15th World Congress on Brain Injury
March, 2025

NeuroRecovery Lab
ADVANCING NEUROREHABILITATION THROUGH NEUROMODULATION

CHU de Liège
CLINIQUE DE LA CONSCIENCE ET DE NEUROREVALIDATION

Exploring Neurophysiological & Neuroimaging Alterations in Concussion

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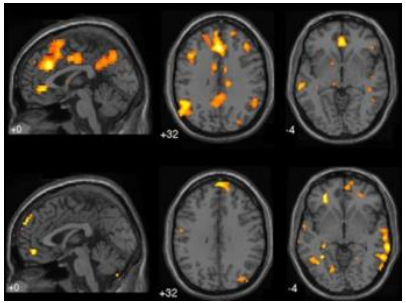
GIGA-Consciousness, University of Liege
NeuroRehab & Consciousness Clinic
University Hospital of Liege

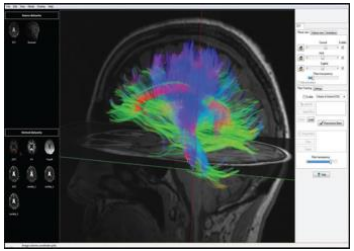
Disclosures

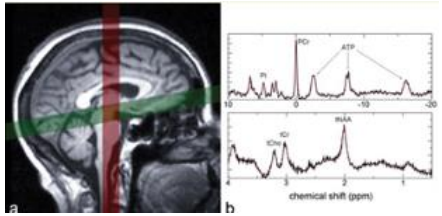
- Nothing to disclose

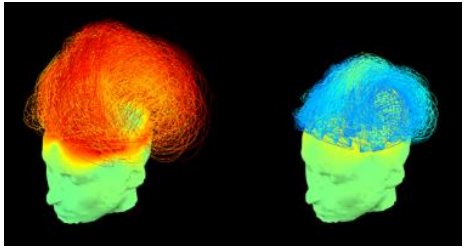
Advanced imaging techniques

- 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
- …









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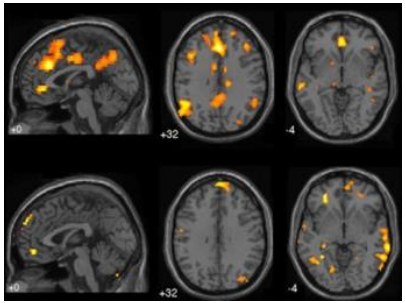
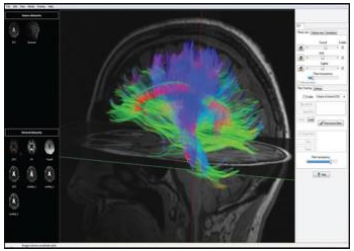
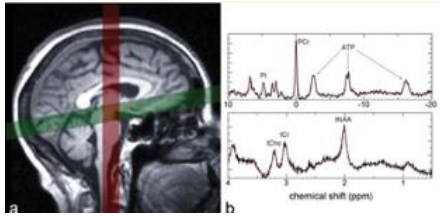
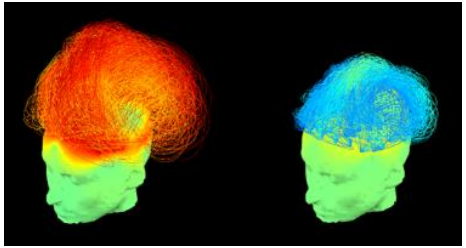
➔ in SRC & general population

For diagnosis, prognosis & head impacts









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

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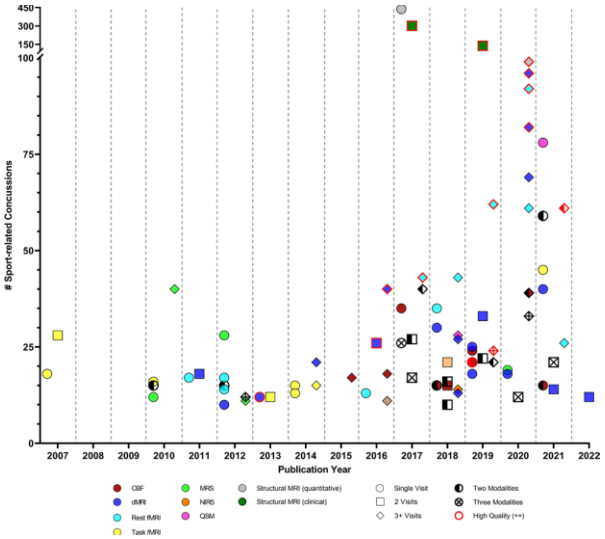
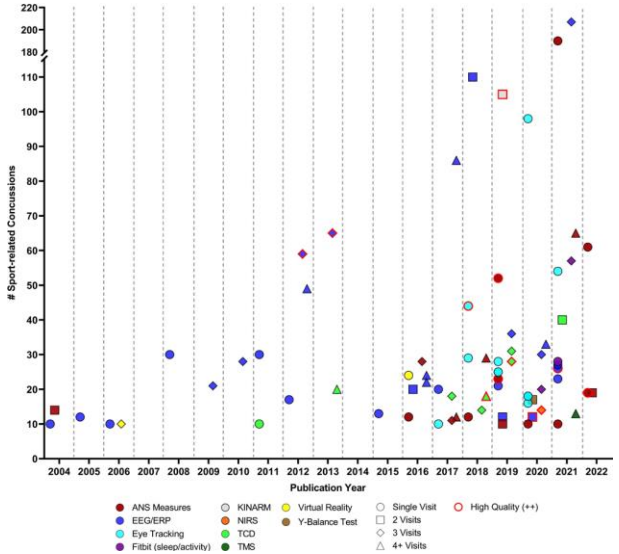
Neuroimaging



Electrophysiology



Tabor et al. BJSM 2023

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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

SRC & general population - scoping review
80 studies

- 10 conventional MRI
- 24 diffusion weighted imaging
- 23 fMRI
- 9 EEG/MEG
- 14 other techniques (eg, fNRIS)

Mortaheb et al. Frontiers Neurol. 2021

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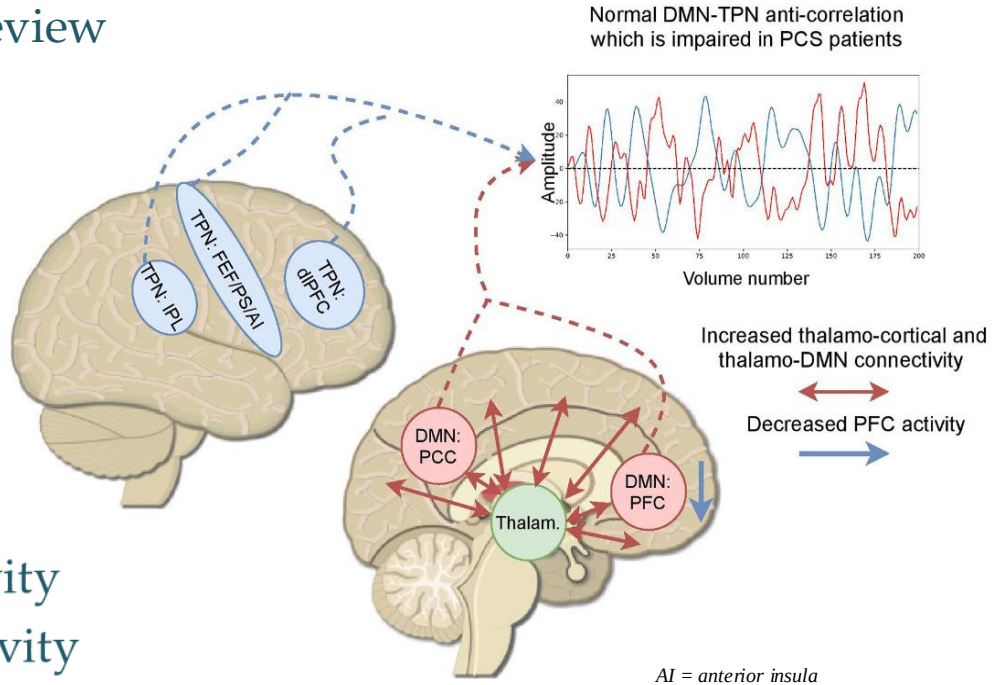


fMRI: inter- & intra-network connectivity

➔ Increased thalamo-cortical connectivity

➔ Reduced anti-correlation DMN/DAN

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

Thalamo-cortical connectivity

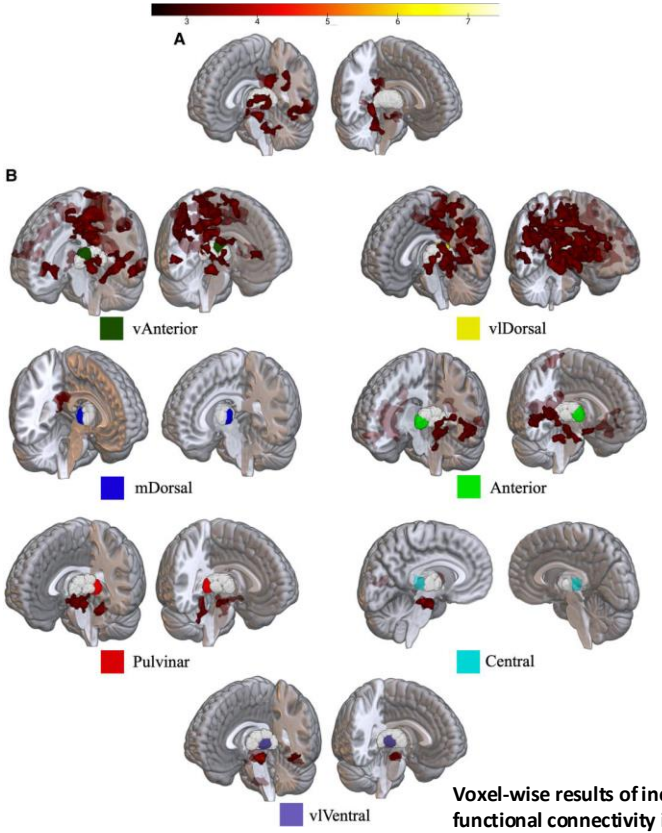
Longitudinal study – CENTER TBI
108 patients GCS 13–15 & normal CT
& 76 controls

Woodrow at al. Brain 2023

Thalamo-cortical connectivity

Longitudinal study – CENTER TBI
108 patients GCS 13–15 & normal CT
& 76 controls

- 47% incomplete recovery 6 month
- Normal structural MRI
- Acute increased thalamo-cortical connectivity
- Predictive of persistent symptoms



Voxel-wise results of increased functional connectivity in mTBI compared to controls

Woodrow at al. Brain 2023

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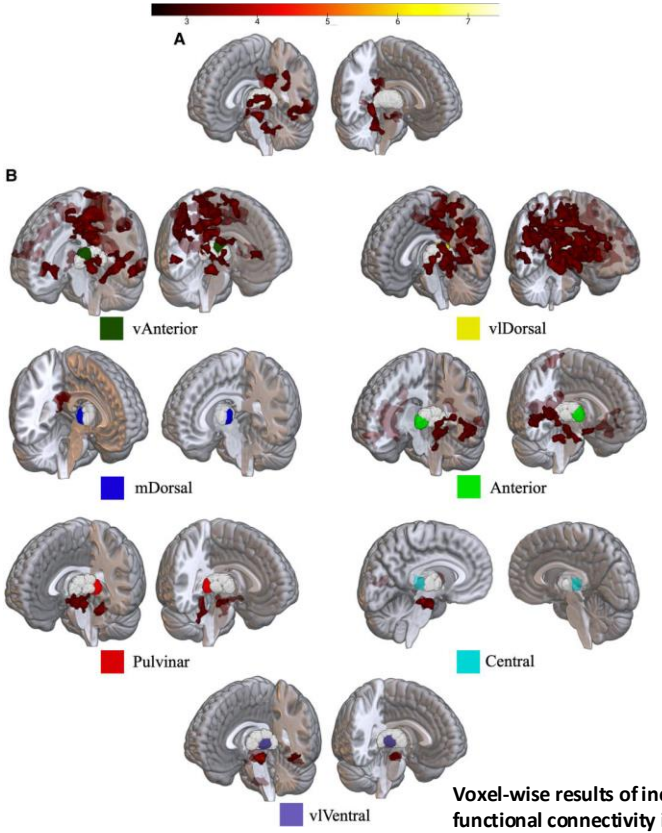
➔ Potential compensatory mechanism leading to chronic alterations



Voxel-wise results of increased functional connectivity in mTBI compared to controls

Woodrow at al. Brain 2023

Long-term alterations

Observational longitudinal study

- N= 187 - 25 concussed & 27 injury-free athletes
- fMRI (functional connectivity, CBF, DTI)
- 1. baseline, 2. symptomatic, 3. RTP – medical clearance, 4. 1-3 month & 5. 1-year post-RTP

Chruchill et al. Neurology 2025

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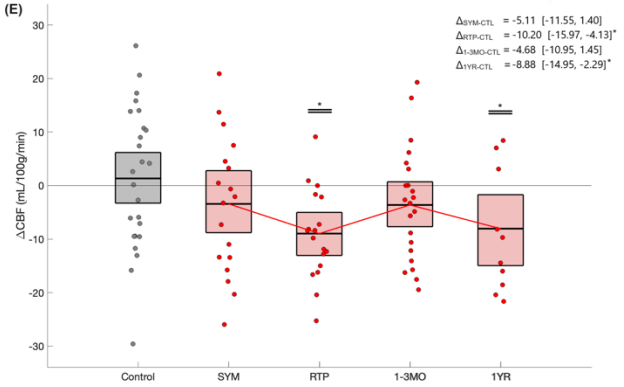
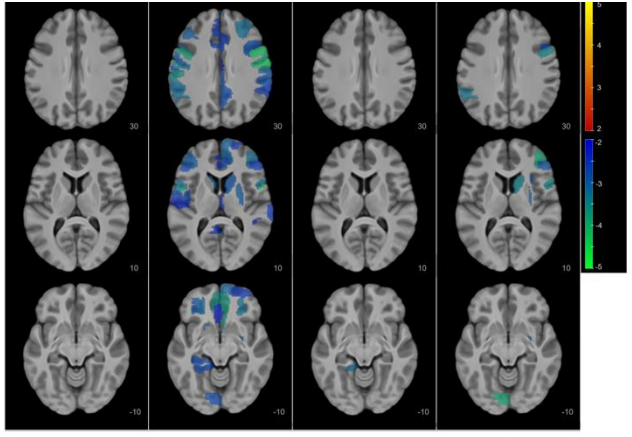
CBF : decreased symptomatic
remained decreased at RTP & 1-Y





Medial temporal regions

Chruchill et al. Neurology 2025

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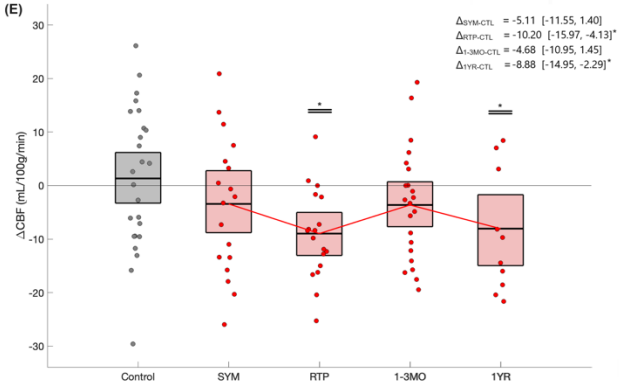

CBF : decreased symptomatic
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DTI : increased MD & decreased FA at sympt.
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➤ did not exceed longitudinal variability compared to injured-free athletes

Chruchill et al. Neurology 2024; Thibaut & Martens, Neurology 2025

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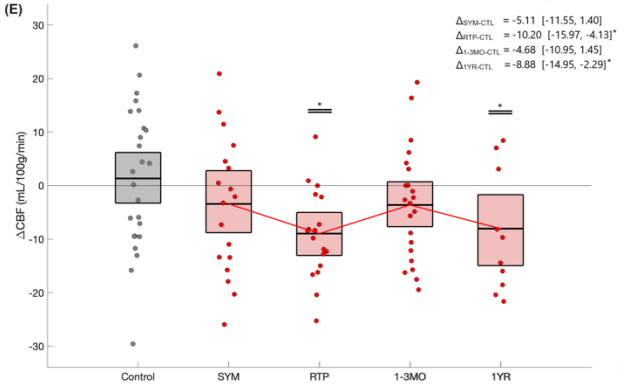

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➤ did not exceed longitudinal variability compared to injured-free athletes

➔ **Relevance of longitudinal studies & controls/injured-free athletes**

Chruchill et al. Neurology 2024; Thibaut & Martens, Neurology 2025

Short-term & subclinical alterations

Head impacts

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

Vinet et al. JNS, 2024

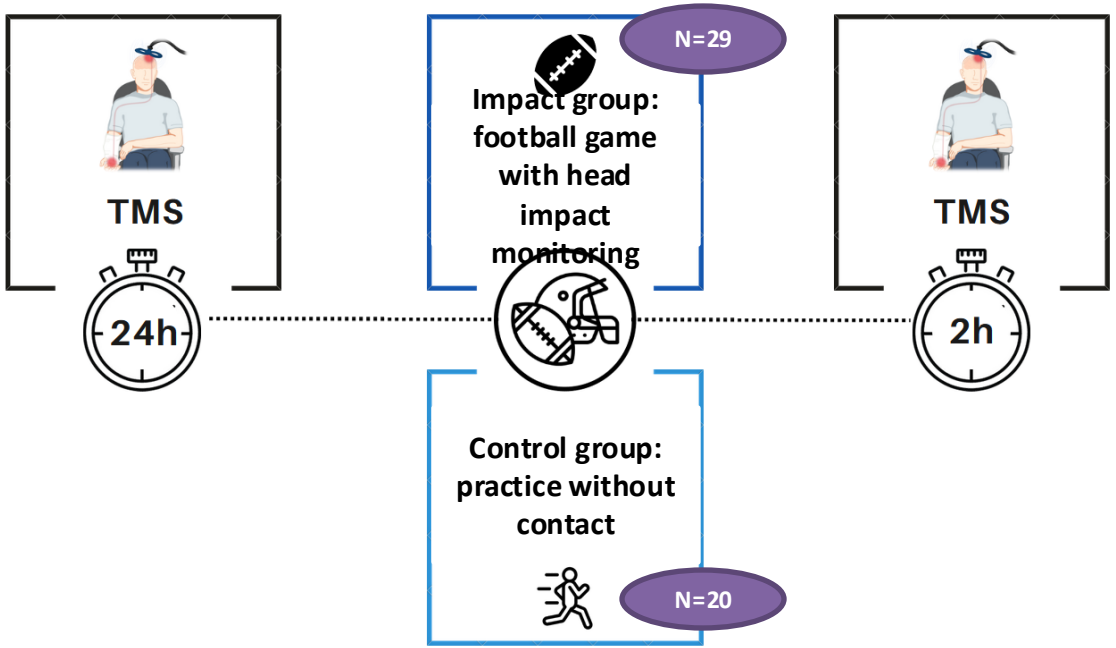
Short-term & subclinical alterations

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 years
185 cm
95 kg

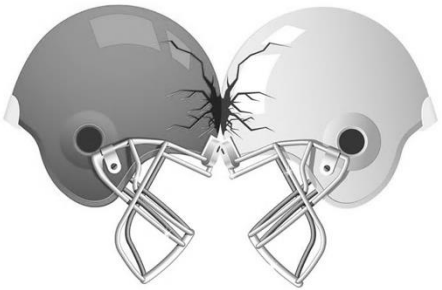


Vinet et al. JNS, 2024

Short-term & subclinical alterations

Head impact exposure (game)

10*g*+



n = **11,6** impacts / player

F tot = **234** *g* / player

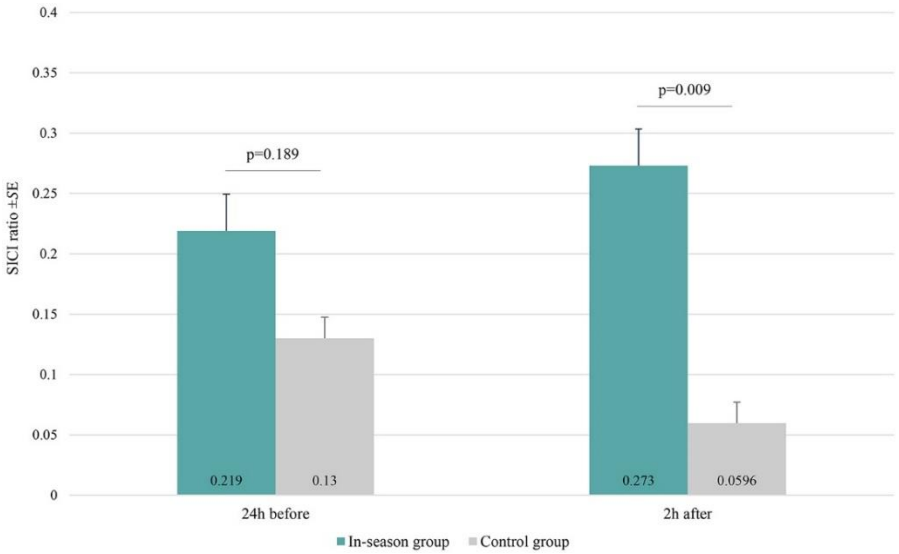
F = **18,9** *g* / impact

Impact category	N players	N impacts
10 – 24 *g*	29	9
25 – 39 *g*	25	2
40 – 59 *g*	14	1
≥ 60 *g*	5	1

Vinet et al. JNS, 2024

Short-term & subclinical alterations

Intracortical inhibition – TMS

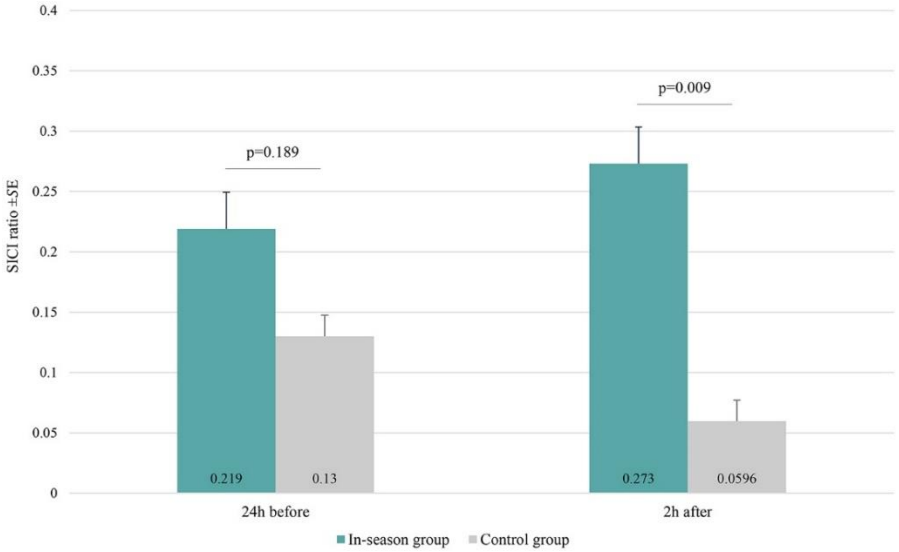


➔ Short term changes in cortical excitability following head impacts during games

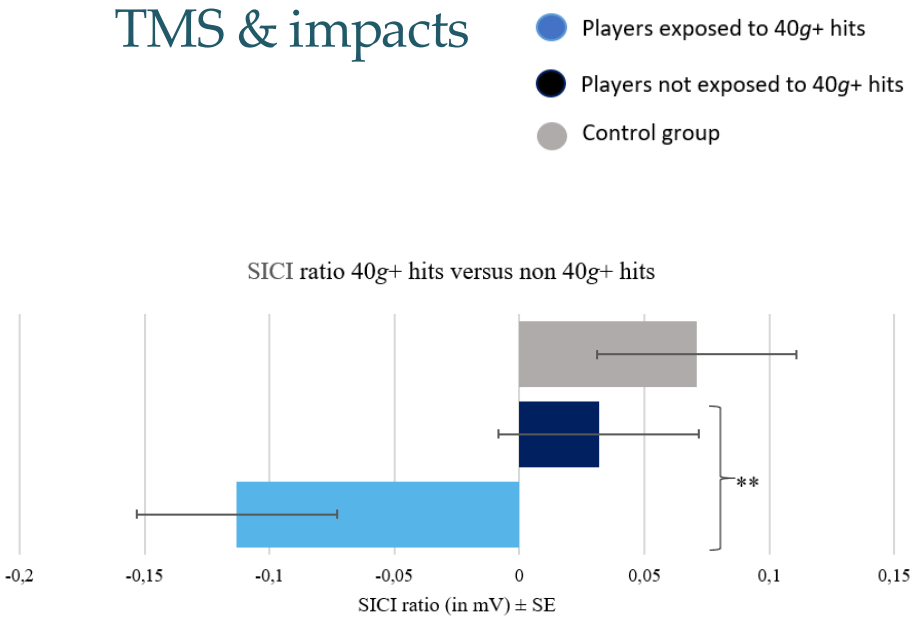
Vinet et al. JNS, 2024

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 et al. JNS, 2024

In clinical partice?

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NeuroRecovery Lab

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Concussion care pathway

NeuroRecovery Lab

Who ?

Mild head trauma

Moderate head trauma

When ?

D0 if identification of 1 Red Flag

From D14 if persistence of post-concussion symptoms

What is ?

Neuropsy.

PM&R & neuro

EEG & (f)MRI

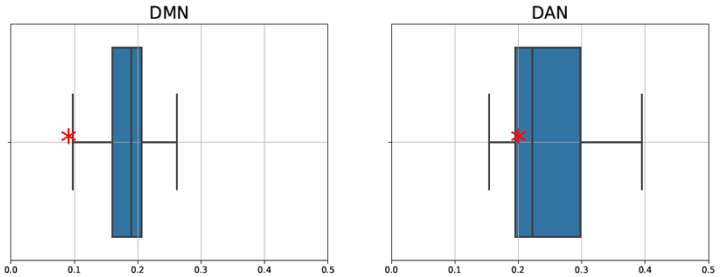
....

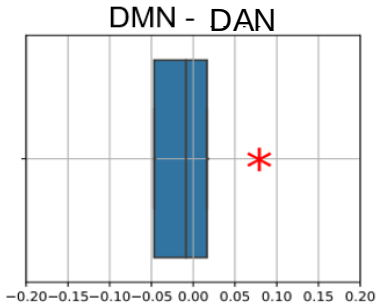
- Neuropsychological evaluation
- PM&R evaluation
- Clinical & high-density EEG
- Structural & functional MRI

Concussion care pathway

fMRI

* Connectivity index





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

Concussion care pathway

fMRI

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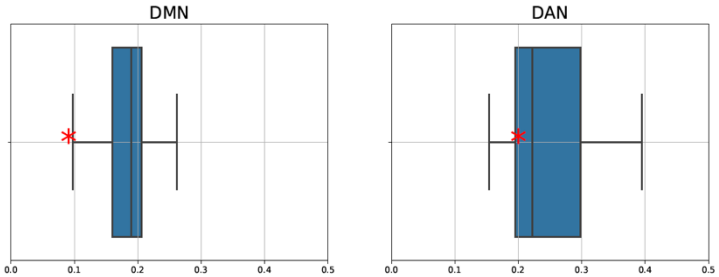
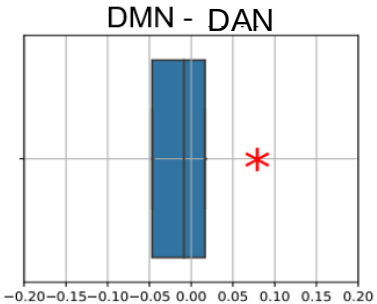
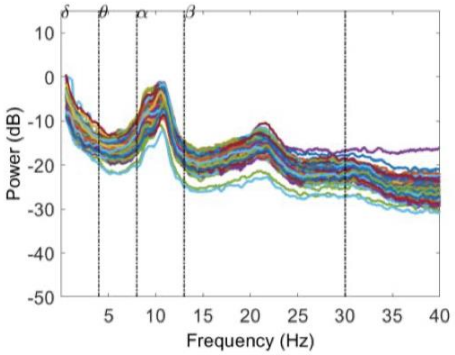
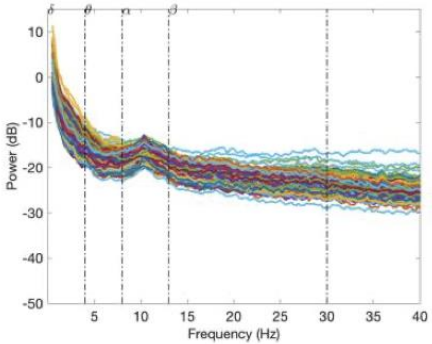




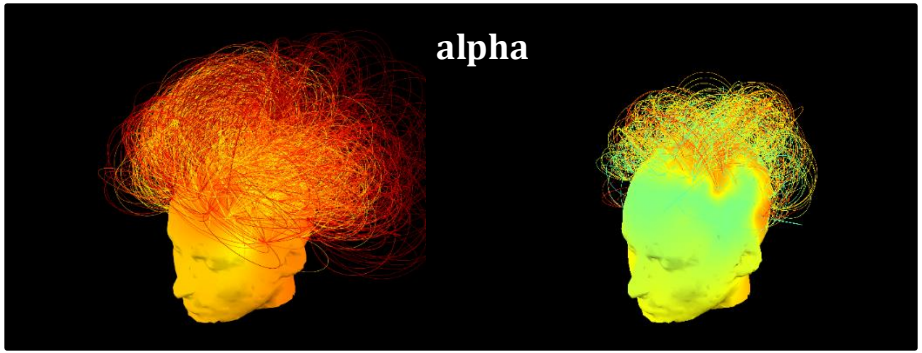
HD-EEG





Healthy control

Patient



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fMRI

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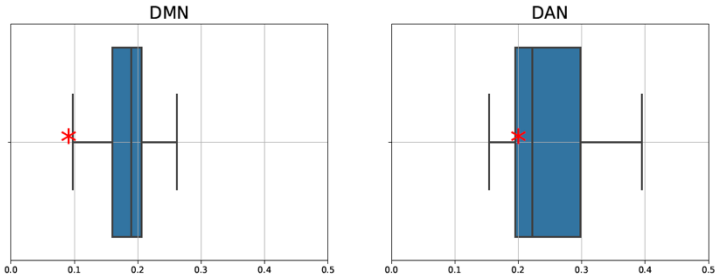

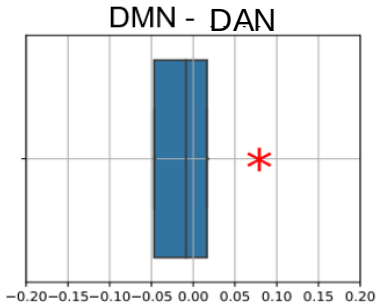

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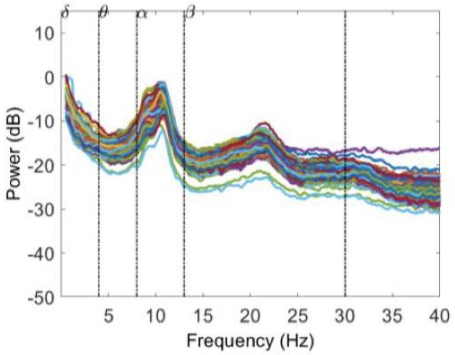

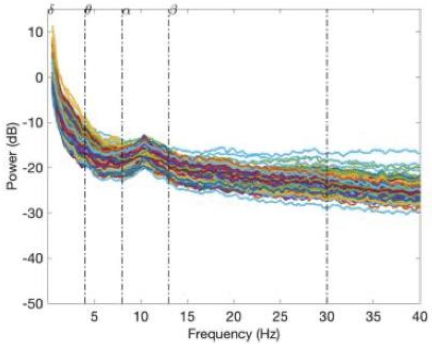

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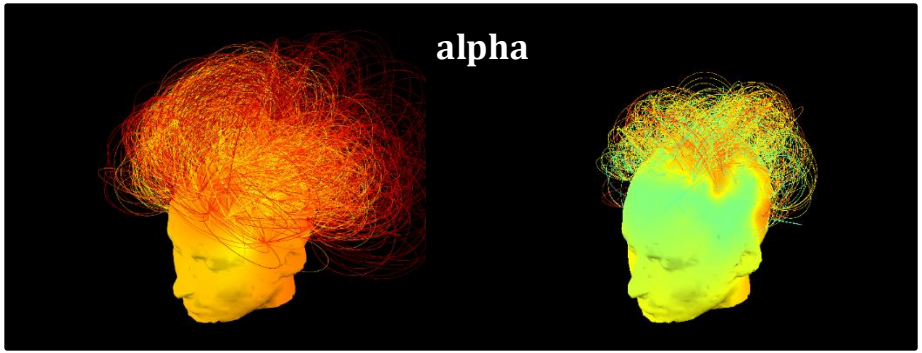

LOURAS - poster session Friday 21th 2.30pm

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

➔ thalamo-cortical connectivity

➔ intra & inter networks connectivity

➔ importance of control groups, especially in SRC

➔ alterations persists beyong clinical clearence

Need for clinical translation (fMRI → EEG) & enhanced specificity

COMA SCIENCE GROUP

fnrs FREEDOM TO RESEARCH

LIÈGE université GIGA institute CONSCIOUSNESS

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Thank you !

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www.giganeurorecovery.uliege.be