# Tracking Depth of Anesthesia through Median Nerve Stimulation features

Valérie Marissens Cueva
valerie.marissens@loria.fr

Supervisors:
Fabien Lotte, Laurent Bougrain, Sébastien Rimbert

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# Monitors to avoid Accidental Awareness during General Anesthesia

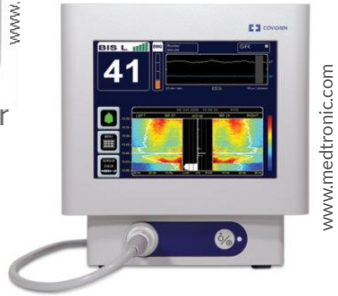
**PROBLEM:** **Awareness still occurs** with current monitors [1, 2, 3, 4, 5] : indices were developed from adult cohorts [5], might be falsely increased with EMG activity [3, 4] and are less accurate with age [5]

**OUR SOLUTION:** Actively analyze EEG responses to **Median Nerve Stimulation** (MNS) [6]


NeuroSENSE monitor


SedLine monitor


Narcotrend monitor




Bispectral Index monitor

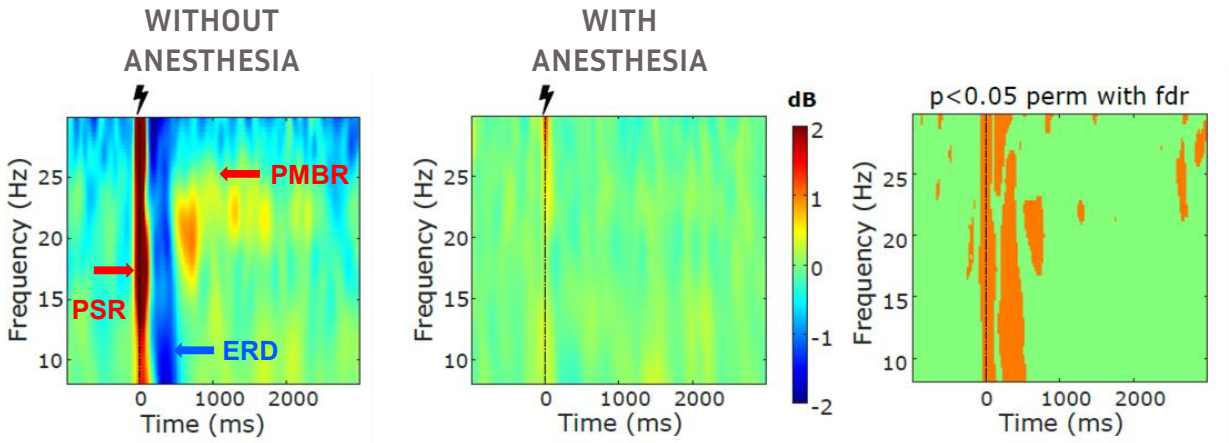
Thomas Hendry, Neuromod, 2024

[1] Bruhn et al. Anesth, 2000.
[2] Myles et al. Lancet, 2004.
[3] Sebel et al. Anesth. Analg. 2004.
[4] Aho et al. Acta Anaesthesiol Scan, 2012.
[5] Laferrière-Langlois et al. Anesth. Analg., 2024.
[6] Rimbert et al, Front. Neurosci, 2019.

# Median Nerve Stimulation-based BCI to monitor anesthesia

MNS induces sensorimotor modulations visible via EEG and variable with the depth of anesthesia [7].

**IDEA**: Follow this pattern through the anesthesia.



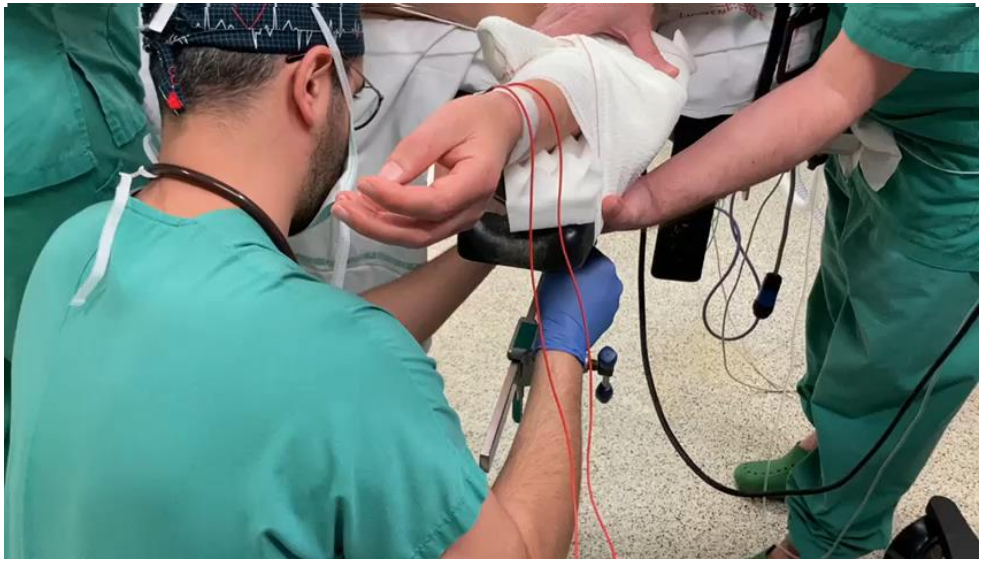

Grand average time frequency analysis across 8 subjects for electrode C4

PSR: Post-Stimulation Rebound
ERD: Event Related Desynchronization
PMBR: Post-Movement Beta Rebound

[7] Marissens Cueva et al. 9th Int.. Graz BCI Conf. 2024.

# Data collection: clinical protocol at CHU Brugmann

14 patients: 8 females; 50 ± 14.3 years old [8]



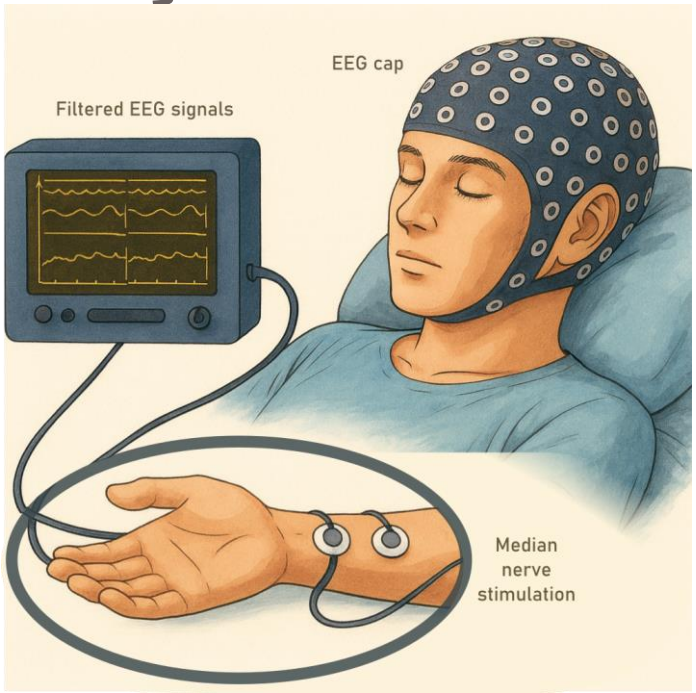



Figure inspired by Sigl and Chamoun, J Clin Monit, 1994

[8] Rimbert et al. JMIR Res. Protoc, 2023.

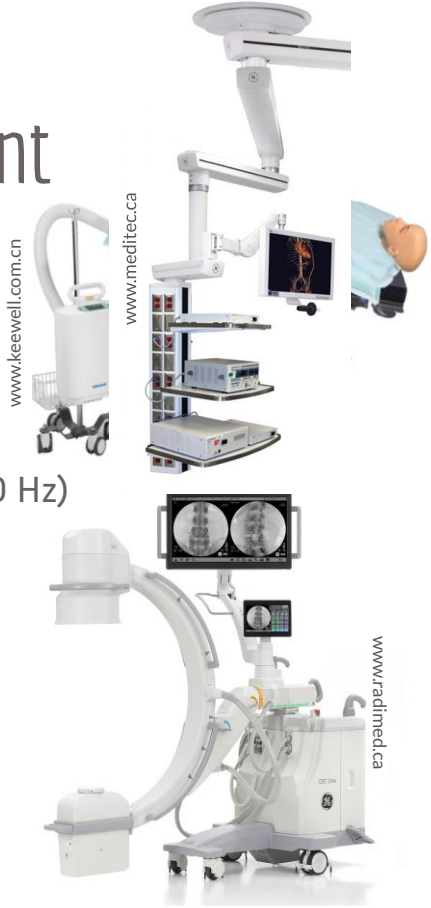
# EEG recording difficulties in a clinical environment

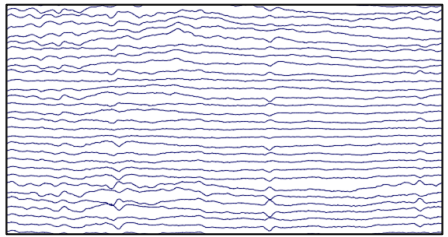
Inclusion of subjects:

- consentment
- position during surgery
- unmaintained surgery
- dysfunctional equipment

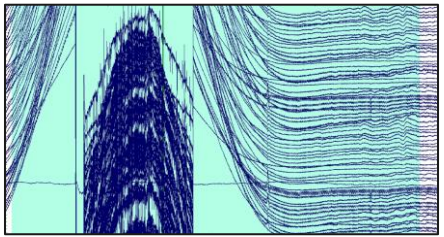

Interferences:

- hot air blankets [12]
- electrocautery [13]
- individual socket
- line noise (50 Hz or 60 Hz)
- movement

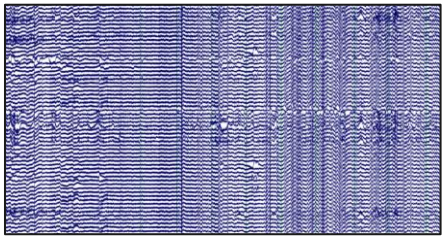


CLEAN



ELECTROCAUTERY

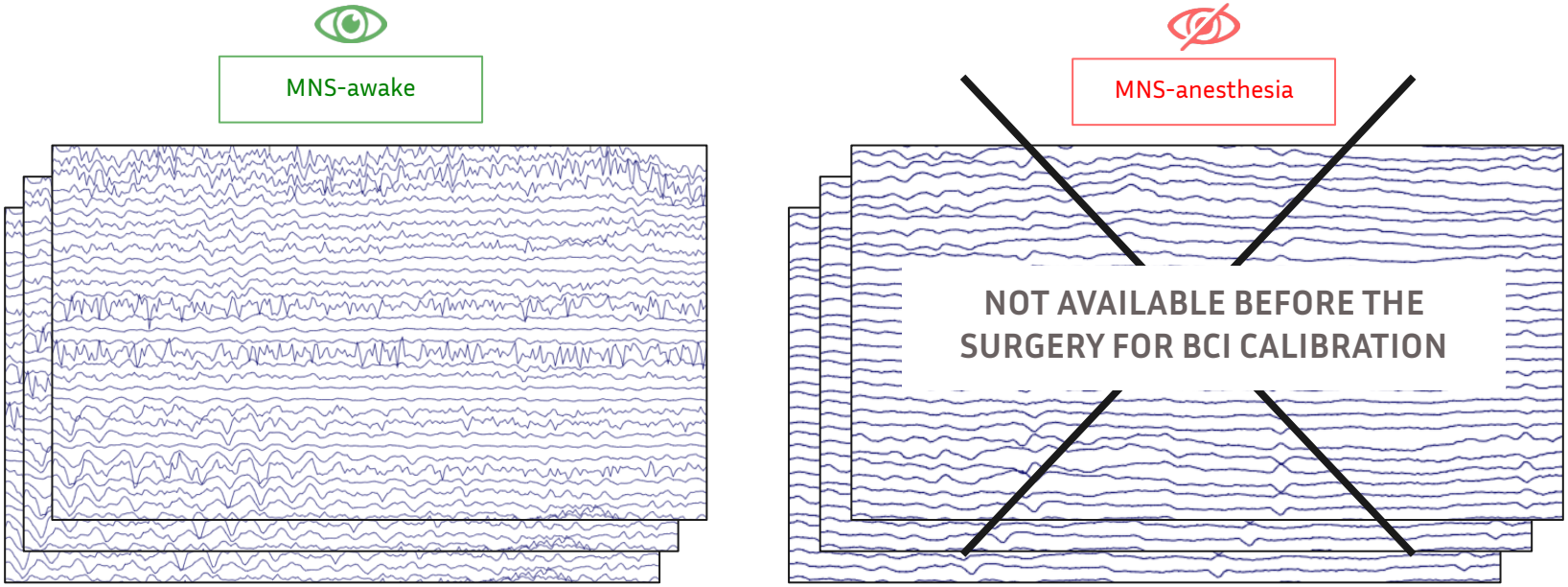


LINE

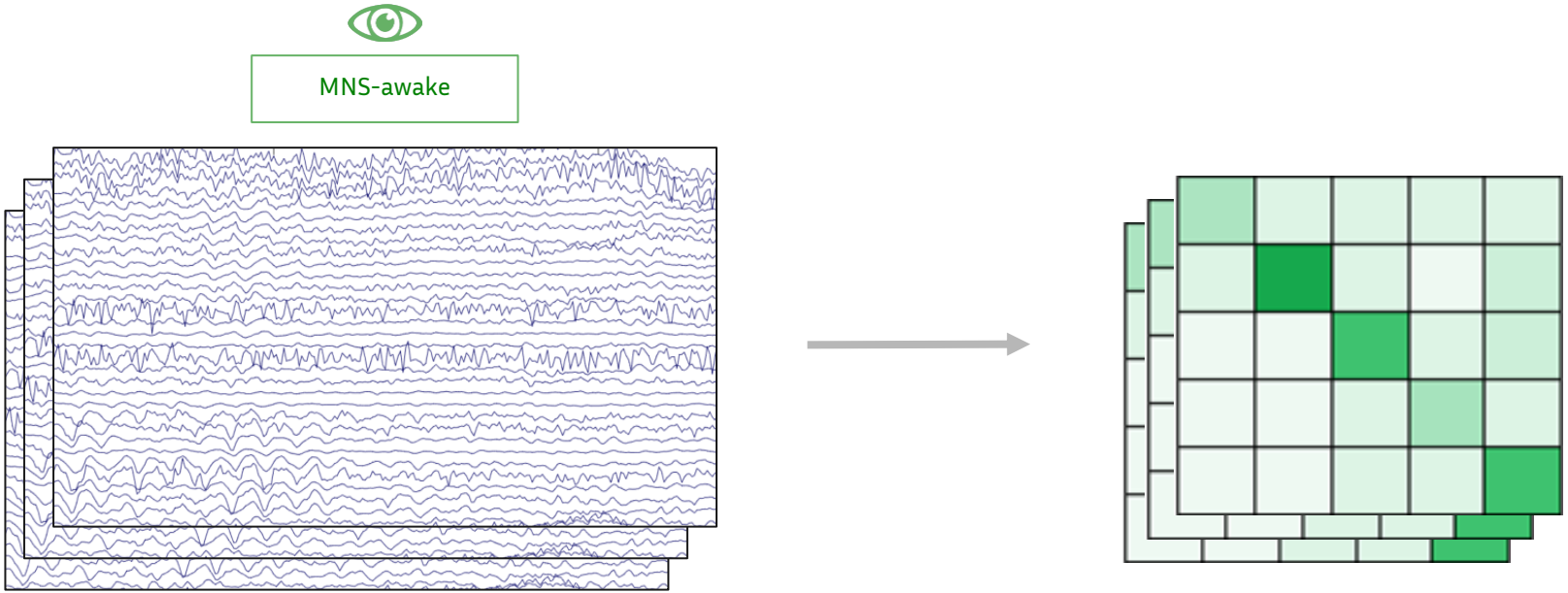
[12] Hemmerling et al. Anesth. Analg. 2002.
[13] Hight et al. Can. J. Anesth. 2021

# Data collection: awake & anesthetized states

**GOAL**: Classify brain state as either **MNS-awake** or **MNS-anesthesia** using a BCI.



# One-Class Riemannian Minimum Distance to the Mean (OCR-MDM)




[9] Congedo et al. 8th Inter. BCI Conf. 2019.
[10] Barachant et al. IEEE Trans. Biomed. Eng. 2012.
[11] Marissens Cueva et al. 5th Int. Neuroergonomics Conf, 2024.

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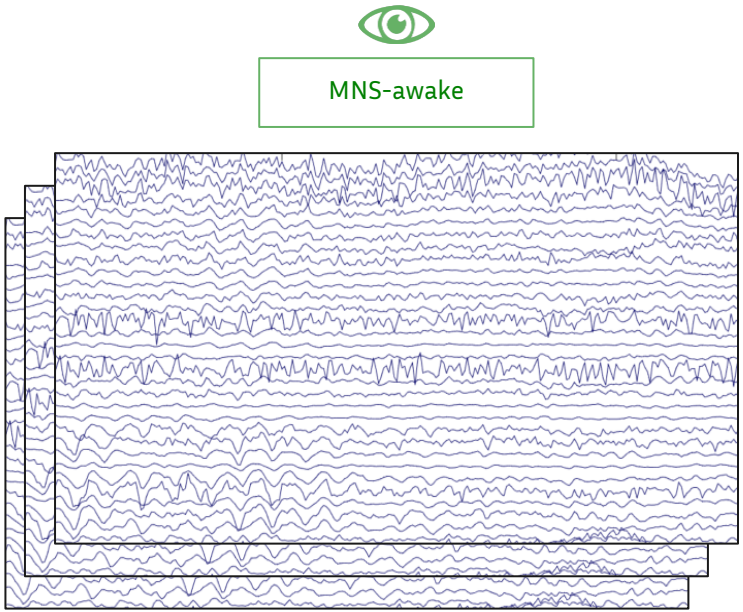


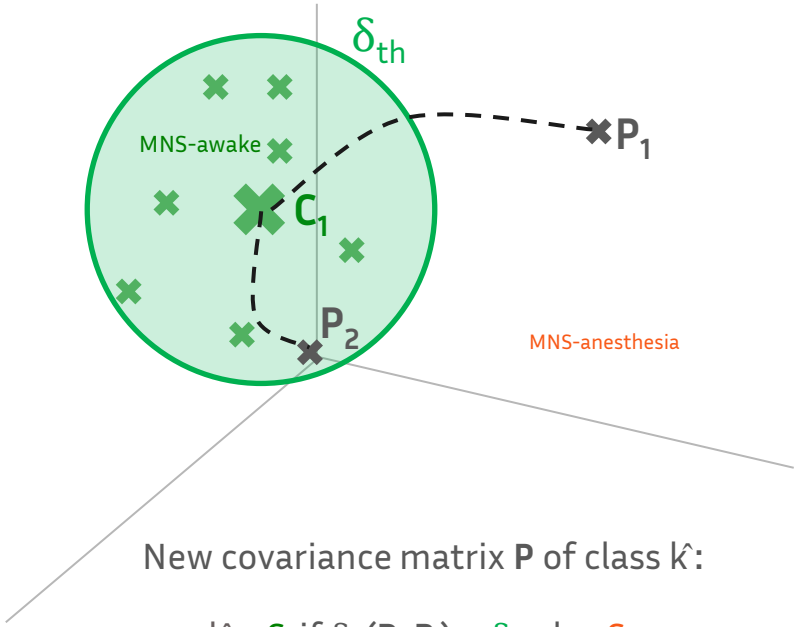


New covariance matrix **P** of class $\hat{k}$:

$\hat{k} = C_1$ if $\delta_R(\mathbf{P}, \mathbf{P}_i) \leq \delta_{th}$ else $C_2$
with $\delta_R$ the Riemannian distance:
$\delta_R(\mathbf{P}, \mathbf{P}_i) = ||\log(\mathbf{P}^{-½}\, \mathbf{P}_i\, \mathbf{P}^{-½})||_F$

[9] Congedo et al. 8th Inter. BCI Conf. 2019.
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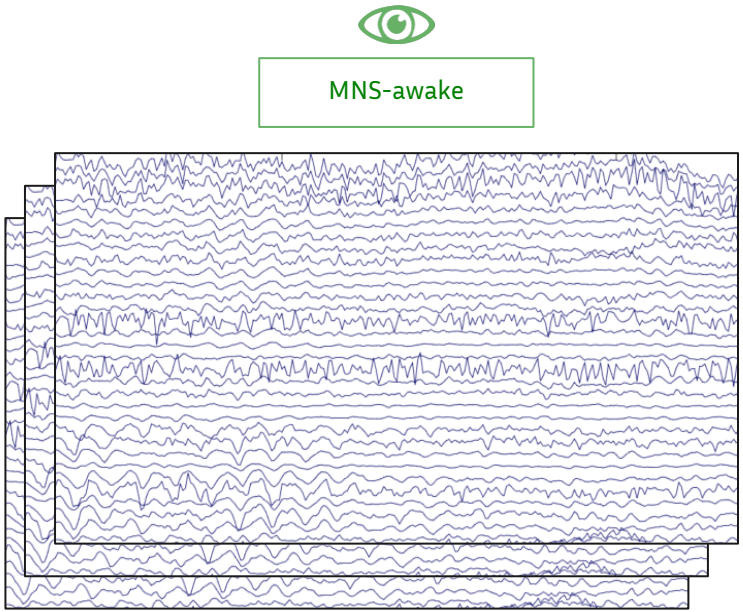


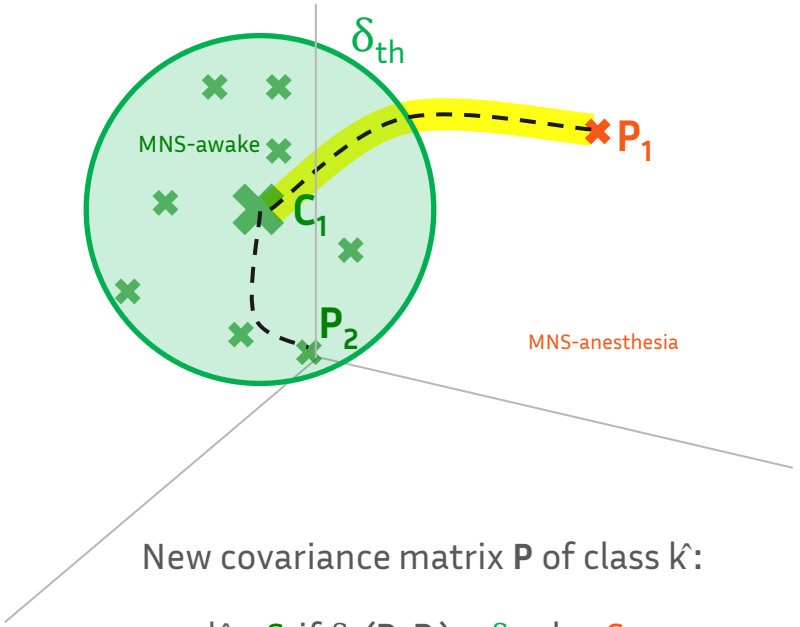


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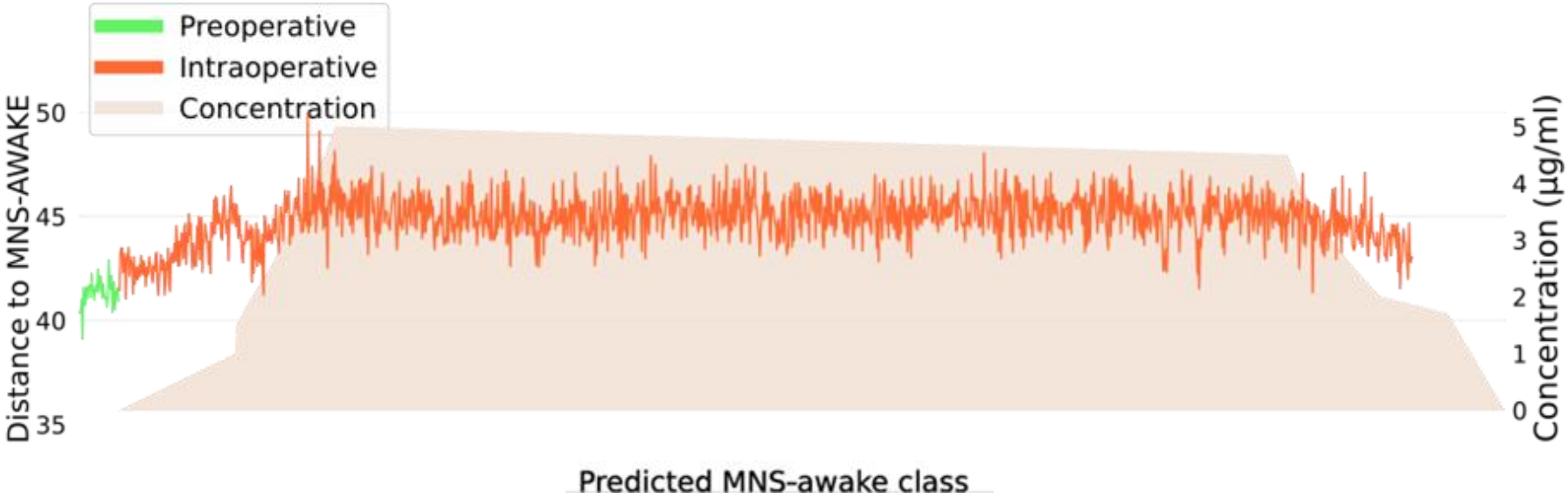
# Towards a quantitative anesthesia index

Distance to the **MNS-awake centroid** evolves gradually with the depth of anesthesia

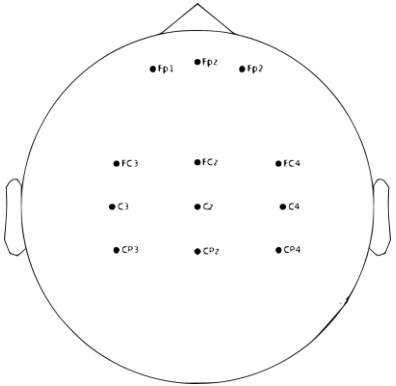


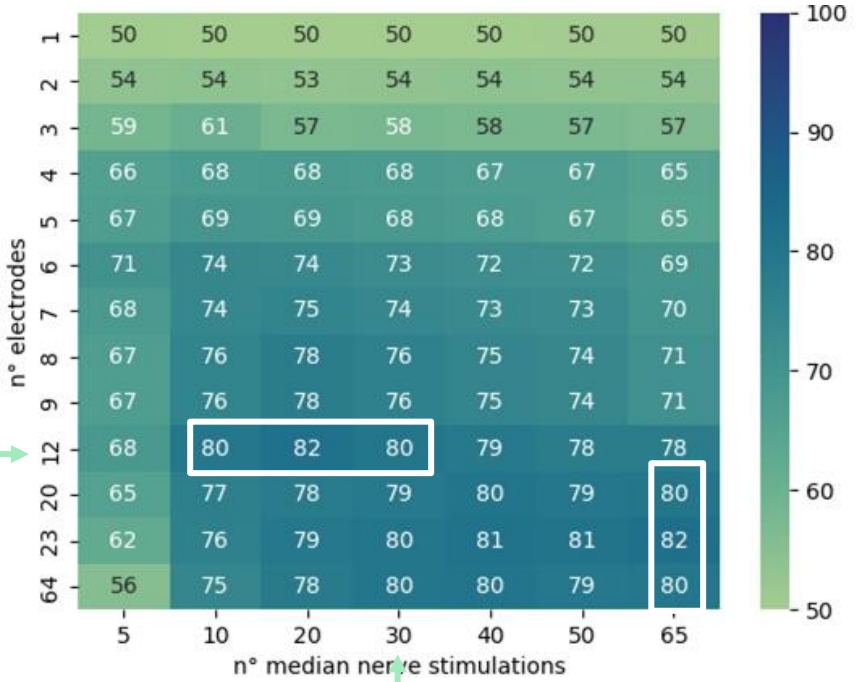

[11] Marissens Cueva et al. 5th Int. Neuroergonomics Conf, 2024.

# OCR-MDM performance wrt montage and number of MNS

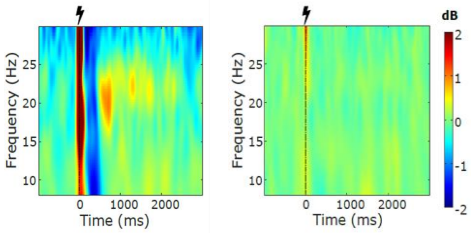
Test balanced accuracy in the **MNS-awake** vs **MNS-anesthesia** classification:

C3, C4, Cz, FC4, FC3, FCz, CP4, CP3, CPz, Fp1, Fpz, Fp2



# Next steps: movement detection using MNS

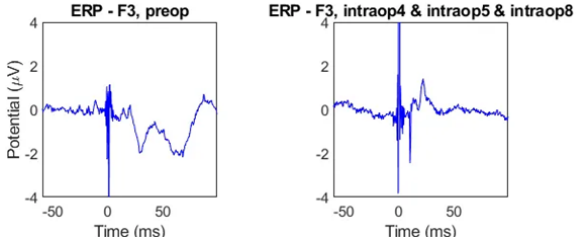



Riemannian fusion of EEG-based features for motor imagery detection under propofol sedation, *submitted*.

Covariance Matrices

Connectivity Matrices

NEW EEG FEATURES




Spectral Entropy

Somatosensory Evoked Potentials

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Université de Lorraine

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Inria Center at the University of Bordeaux

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BCI4IA project
2022-2026

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# Thank you for your attention!

**Contact:** valerie.marissens@loria.fr