NeuroRecovery Lab
ADVANCING NEUROREHABILITATION THROUGH NEUROMODULATION

CHU de Liège
CLINIQUE DE LA CONSCIENCE ET DE NEUROREVALIDATION

Exploring Neurophysiological & Neuroimaging Alterations in Concussion

Aurore THIBAUT, PhD
FNRS & NeuroRecovery Lab
GIGA-Consciousness, University of Liege
NeuroRehab & Consciousness Clinic
University Hospital of Liege

RÉSEAU FRANCOPHONE OLYMPIQUE DE LA RECHERCHE EN MÉDECINE DU SPORT
ReFORM

Concussions & persistent symptoms

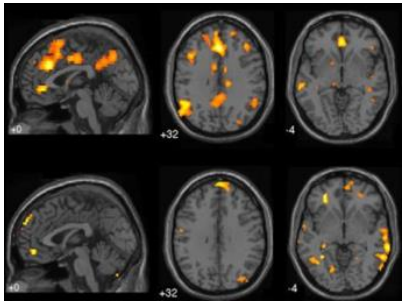
- Concussion or mild TBI = 90% total TBI
- 30-50% develop persistent post concussion symptoms
  - Somatic, cognitive, emotional, sleep disturbances
- 10-27% unemployed at 12 month (TRACK-TBI)
- Standard exams usually normal (CT-MRI)

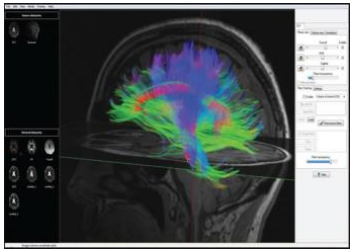
➔ Lack of uniformity for the diagnostic & management
➔ Underdiagnosed (& reported) – silent epidemic

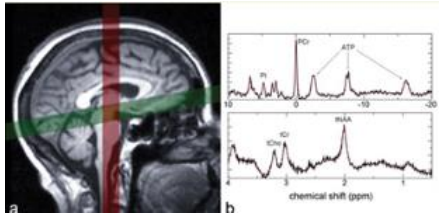
Dewan *et al.*, 2018; Korley *et al.*, 2019; Gaudette *et al.*, 2022

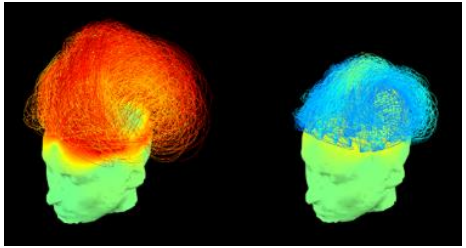
Advanced imaging techniques

- Functional Magnetic Resonance Imaging - fMRI
- Diffusion Tensor Imaging – DTI
- Susceptibility Weighted Imaging – SWI
- Magnetic Resonance Spectroscopy – MRS
- Positron Emission Tomography – PET
- Electrophysiology – EEG
- Transcranial Magnetic Stimulation – TMS
- …









New (exploratory) imaging techniques

Amsterdam Consensus Conference 2022
205 studies – 81 (f)MRI & 29 EEG

Systematic review

Role of biomarkers and emerging technologies in defining and assessing neurobiological recovery after sport-related concussion: a systematic review

Jason B Tabor [1], Benjamin L Brett [2], Lindsay Nelson,[2] Timothy Meier,[2] Linden C Penner,[1] Andrew R Mayer,[3] Ruben J Echemendia [4,5] Thomas McAllister [6], William P Meehan, III,[7,8] Jon Patricios [9], Michael Makdissi,[10,11] Silvia Bressan,[12] Gavin A Davis [13], Zahra Premji [14], Kathryn J Schneider [1], Henrik Zetterberg,[15] Michael McCrea [2]

Tabor et al. BJSM 2023

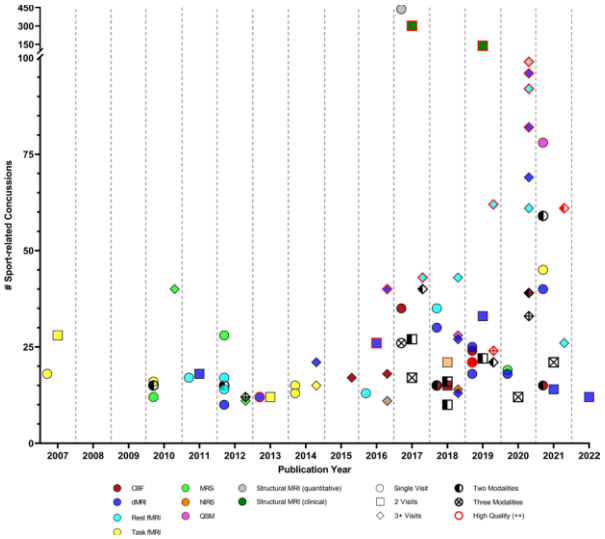
New (exploratory) imaging techniques

Systematic review

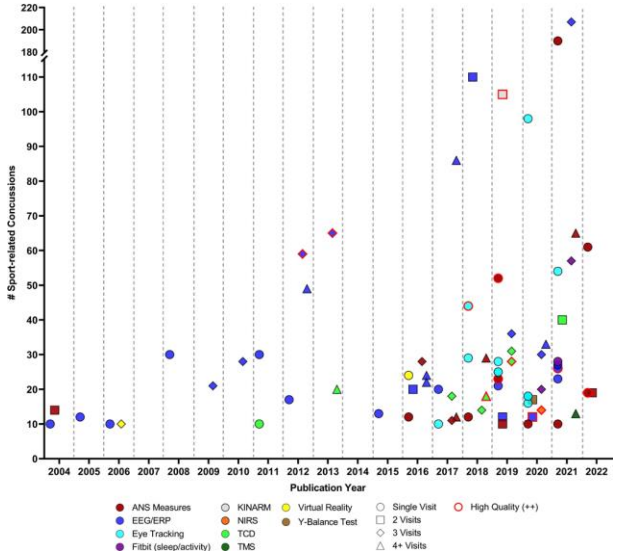
Amsterdam Consensus Conference 2022
205 studies – 81 (f)MRI & 29 EEG

Role of biomarkers and emerging technologies in defining and assessing neurobiological recovery after sport-related concussion: a systematic review

Neuroimaging



Electrophysiology



Tabor et al. BJSM 2023

New (exploratory) imaging techniques

Amsterdam Consensus Conference 2022
205 studies – 81 (f)MRI & 29 EEG

Systematic review

Role of biomarkers and emerging technologies in defining and assessing neurobiological recovery after sport-related concussion: a systematic review

Key messages

➔ Use in research for diagnosis & prognosis

➔ Promising sensitivity for assessing acute neurobiological effects

➔ Microstructual & functional alterations

➔ Alterations persists beyong clinical clearence

BUT *heterogeneity & mixed findings*

& lack of specificity

KEY RECOMMENDATIONS

⇒ Advances in neuroimaging, fluid biomarkers, genetic testing and emerging technologies continue to provide valuable research tools for the investigation of sport-related concussion neurobiology in the areas of diagnosis, prognosis and recovery.

⇒ While these technologies show potential for eventual clinical use, their translation is limited by methodological inconsistencies and a lack of generalisability, based on the existing evidence.

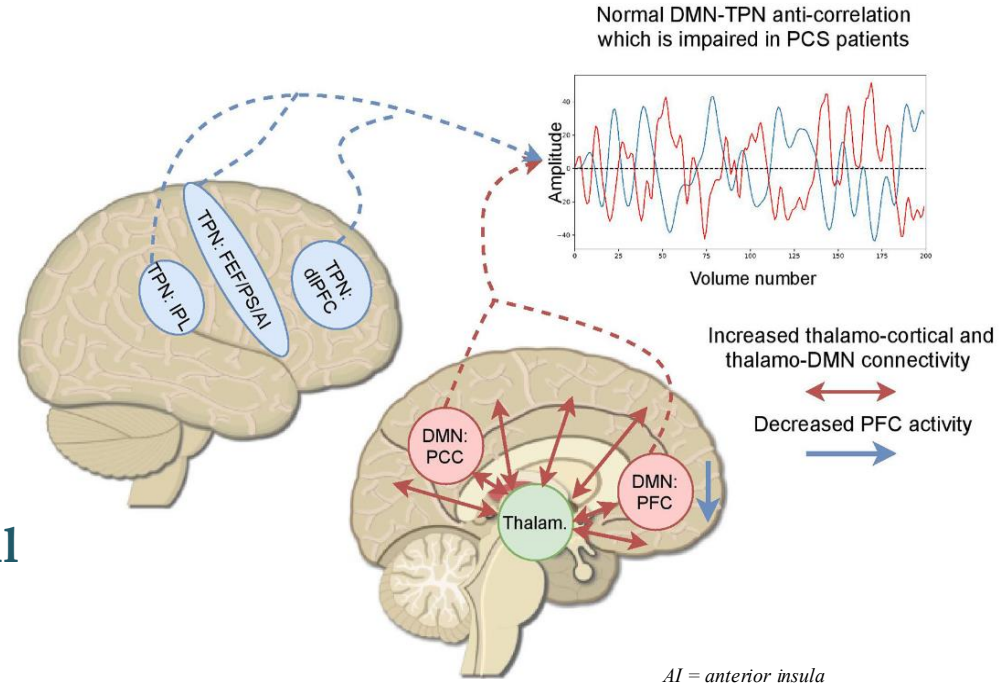
⇒ Progression to further validate their clinical utility will require large, multisite, prospective longitudinal studies implementing standardised operating procedures, common data elements, consistent data collection time points and more sophisticated biostatistical approaches to data analysis.

Tabor et al. BJSM 2023

Functional network alterations

Scoping review - 80 studies

- 10 conventional MRI
- 24 DWI
- 23 fMRI
- 9 EEG/MEG
- 14 others (eg, fNRIS)



fMRI : DMN/TPN & thalamo-cortical

BUT *heterogeneity & mixed findings*

& lack of longitudinal studies & control groups

AI = anterior insula
dlPFC = dorsolateral prefrontal cortex
FEF = frontal eye fields
IPL = inferior parietal lobe
PCC = posterior cingulate cortex
PFC = prefrontal cortex
PS = precentral sulcus

Mortaheb et al. Frontiers Neurol. 2021

Long term alterations

Observational longitudinal study

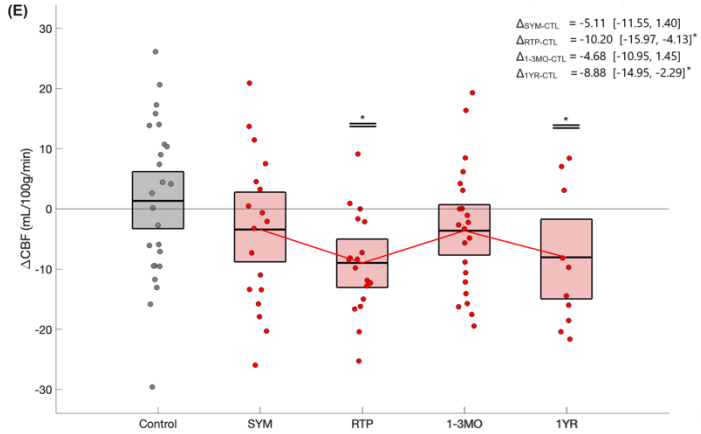
- N= 187 - 25 concussed & 27 injury-free athletes (male & female)
- fMRI (functional connectivity, CBF, DTI)
- Baseline -> symptomatic -> RTP – medical clearance -> 1-3 month -> 1-year

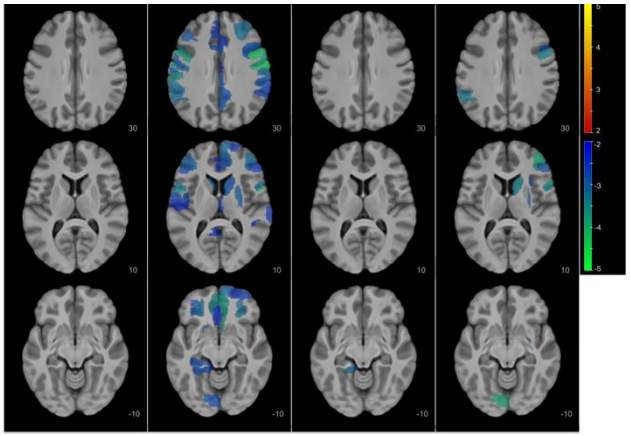
Chruchill et al. Neurology 2025

Long term alterations

Observational longitudinal study

- N= 187 - 25 concussed & 27 injury-free athletes (male & female)
- fMRI (functional connectivity, CBF, DTI)
- Baseline -> symptomatic -> RTP – medical clearance -> 1-3 month -> 1-year





Medial temporal regions

CBF : decreased at symptomatic
persisted beyond medical clearance & 1-year

Chruchill et al. Neurology 2025

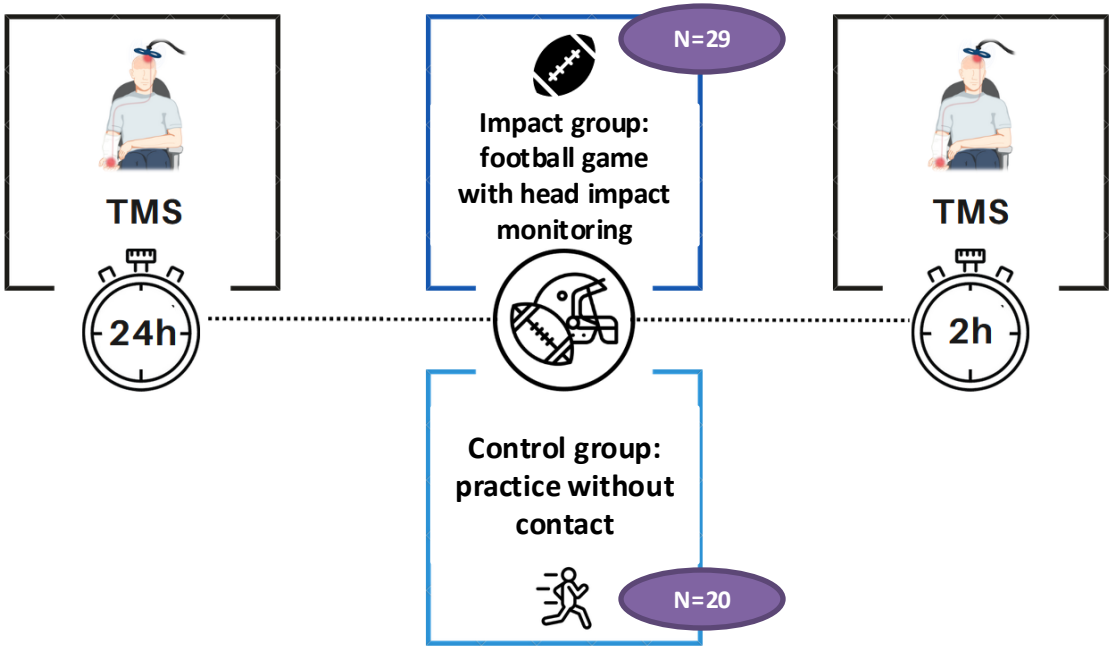
Short term & subclinical alterations

Head impacts

➔ Assess intracortical inhibition (**TMS**) post game (impacts) versus post training (without impacts)

Male athletes (n=29)
Varsity football
McGill & UdeM
2021-2022 seasons
Random assignment

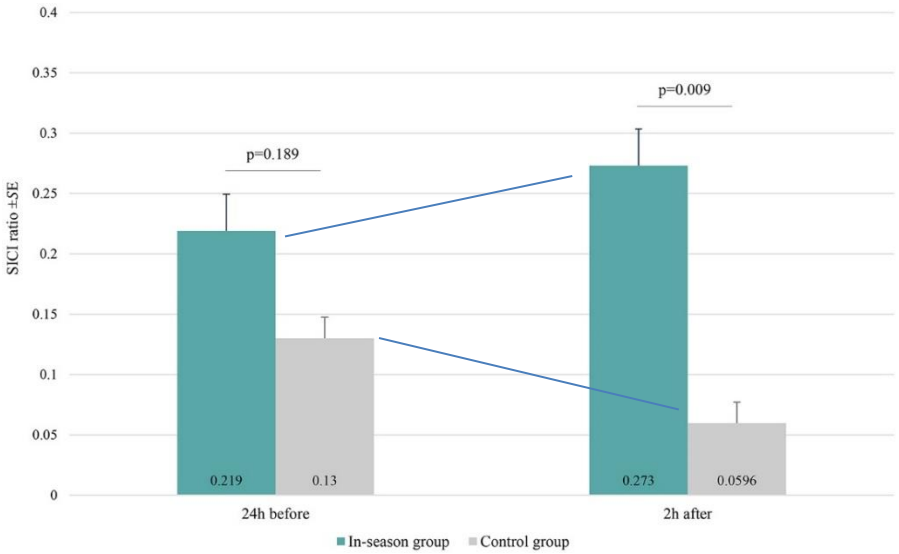
23 yo
185 cm
95 kg



Vinet & Martens et al. JNS, 2024

Short term & subclinical alterations

Intracortical inhibition – TMS

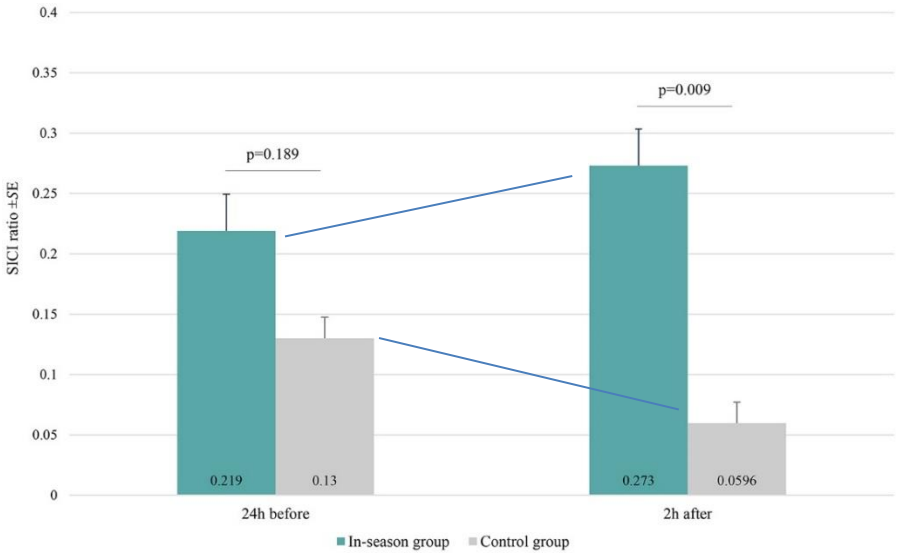


➔ Short term changes in cortical excitability following head impacts during games

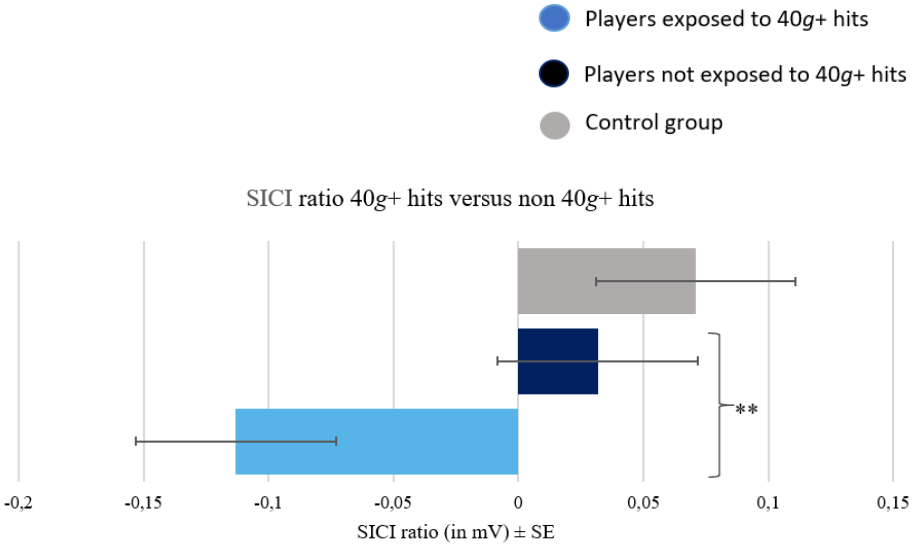
Vinet & Martens et al. JNS, 2024

Short term & subclinical alterations

Intracortical inhibition – TMS



TMS & impacts



➔ Short term changes in cortical excitability following head impacts during games

➔ Deleterious intracortical disinhibition with 40+g impacts (neurometabolic cascade)

Vinet & Martens et al. JNS, 2024

In clinical practice?

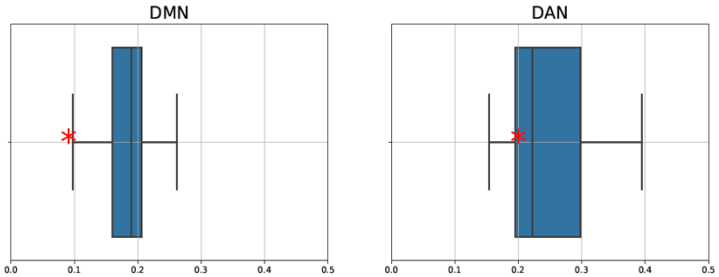
Concussion care pathway CHU Liège

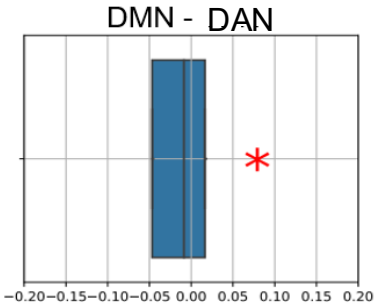
- Neuropsy & physiotherapy
- PM&R & neurology
- Clinical & high-density EEG
- Structural & functional MRI

Concussion care pathway

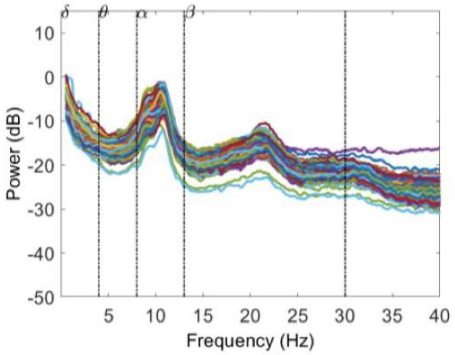
fMRI

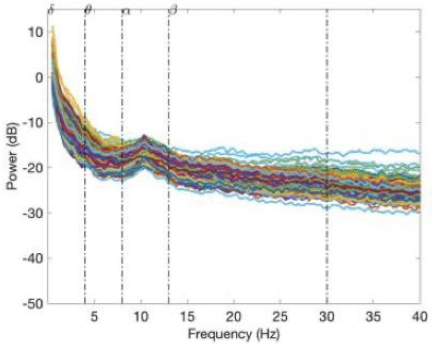
* Connectivity index





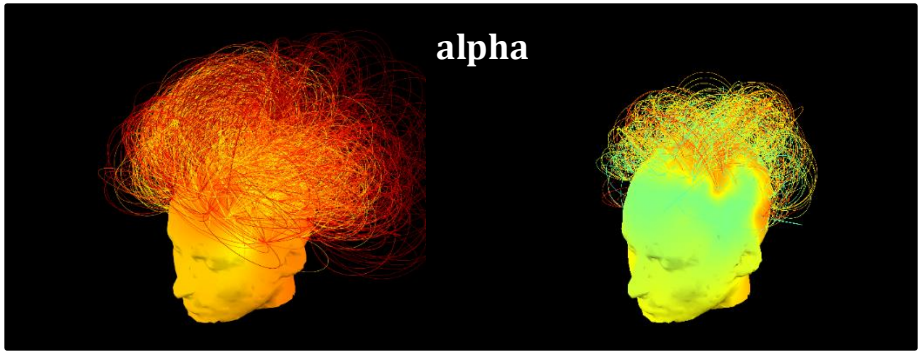
HD-EEG





Control

Patient



Schaefer, et al, Cereb Cortex 2018, Brett et al, Brain Imaging Behav. 2022 , Mortaheb et al. Front Neurol. 2021

Conclusions

Added value to understand 1. pathophysiological mechanisms of concussion

2. course of (subclinical) recovery

Objectification of microstructual & functional alterations

➔ Functional connectivity // persistent symptoms

➔ Subclinical & long-term alterations beyong clinical clearence

Use in clinical practice?

Large scale longitudinal studies

Need for clinical translation (fMRI ➔ EEG)

Enhanced specificity for patient's level interpretation

FREEDOM TO RESEARCH

LIÈGE université
GIGA institute
CONSCIOUSNESS

RÉSEAU FRANCOPHONE OLYMPIQUE DE LA RECHERCHE EN MÉDECINE DU SPORT
ReFORM

SPORT 2
CHU de Liège

CHU de Liège
CLINIQUE DE LA CONSCIENCE ET DE NEUROREVALIDATION

Thank you !

athibaut@uliege.be

www.giganeurorecovery.uliege.be

NeuroRecovery Lab
ADVANCING NEUROREHABILITATION THROUGH NEUROMODULATION