

# Exploring Cerebral Motor Activity during Propofol Sedation

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Workshop Session 1 - BCI Technology and General Anesthesia





**Accidental Awareness during General Anesthesia (AAGA)** is an unexpected awakening of the patient during a surgical procedure under general anesthesia ([Almeida, 2015](#); [Pandit et al., 2014](#))

# Introduction

*"I couldn't breathe, **couldn't move** or open my eyes, or tell the doctor that I wasn't asleep."*

Donna Penner, (Canada, 2008)



# Introduction

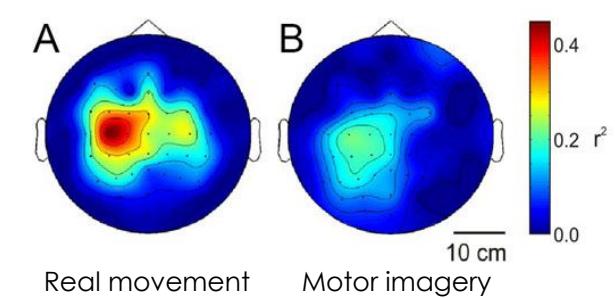
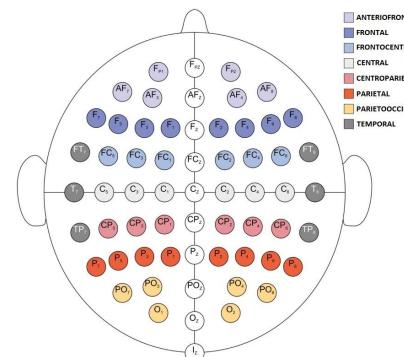
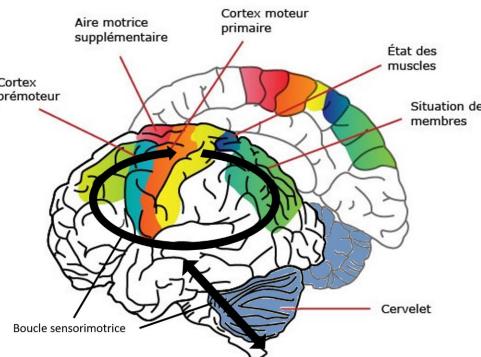
"I couldn't breathe, **couldn't move** or open my eyes, or tell the doctor that I wasn't asleep." [Donna Penner](#)

The first reaction from a patient is usually **to move** to alert the medical staff of this terrifying situation ([Ghoneim et al., 2009](#))

However, in the majority of surgeries, **the patient is curarized**, which causes a neuromuscular blockage and inhibits any movement ([Tasbighou et al., 2018](#))



**Can we detect the intention of movement during intraoperative awareness with a BCI ?**  
[\(Blockland et al., 2016\)](#)

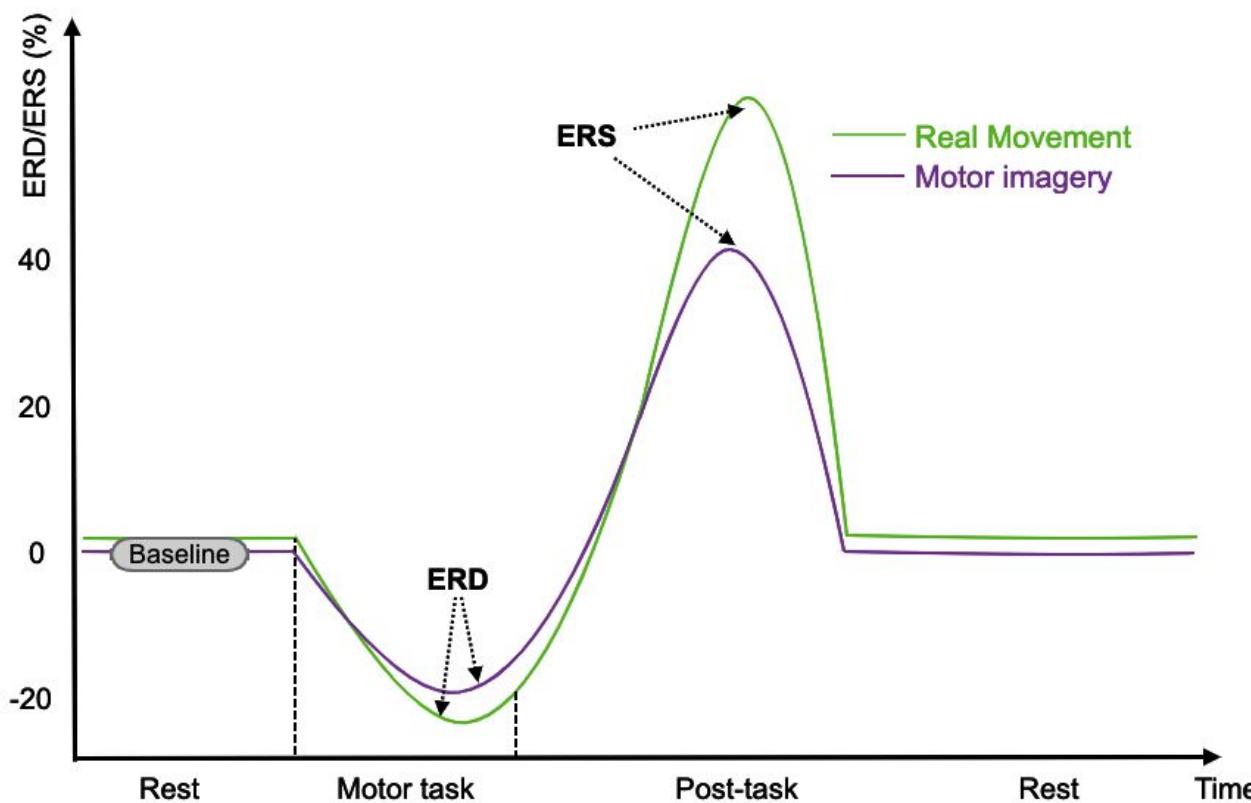


# Introduction – ERD and ERS

**ERD:** Event-related desynchronization

**ERS:** Event-related synchronization

Figure from (Rimbert et al., 2019)



(Kilavik et al., 2013; Pfurtscheller et al., 2001; Pfurtscheller & Aranibar, 1997)

ERD and ERS are modulated in the mu (7-13 Hz) and beta (15-30 Hz) frequency bands

# **Problematic of using BCI for general anesthesia**

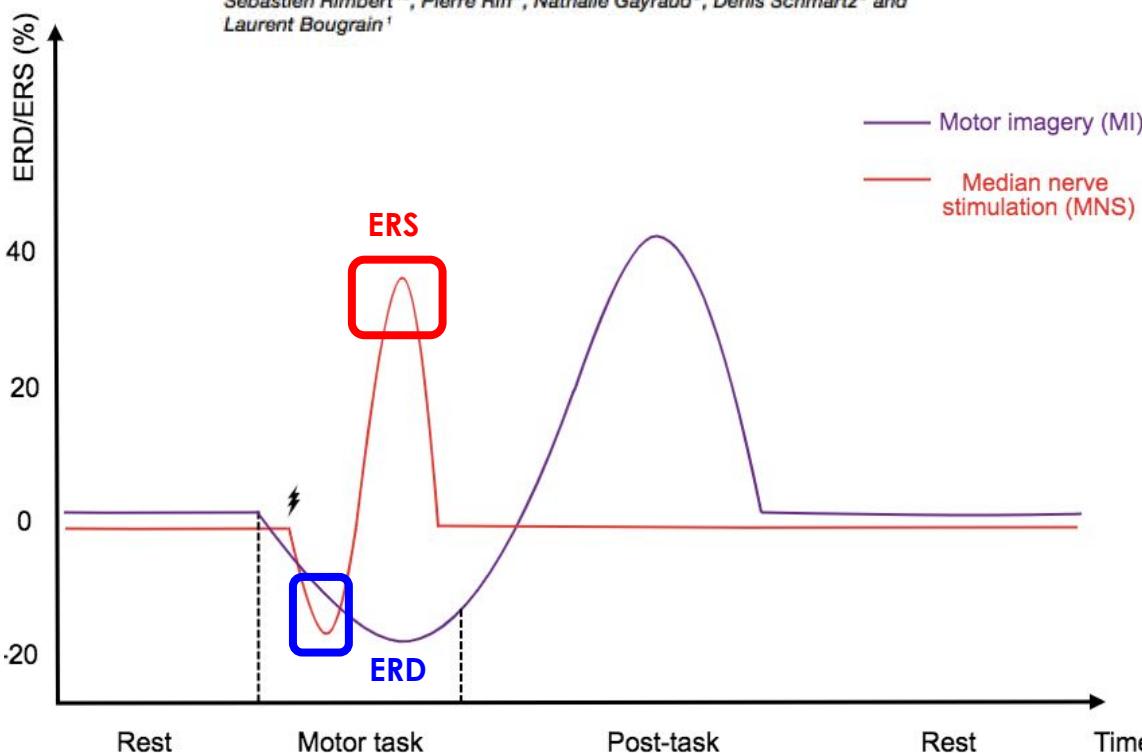
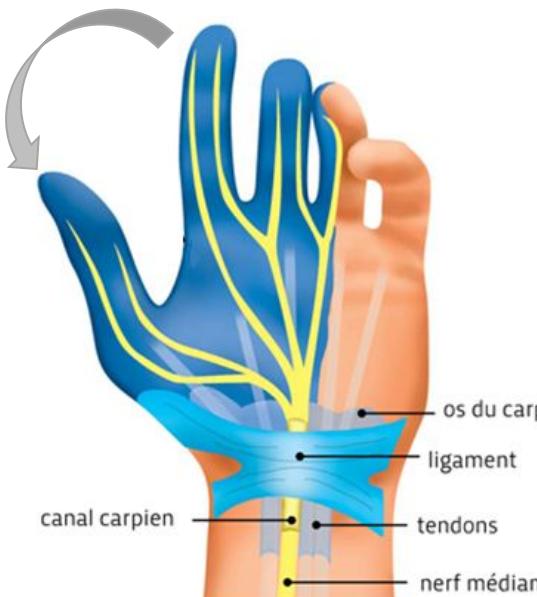
- Practical performance of BCI remains insufficient, typically (below 75% for two MI classes)
- Performance also shows significant inter-and intra-individual variability
- Many of them rely on synchronous active communication
- Mainly used in laboratory environment ([Lotte, 2013](#))

**Solution: Develop a new paradigm of high-performance and usable motor BCI based on median nerve stimulation**

# ERD and ERS with median nerve stimulation

## Median Nerve Stimulation Based BCI: A New Approach to Detect Intraoperative Awareness During General Anesthesia

Thumb movement reflex

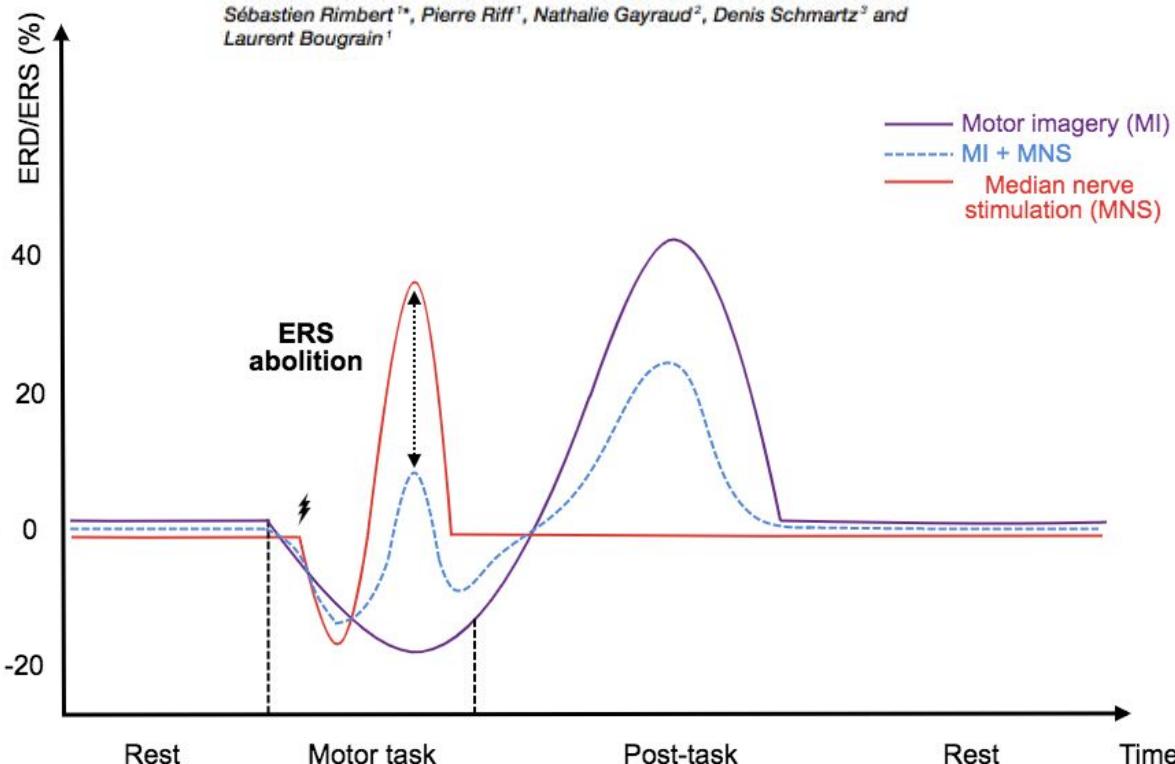
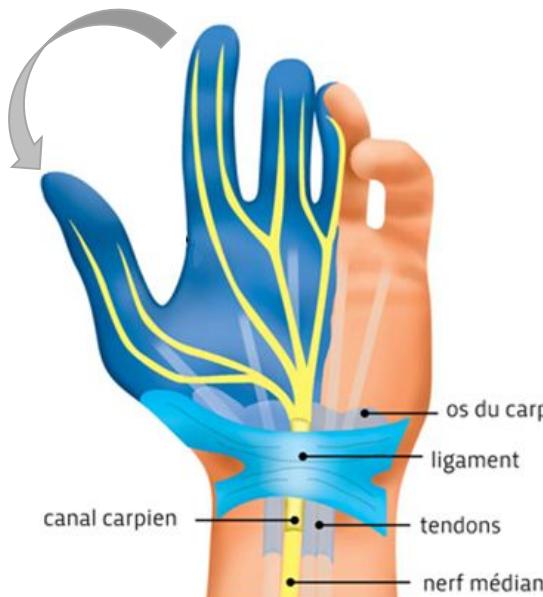


Event-related  
(de)-synchronizaton related  
to a Median Nerve  
Stimulation (MNS)  
(Neuper et al., 2001)  
(Salenius et al., 1997)

# ERD and ERS with median nerve stimulation

## Median Nerve Stimulation Based BCI: A New Approach to Detect Intraoperative Awareness During General Anesthesia

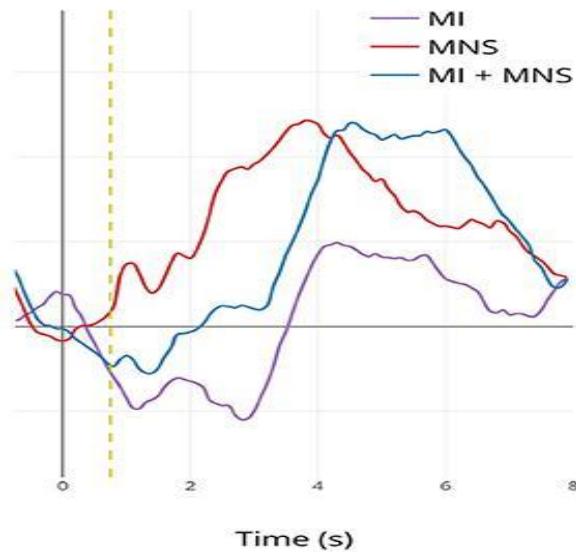
Thumb movement reflex



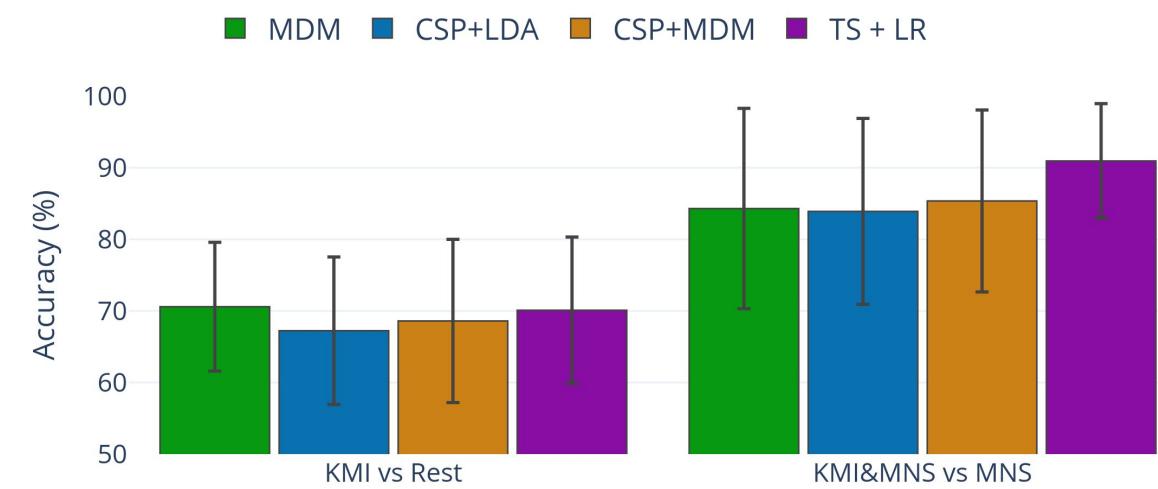
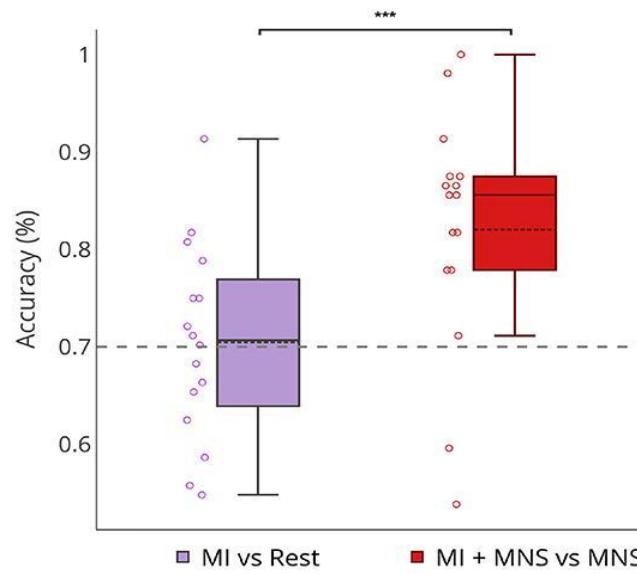
ERS abolition during MI  
+ MNS

(Neuper et al., 2001)  
(Salenius et al., 1997)  
(Kilavik et al., 2015-  
(Rimbert et al., 2019)

# Median nerve stimulation improve BCI performances



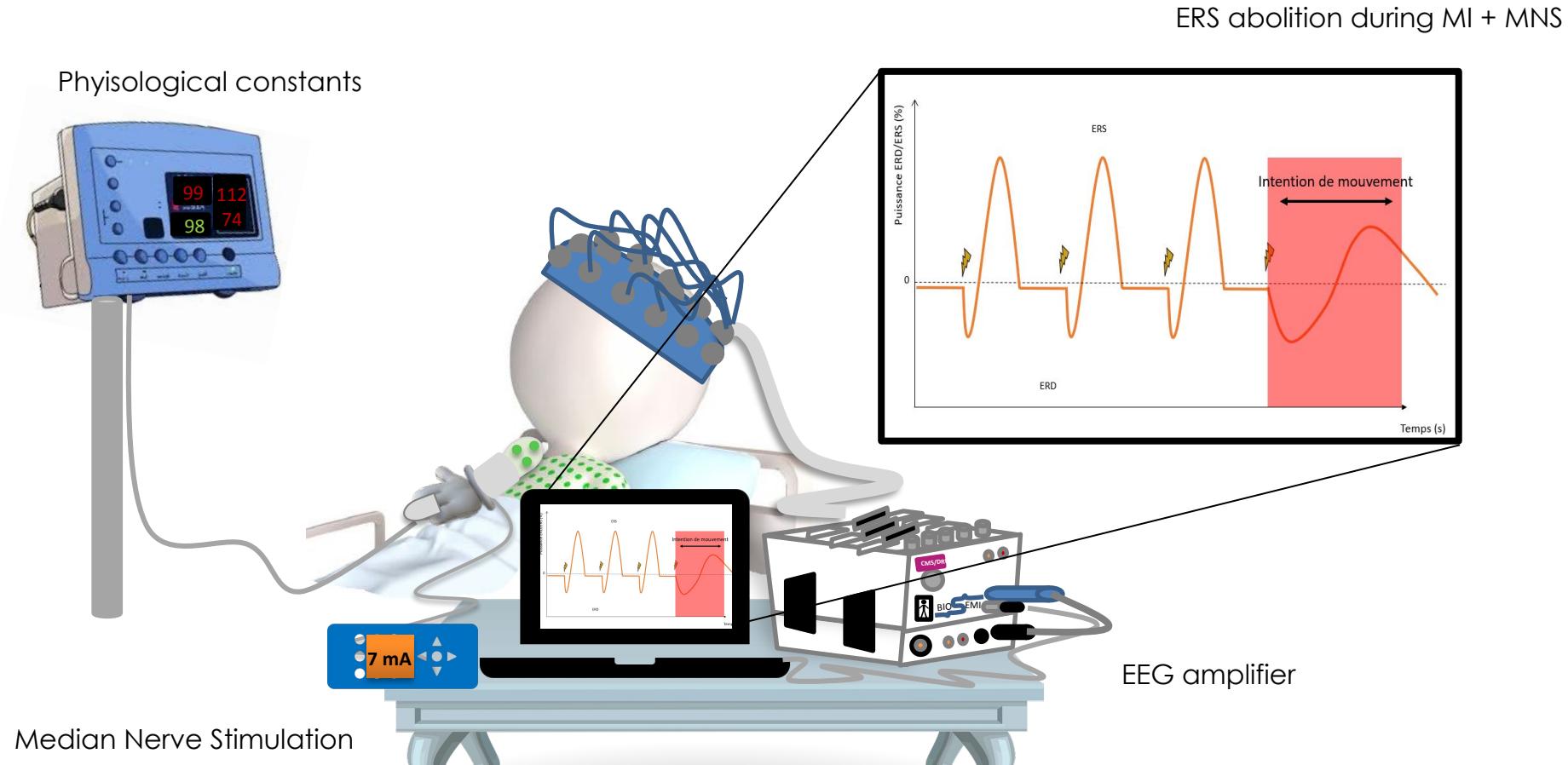
(Rimbert et al., Frontiers in Neuroscience, 2019)



Rimbert (2025) Improving motor imagery detection with a Brain-Computer Interface based on median nerve stimulation (in preparation)

**21 % improvement to detect kinesthetic motor imager with Median Nerve Stimulation**

# BCI based on median nerve stimulation for general anesthesia

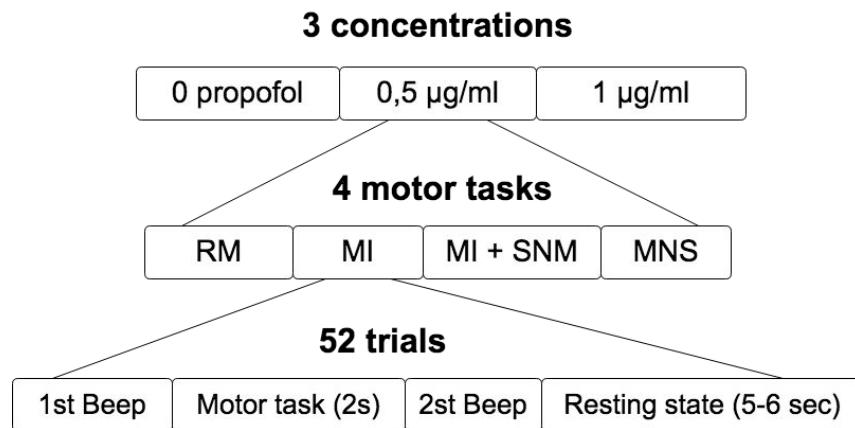


# Aim of the study

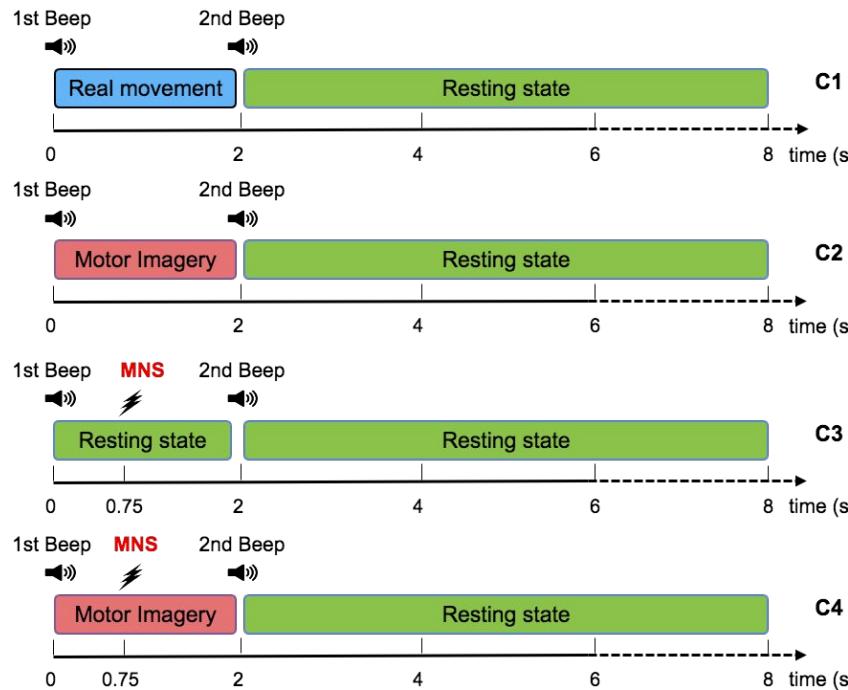
## **Investigating the influence of propofol on the cerebral motor activity**

1. How is propofol influencing the EEG signal over the motor cortex?  
Will the ERD and ERS be modulated with propofol?
2. Will propofol have an effect on classification?  
Can a BCI based on MNS be considered to detect an AAGA?

# Material and methods - MOTANA Clinical Protocol

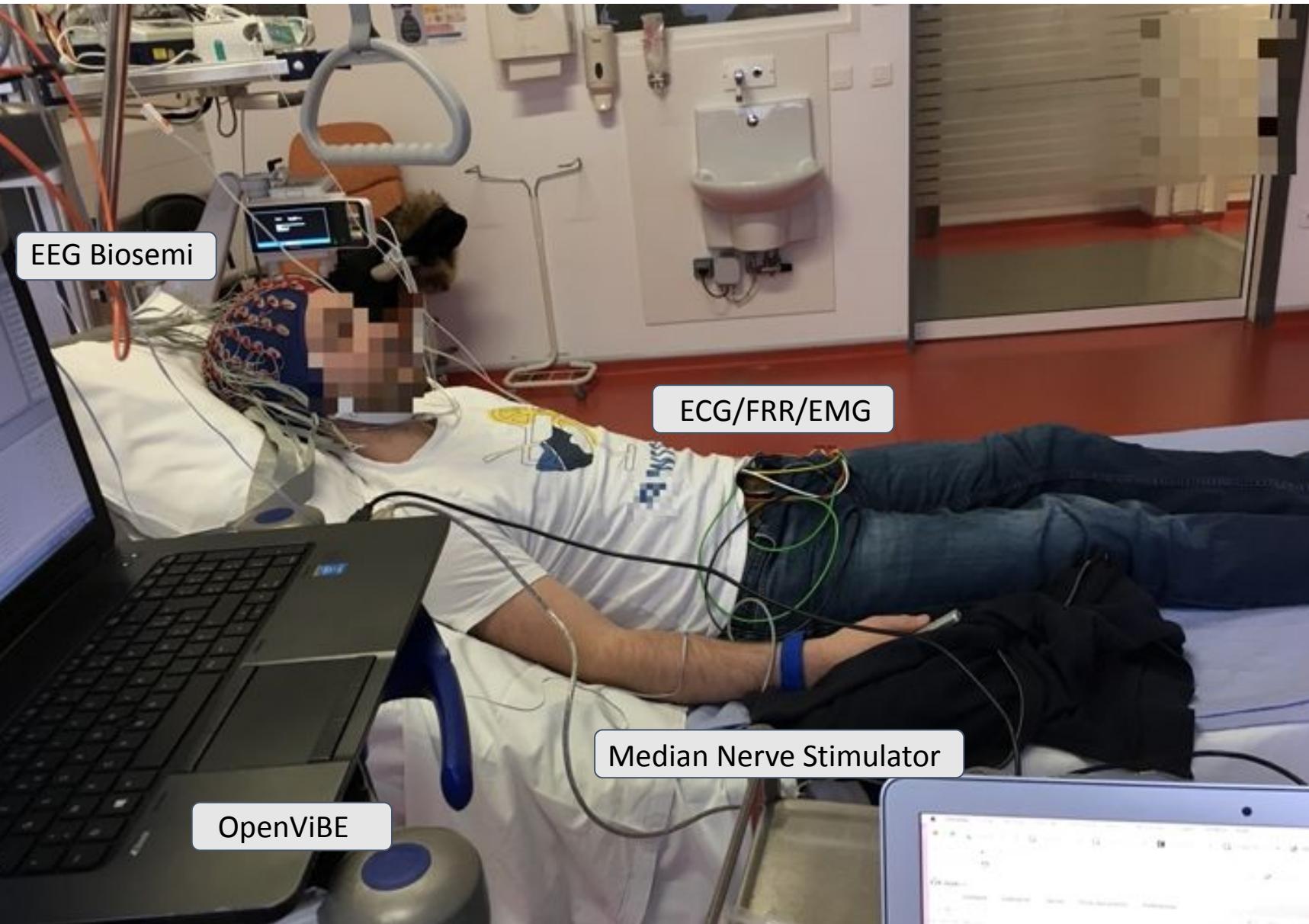


- 26 right-handed healthy subjects included
- 3 concentrations of propofol (0, 0.5 and 1 microg/mL)
- 4 motor conditions performed: RM, MI, MNS and MNS+MI
- The order of the 4 motor tasks were randomized
- Between 51-64 trials per task



- 128 electrodes from Biosemi amplifier
- Using OpenVIBE software
- Subjects had to imagine an isometric grasp between the thumb and the index finger on a pointer butter
- 2-seconds MI and 6-seconds of resting state
- 4-14 mA for the MNS
- Eyes-closed condition ([Rimbert et al., 2017](#))

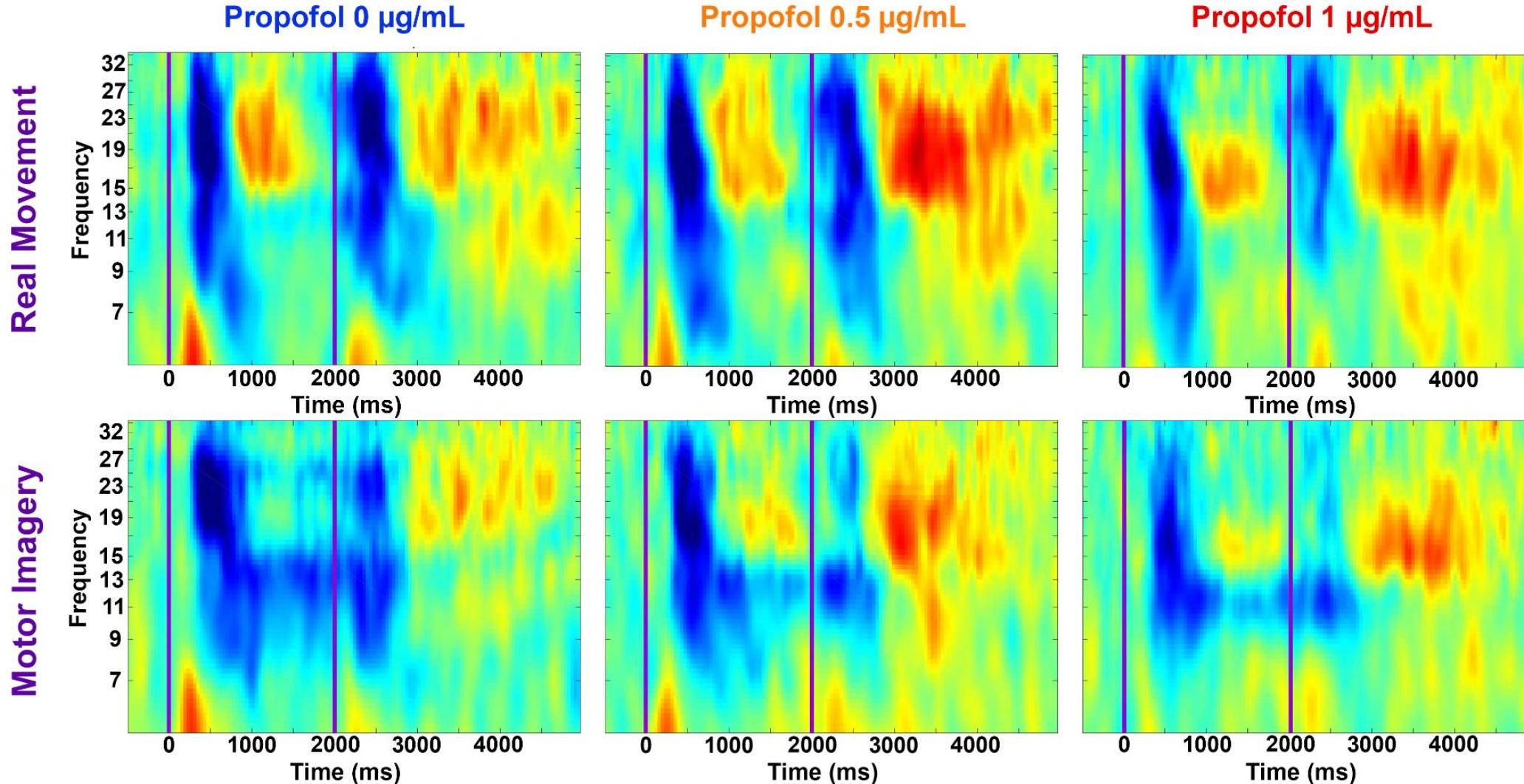
# Data collection at the CHRU-Nancy hospital



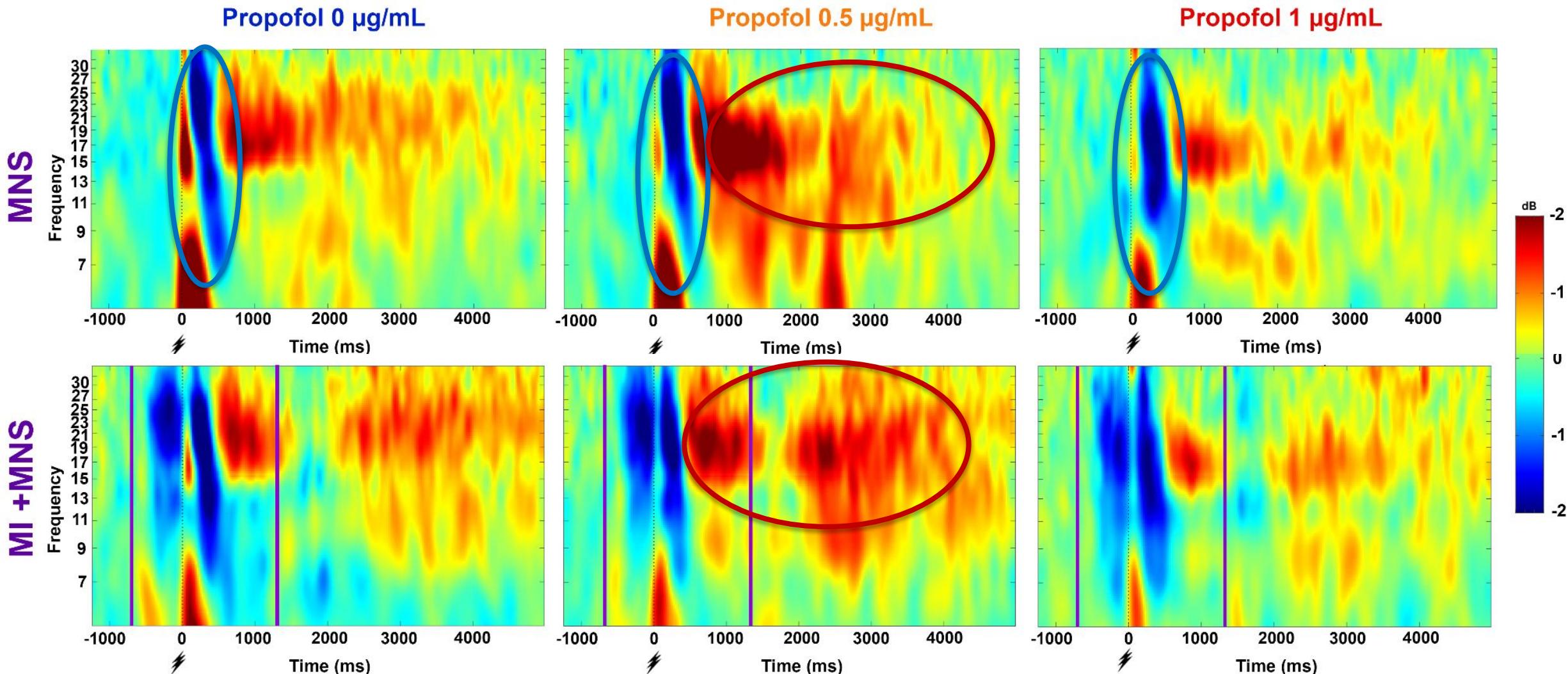
## Inclusion criteria

- male
- age between 18 and 28 years old
- body mass index 22-28
- right-handed

# Results – Time frequency

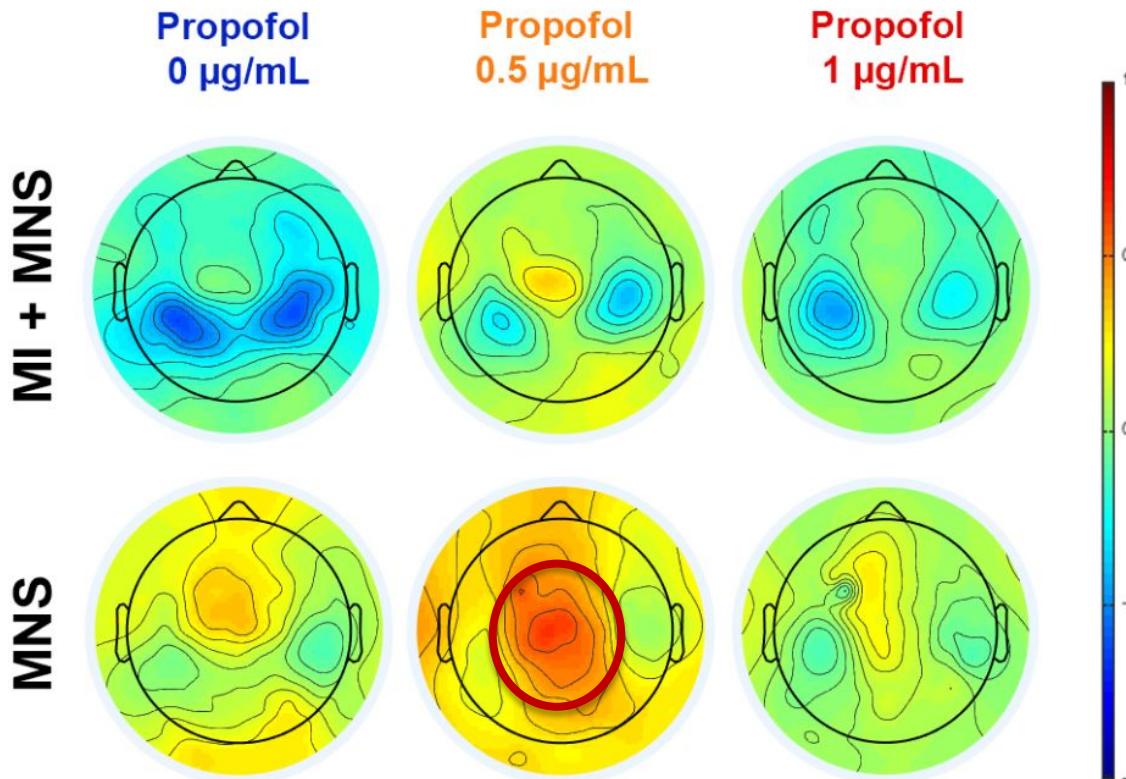


# Results – Time frequency

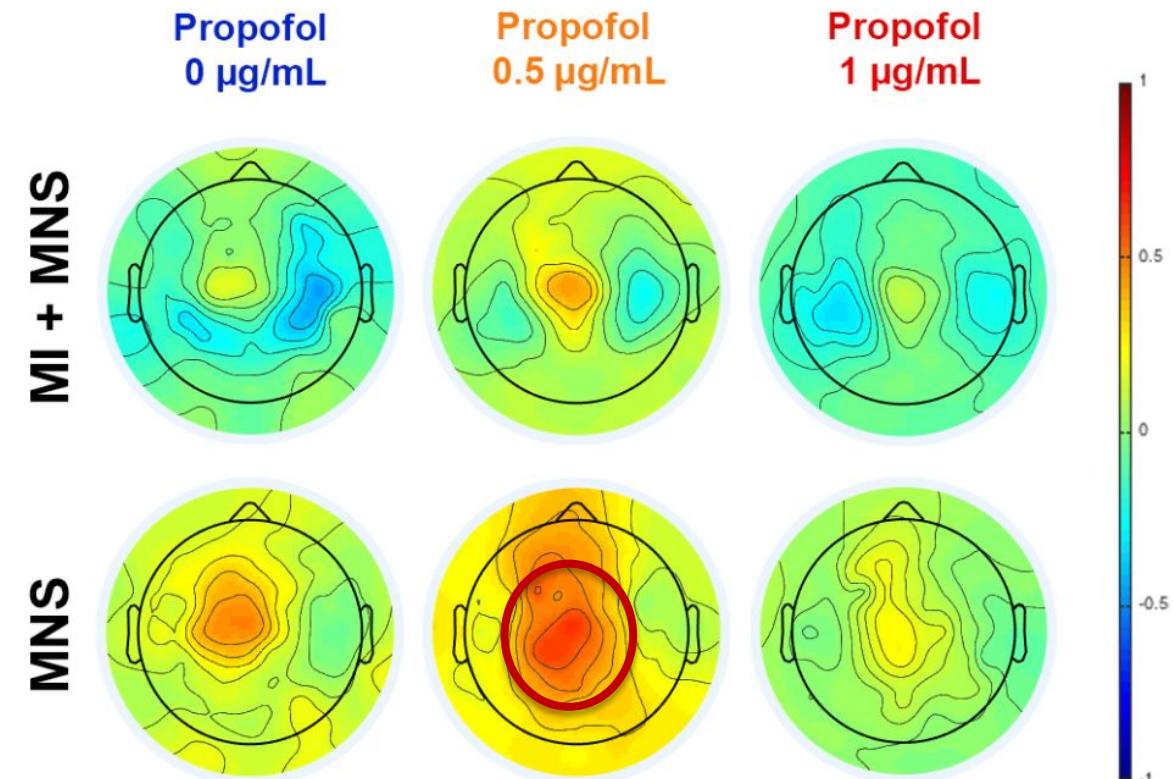


# Results – Topographic map

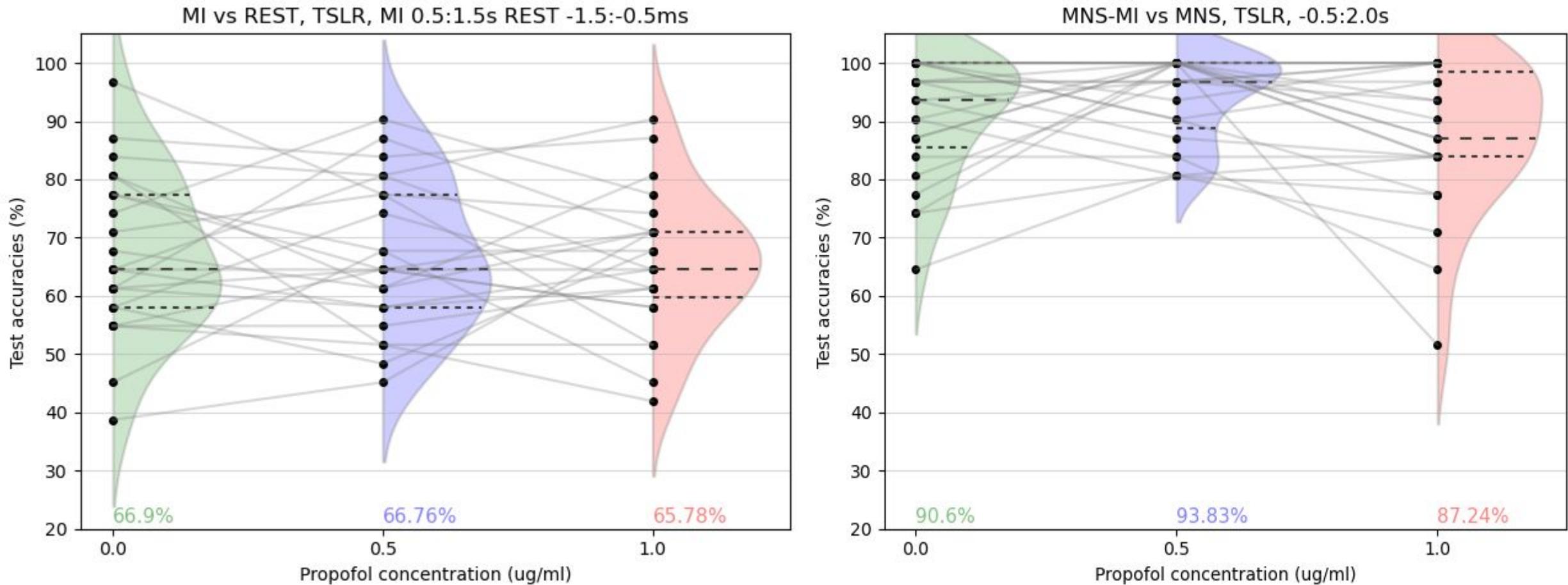
A. 8-30 Hz



B. 15-30 Hz



# Results – Classification



# Discussion

- For the 3 motor tasks (MI, MNS and MI+MNS), we observe few changes in terms of ERDs and ERSs patterns ([Blockland et al., 2016](#))
- MNS may be an easily implementable, rapid and highly effective technique to detect motor intention during general anesthesia. 22% of improvement in terms of accuracy.
- 5% of accuracy decrease for 1 microg/ml of propofol

# Future works

- Investigate ERD/ERS modulations after MNS during general anesthesia, not only with sedation

# People involved in BCI4IA project



## CHRU Nancy



Claude Meistelman, Head of Anesthesiology service, CHRU-Brabois (France)



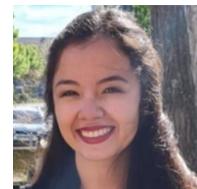
Philippe Guerci, MCF Anesthésiste, CHRU-Brabois (France)



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Javad Bidgoli, Chef du service Anesthésie-réanimation, CHRU-Brugmann (Belgium)



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Laure Buhry,  
MCF Université de Lorraine

## Loria Nancy



Ana Maria Cebolla Alvarez  
Professeur à l'Université Libre de Bruxelles



Guy Cheron  
Professeur à l'Université Libre de Bruxelles

## ULB Bruxelles

# Projects In Progress

**BCI4IA:** A New BCI Paradigm To Detect Intraoperative Awareness During General Anesthesia

**STIM-BCI:** Using somesthetic STIMulations to design next-generation motor BCIs

**D-CodeBrain:** Analysis and decoding of brain activity for motor profiling

**Neuro-PULSE:** Prognostication Using Late Somatosensory Evoked – potentials



Looking for post-doc students !

Come to our future workshop!



Exploring Altered States of Consciousness Through EEG and Brain-Computer Interfaces

# Acknowledgments



Fabien Lotte



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Marissens-Cueva



Laurent Bougrain

Many thanks to the amazing Potioc team !



# Exploring Cerebral Motor Activity during Propofol Sedation

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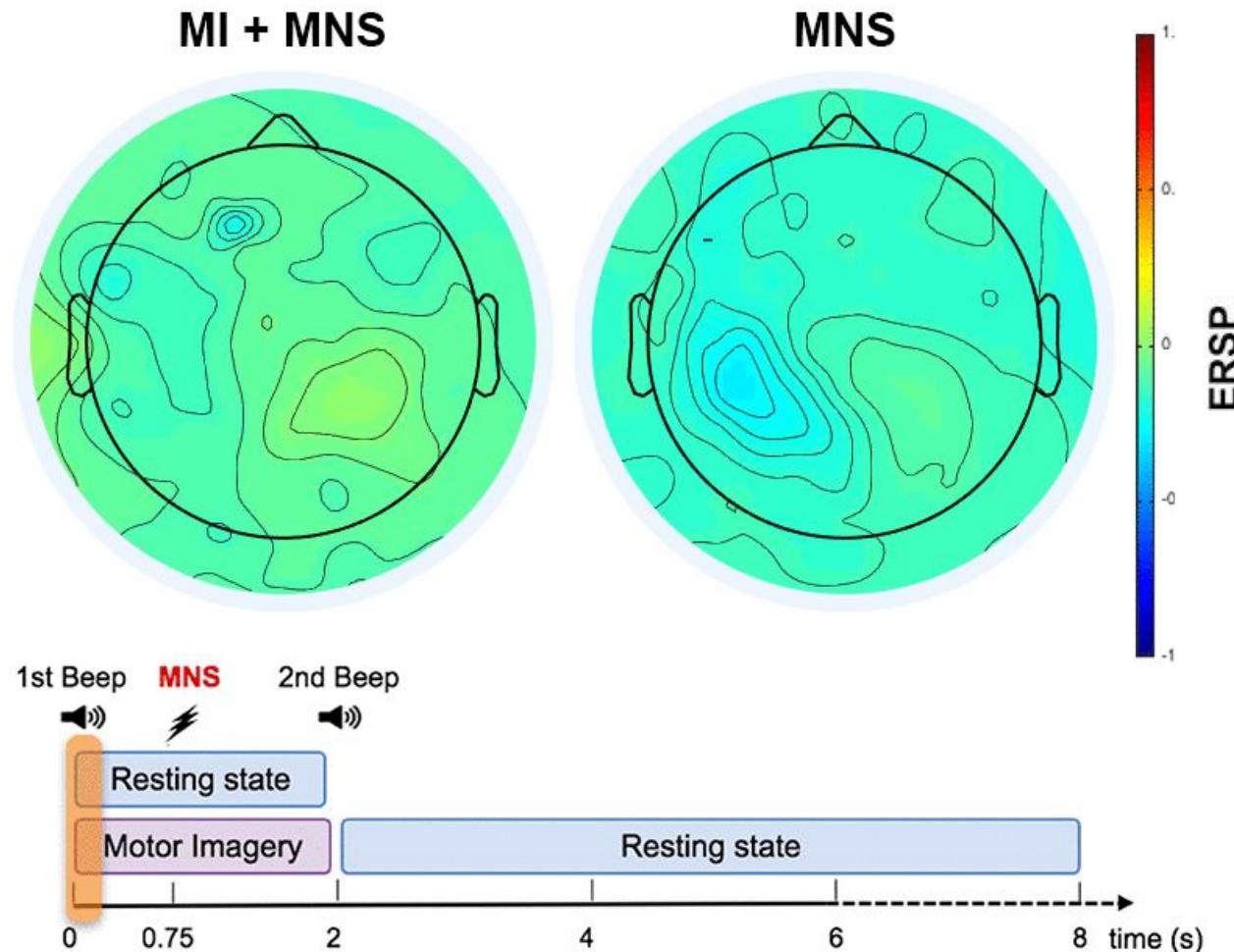
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# Introduction – ERD and ERS with median nerve stimulation

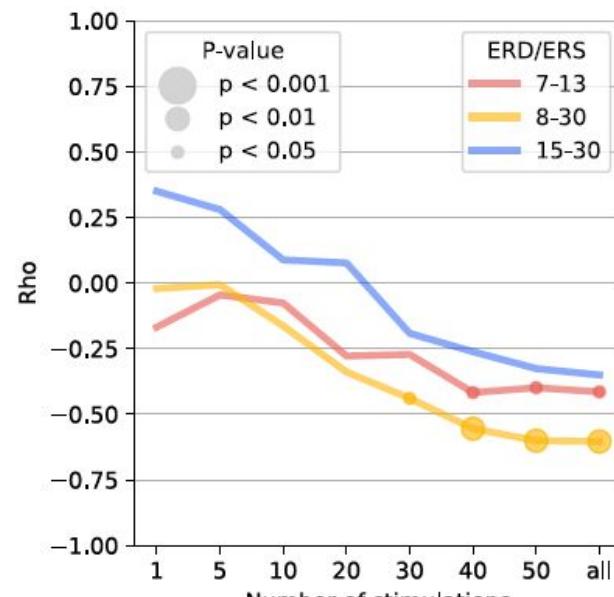
New database (52 subjects)



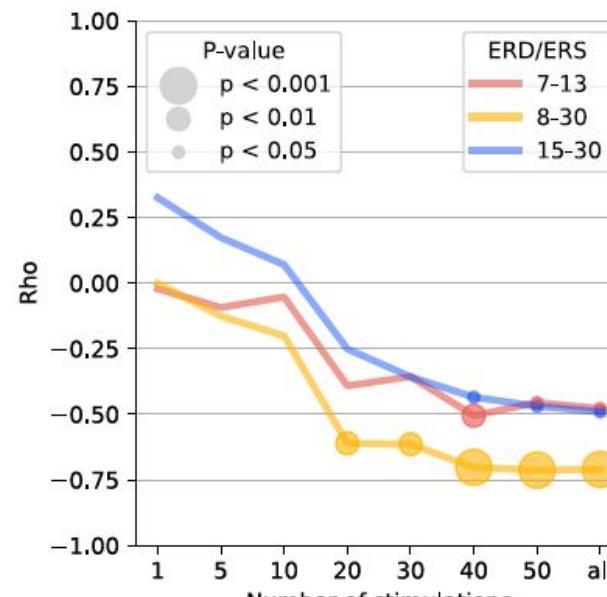
# Results – how many MNS are needed ?

We investigated how many median nerve stimulations is necessary to obtain significant correlations with BCI performances.

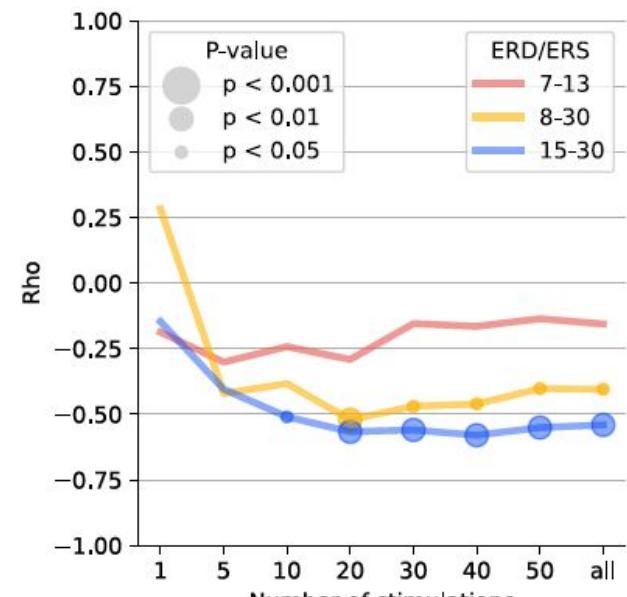
We found strong correlations with 20 MNS for 8-30 Hz band.



(a) BCI performances in mu



(b) BCI performances in mu+beta



(c) BCI performances in beta

V. Marissens-Cueva et al., (2025) Reliable predictor of BCI motor imagery performance using median nerve stimulation. Journal of Neural Engineering (in review)

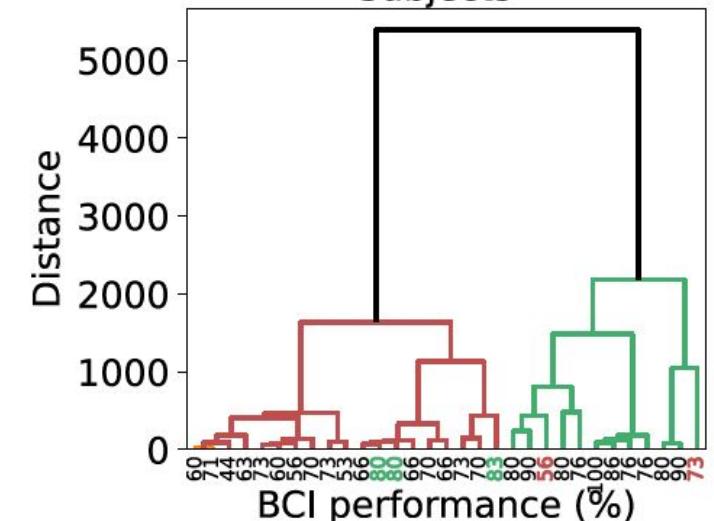
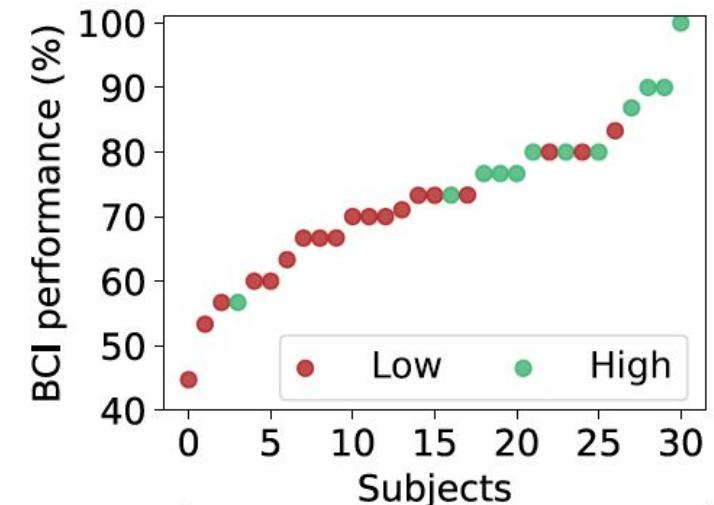
# Results – can we predict MI-BCI expertise from MNS ?

Classification of subjects by MI-BCI expertise based on post-MNS ERD features

	LDA	LASSO	ElasticNet
low vs. high performers	<b>74.19*</b>	<b>74.19*</b>	58.06
low vs. medium vs. high performers	58.06	45.16	45.16

\* $p < 0.05$

- Hierarchical clustering (HC) based on post-MNS ERD features was used to compare the clusters identified in an unsupervised way, with the BCI expertise groups
- HC achieved an unsupervised classification accuracy of 83% for binary grouping (low vs. high performers) by matching the clusters with groups defined by the median BCI accuracy.



# Acknowledgments



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Head of Neurorhythms, Université de  
Lorraine, Nancy (France)



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PhD student at Inria Bordeaux  
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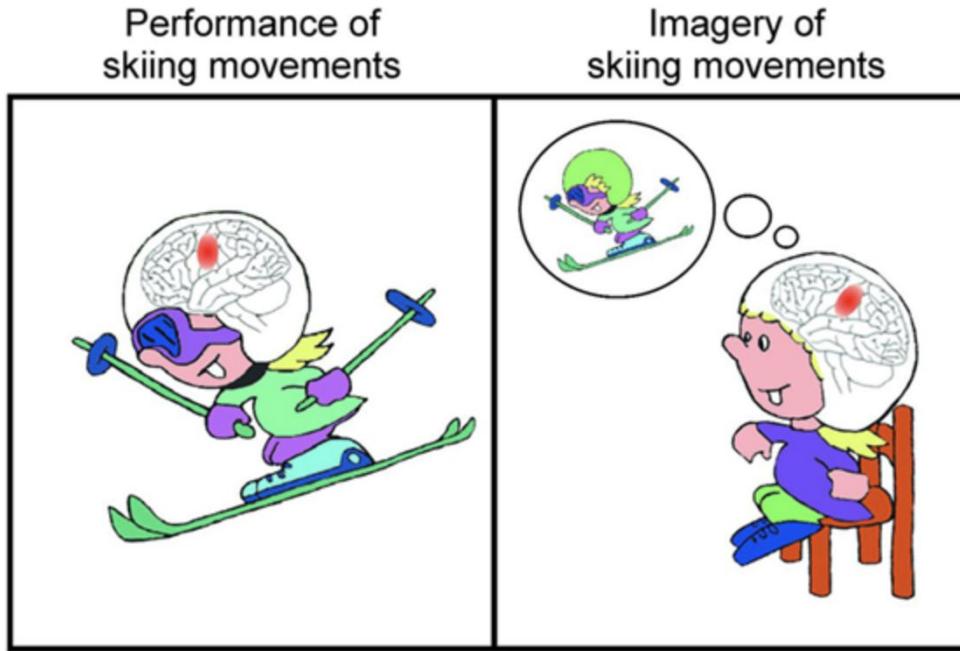
# Introduction

## Brain-Computer Interfaces based on Motor Imageries



« Brain-computer interfaces (BCIs) are communication systems that enable to send commands to computer by means of brain signals alone. These brain signals are usually measured using electroencephalography (EEG), and then processed by the BCI. »  
[\(Wolpaw & Wolpaw, 2012\)](#)

# Introduction – Kinesthetic motor imagery



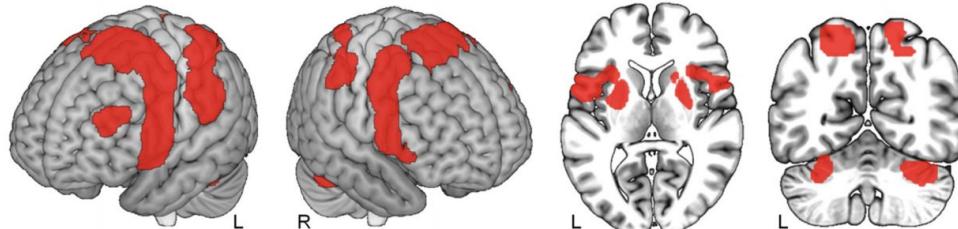
Motor imagery is the ability to imagine performing a movement without executing it  
(Guillot et al., 2009; Jeannerod, 1995)

Visual Motor Imagery (VMI) VS. Kinesthetic Motor Imagery (KMI)  
(Guillot et al., 2010)

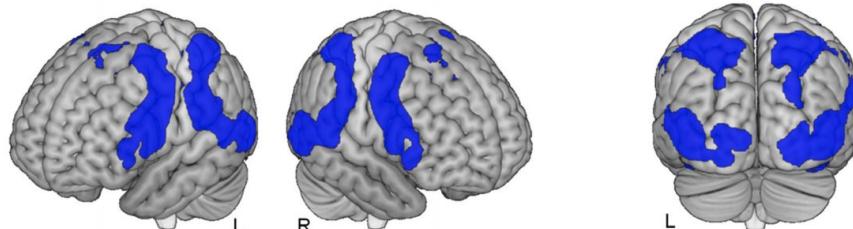
# Introduction – Kinesthetic motor imagery

KMI activates the primary motor cortex and the additional motor areas (Hétu et al., 2013)

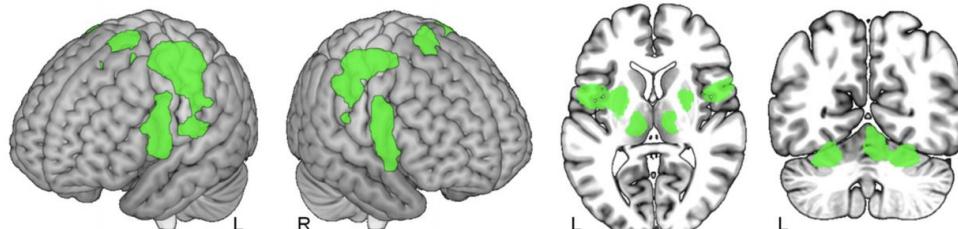
Motor Imagery



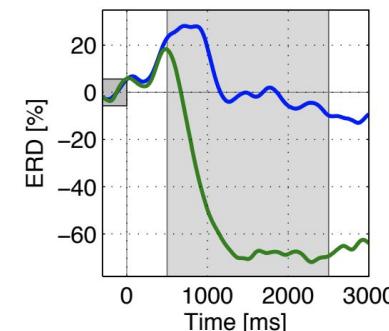
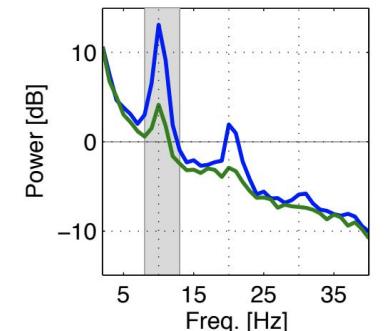
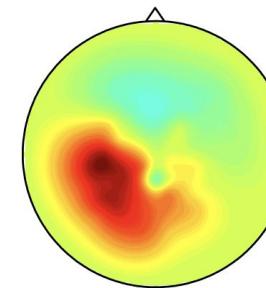
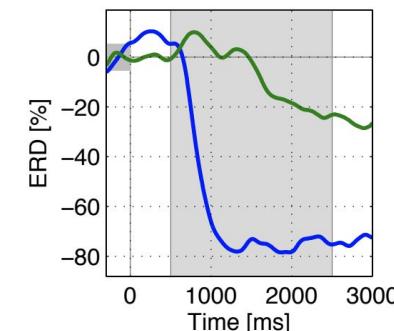
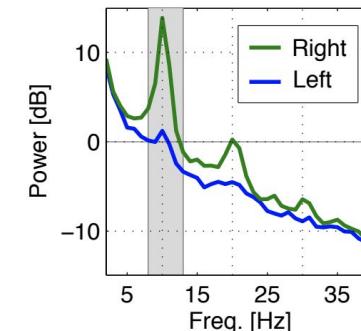
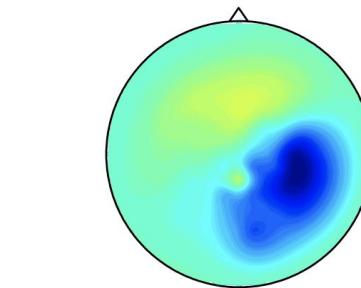
Action Observation



Movement Execution

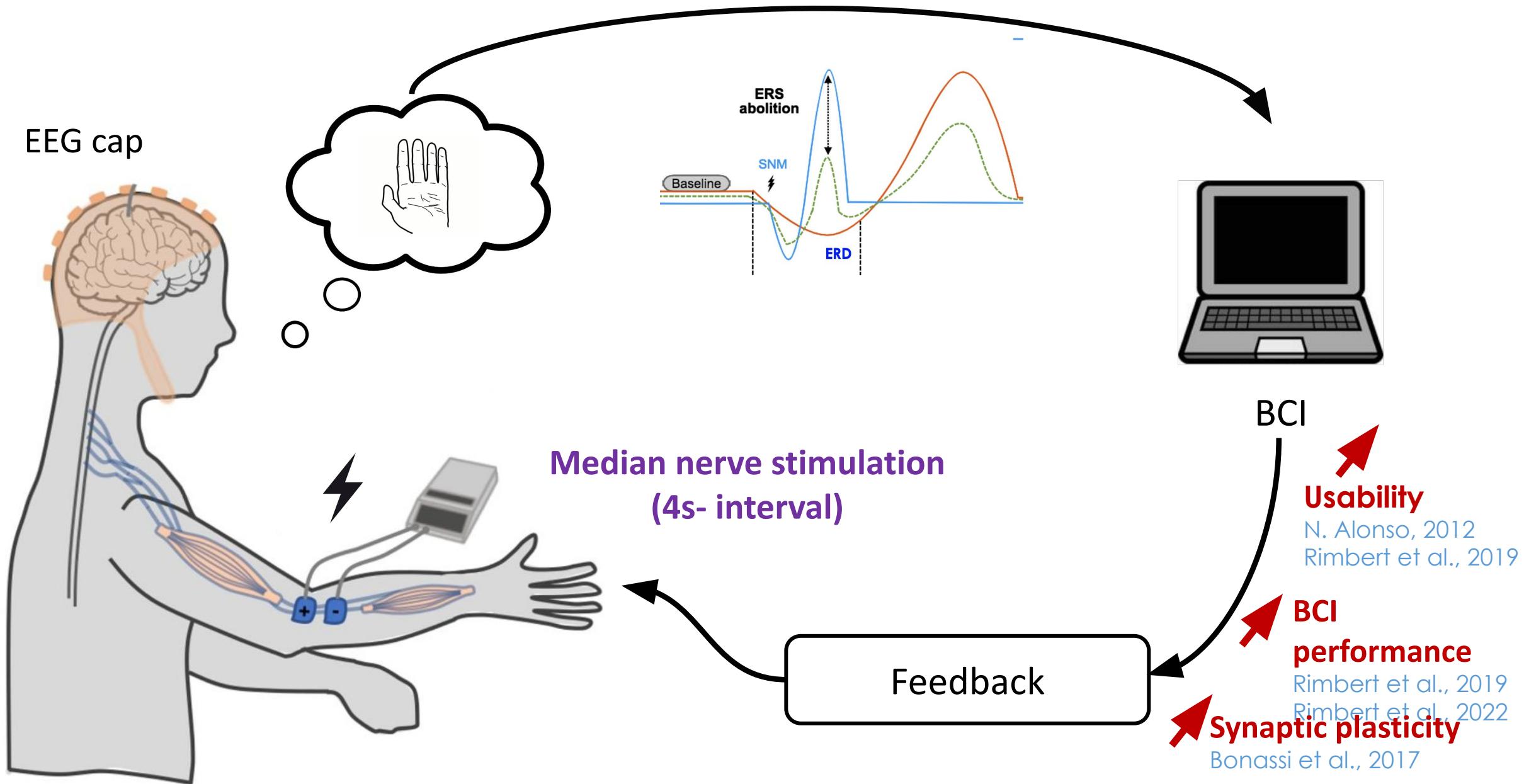


Very similar activation at the cerebral level  
(Hardwick et al., 2018)



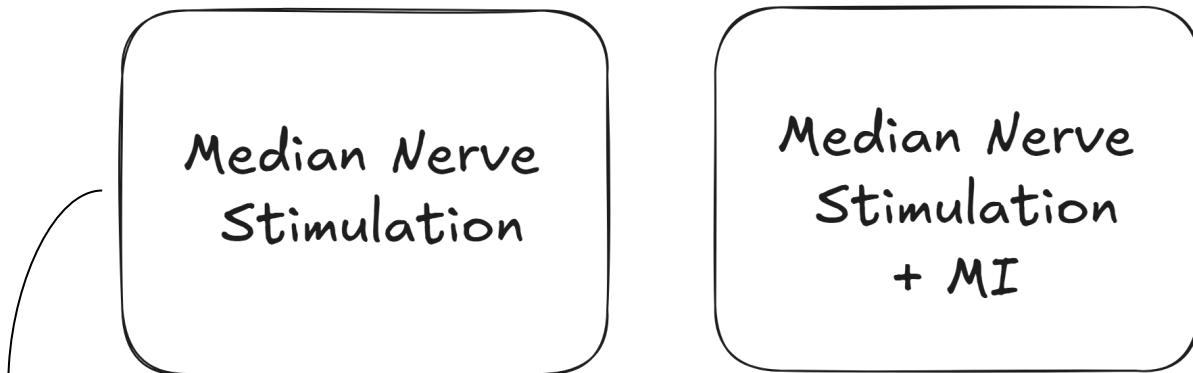
(Samek et al., 2016)

# BCI based on somesthetic stimulations



# Aim of the study

**Two class for Median Nerve Stimulation based-BCI**



Can we extract informations from the user ?

- Adapt the BCI parameters to maintain high levels of motivation for subjects
- Subject selection step prior to an experiment, for example to harmonize the study population