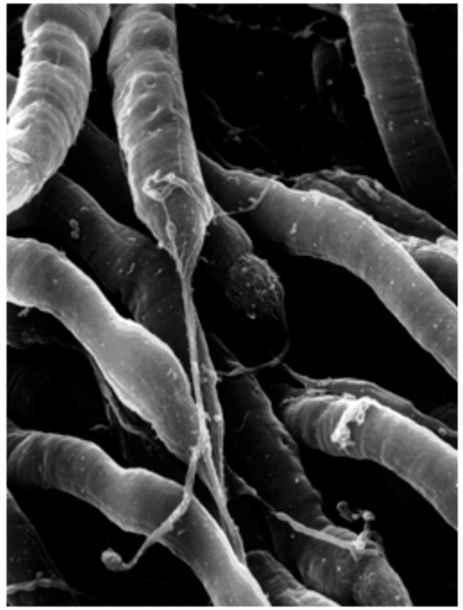
Colors & GUIs

Perception of color

Retina

- **Rods** (bâtonnets): **grayscale**, broad spectrum
- **Cones: red, green, blue** sensitive

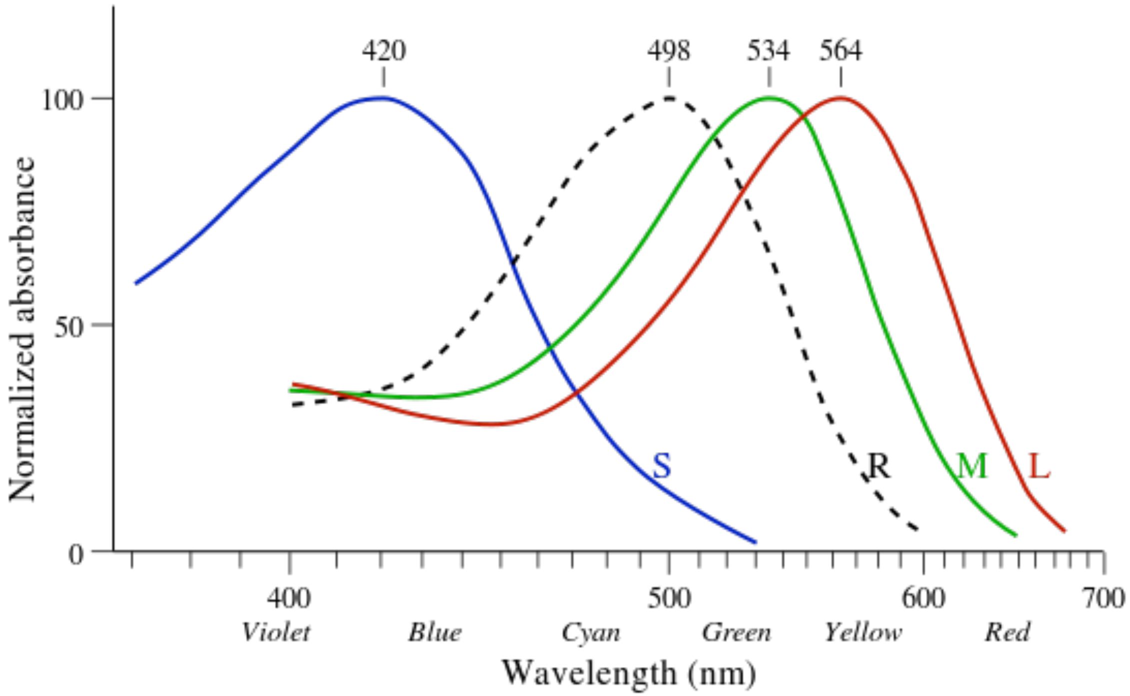


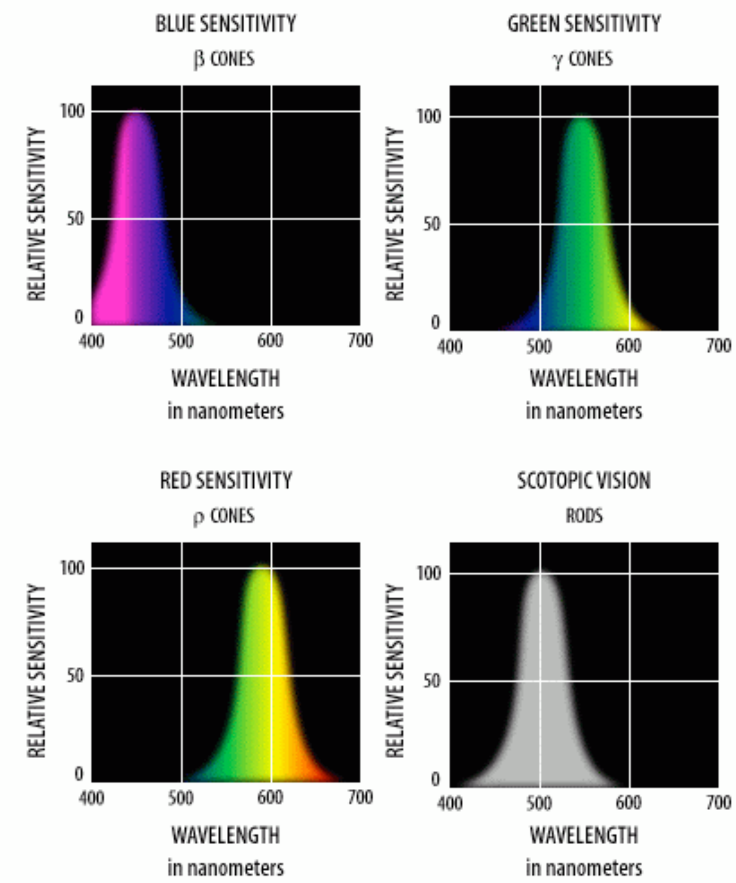


Perception of color

Indirect measurement

- The visual system does not detect colors, but **mixtures** of them
- An **infinite** number of combinations are perceived **identically**!

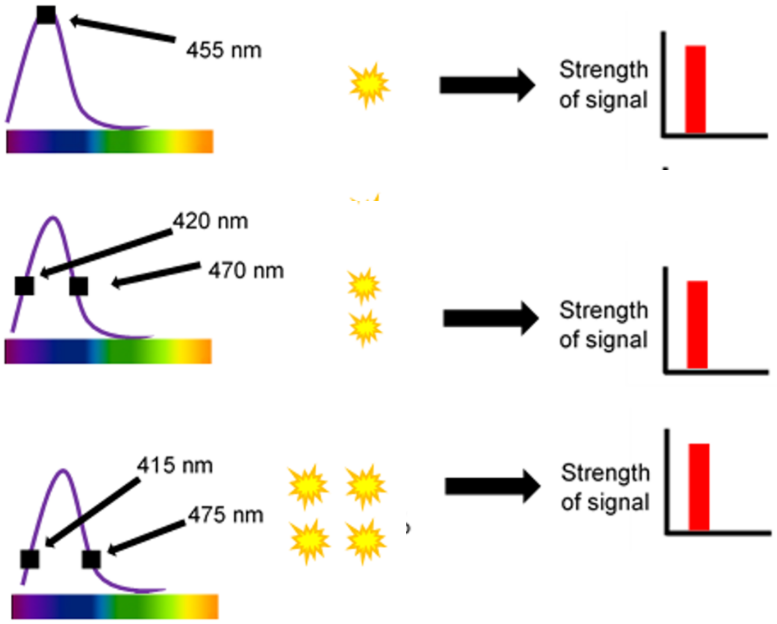


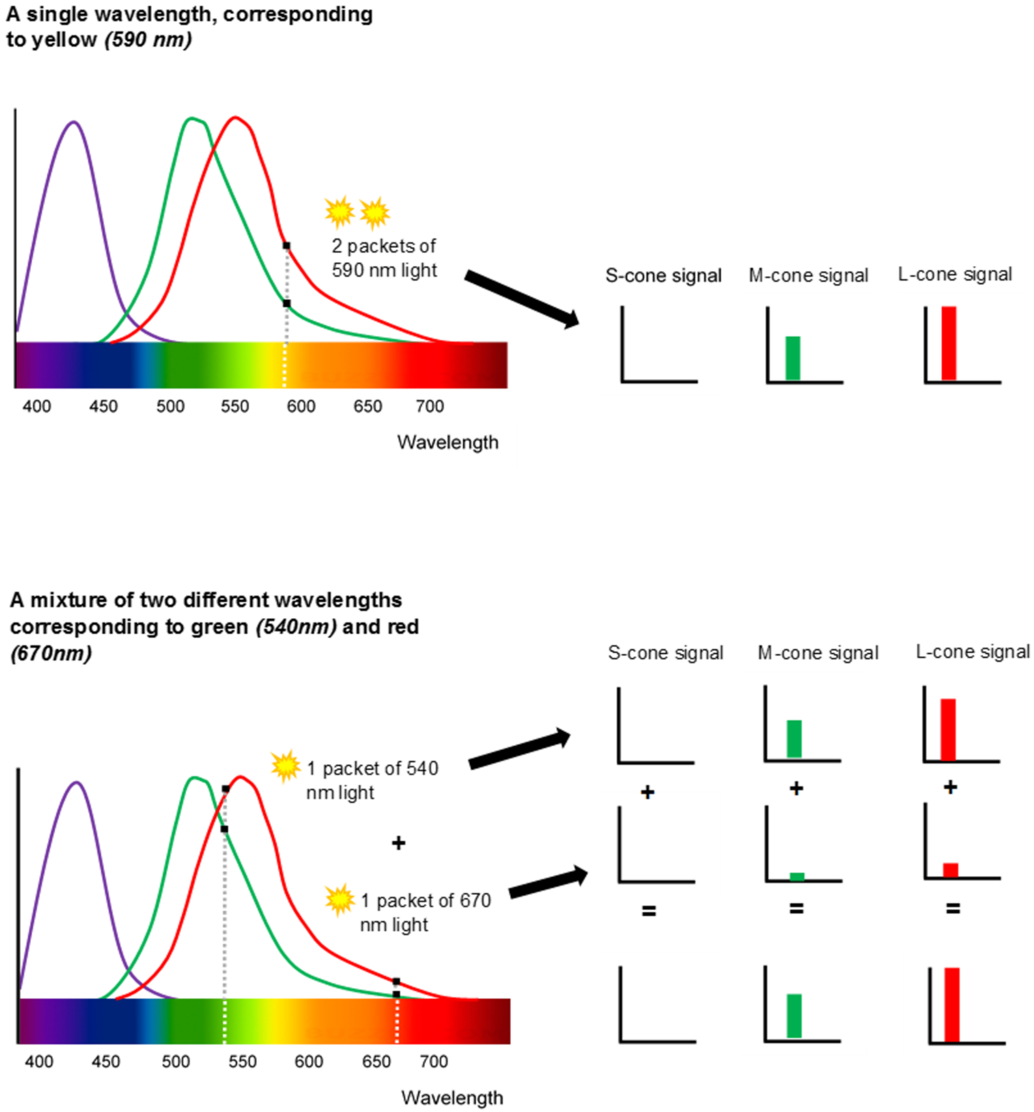


Perception of color

Metameric colors

- Different color distributions
- That are perceived identically



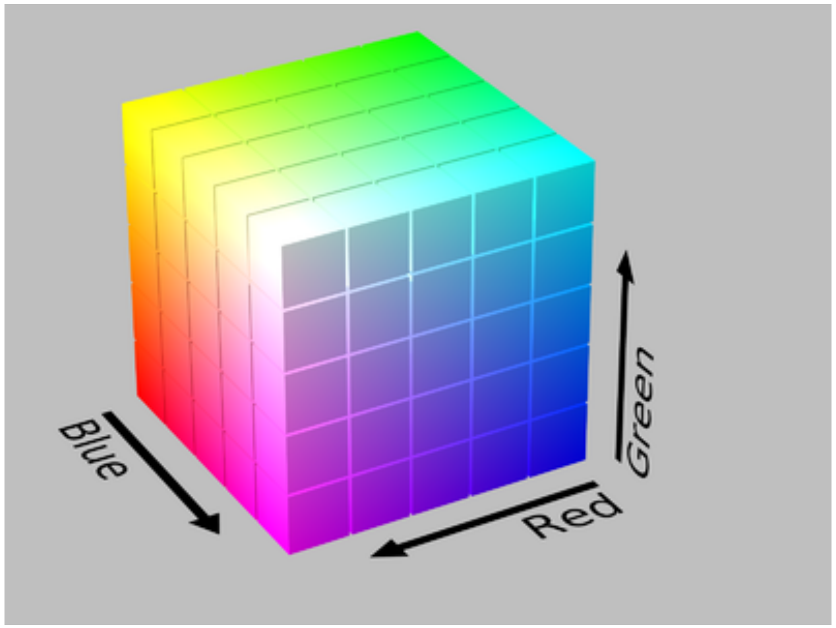


https://theneurosphere.com/2015/12/07/why-are-all-the-colours-we-experience-composed-of-three-primaries/

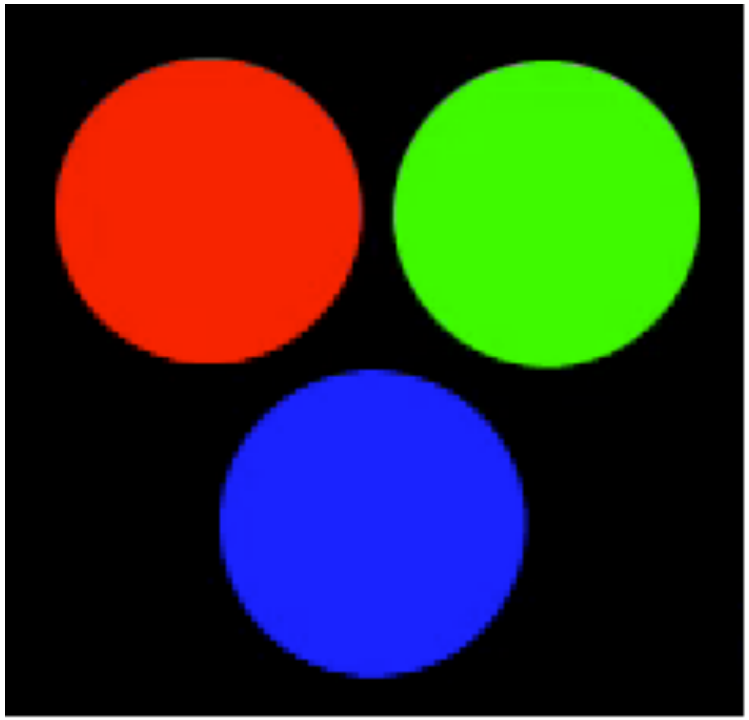
RGB color model

Additive model

- Light **emission** (screens)
- Each pixel has 3 **R, G, B** subpixels
- Screens display colors **as we see them** (not as they are!)



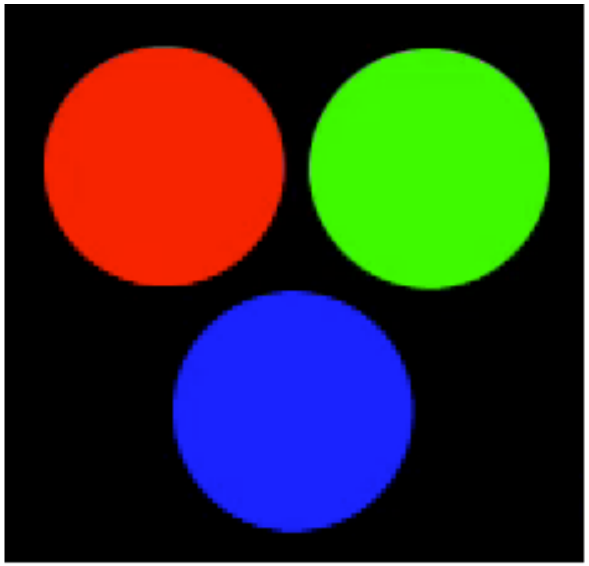
wikipedia



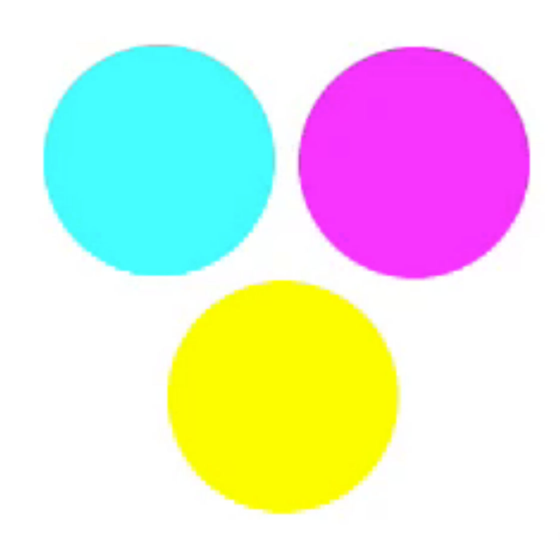
CMY(K) Model

Subtractive model

- Light **reflection** (paper prints)
- **Complementary** colors: Cyan, Magenta, Yellow
- Printers: **CMYK** : CMY + blacK
- High-end printing (art books): more colors because of imperfect pigments



additive

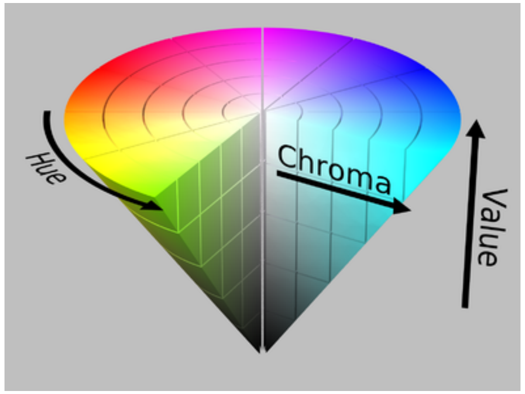


substractive

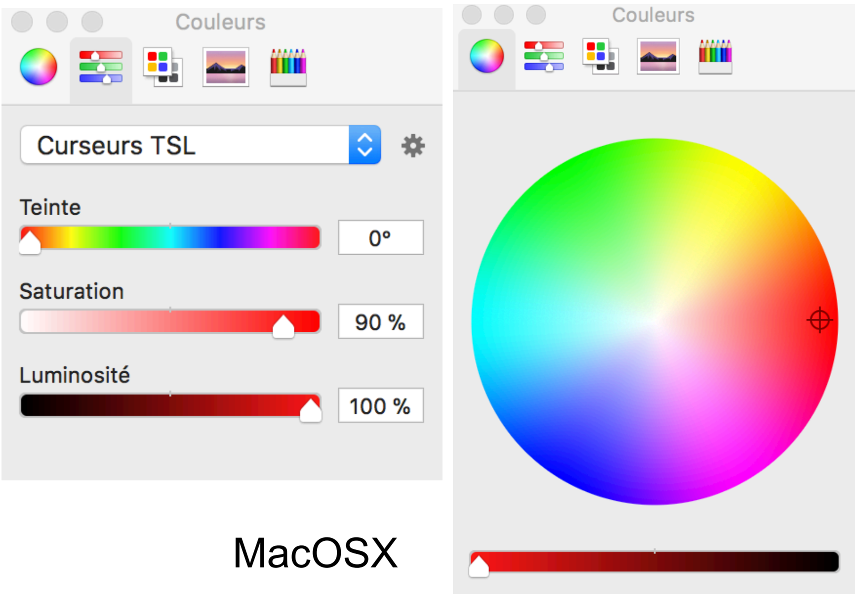
HSV Model

- Equivalent to **RGB**
- More appropriate for describing colors
    - **Hue** (teinte):
      primary color (wavelength)
    - **Saturation** (chroma):
      proportion of secondary colors
    - **Value** (brightness)

- Variant: **HSL** Model
  different calculation of S and L (light)



wikipedia



MacOSX

CIE Lab

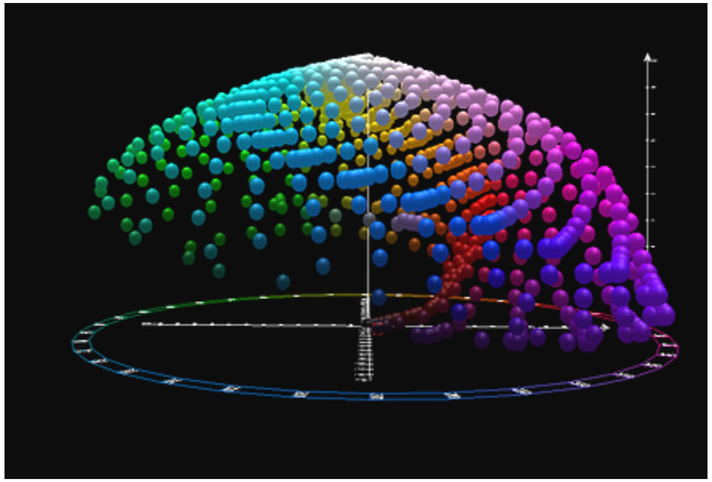
CIE L*a*b*

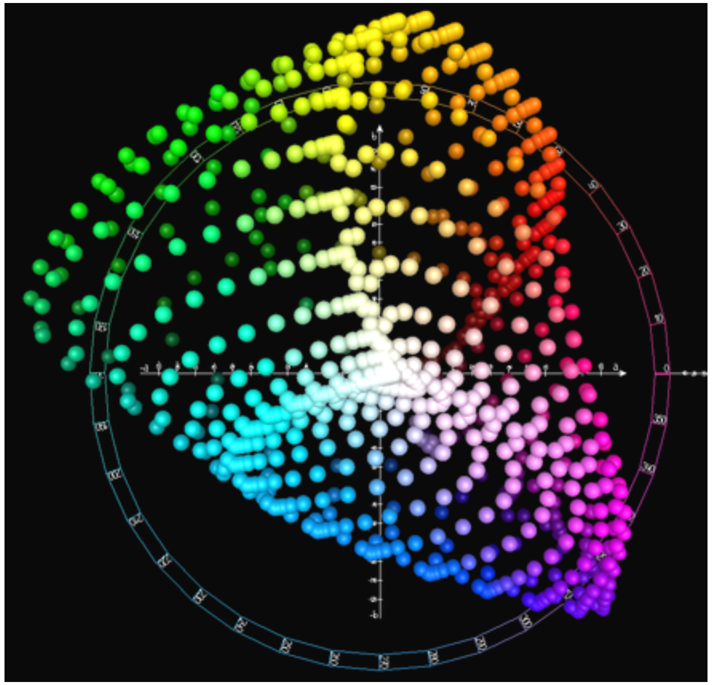
- **Device-independent** color space
- Takes **human perception** into account
- Distance respects **perceived** color difference

- **L*** = black to white
- **a*** = value on a green → red axis
- **b*** = value on a blue → yellow axis

Also

- CIE L*u*v* for screens
- CIE xy, etc.



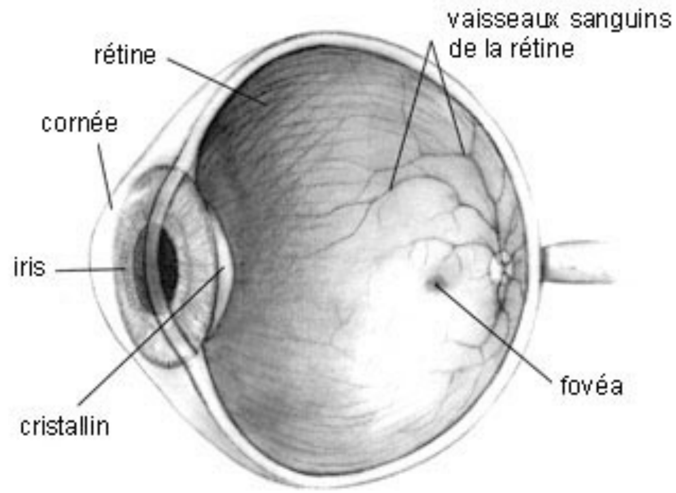


wikipedia

Retinal sensitivity

Retina

- 75 to 150 million **rods** (grayscale)
- 7 million **cones** (R, G, B colors)



The eye is 10 times more sensitive to variations in V (brightness) than in H (hue)!

At night all cats are gray !

Retinal sensitivity & GUIs

Similar brightness makes it hard to read

texte vert brillant sur fond rouge brillant

same H & S

texte vert brillant sur fond rouge foncé

Bright green on **bright** red :

- **same Value**
- difficult / unpleasant

Bright green on **dark** red :

- **different Value**
- easier to read

Golden Rule

- **Contrast Value rather than Hue**
- Use at least a **brightness ratio of 1/3** (1/10 if possible) between the background and the foreground

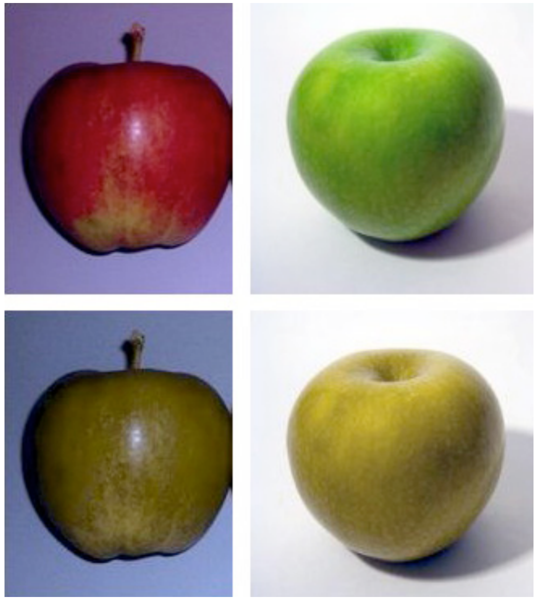
Color vision deficiency

Quite common

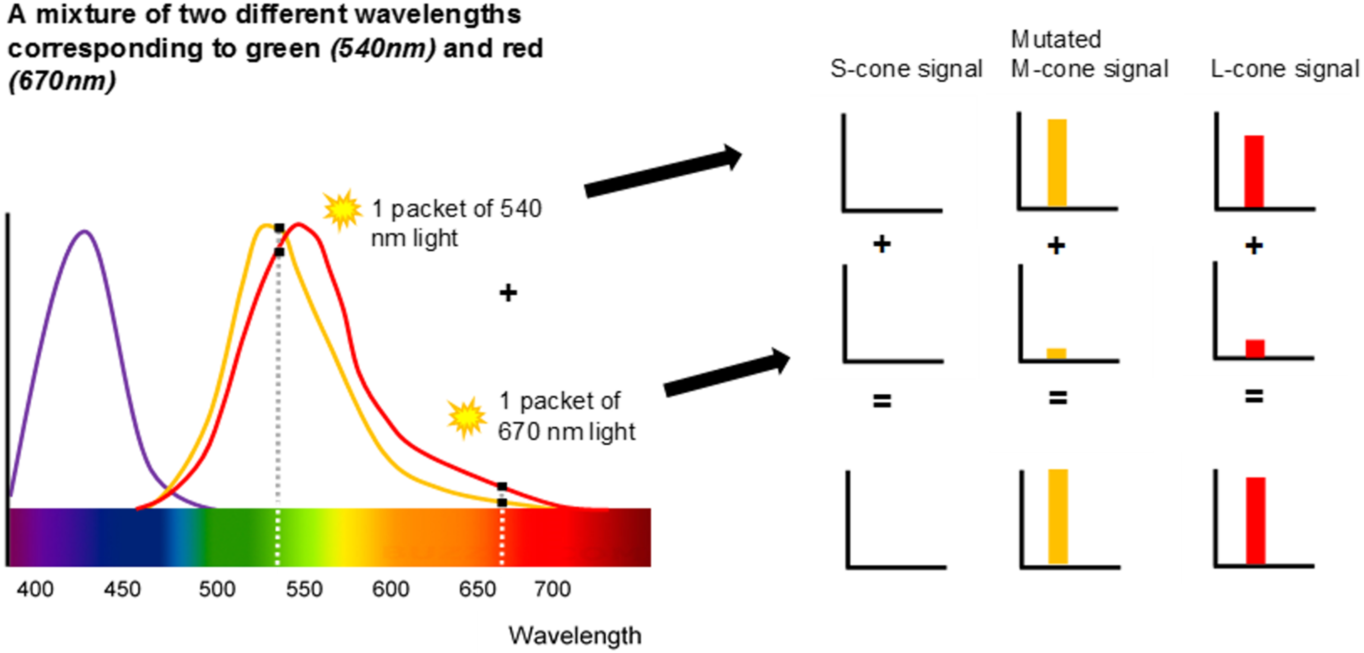
- 8% of men
- Green-red confusion is most common

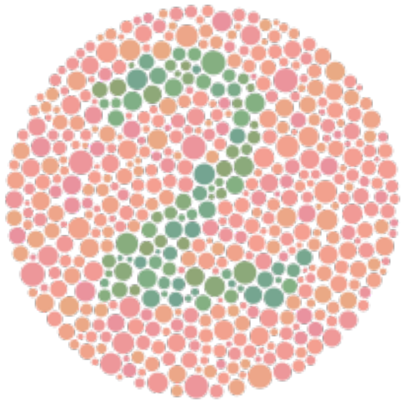
One more reason to contrast V!

- rather than Hue



Vision deutéranope
en bas (Wikipedia)

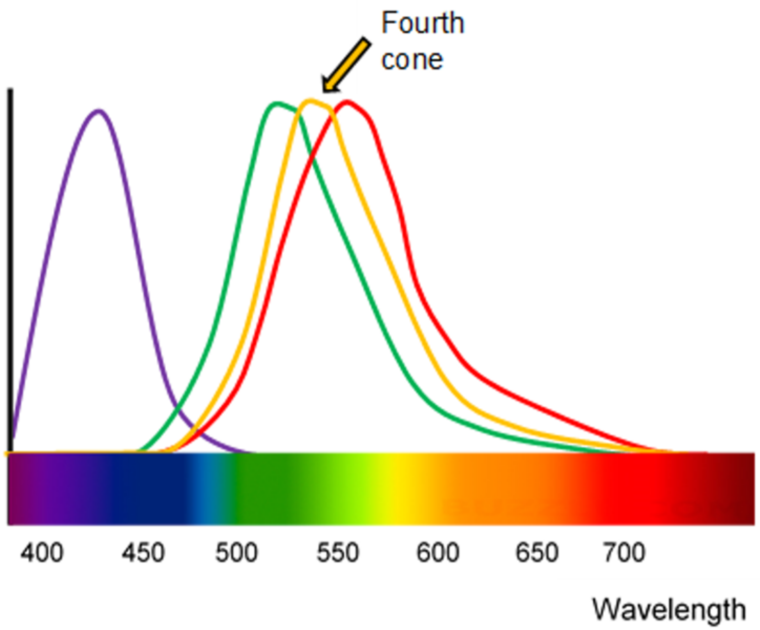




test d'Ishihara (Wikipedia)

Tetrachromacy & more

- **Tetrachromacy** (4 rods)
  - Birds and... some women(?)
- **14 rods:** Silver spinyfin (Dirette Argentée)!



RGB vs. tetrachromacy

https://theneurosphere.com/2015/12/17/the-mystery-of-tetrachromacy-if-12-of-women-have-four-cone-types-in-their-eyes-why-do-so-few-of-them-actually-see-more-colours/

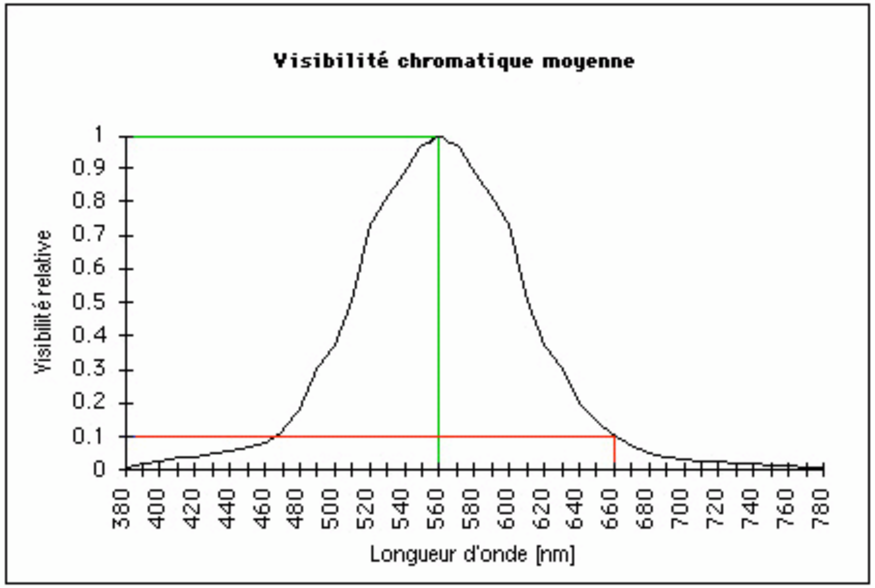
Wavelength dependency

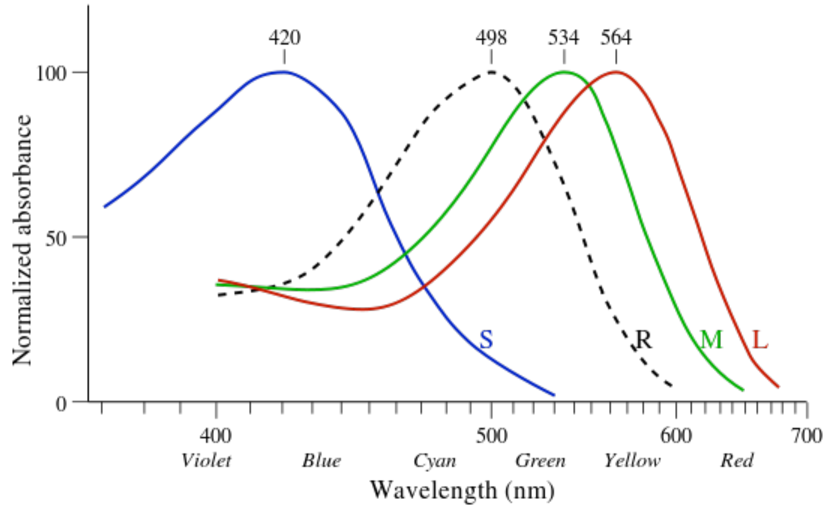
Human vision more efficient

- In the **center** of the spectrum (yellow, green)

Example

- **blue** text on **dark red** background hard to read

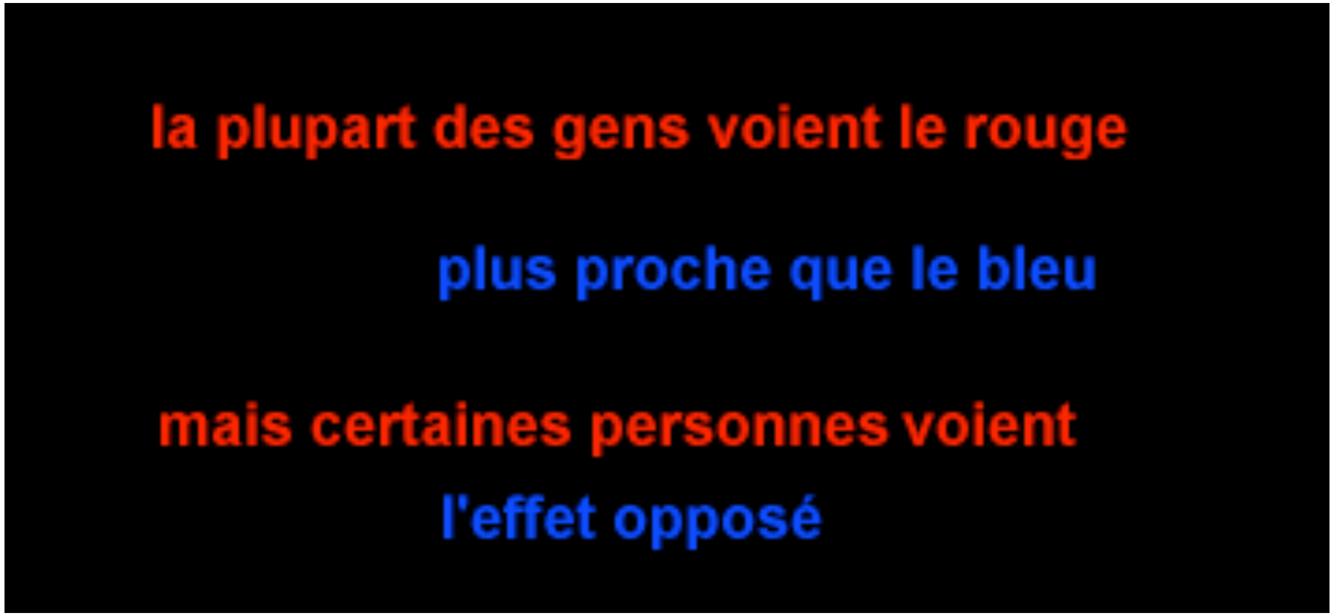




Wavelength dependency

Chromatic aberration

- Different focus for R, G and B



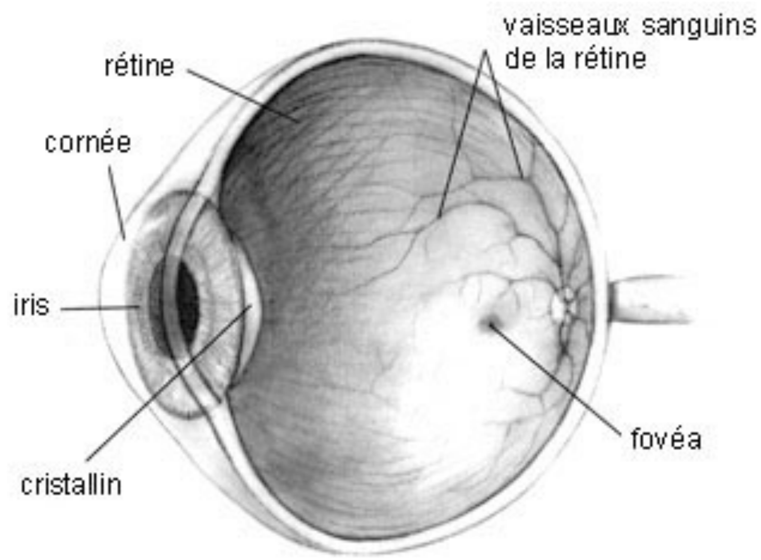
Spatial dependency

Much greater sensitivity

- On the **fovea**, in the center of the retina
- Area used for reading

Focus of attention

- Vision **accurate** on a **small** angle
  (eye **saccades**)



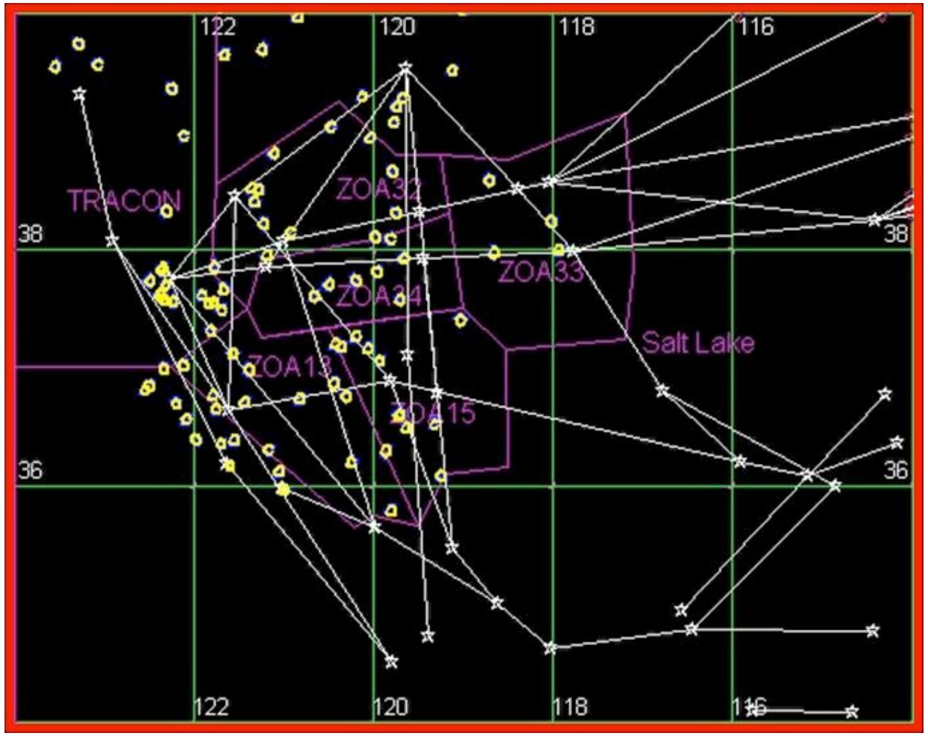
Spatial dependency

Focus of attention

- Vision **accurate** on a **small** angle

Alerts & critical systems

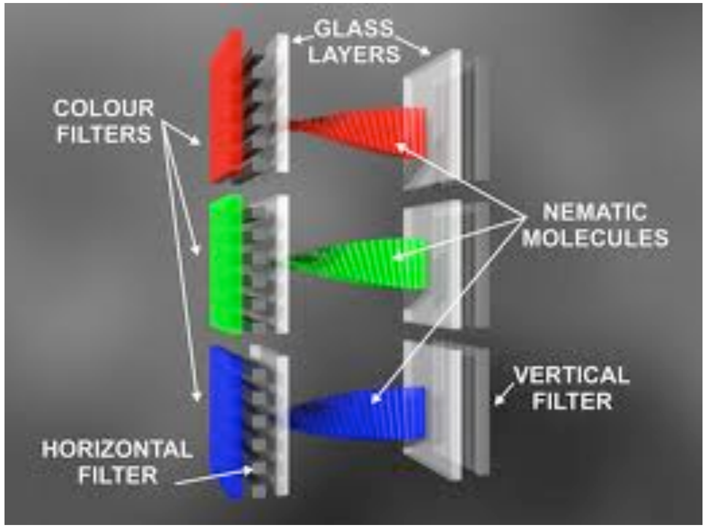
- Bad perception in **peripheral** vision
- Try to reduce eye
  back and forth movements
- Example: *air traffic control*

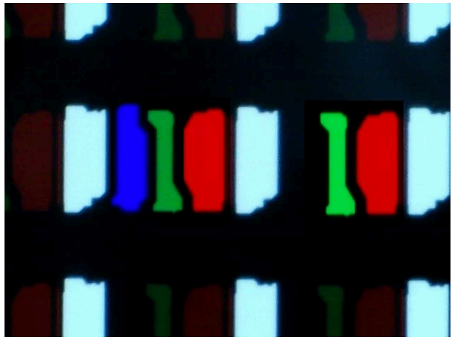


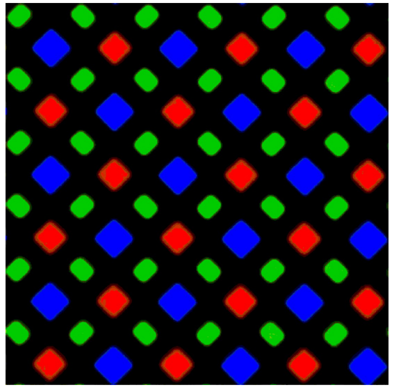
Color encoding

- Often **24 bits per pixel** : 8 bits for each R/G/B component
- **3 x 8bits = (2^8)^3 =** **16 million colors**

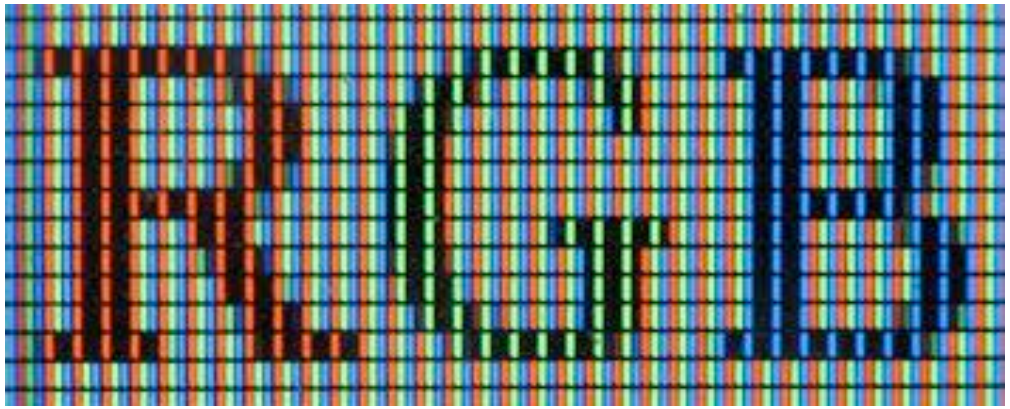
Why?



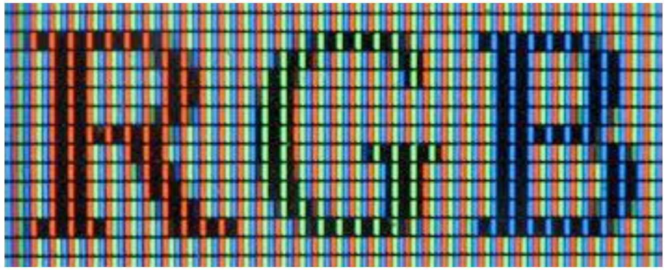




different pixel configurations (above: iPhone X)



Color encoding



Why 16 million colors?

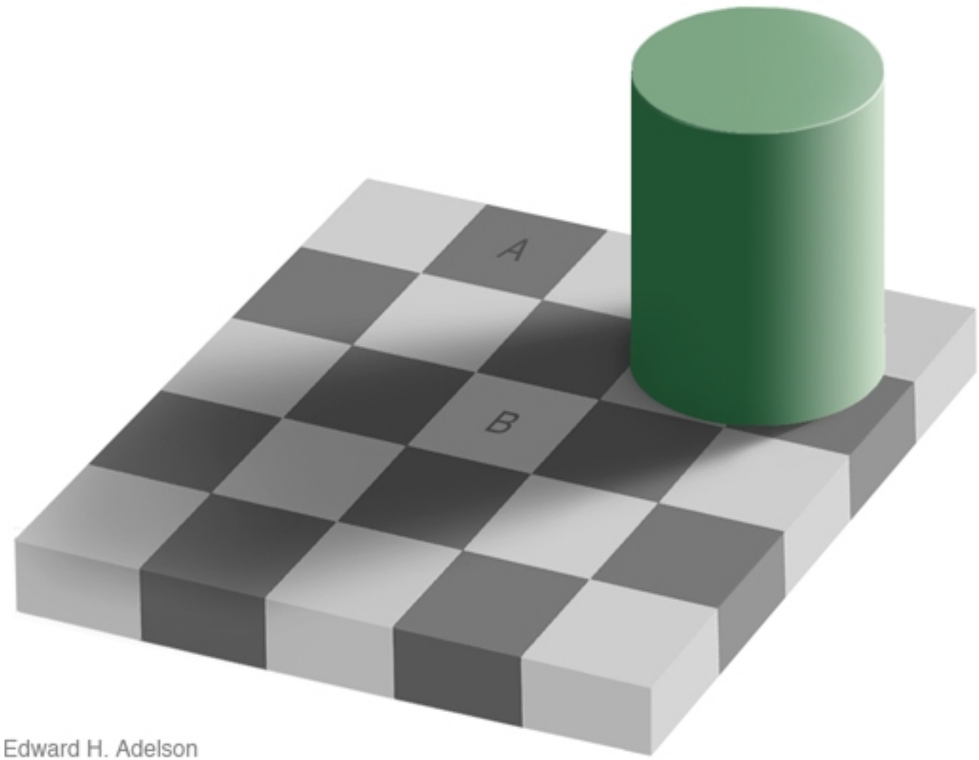
- We can distinguish about **120/150 different hues**
- But high **adaptability to luminance** (pupil)
  - **Black** leaf in full sun: **1000** candela/m2
  - **White** sheet on desk: **50** candela/m2
- **=>16 million colors** is enough, but in an **office environment!**

Other common formats

- **HDR** (High Dynamic range): 3x10 / 3x12
- **32 bits**: 24 for color + 8 for **transparency** (alpha layer)

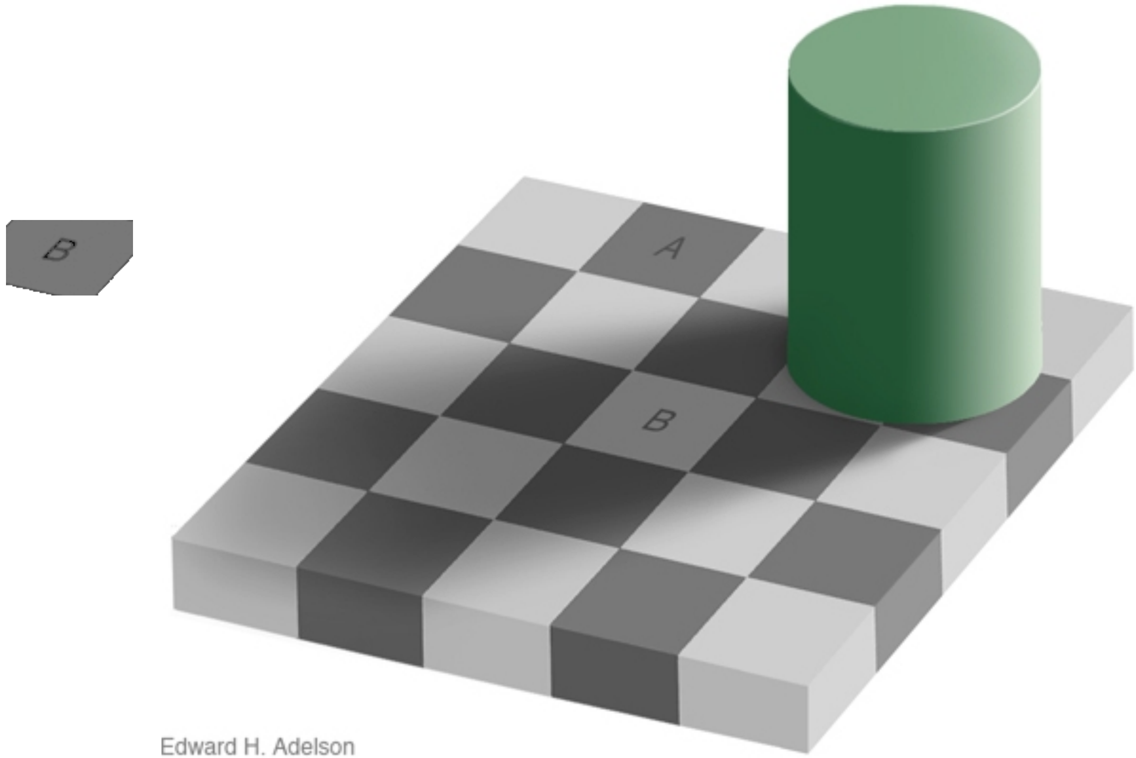
Contrast

- High **adaptability to luminance**
- By also strong **Contrast** effects:
  - How a video projector can produce **black** text on a **white** screen?
  - Which of A or B is the darker?



Edward H. Adelson

Contrast



Gamma correction

Luminance and Brightness

- **Luminance**: ***measurable*** quantity of light
- **Brightness**: ***perceived*** quantity of light - **not proportional** to luminance!

Empirical estimation

- **Brightness = Luminance ^{n}** (n depends on experimental conditions)

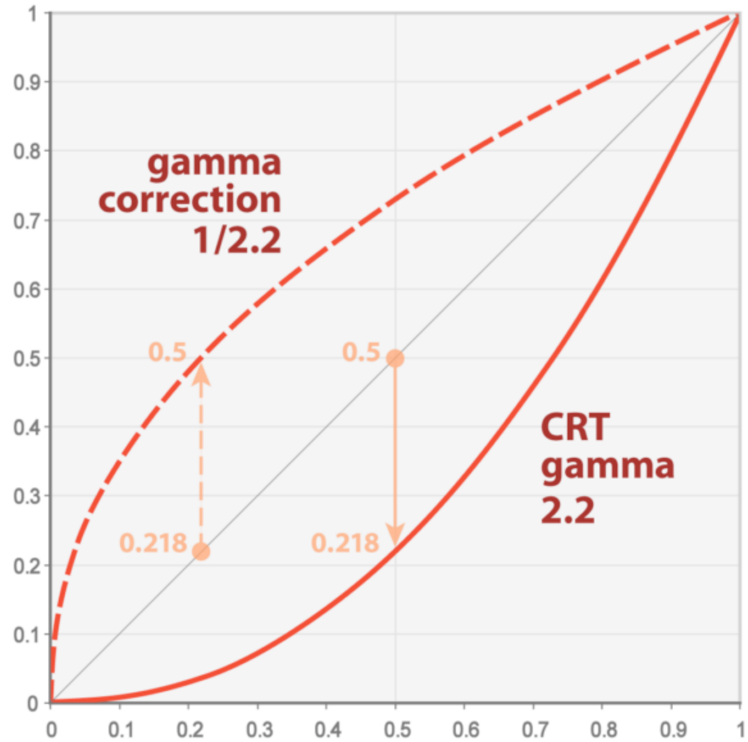
Gamma correction

- **Luminance = Voltage ^{gamma}**
  - ➡ Brightness = $\mathbf{L^{n} = (V^{gamma})^{n} = V}$
  - ➡ Linear relationship if **gamma** well chosen

Gamma correction

In practice: ambient light

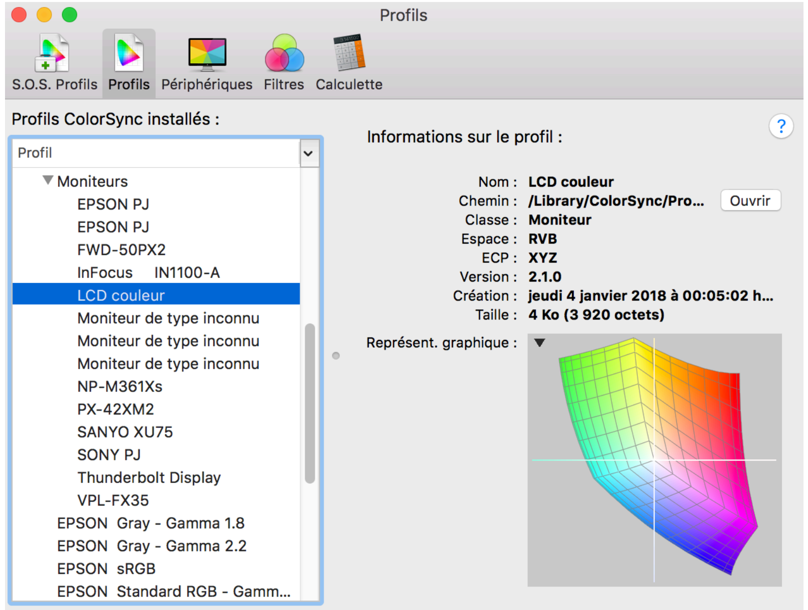
- **L = V $^{\text{gamma}}$ + A** (ambient light)
- Typically :
  - 2,5 in the dark
  - 1,5 in an office
- Generally **Gamma** = 2,2



Color profiles

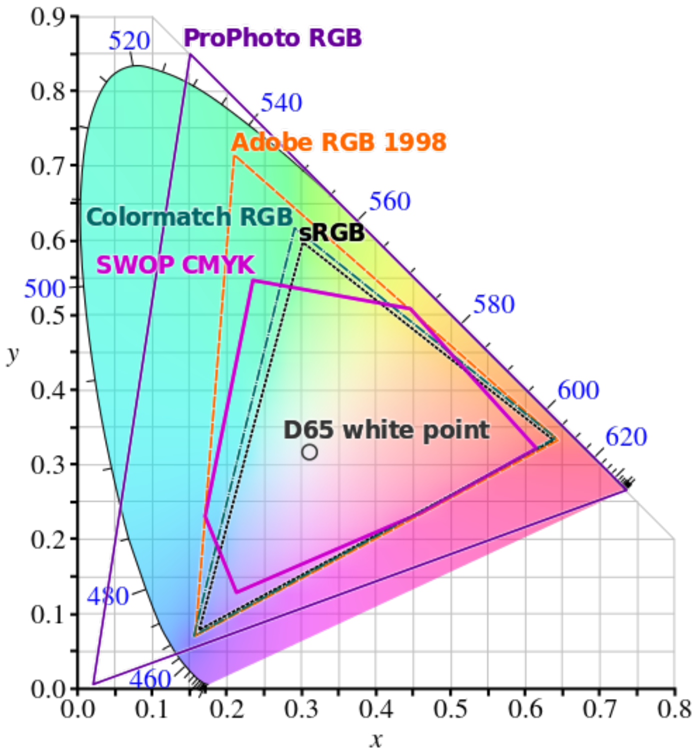
ICC profile

- Describes how a **device** renders **colors**
- Goal: harmonize **rendering**
- Example: *ColorSync* tool



sRGB

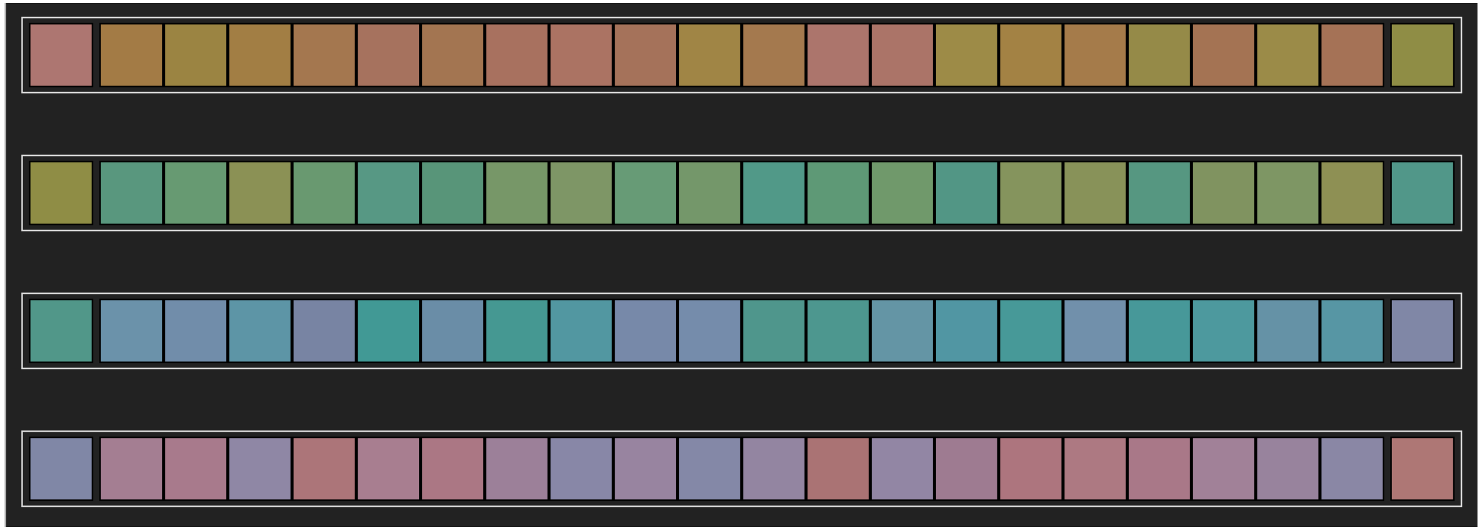
- **Color space** created by Microsoft & HP
- Often used as a **standard** profile
- Used in **CSS**
- Some limitations: modern devices may have a larger **gamut**



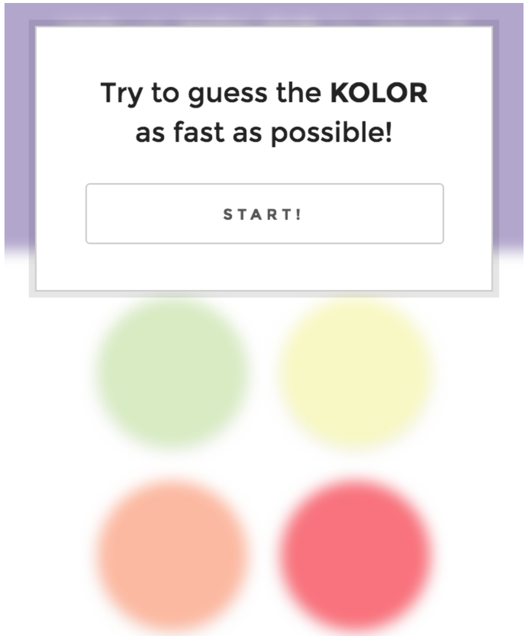
Gamuts in CIEyx space

(Wikipedia)

Let's play

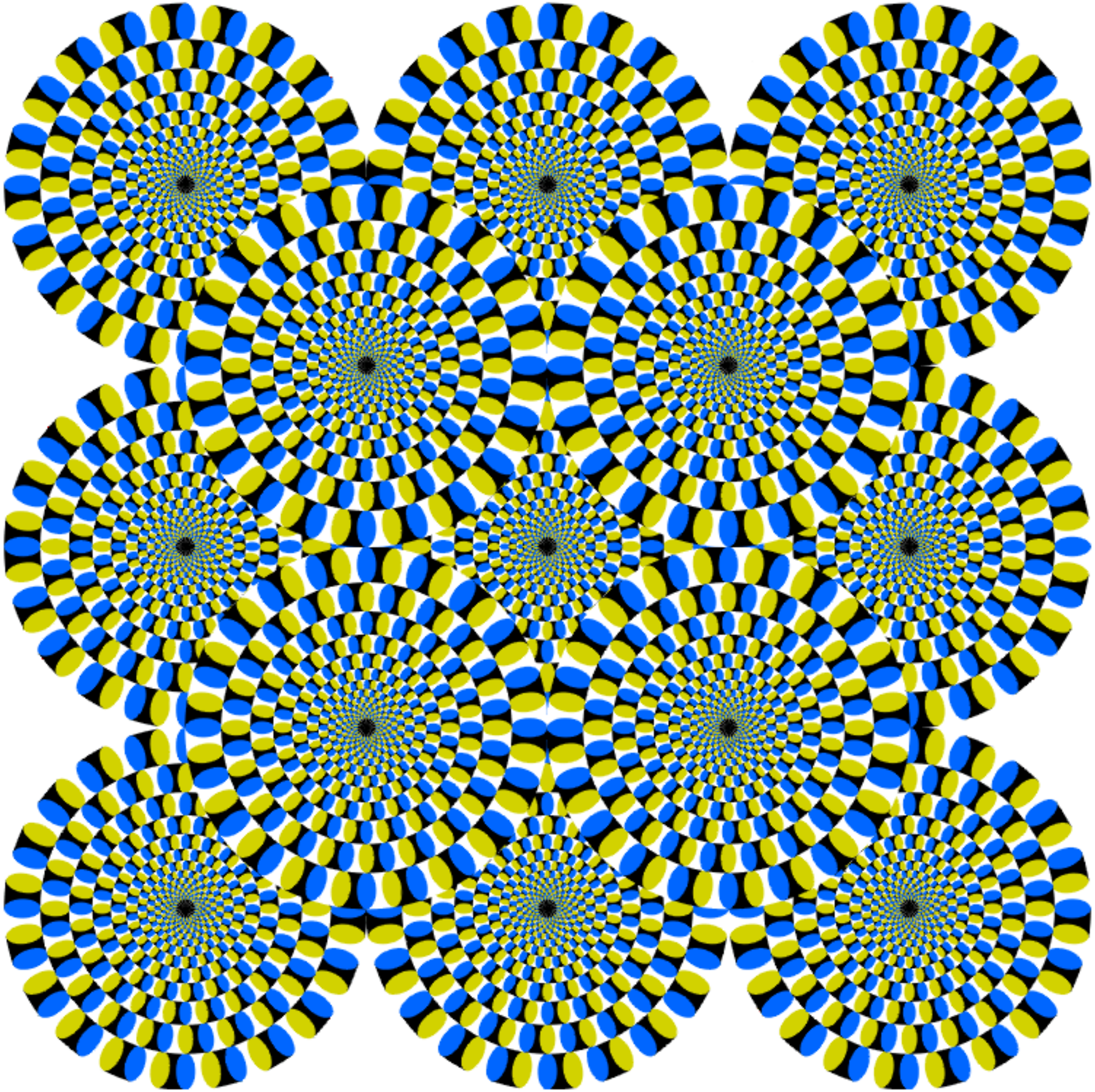


- http://www.xrite.com/online-color-test-challenge
- http://kolor.moro.es
- https://www.arealme.com/colors/en/
- https://www.colorlitelens.com/color-matching.html

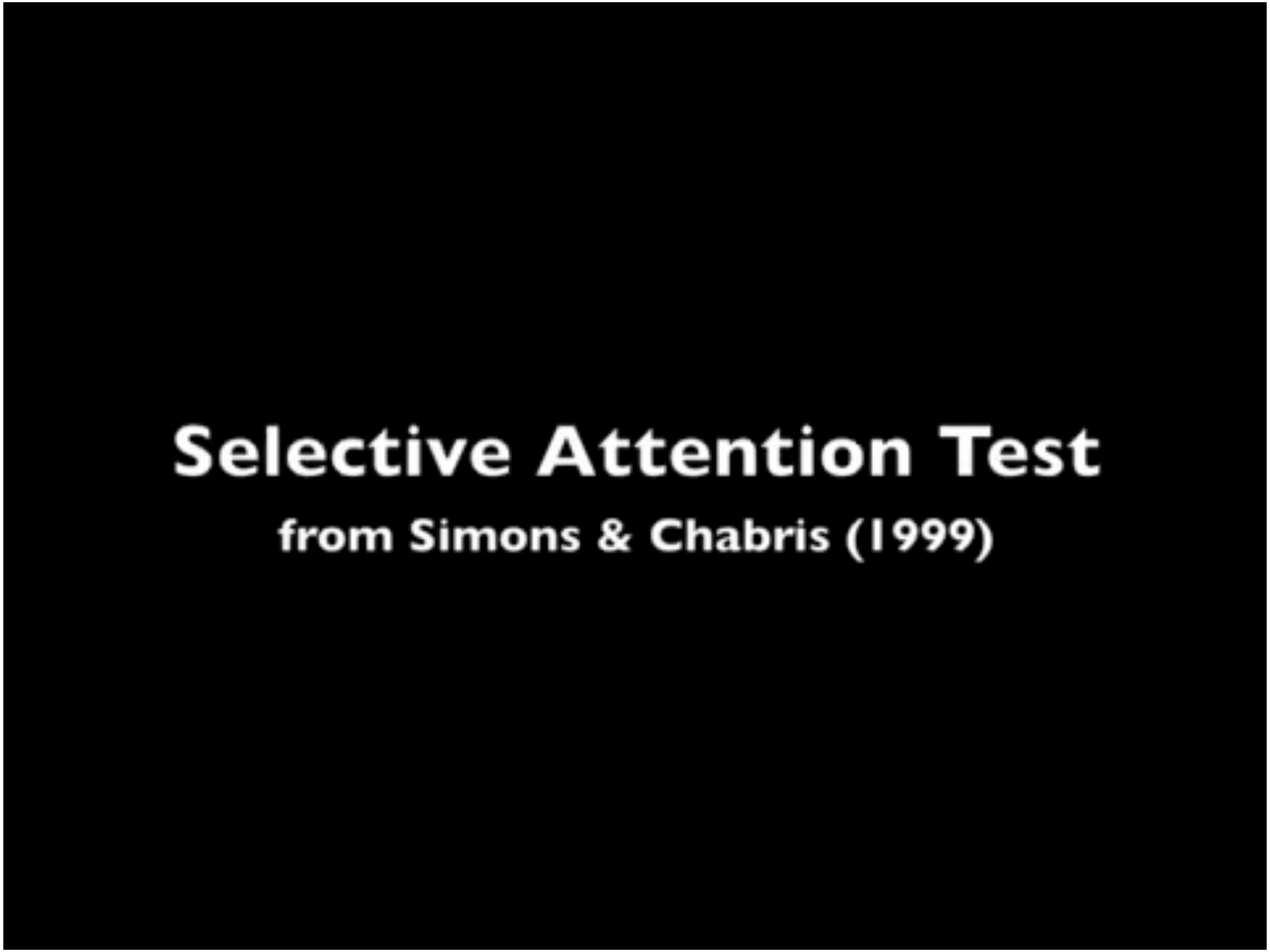


What is the color of this dress?

Girl or boy?



Selective attention



The Monkey Business Illusion

Daniel J. Simons

The "Door" Study

from Simons & Levin (1998)

Ergonomic Criteria

Ergonomic Criteria
(Bastien et Scapin)

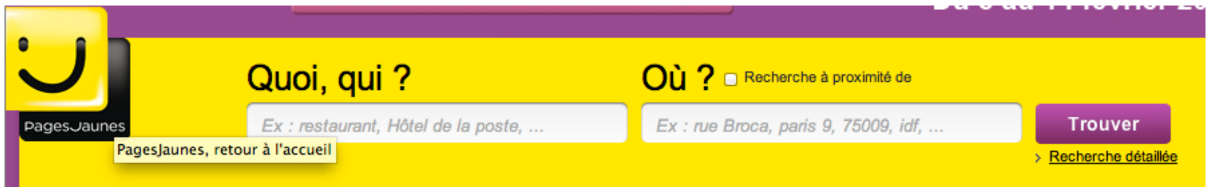
1. **Guiding**
2. **Workload**
3. **Explicit Control**
4. **Adaptability**
5. **Error Management**
6. **Homogeneity / Consistency**
7. **Significance of Codes and Denominations**
8. **Compatibility**

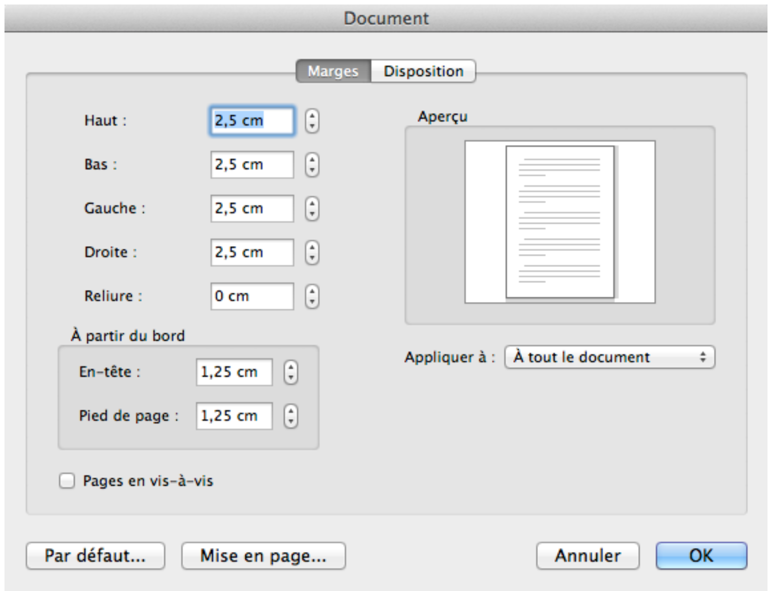
- *Rapport INRIA No 156, juin 1993*
- *http://www.ergoweb.ca/criteres.html*
- *http://www.ergolab.net/articles/criteres-ergonomiques-1.php*

1. Guiding

1.1 Incentives

- **Identify state of context**
  - to lead the user to take appropriate actions:
  - *"where am I, what can I do, how do I get out..."*
- Examples
  - formats, units, current status, online help

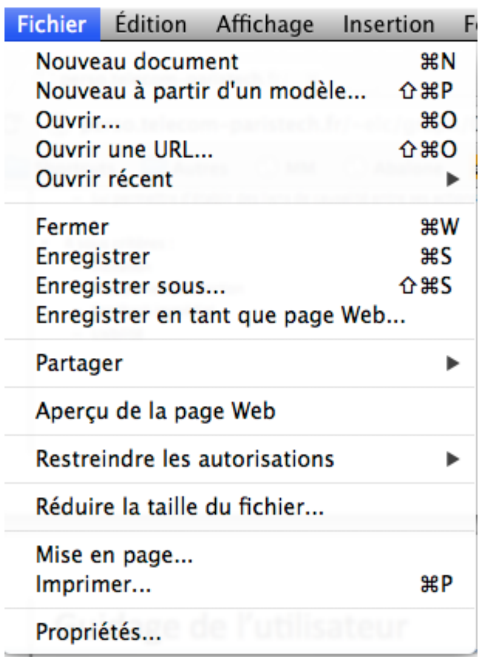


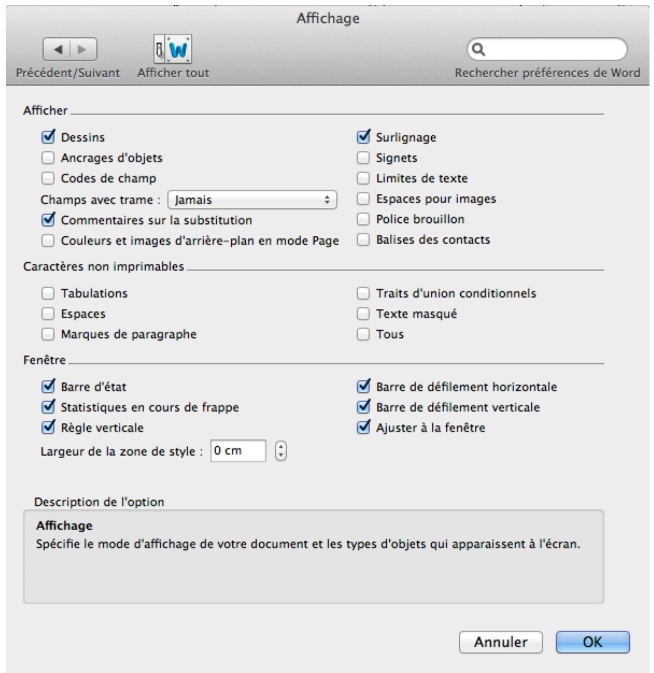


1. Guiding

1.2 Grouping / distinction between items

- **Visual organization** (location, format, color)
    - according to relationships between items, categories, etc.
- Examples
    - hierarchical lists, menus, groups, boxes

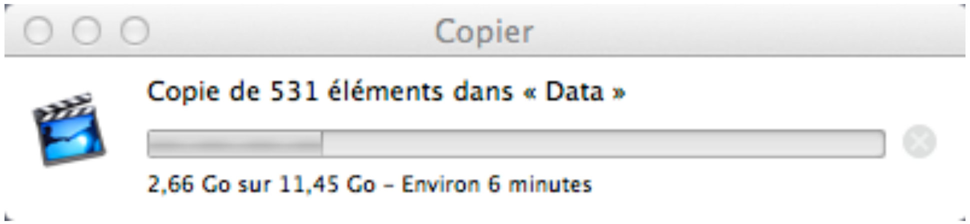




1. Guiding

1.3 Immediate feedback

- **Provide an answer** as quickly as possible
- Example
  - long operation ➔ **visual feedback** (clock, gray ...)



1. Guiding

1.4 Readability

- **Presentation**
    - color, contrast, size, text spacing

contrast and color

capitalize text

avoid many short lines

prefer **non-serif** fonts

avoid **italics**

line spacing

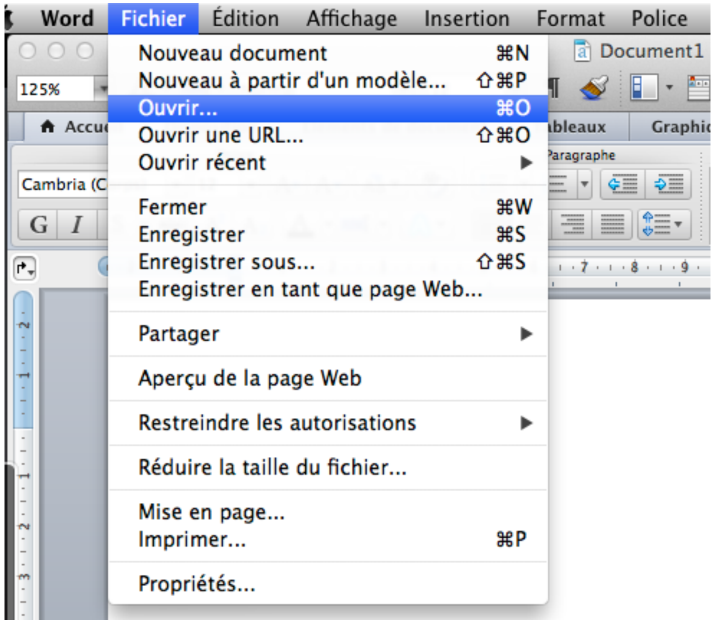
...

2. Workload

2.1 Brevity

- **Limit reading** and intermediate steps
  - short entries, short items, minimal actions

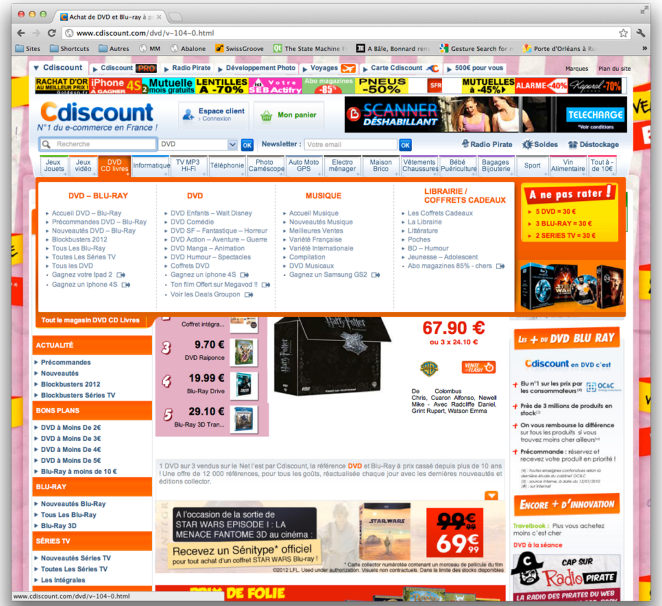
- Examples
  - abbreviations, shortcuts
  - avoid sub-sub menus



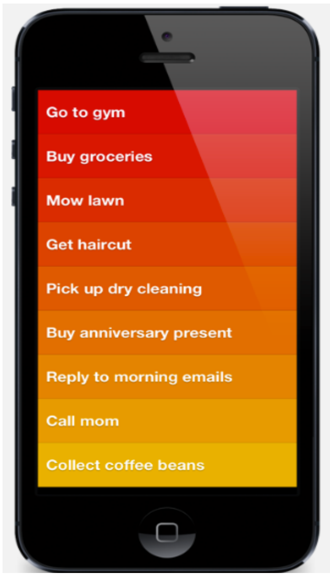
2.Workload

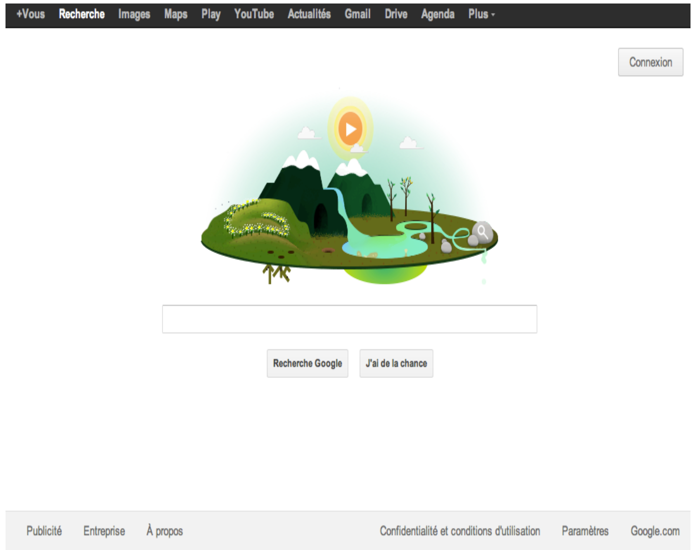
2.2 Information Density

- Avoid forcing the user to memorize **long/complex procedures**



- Examples
  - display only **what is needed**
  - avoid having to **remember previous data**
  - precalculate what that can be



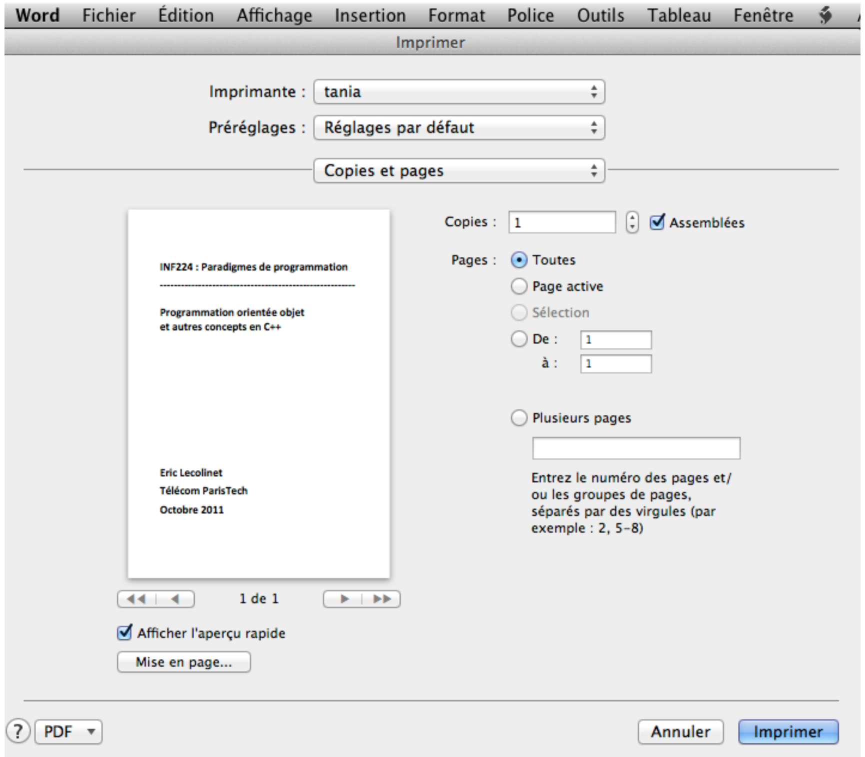


3. Explicit Control

3.1 Explicit actions

- The system should execute only the **requested** operations,

- Examples
  - explicit **confirmation** (Enter key, OK button)
  - avoid **implicit** actions

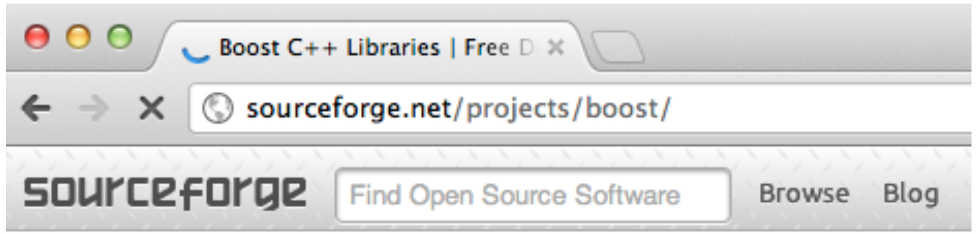


"Print" should not perform "Save"

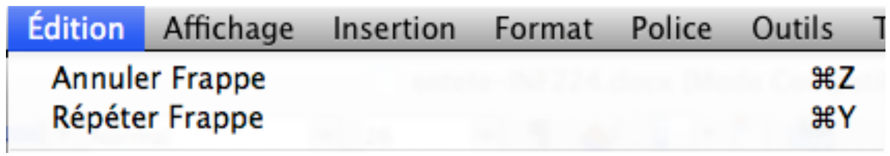
3. Explicit Control

3.2 User control

- The user must be **"in control"**



- Examples
  - Stop, Undo/Redo
  - Avoid moving the cursor programmatically

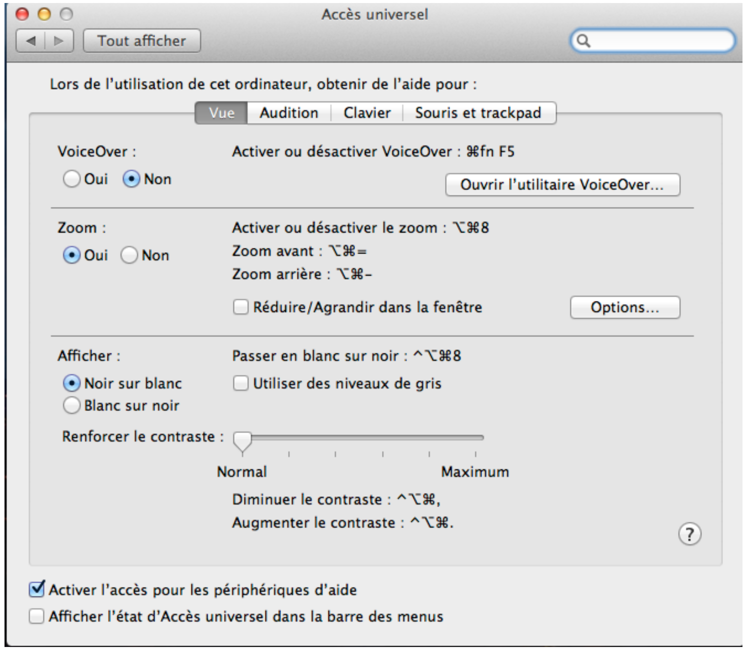


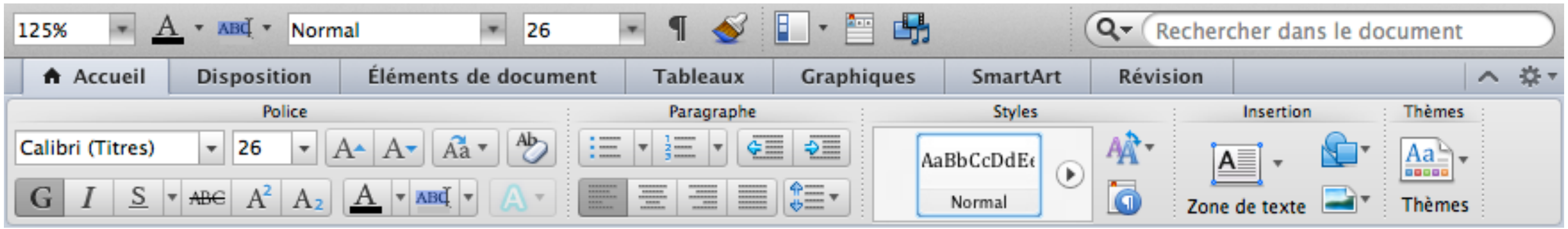
4. Adaptability

4.1 Flexibility

- Ability of the user interface to **adapt** to users
  - customization
  - offer several ways to achieve a goal

- Example: preference setting



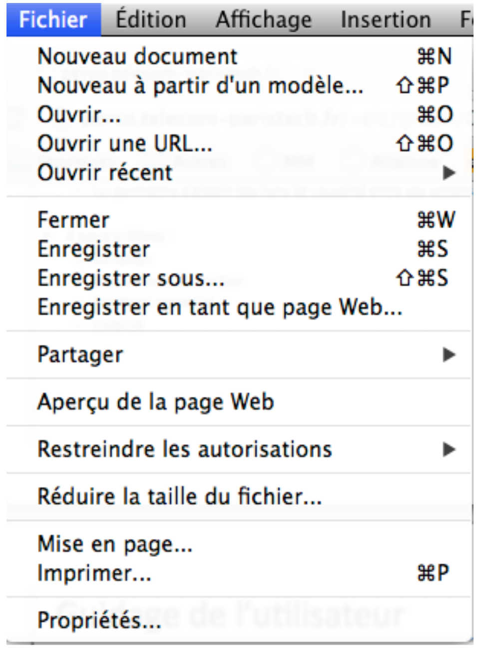


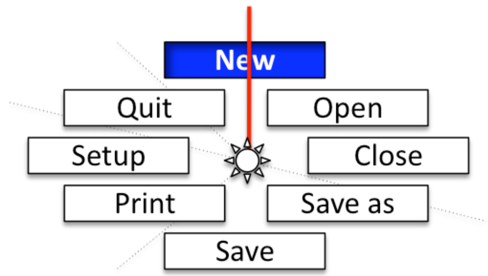
4. Adaptability

4.2 Take experience into account

- **Novice users:**
  - guided interaction, cascaded menus

- **Expert users:**
  - keyboard shortcuts, contextual menus
  - inhibit auto-guidance, more concise messages

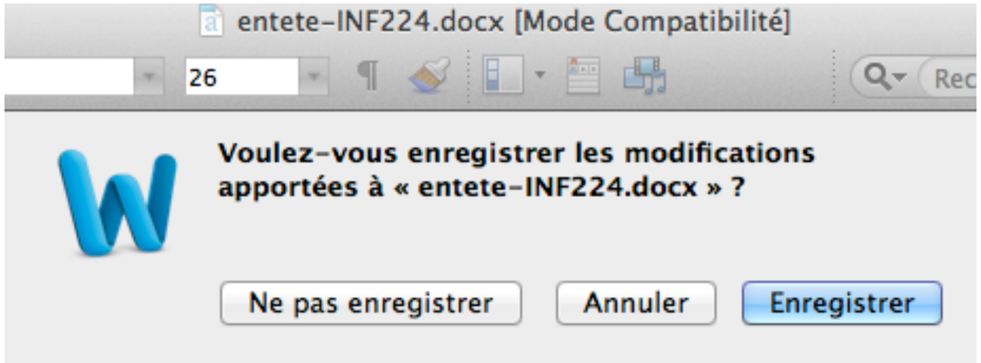




5. Error Management

5.1 Protection

- Detect errors during **input, before validating**
- Examples
  - confirmation of end of session
  - consider possible accidental actions

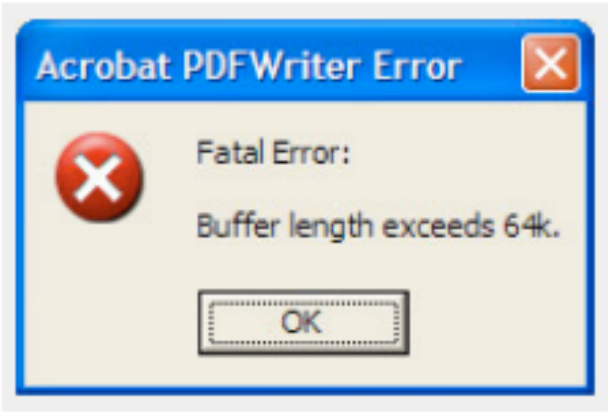


5. Error Management

5.2 Quality of messages

- **Relevance, readability, accuracy**

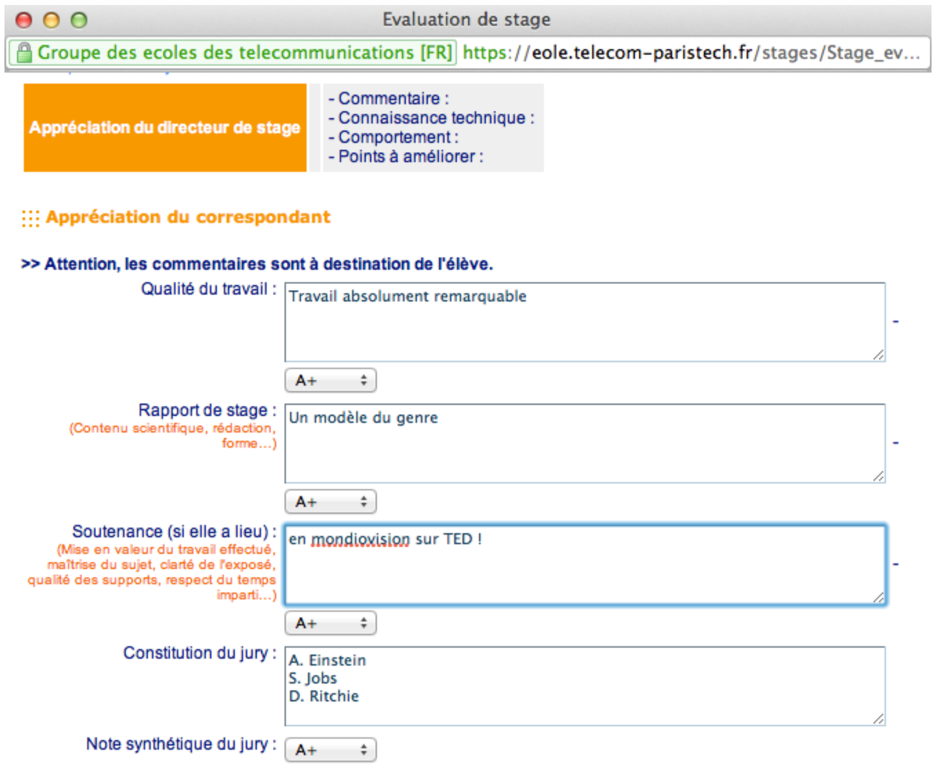
- Examples
  - invalid key ➔ no action or appropriate message
  - short messages, specific terms, avoid humour!



5. Error Management

5.3 Correction

- Make it possible for the user to **correct**:
  - during input
  - only the wrong part (so that she does not have to retype everything)

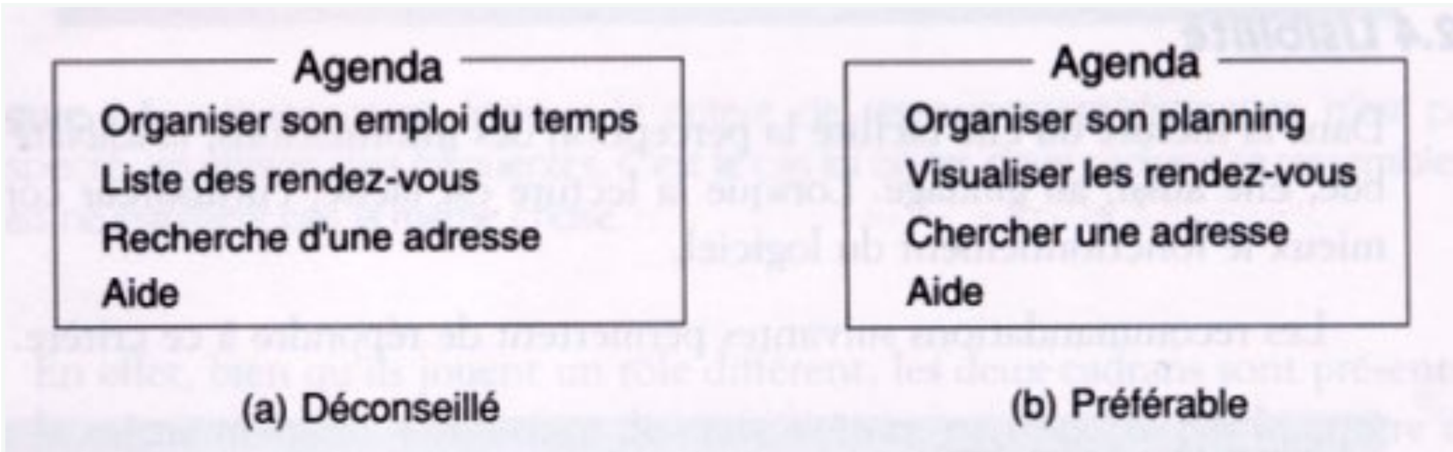


example: don't loose data on a timeout

6. Homogeneity / Consistency

Homogeneity of design choices

- **Similar screen formats**
- **Uniformity of:**
  - menus
  - formats
  - headings
  - procedures



7. Codes and Denominations

Adequacy of displayed objects and referents

- **Informative** and **distinguishable** titles
    - **Explicit** abbreviation rules
    - **Significant** codes and names

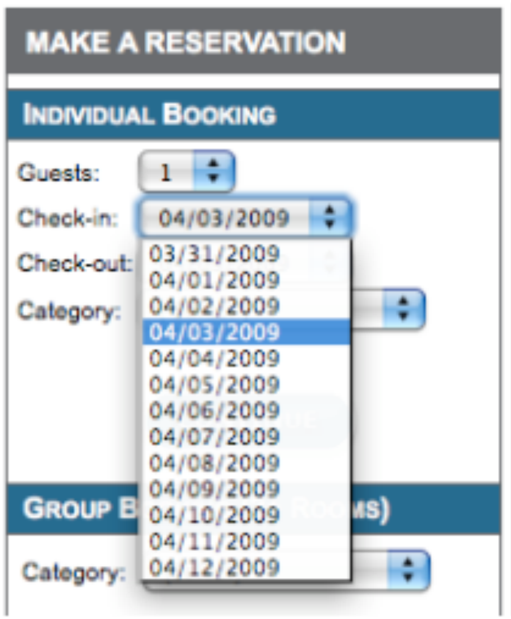
- Example: M and F rather than 1 and 2

8. Compatibility

8.1 Coherency between

- System dialogue and users' **habits** or what they **imagine** of the system

- Examples
  - follow standards and paper conventions
  - standard terminology, international conventions
  - beware of **dates**, **numbers, units!**



8. Compatibility

8.2 Degree of similarity (transfer)

- Between environments or applications :
- ➔ style guides (Mac, Windows, Java...)