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Densifying Optodes Montage to Enhance Cerebellar fNIRS

G. Rocco¹, É. Delaire², S. Ramanoël¹, O. Meste¹, M.N. Magnié-Mauro¹, C. Grova², J. Lebrun¹

¹ Université Côte d'Azur, Nice, France ; ² Concordia University, Montreal, Canada
Presenting Author email address: giulia.rocco@i3s.unice.fr

Abstract: In this preliminary study, we introduce the use of personalized high-density optodes montage for cerebellar fNIRS acquisitions. One subject performed left or right finger tapping tasks consecutively with fNIRS and fMRI. Conclusive ipsilateral cerebellar activations were observed in the fNIRS HRF and supported by strong clusters in the fMRI.

Introduction: The recent blossoming of cerebellar neuroscience calls for novel and flexible techniques for further investigations. In a previous study, we proved the feasibility, through simple montage, of measuring cerebellar hemodynamics with fNIRS¹, and further validated it with fMRI². To better tackle the physiological challenge of accessing the cerebellum with NIRS, we assess here the advantage of using personalized high-density layouts of optodes, optimized in terms of sensitivity, and their impact on the HRF estimation.

Methods: One healthy right-handed male subject (27y) was recruited. A Monte-Carlo based method, implemented on NIRSTORM, was used to derive a personalized dense optodes positioning³, sensitivity-optimized using the subject's anatomical MRI (T1-weighted). The subject participated consecutively in one CW-fNIRS and one fMRI session, by performing an auditory cued finger tapping task with alternating hands (20 trials: 10s activity + 30 to 38s random rest). Guided by a neuronavigation system, the optodes (incl. one SS per hemisphere) were glued on the subject's head. fMRI was acquired using GRE-EPI sequences (3.7 mm3, TR = 2 s, TE = 25 ms, 41 slices). Both fNIRS and fMRI signals were processed following standard pipelines and a GLM block-design framework for single participant.

Results: A high sensitivity montage was achieved with 3 sources and 5 detectors for each cerebellar hemisphere (Fig 1A). Ipsilateral cerebellar activations were clearly observed (Fig 1B, for readability only S7D7, S7D9 are displayed for the left hemisphere, and S2D3, S3D1 for the right one). Accordingly, strong ipsilateral clusters were found in the fMRI ($p < 0.001$ FWE corrected at peak level) (Fig 1C). Precisely, [Left] (resp. [Right]) condition elicited activations in Crus-1 and lobule 8 cerebellar regions. Critically, Crus-1 activations were bilateral, though stronger in the ipsilateral cluster for each condition, matching well with the hemodynamics as measured by fNIRS.

Conclusion: This study demonstrates the feasibility and interest of personalized high-density fNIRS cerebellar montage to improve the quality of the acquired hemodynamic signals. This approach provides the potential to perform cerebellar 3D source reconstruction and also coherent spatio-temporal filtering to better separate the bona fide neuronal activity from physiological confounding components. At the more practical level, more participants are currently being recruited to fully assess the inter-subject variability.

References:

1. Rocco *et al.*, IEEE EMBC, (2021).
2. Rocco *et al.*, IEEE ISBI, (2022).
3. Machado *et al.*, J. Neurosci. Methods 309(1), (2018).

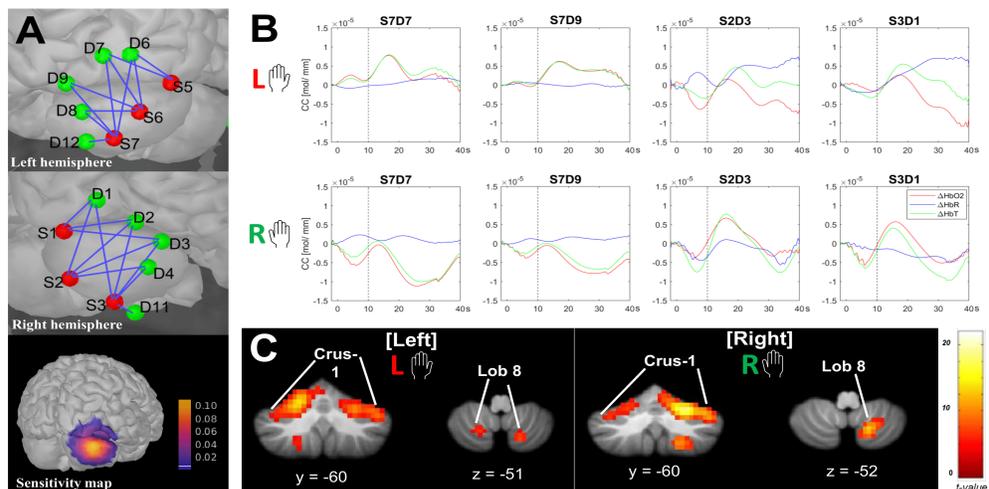


Figure 1. A: personalized fNIRS montage. B: fNIRS HRF results. C: fMRI activated clusters



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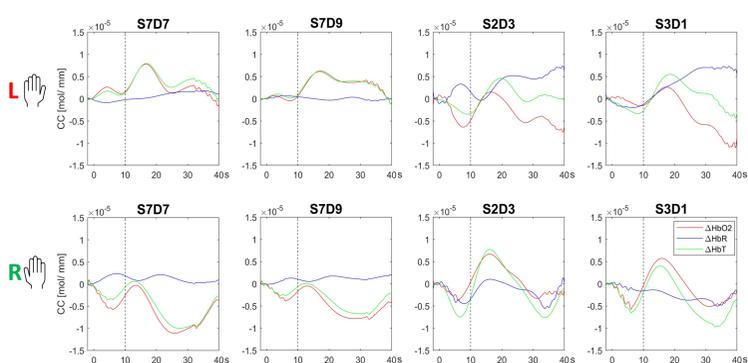
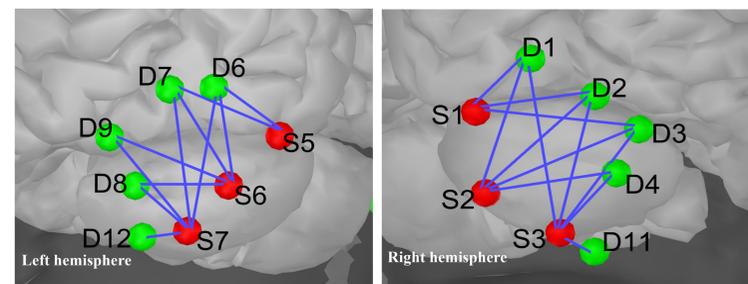
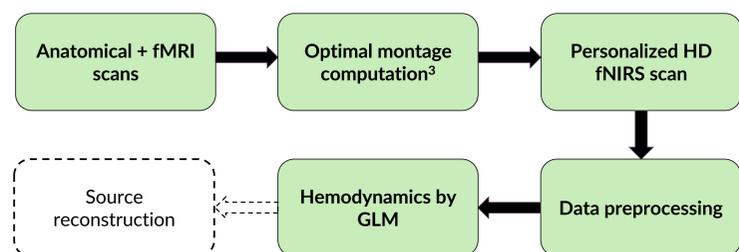
FRAMEWORK

- Novel & flexible techniques for cerebellar neuroscience
- Pioneered the feasibility of fNIRS for cerebellar hemodynamics¹ and further validated with fMRI²

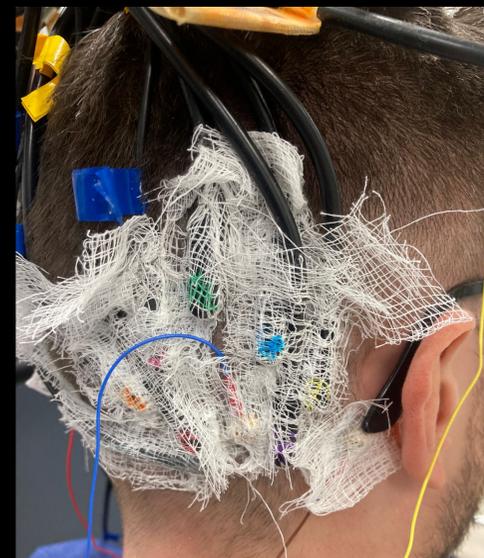
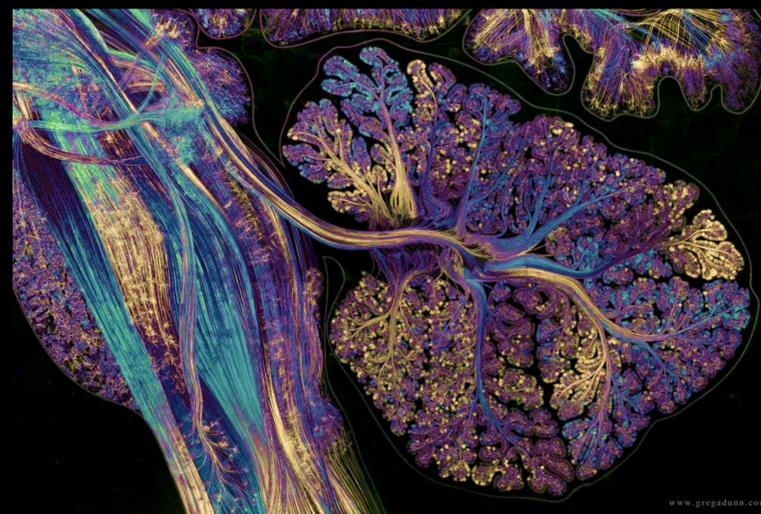
💡 Can a personalized high-density montage help to increase the sensitivity and better access the cerebellum?

METHODS & RESULTS

- One subject performed a block-design finger tapping task consecutively with fMRI and fNIRS



- ✓ Bilateral activations in Crus I, Lobules VIIIB of the cerebellum, consistent for fNIRS & fMRI results
- ✓ Good match on hemodynamics for fMRI & fNIRS
- ✗ Working on better denoising from the confounds

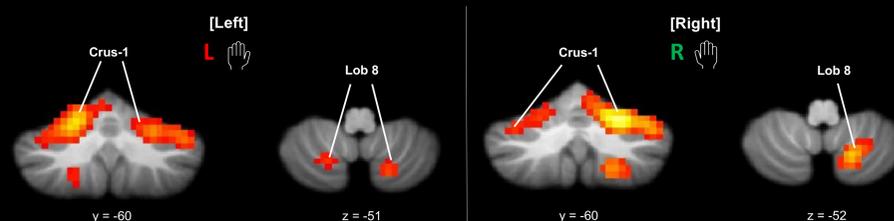


Personalized high-density optodes montage to enhance cerebellar fNIRS towards source reconstruction

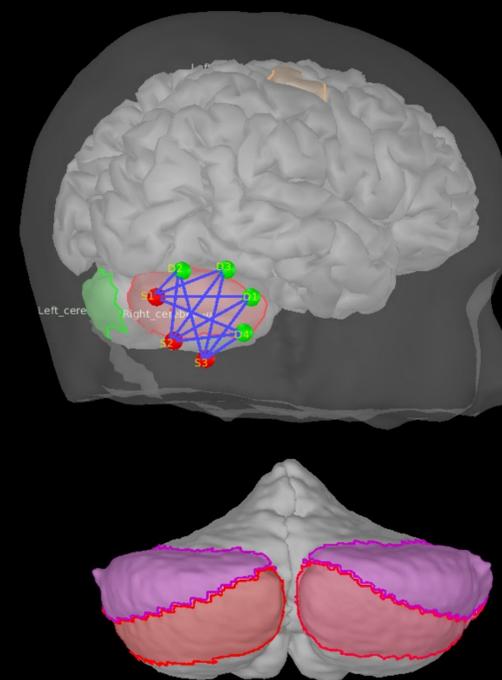


Are you sure you are measuring cerebellum activation? How?

- Subject-specific ROI-based montage
- No occipital confounds in the protocol
- Consistent with fMRI BOLD

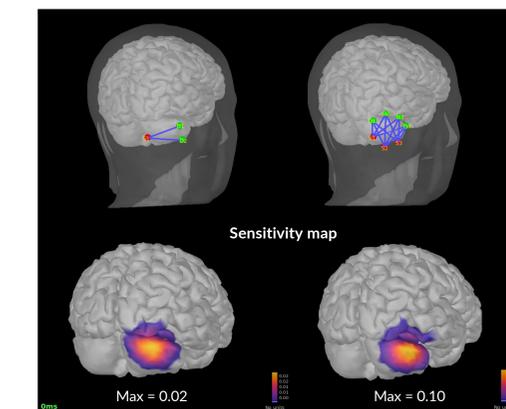


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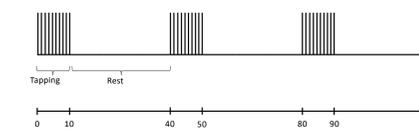


EXTRA FIGURES & MORE

- The sensitivity is 5 times higher!

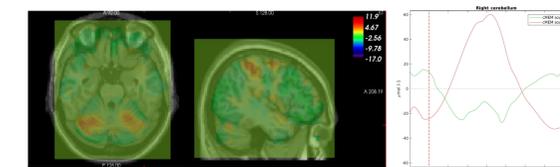


- Protocol: 20 trials (left + right hands) + random rest interval 30-40 s

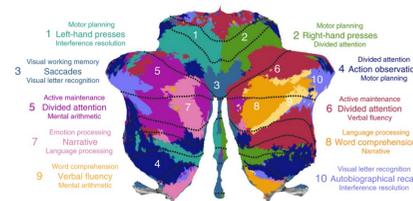


- fNIRS processing : Intensity to OD, Motion correction (TDDR), Detrending, Band-pass filtering (IIR filter order = 5 with $f_{cut} = 0.01 - 0.09$ Hz, OD to concentration without correction (DPF = 1), GLM subject level (OLS, Gaussians with $[\sigma \Delta t] = [0.5 \ 0.5]$, regression of the average of all SS)
- fMRI processing : Realignment, Coregistration, Normalization, Smoothing, GLM subject level (canonical HRF, $p < 0.001$ FWE corrected at peak level)

- Source reconstruction (on-going ...)



Cerebellum involved also in cognition and emotion ...



from King's Cerebellar Atlas (2019) © Nature PG

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1. Rocco et al., in IEEE EMBC, (2021). <https://doi.org/10.1109/EMBC46164.2021.9629565>
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✉ giulia.rocco@i3s.unice.fr

