When fNIRS meets fMRI to complement cerebellar exploration

G. ROCCO [1], S. RAMANOËL [1,2], C. HABAS [3,4], A. ARLEO [2,5], O. MESTE [1], M.N. MAGNIÉ-MAURO [1,6], J. LEBRUN [1,5]

[1] Université Côte d'Azur, Nice, [2] Sorbonne Université, Paris, [3] Hôpital des XV-XX, Paris, [4] Université Versailles St Quentin en Yvelines, Paris, [5] CNRS, [6] CHU Nice, France

IEEE ISBI 2022 International Symposium on Biomedical Imaging
28-31 March 2022, ITC Royal Bengal, Kolkata, India

MOTIVATION

- Need for faster, cheaper techniques for functional studies in thriving **cerebellar neuroscience**
- A recent breakthrough in cerebellar EEG [1] paved the way for our first acquisition with fNIRS [2]

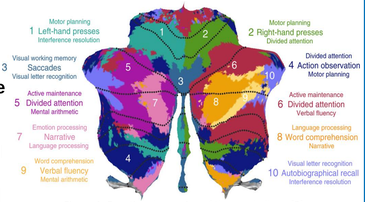
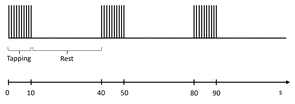


Figure 1: Functional mapping of the cerebellum [3]

fMRI validation of our fNIRS findings [2] + **joint sequential fNIRS/fMRI for finer spatio-temporal assessment of the neurovascular response**

METHODS

- One right-handed subject from our cohort selected to perform a **finger tapping** task with sequential fNIRS and fMRI recordings
- 3 runs summing up to 20 blocks (10 left hand + 10 right) and each block consisting of 10 s of activity + 30 to 35 s of rest



- **2 long** channels (Source-Detector = 3cm) and **2 short separation** channels on each cerebellar hemisphere using NIRx Sport2 device
- fMRI data acquired on a 3T Siemens Magnetom Skyra MRI system. Volumes acquired using a T2* weighted SMS-EPI sequence (vox= 2.5mm) with **temporal resolution of 1 second**.
- General Linear Model (GLM) block-design analysis for single participant
- Test of specific pipelines in Homer3 (fNIRS) and SPM12 (fMRI) for artifact removal before applying the GLM framework

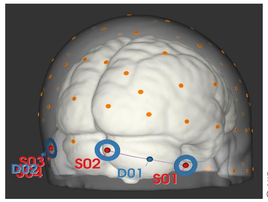


Figure 2: Optodes location on the cerebellum

RESULTS

fMRI processing:

- Volumes were realigned, coregistered (T1), normalized (MNI), smoothed (8mm)
- Data analyzed using a single participant GLM for block design
- Three regressors (Right and Left tapping, Rest) convolved with a canonical HRF.
- Significance threshold $p < 0.05$ FWE corrected at voxel level

fNIRS processing:

- Spline based Motion correction
- Band-pass filtering: 0.01 – 0.09 Hz
- Variations in oxy/deoxy concentrations (ΔHbO and ΔHbR) derived from Optical density
- GLM: Regressors: nearest short separation channel – Solving method: iterative weighted least squares - HRF model: Gaussians ($\sigma = 1$, step = 1 s)

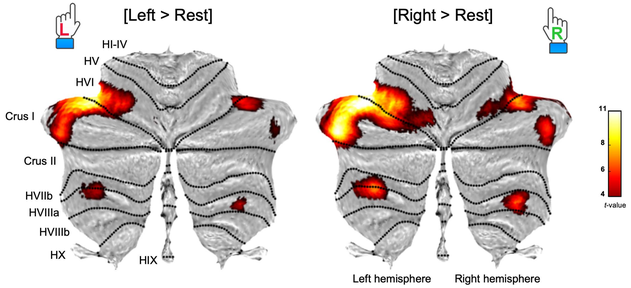


Figure 3: Cerebellum regions showing significant differences between conditions and represented on a two-dimensional template with lobules indicated by roman numerals from I to X with a prepended H for the hemispheric compartment. Statistical significance threshold for the peak level was set at $p < 0.05$ FWE corrected for multiple comparisons with extent threshold defined as 5 voxels.

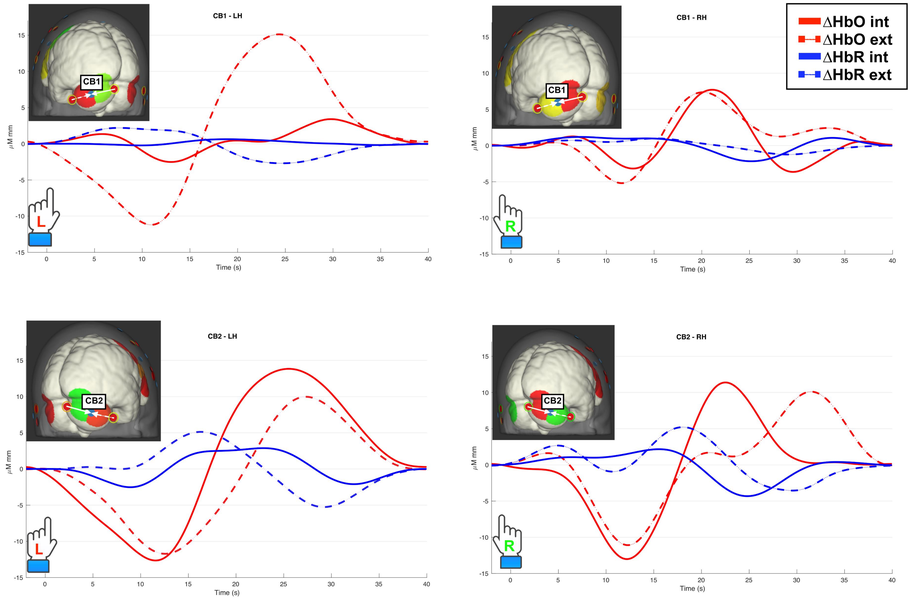


Figure 4: fNIRS block averages for each channel and hemisphere. Each subplot displays ΔHbO (red) and ΔHbR (blue) curves for the internal channel (solid line) and the external channel (dashed line) for each hemisphere (top left of each subplot) and the relative hand movement (left or right, bottom left of each subplot).

- With **fNIRS (Fig. 4):**
  - ✓ for **subdominant** hand movement: ipsilateral and strong contralateral activations
  - ✓ for **dominant** hand: weaker contralateral activation as in [4]
  - ✓ HRF (Hemodynamic Response Function) latencies still high (~10s) as in [2]
- With **fMRI (Fig.3):**
  - ✓ Bilateral activations from the fMRI analysis in Crus I, Lobules VI, VIIIA, VIIB of the cerebellum, **consistent with fNIRS results**
- The hemodynamics measured by **fNIRS** convey similar information to the ones from **fMRI**, but also **complementary** space – time granularity
  - ✓ better time resolution (7Hz) for fNIRS enables getting data between fMRI 1Hz acquisitions

CONCLUSIONS

- **Validation** of **fNIRS** as a viable tool for cerebellar explorations, **consistent with fMRI**
- Combining fMRI and fNIRS is a promising approach to investigate neural activation with **finer time/space resolution**
- Possibility to perform functional studies of the **synergies** between brain cortex, cerebellar circuitry, and deep brain structures, e.g. basal ganglia
- Peculiar hemodynamics at the cerebellar level call for further investigations of the interplay between ipsi- and contra-lateral responses and **hemisphere dominance**
- **Multimodal investigations** by adding **EEG** for a robust exploration of the finest timing aspects of cerebellar neural responses to fully complement **fNIRS/fMRI**

REFERENCES

[1] **Todd N.P., Govender S., and Colebatch J.G.** The human electrocerebellogram (ECeG) recorded non-invasively using scalp electrodes. *Neuroscience letters 2018,* 682: 124-131.

[2] **Rocco G., et al.** A Chiral fNIRS Spotlight on Cerebellar Activation in a Finger Tapping Task. *In Proc. IEEE EMBC 2021,* 1018-1021.

[3] **King M, et al.** Functional boundaries in the human cerebellum revealed by a multi-domain task battery. *Nature Neuroscience 2019*, 22(8):1371-1378.

[4] **Jäncke L., et al.** The effect of finger-movement speed of the dominant and the subdominant hand on cerebellar activation: a functional magnetic resonance imaging study. *Neuroimage 1999,* 9 (5): 497-507.

ACKNOWLEDGEMENTS

This project funded by EU H2020 COFUND programme "BoostUrCareer", Marie Sklodowska-Curie grant agreement no. 847581. Made possible thanks to NIRx, Berlin, and A. Anglade, CNRS research engineer at I3S. Ethically approved by UCA CERNI nº 2021-043 and CPP Ile de France V nº 16122.

CONTACT

Email: giulia.rocco@i3s.unice.fr

OSF Project: MuExC3Po, DOI:10.17605/OSF.IO/P6JMV