



# Locked-in syndrome, eyes and laws for embodied cognition ?

*Perrine Séguin*

*MD in physical and rehabilitation medicine  
PhD student in neurosciences*

**Lyon Neuroscience Research Center (France)**

**Integrative, Multisensory,  
Perception, Action and Cognition  
(IMPACT) :**  
**Alessandro Farné**

**Cognition, Computation, Neurophysiology  
(COPHY) :**  
**Jérémie Mattout  
Emmanuel Maby**

**Cognition Auditive et  
Psychoacoustique (CAP) :**  
**Fabien Perrin**

# Restoring communication in global paralysis

Severe and global motor impairment:  
▪ Locked-in syndrome (LIS)  
▪ Amyotrophic Lateral Sclerosis (ALS)

A particular case for embodied cognition research:  
- Normal development  
- Severe acquired restriction of motor actions

Kyselo & Di Paolo, 2015:  
« LIS, a challenge for embodied cognition »

Alphabet board



« The diving bell and the butterfly » movie

Enough residual (oculo-)motor control ?

Yes

Eye-based  
Controller

No

Brain computer-  
interfaces



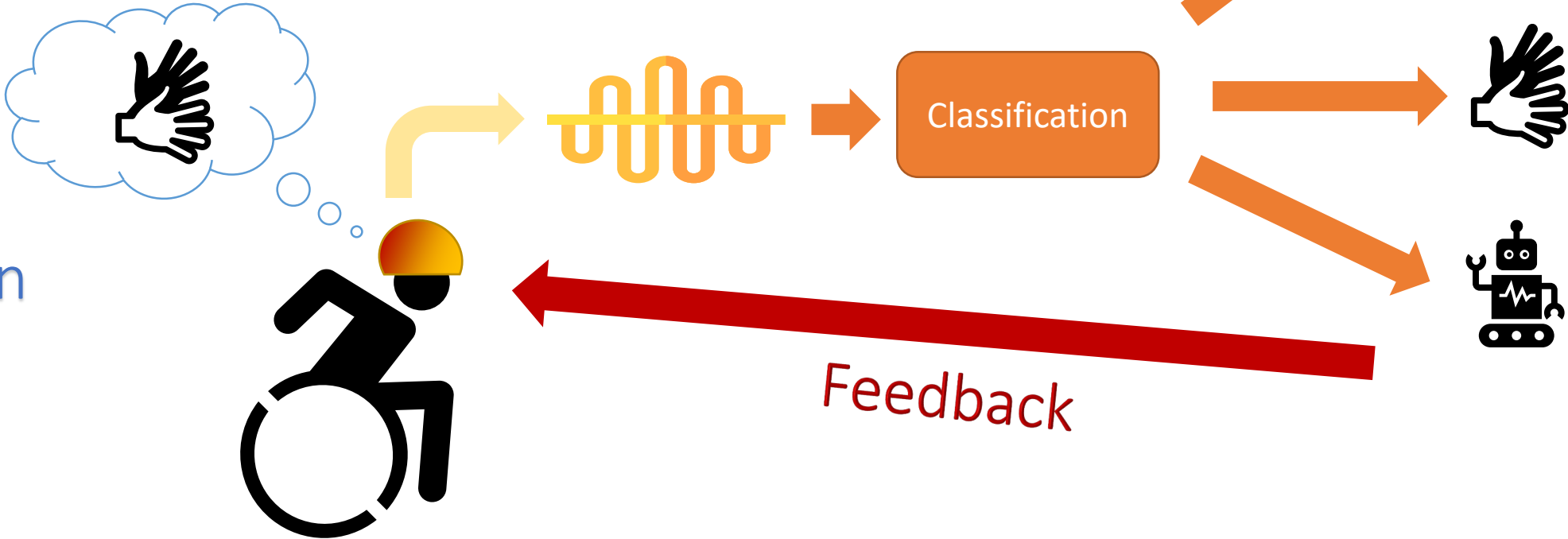
ALIS



# Brain-computer interface (BCI):

From mental action to effectors feedbacks

Definition



Calibration

Test

# RESTORING COMMUNICATION USING BRAIN-COMPUTER INTERFACES: A PROMISE HARD TO KEEP

## Brain computer interfaces data

No longitudinal reliable communication in the complete locked-in state

*Spüler, 2019*

VISUAL TASKS are impacted by oculomotor restriction

*Brunner, 2010 ; Treder, 2010 ; Marchetti, 2013*

AUDITORY TASKS seem to be impacted too ...

**E.g.:** 17/18 healthy subjects with online control, vs 2/7 patients (3 LIS, 4 ALS)

*Séguin et al, submitted*

“Results suggest that AAC-BCI systems show promise for supporting communication for people with severe speech and physical impairment, but **they remain ineffective for some individuals.**“

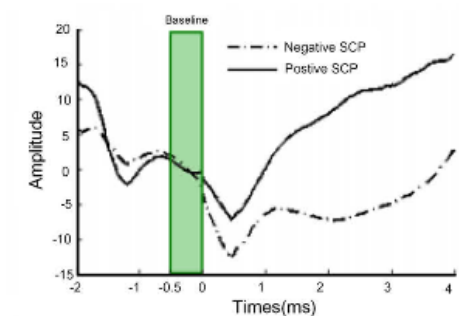
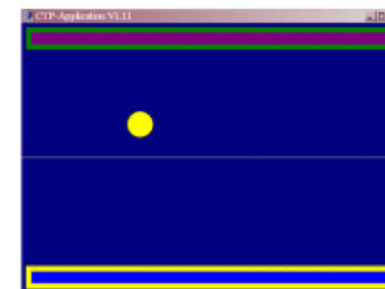
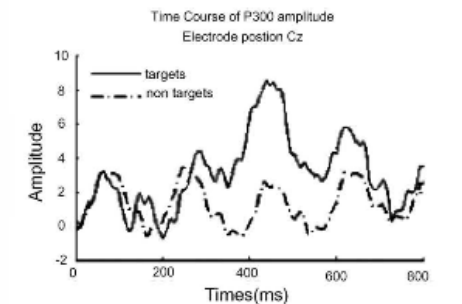
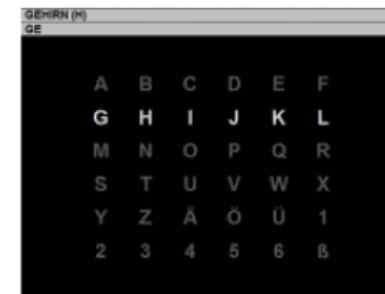
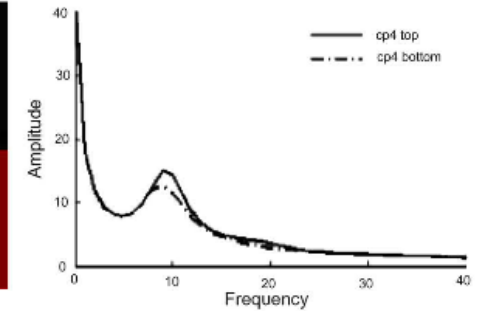
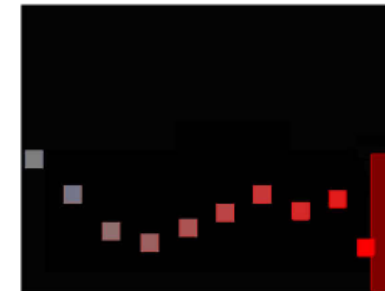
*Peters et al, 2022 (Meta-analysis)*

# CONTROLLING A NON-INVASIVE BCI: MULTIPLE PARADIGMS BUT A COMMON ATTENTION-BASED PRINCIPLE

- SYNCHRONOUS BCI (P300, Steady-state)
  - The subject focus on external stimulations
- ASYNCHRONOUS BCI (Motor imagery, ...)
  - The subject focus on her/himself

➔ Replacing motor command by mental command

➔ A common requirement : attention orientation



# THEORETICAL BACKGROUND

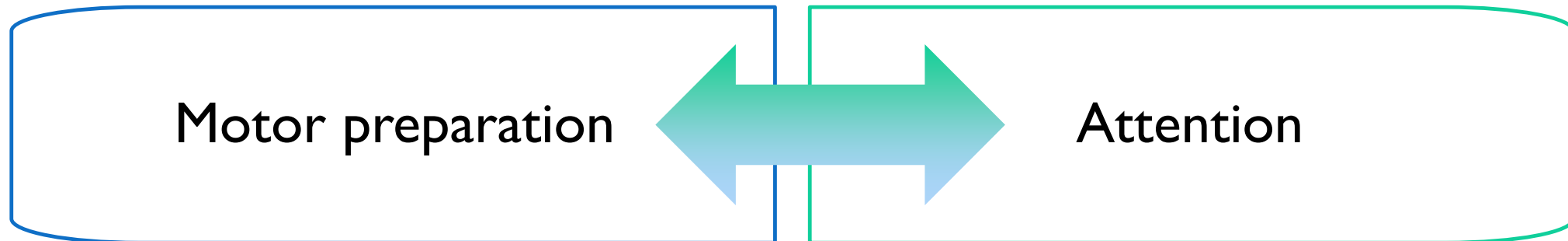
## Pre-motor theory of attention

*Rizzolatti, 1987*

## Active inference

*Friston, 2010*

*Parr and Friston, 2019*



# HYPOTHESE

Pre-motor theory of attention

*Rizzolatti, 1987*

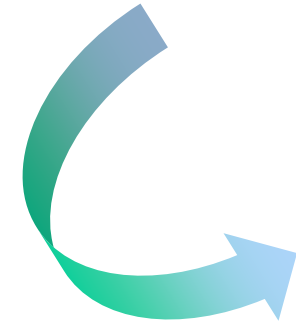
Active inference

*Friston, 2010*

Severe (oculo-)motor  
impairment

Attention impairment

Poor BCI control



# CONVERGING EVIDENCE

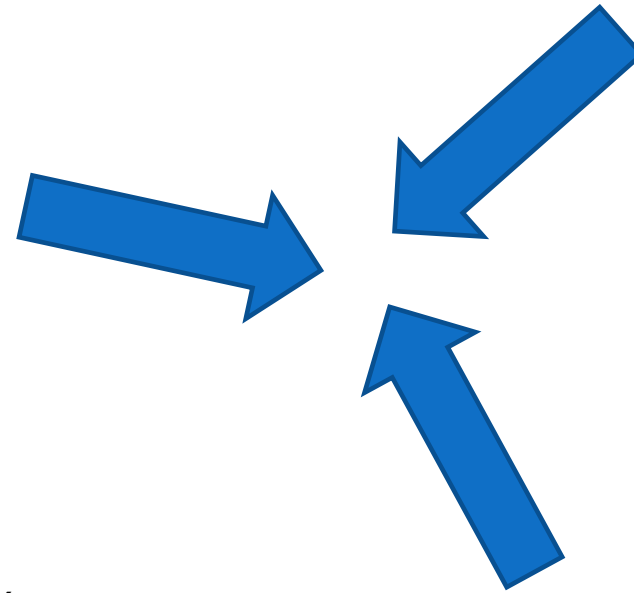
Why BCIs work poorly  
with the patients who need them the most ?

## *Physiological and clinical data*

- *An overlapping functional anatomy between motricity and cognition*
- *Whatever the etiology, cognitive impairments do come with motor ones.*

*Conson, 2008 ; Lugo, 2016*

**BCI data**



## **Cognitive & Theoretical Neurosciences**

- *Motor activity modulates perception*
- *Restricted motor preparation comes with restricted attentional span*

*Brown, 2011 ; Burianova, 2016*



## **SUMMARY**

- Whatever the etiology, cognitive impairments do come with motor ones.
- Precisely, attentional processes could be altered in most of these patients, concomittantly with their motor disorders or secondary because of a negative plasticity.

## **PERSPECTIVES**

- We should take into account the heterogeneti of clinical profiles : etiologies, neuropsychological tests, oculomotor tests, ...
- We should report negative BCI results (and learn from them)
- We need to better understand and assess the impact of motor impairments onto cognition and take inspiration from other fields

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## Patients



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