Pierre Ducoudray – Julien Plaquevent – Cyril Schmitt

VGIS – 2010

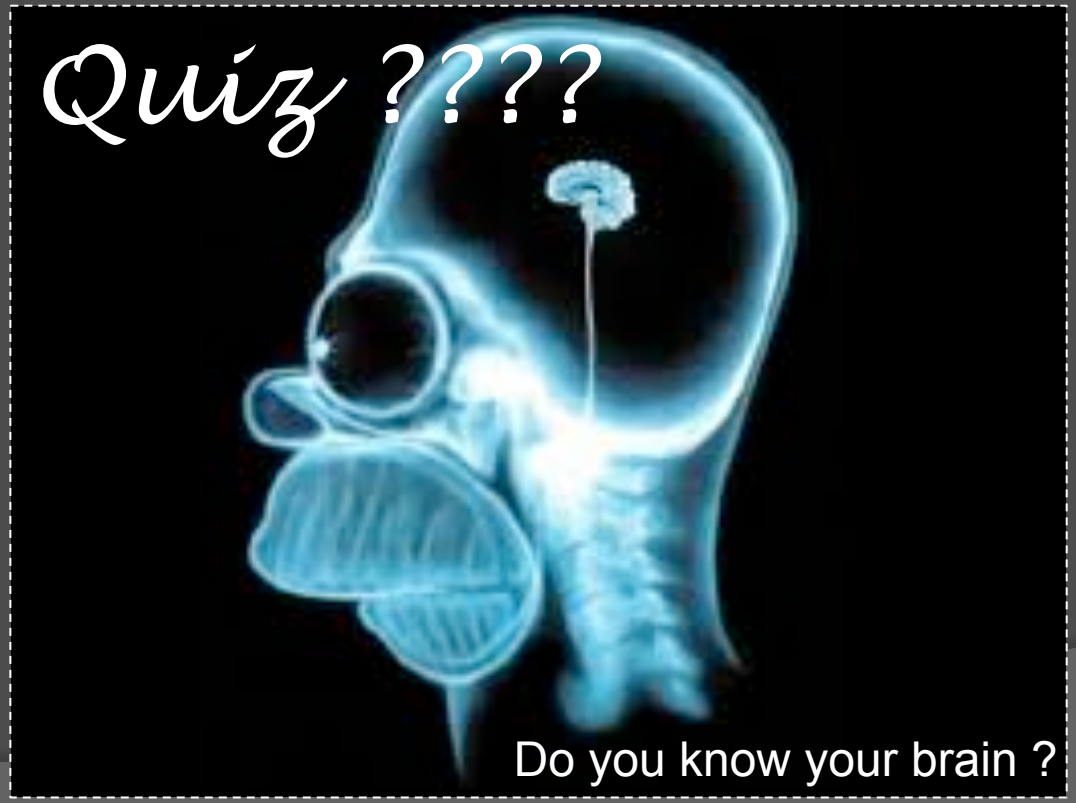
BRAIN-COMPUTER INTERFACES

TABLE OF CONTENTS

INTRODUCTION

- Communication between brain and an external device
- Began in the 1970s at UCLA
- Goal:
  - Assisting
  - Augmenting
  - Repairing
- The video which creates the buzz:
  - http://www.youtube.com/watch?v=gnWSah4RD2E

A LITTLE BIT OF ANATOMY



A LITTLE BIT OF ANATOMY

- How heavy is your brain ?
  - 600 g
  - 1,3kg
  - 2,2kg

Answer : 1,3 kg…. but some of us are more lucky than others

A LITTLE BIT OF ANATOMY

- How many main parts is your brain composed ?
  - 1
  - 2
  - 3

Answer : 3

A LITTLE BIT OF ANATOMY

- How many nerve cells are in the brain ?
  - 100 millions
  - 10 billons
  - 100 billions

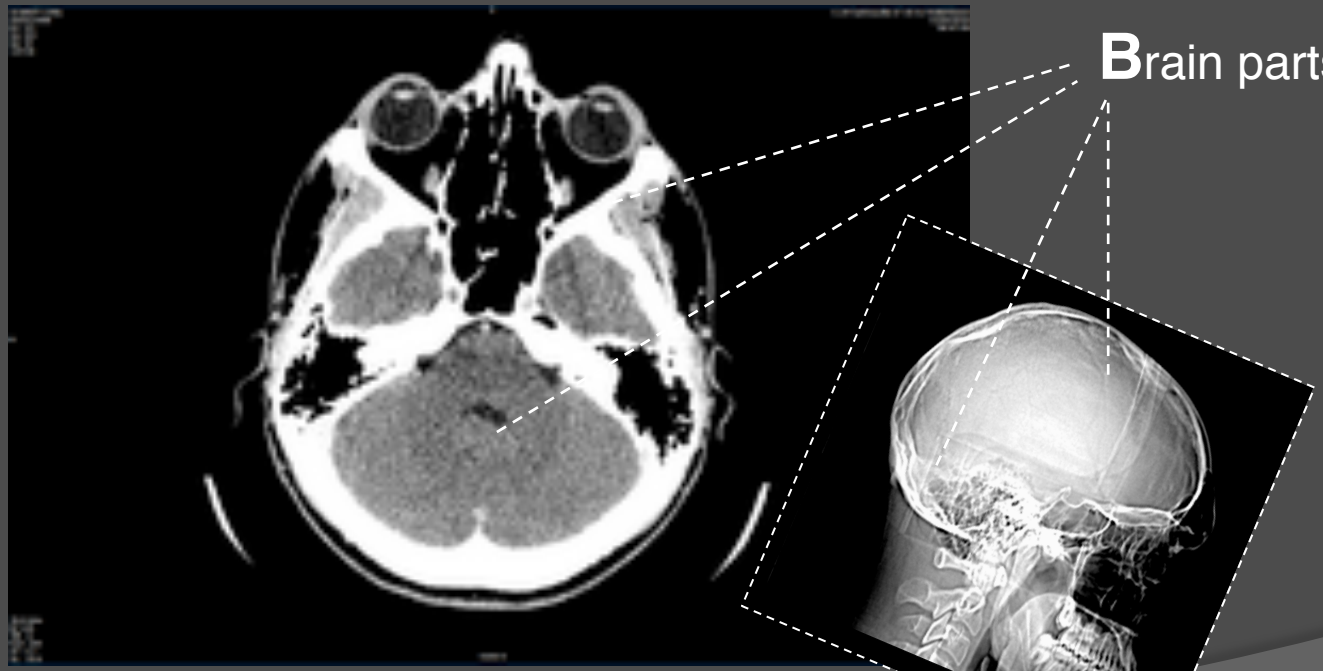
Answer : 100 billions called neurons

A LITTLE BIT OF ANATOMY

- If you have Parkingson's disease, what part of the brain is affected ?
  - Lower Brain
  - Midbrain
  - Higher brain

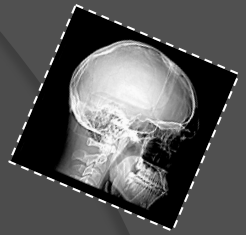
Answer : Midbrain

A LITTLE BIT OF ANATOMY

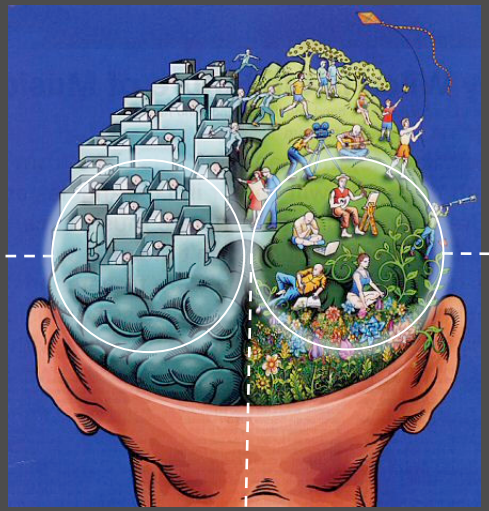


Brain parts

A LITTLE BIT OF ANATOMY



- The brain is divided in three parts



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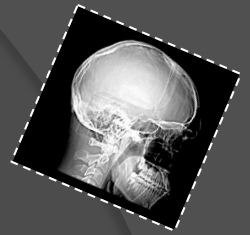
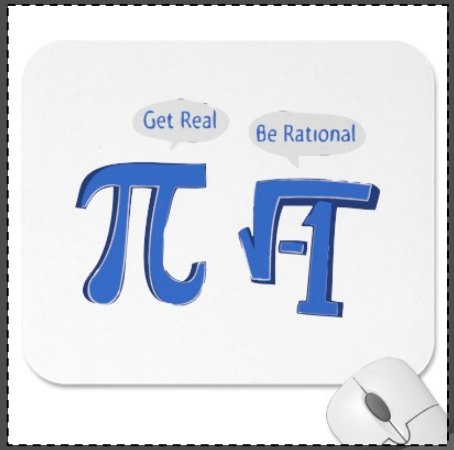


- Left Brain
  - Verbal language
  - Analytical
  - Rational



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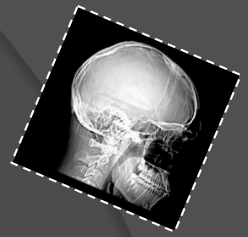


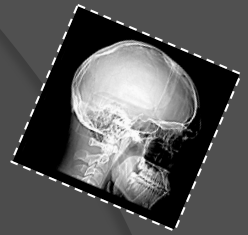
- Right Brain

  - Visual
  - Non verbal language
  - Intuitive

A LITTLE BIT OF ANATOMY

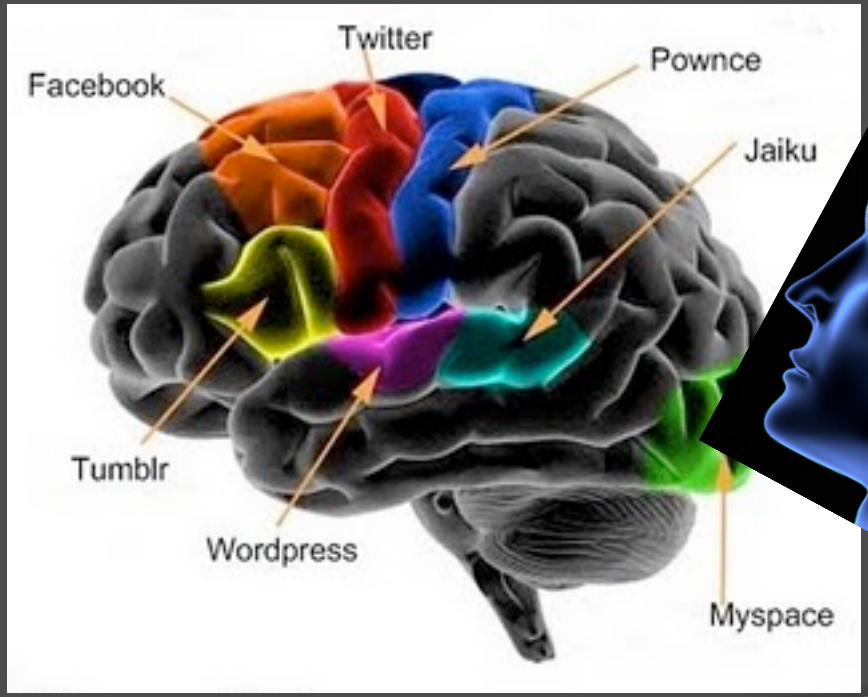
- Dancer test

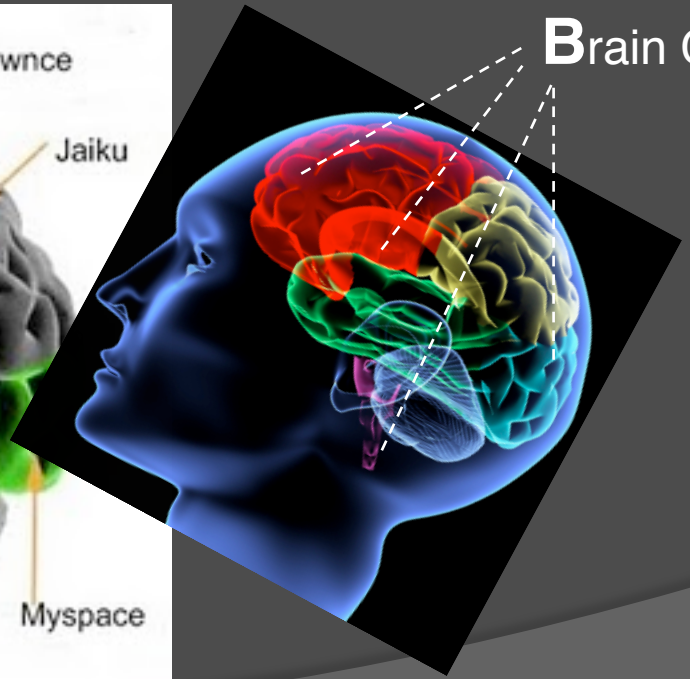
A LITTLE BIT OF ANATOMY



- Those two parts :
  - Are linked together by the Middle Brain
  - 83% of the encephalon mass
  - Control the half opposite part of the body
  - Are composed in several lobes

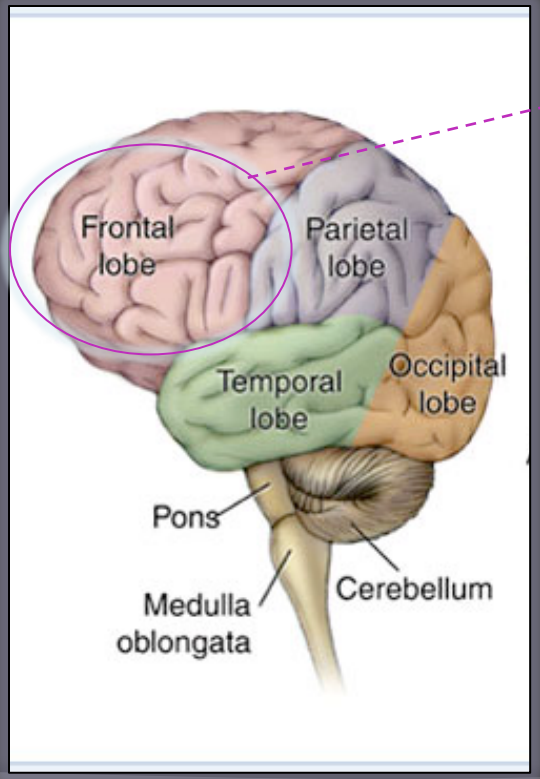
A LITTLE BIT OF ANATOMY





Brain Composition

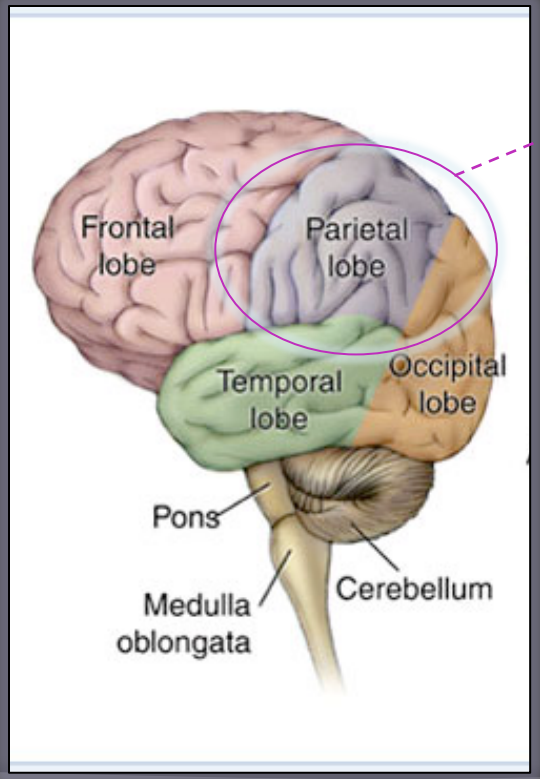
A LITTLE BIT OF ANATOMY



Frontal Lobe

- Control skilled muscle movements
- Mood
- Planning, future
- Setting goals

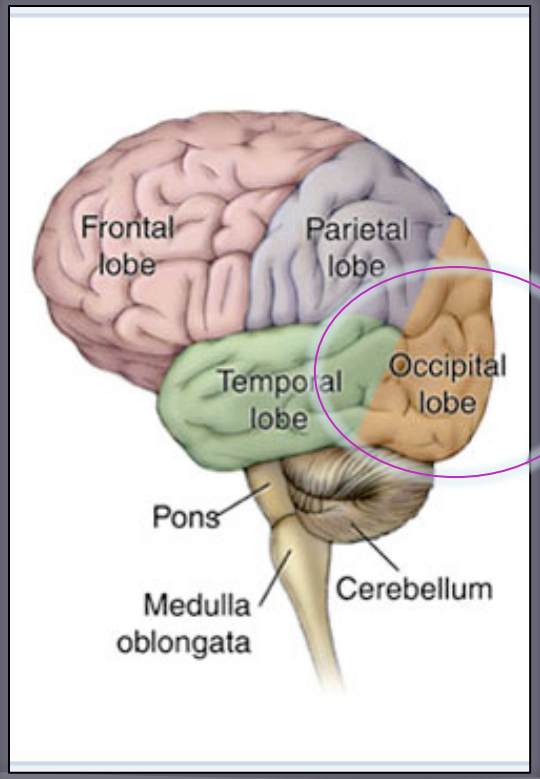
A LITTLE BIT OF ANATOMY



Parietal Lobe

- Temperature
- taste
- Touch
- Arithmetic reading

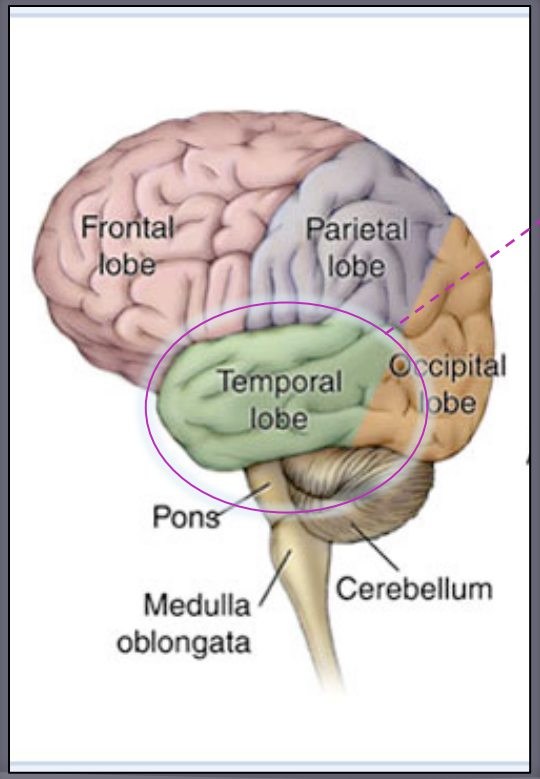
A LITTLE BIT OF ANATOMY



Occipital Lobe

- Process visual information

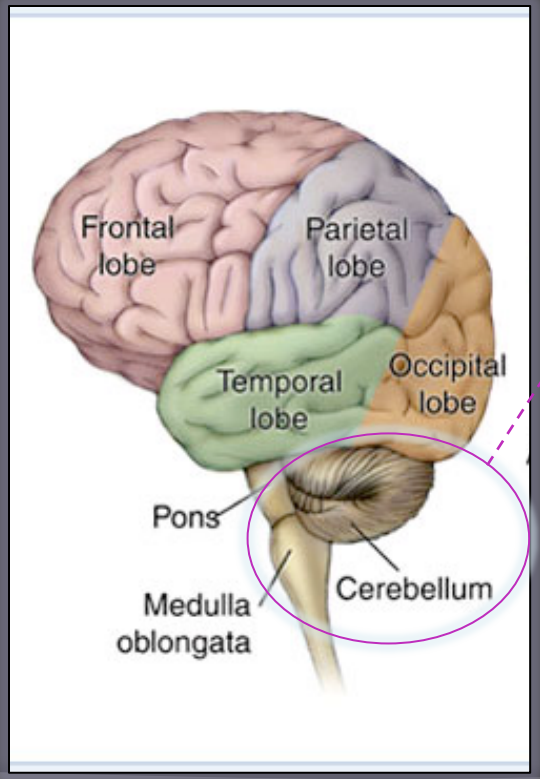
A LITTLE BIT OF ANATOMY



Temporal Lobe

- Hearing
- Memory
- Language

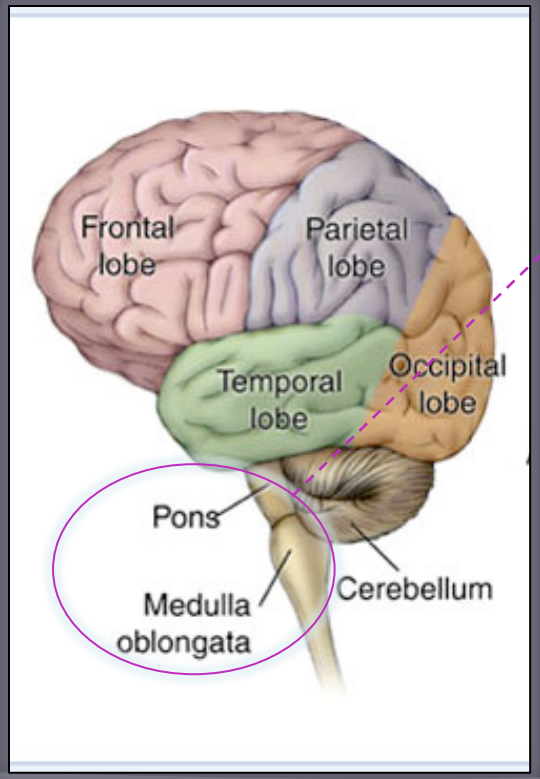
A LITTLE BIT OF ANATOMY



Cerebellum

- Governs movements

A LITTLE BIT OF ANATOMY



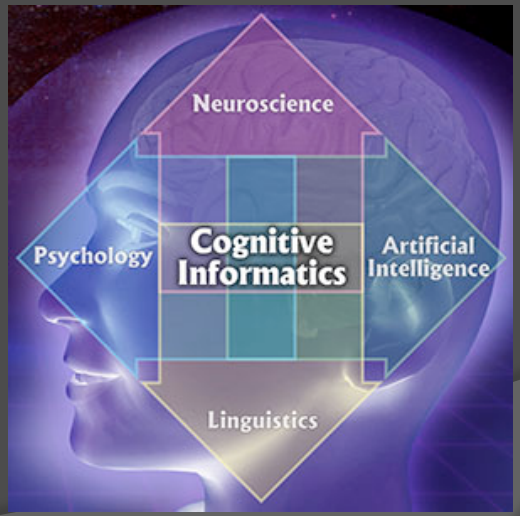
Pons / Medulla Oblogata

- Respiration
- Heart rate
- Swallowing
- Blood pressure

WHY BCI?

- To come up to human's behaviour

  - Cognitive informatics :
    - Psychology
    - Neuro Science
    - Linguistics
    - A.I



WHY BCI?

- Helpfull for brain-damaged people
  - Blindness
  - Motor disabilities
  - Neural diseases (Parkinson)

WHY BCI?

- User Experience
  - Let’s see some UX rules & the Human cognitive process

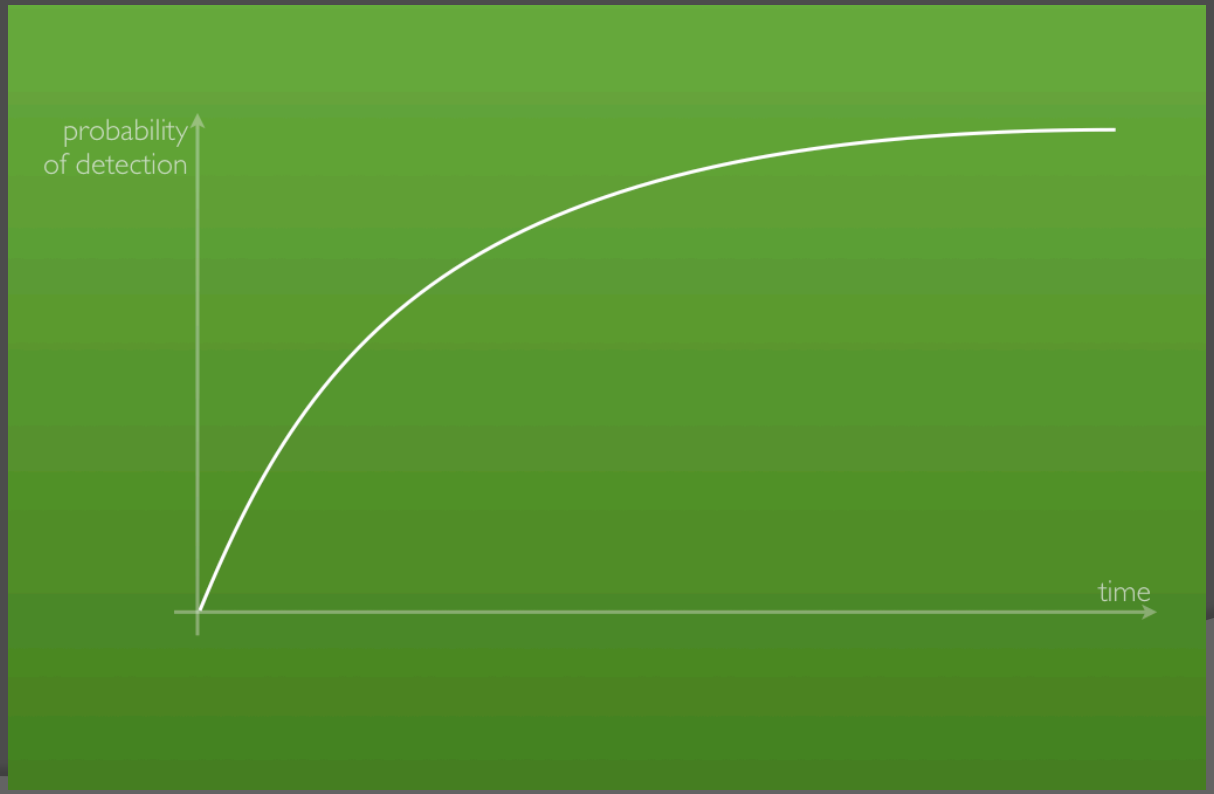
WHY BCI?

- Hicks'law :

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

- With :
  - T : time to choose the good item
  - b : constant
  - n : number of items of the list

WHY BCI?



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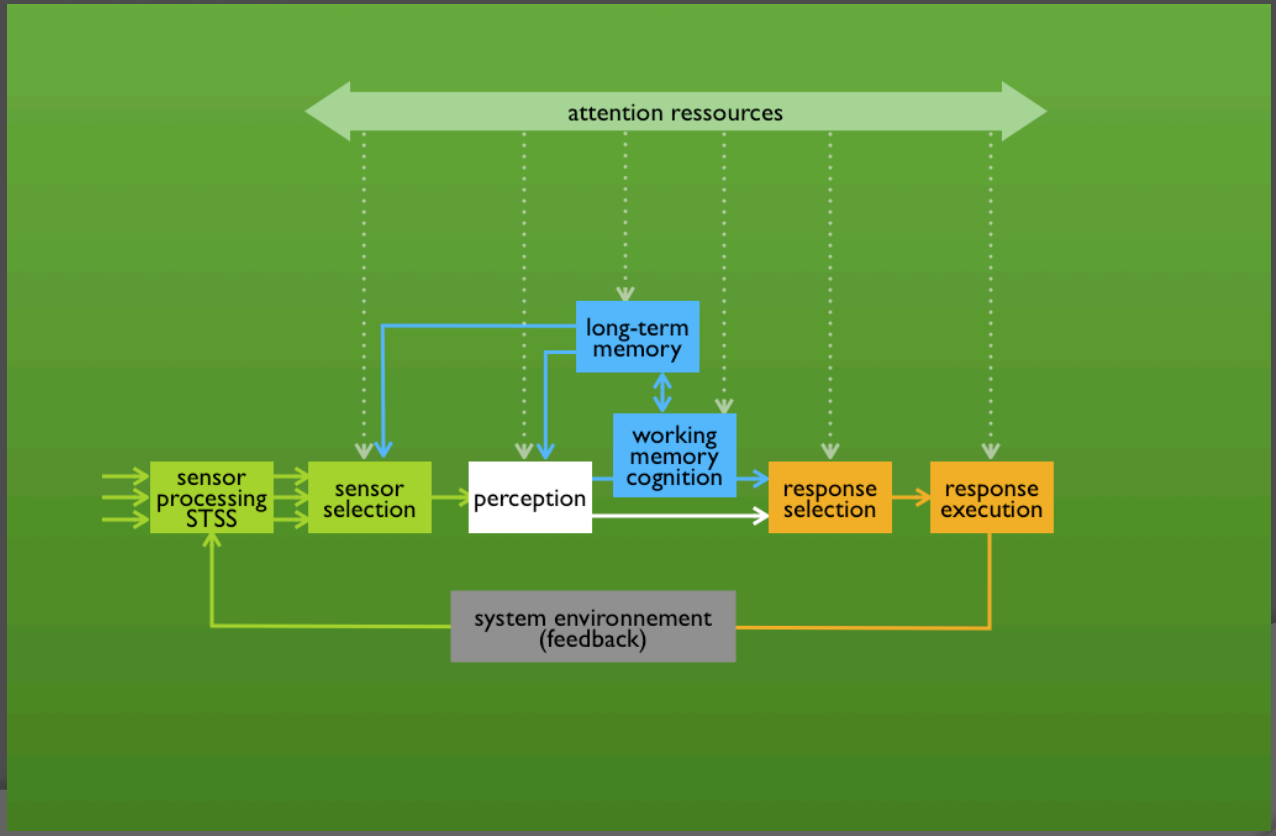
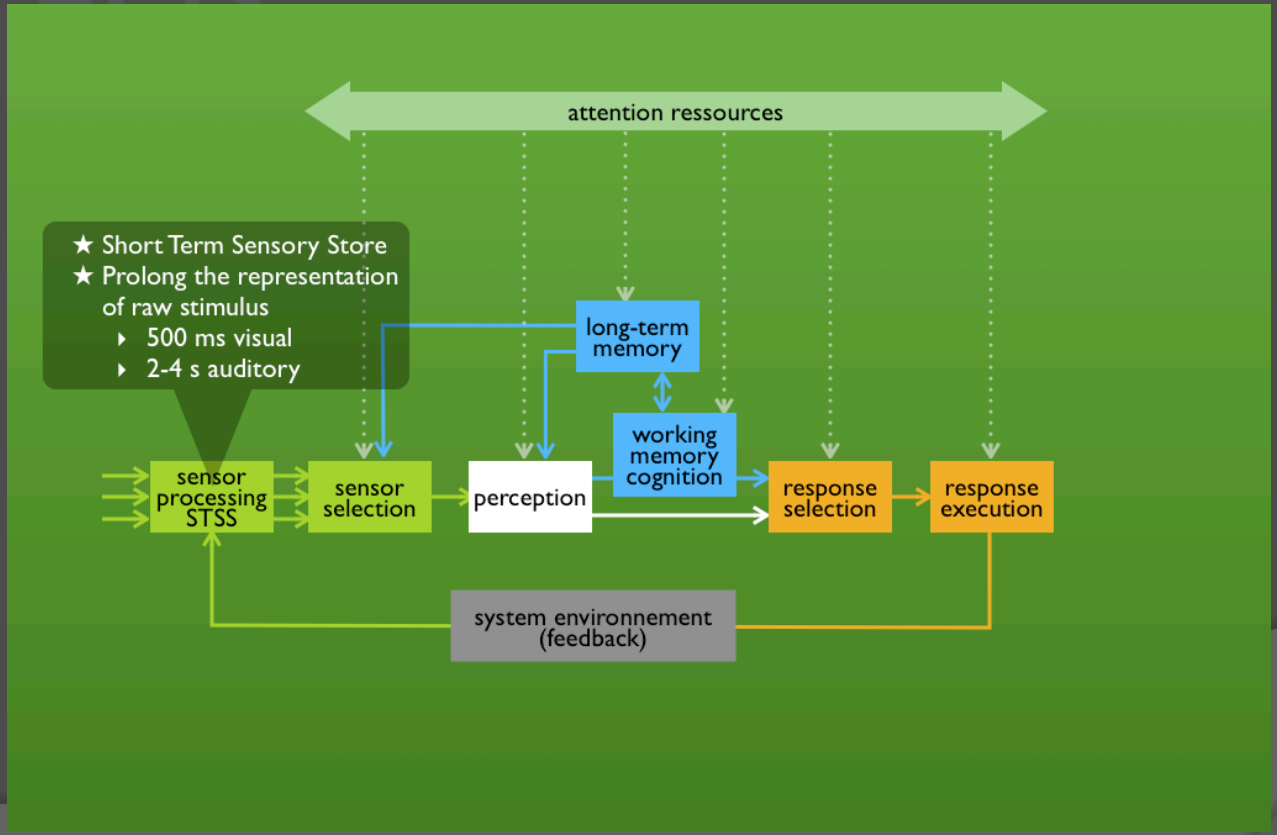

attention ressources
long-term memory
working memory cognition
sensor processing STSS
sensor selection
perception
response selection
response execution
system environnement (feedback)

WHY BCI?


attention ressources
★ Short Term Sensory Store
★ Prolong the representation of raw stimulus
500 ms visual
2-4 s auditory
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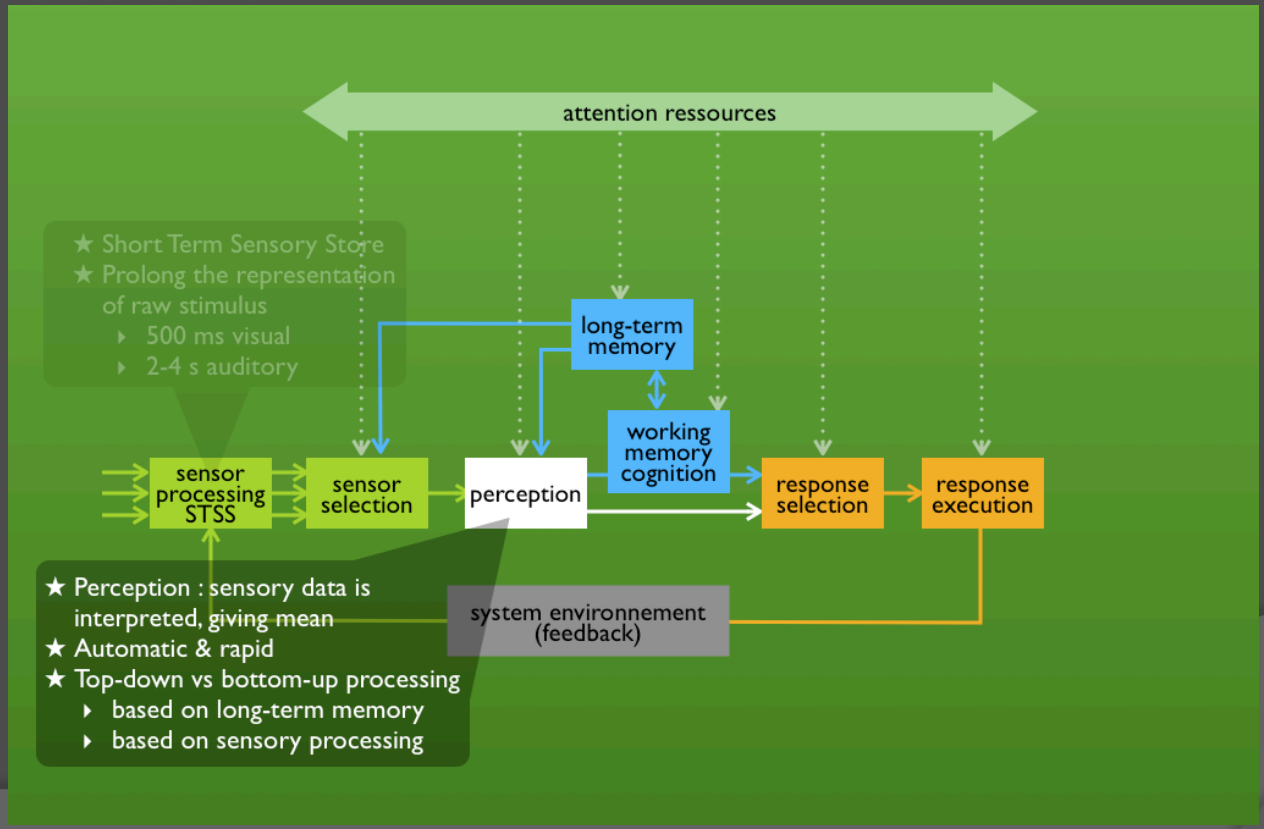
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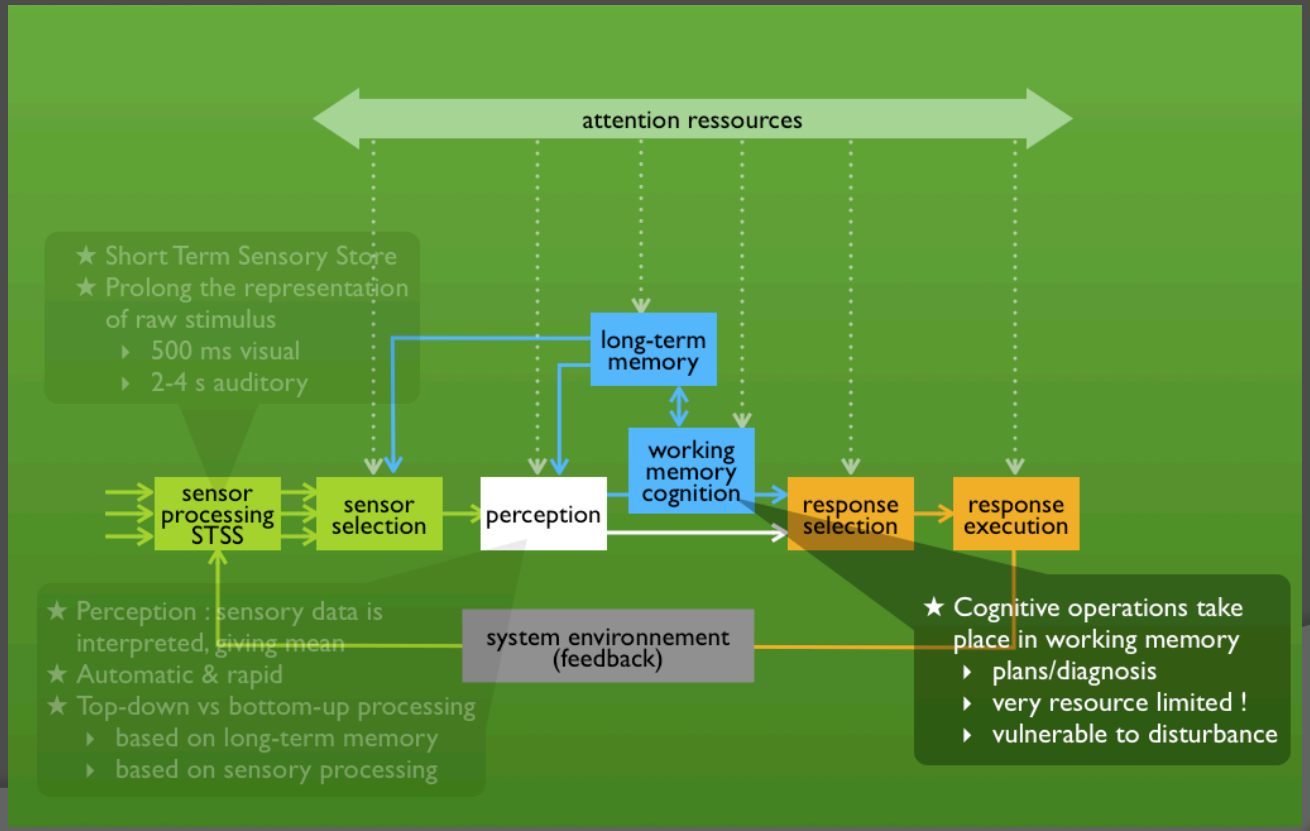
★ Perception : sensory data is interpreted, giving mean
★ Automatic & rapid
★ Top-down vs bottom-up processing
based on long-term memory
based on sensory processing

WHY BCI?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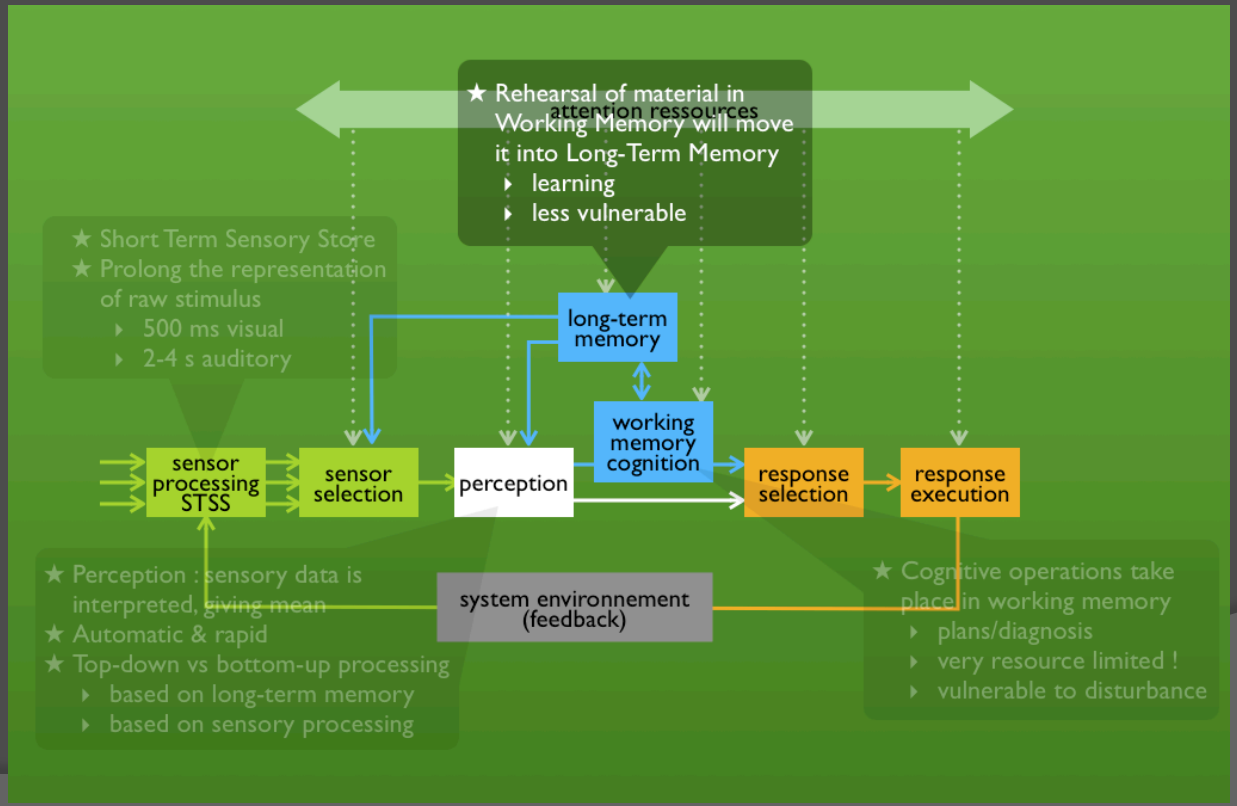
system environnement (feedback)
★ Cognitive operations take place in working memory
plans/diagnosis
very resource limited !
vulnerable to disturbance

WHY BCI?


★ Rehearsal of material in attention ressources Working Memory will move it into Long-Term Memory
learning
less vulnerable
★ Short Term Sensory Store
★ Prolong the representation of raw stimulus
500 ms visual
2-4 s auditory
long-term memory
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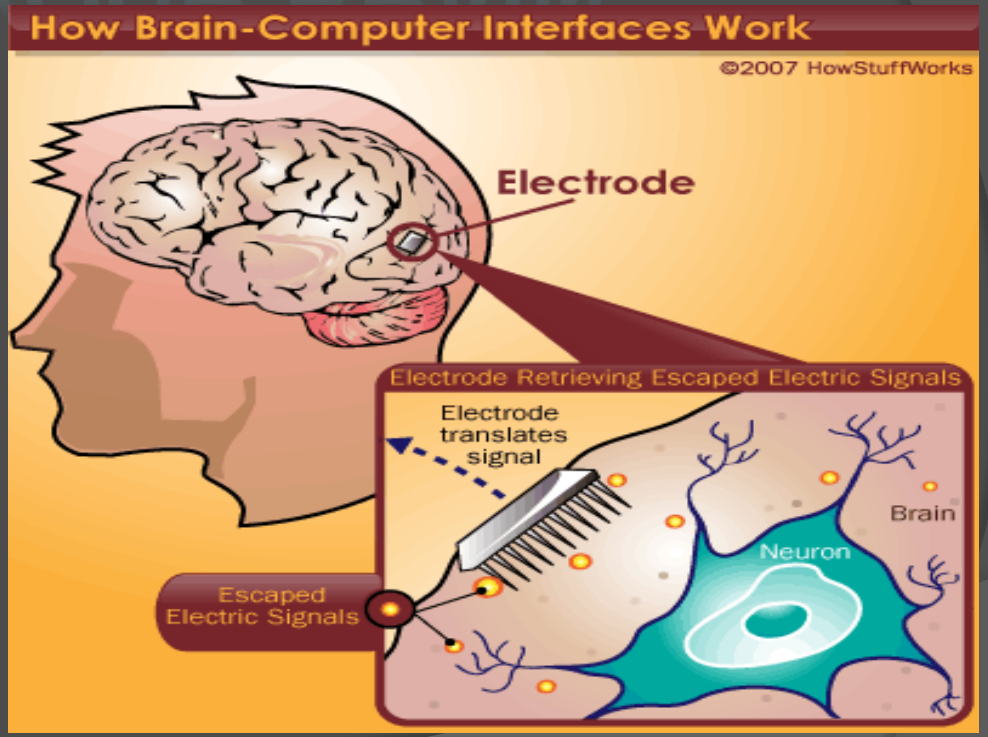
WHY BCI?

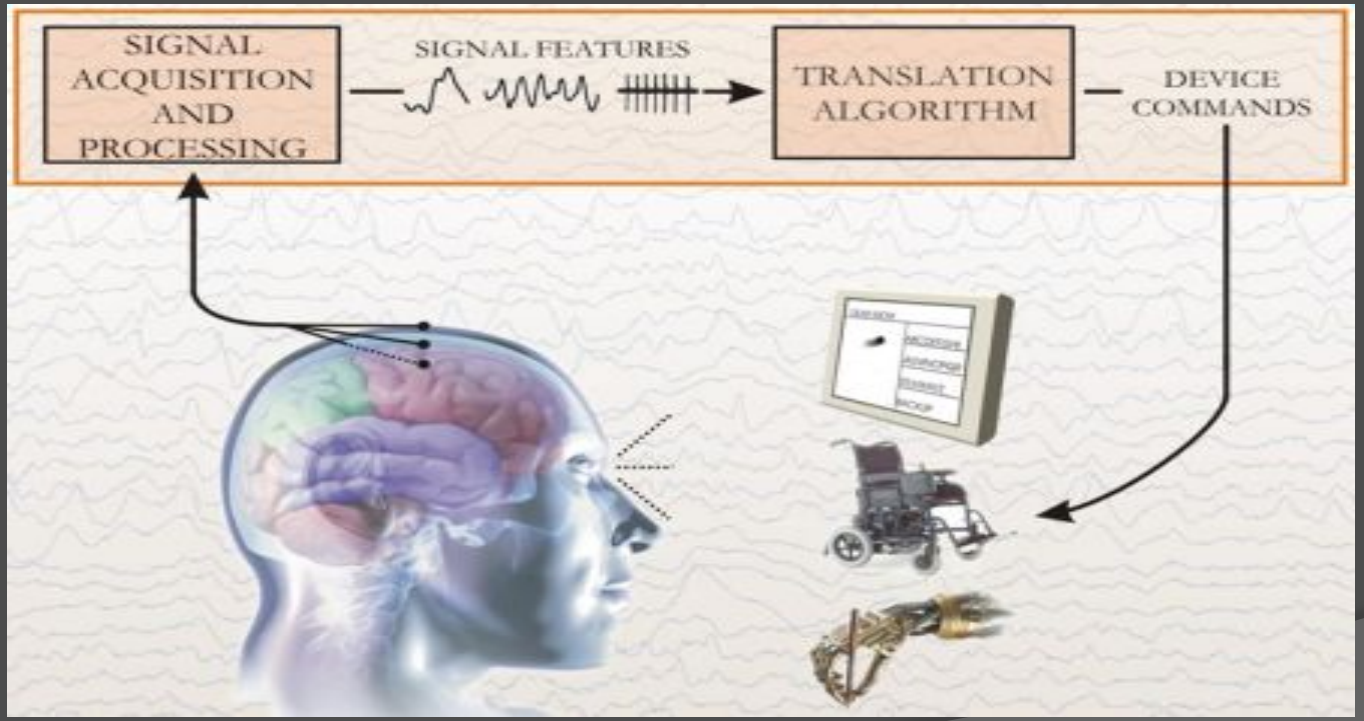
- Brain Computer Interface :
  - Save the detection time
  - Save the response execution time

READING IN YOUR BRAIN

- Principle: connect a device to the central nervous system and analyze its signals



READING IN YOUR BRAIN



READING IN YOUR BRAIN

- Need lots of experiment
- Need to know the brain better
- Technologies:
  1. Invasive
  2. Partially-invasive
  3. Non-invasive

1. Invasive

- Directly implanted in the grey matter of the brain
- Advantage: highest quality signals
- Disadvantages:
  - Dangerous to implant
  - Scar-tissue over the device
- Two examples:
  - Bring sight to blind
  - Artificial hand to tetraplegic

1. Invasive

Bring sight to blind : Jens Naumann

- Material
  - 68-electrode device in the visual cortex
  - 2 cameras mounted on glasses
- Principle
  - Cameras send signals to the device
  - Device produces phosphenes
- Result
  - The device allows to see grey shades in a limited field of view

1. Invasive

Artificial hand to tetraplegic

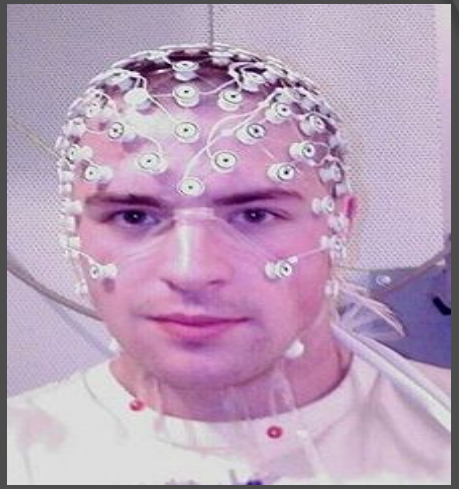
- Material
  - BrainGate implanted in right precentral gyrus
  - Artificial hand
- Principle
  - BrainGate detects signals send by the brain
  - Artificial hand moves in function of the signal
- Result
  - BrainGate allows to move the artificial hand as his own

2. Partially-Invasive

- Implanted inside the skull but outside the brain
- Advantage: lower risk of forming scar-tissue
- Disadvantage: produce worse resolution signal
- Principle: Electrocorticography (ECoG)
- Application: play “Space Invaders”

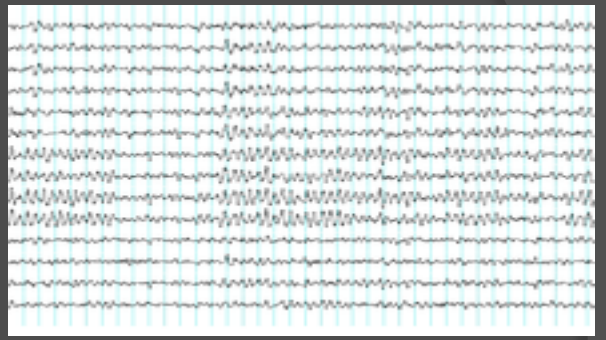
3. Non-Invasive

- Electrodes are placed over the head
- Advantage: no risk for the patient
- Disadvantage: poor signal resolution
- Principle: Electroencephalography (EEG)



3. Non-Invasive

- Fine temporal resolution
- Ease of use
- Portability
- Low set-up cost



- Noise susceptibility
- Slow process: many months of training

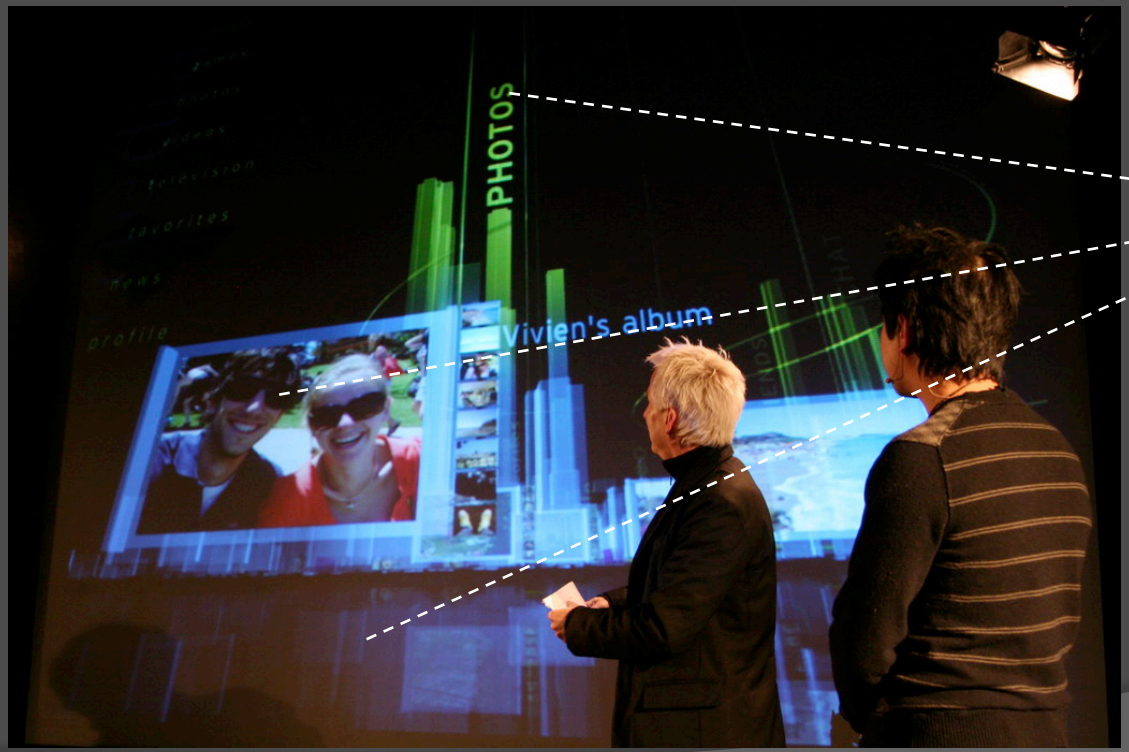
- Different types of waves:
  - Mu: motor cortex – movement or intent to move
  - Beta: motor cortex – movement resisting
  - P300: parietal lobe – recognition

3. Non-Invasive

- Two samples in video:
  - http://www.youtube.com/watch?v=K1SujPeqdXY
  - http://www.youtube.com/watch?v=i-WMzoqGAnY&feature=related

BREAK

COMERCIAL APPLICATIONS



COMERCIAL APPLICATIONS

- emotiv
  - emotive EPOC
  - 299$

COMERCIAL APPLICATIONS

- emotiv
  - SDK
  - From 500$ to 7 500$
  - OPL language

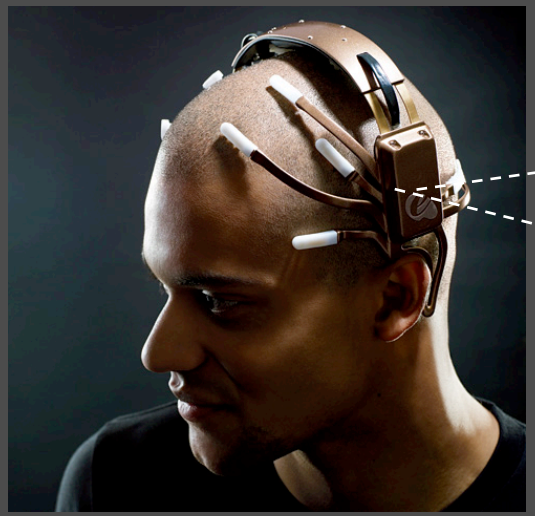
COMERCIAL APPLICATIONS

- Exemple of OPL

```
PROC Main:
   LOCAL bottles%
   LOCAL bottle$(10)
   CLS
   bottles%=99
   bottle$=" bottles"
   PRINT "99 Bottles of Beer"
   PRINT
   WHILE(bottles% > 0)
      PRINT bottles%;bottle$;" of beer on the wall,"
      PRINT bottles%;bottle$;" of beer on the wall."
      PRINT "Take one down and pass it around,"
      bottles%=bottles%-1
      IF(bottles% = 1)
         bottle$=" bottle"
      ENDIF
      IF(bottles% <> 0)
         PRINT "There'll be ";bottles%;bottles$;" of beer on the wall."
      ELSE
         PRINT "There'll be no bottles of beer on the wall."
      ENDIF
      PRINT
   ENDWH
   PAUSE 0
ENDP
```

COMERCIAL APPLICATIONS

- Send your brain data by OSC



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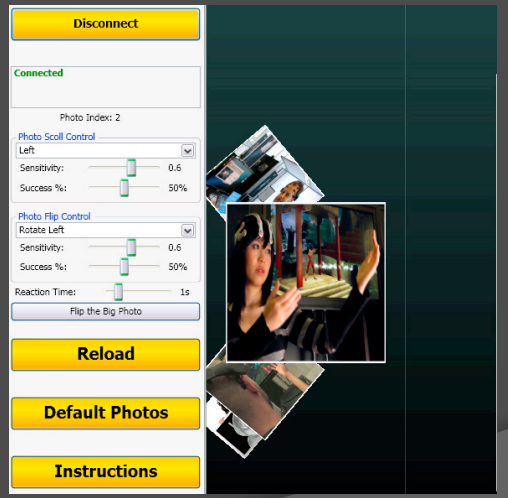
COMERCIAL APPLICATIONS

- emotiv products :
  - Game

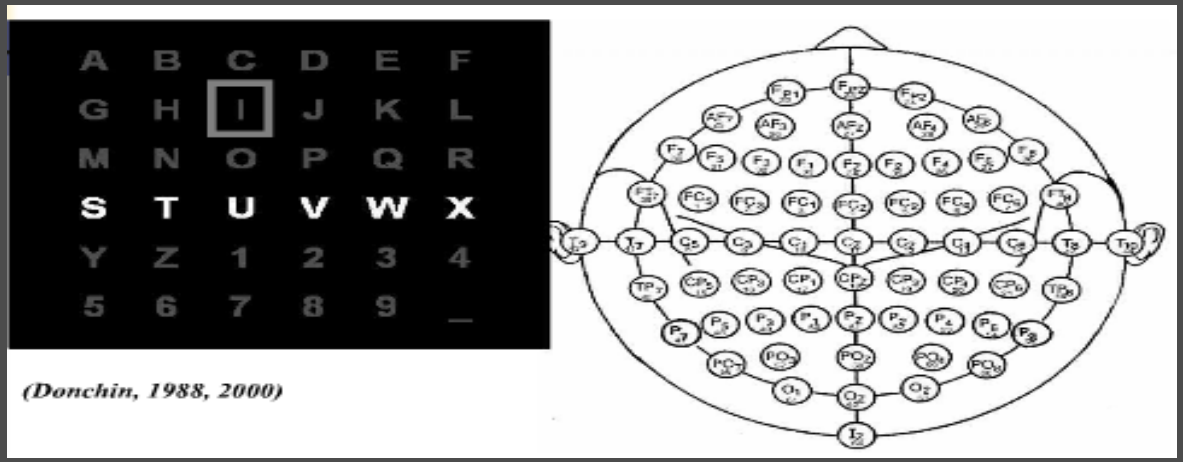
COMERCIAL APPLICATIONS

- emotiv products :
  - Accessibility
  - Pictures management



COMING SOON

- Write by thinking?



- Flashing of rows/columns which contain the desired letter will elicit P300 response at vertex

COMING SOON

- Military research about talk by mind
- Virtual reality

WRITING TO BRAINS

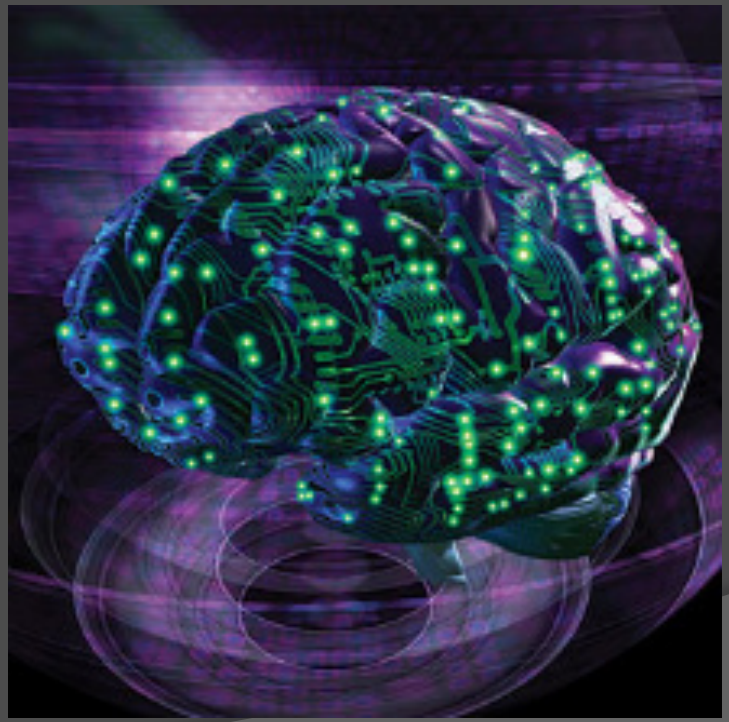
- Galvani's frog zombie
- Physical limits

1. Gero Miesenbock

- Australian Waynflete Professor of Physiology at Oxford
- Principal architect of optogenetics

2. Optogenetics

- Ten years old technic
- Interacting with the brain using light

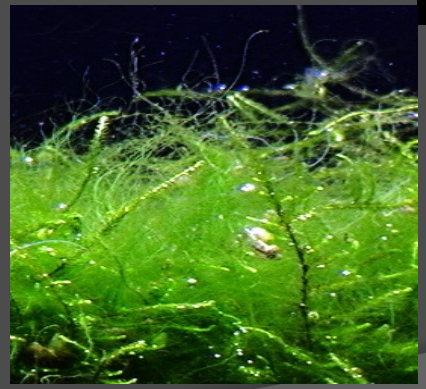


3. Optogenetics actors

- Light-emitting sensors
- Light-driven actuators
- Electrochemical signals

4. Optogenetics technologies

- Use of light responsive proteins encoded in DNA
  - mainly Channelrhodopsin-2 (ChR2) a single-component (1 gene) light-activated cation channel from photosynthetic algae
- Cells grouped anatomically or functionally



5. Optogenetics advantages

- Really fast (about 1 millisecond precision)
- Ability to broadcast to a group of cells
- Non-invasive

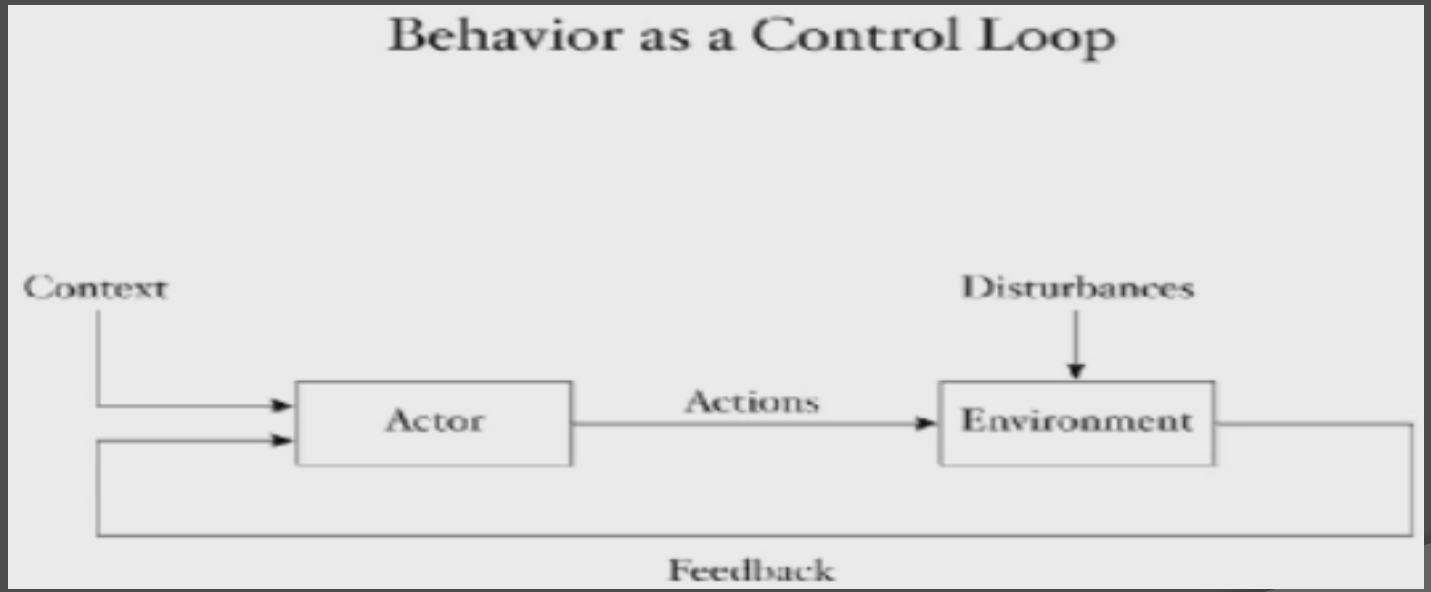
6. Dr. Miesenbock's aim

"If we could record the activity of all neurons,
we would understand the brain."

7. First experiment : headless flies flying

TED Ideas worth spreading

8. Second experiment : reengineering a brain



8. Second experiment : reengineering a brain

- Implant an unpleasant memory in a fruit fly
- 12-neuron brain circuit for memory formation

9. Interest

- Replacing lost functionalities
- Designing new functionalities
- Functionalities are about perception, action, cognition and memory

ETHICS

- Discussion

SOURCES

- http://www.neuroscience.ox.ac.uk/directory/gero-miesenboeck
- http://www.bbci.de/research
- http://www.ted.com/talks/gero_miesenboeck.html
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