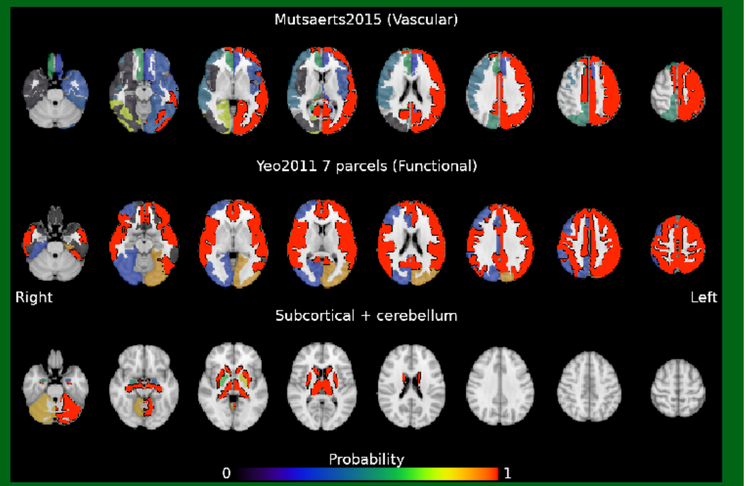
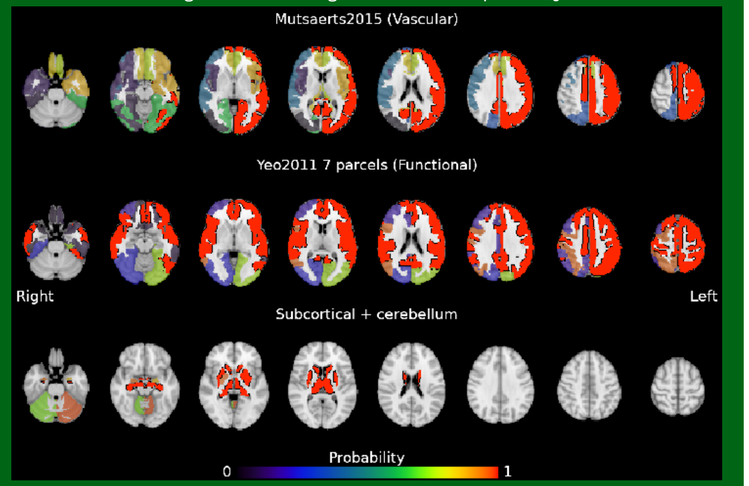
For more information, visit the website:

https://smoia.github.io/cvr-rel-var

Long-term stability of CVR and its lag response presents patterns that are equally explained by vascular anatomy, neural activity, and anatomy.



Above: Figure 1. Probability of ICC_{CVR} to be more homogeneous in the true data than in surrogates. Below: Figure 2. Probability of ICC_{lag}



Long-term stability of cerebrovascular reactivity varies across brain regions

Stefano Moia[1,2], Vicente Ferrer[1,2], Rachael Stickland[3], Ross Markello[4], Eneko Uruñuela[1,2], Maite Termenon[1], César Caballero-Gaudes[1], Molly Bright[3,5]

1. Basque Center on Cognition, Brain and Language, Donostia, Spain, 2. University of the Basque Country UPV/EHU, Donostia, Spain,
3. Physical Therapy and Human Movement Sciences, Feinberg School of Medicine, Northwestern University, Chicago, IL, USA, 4. Montreal Neurological Institute, McGill University, Montreal, QC, Canada,
5. Biomedical Engineering, McCormick School of Engineering, Northwestern University, Evanston, IL, USA

Email: **s.moia@bcbl.eu**

Background

- Cerebrovascular Reactivity (CVR) can be measured with BOLD functional MRI and induced with Breath-Hold (BH) [1] in a highly reliable way [2,3].
- However, the reliability of BH-induced CVR, frequently expressed using the Intraclass Correlation Coefficient (ICC), is not constant across the whole brain, possibly suggesting regional state-like or trait-like driving factors.
- Local variability has been observed not only across different brain tissues, but also across hemispheres and between cortical and subcortical areas [2,3]. The same observation can be extended to the CVR response lag [3]. Despite these observations, little is known about which factors induce this regionally-specific reliability.
- While it is possible that the neural activations elicited by the BH task are responsible for regional differences in CVR reliability, we hypothesize that the observed spatial patterns of long-term stability are associated with the vascular architecture of the brain..
- **Main aim**: We inspect how different architectures of the brain (e.g. a vascular architecture vs a functional network architecture) can specifically explain local differences in the long-term stability of CVR (i.e. be more homogeneous).

Results

- Fig. 1: Concerning ICC_{CVR}, the areas vascularised by the left intermediate and distal anterior, medial, and posterior carotid artery, and the right intermediate anterior carotid artery have high probability of presenting homogeneous reliability beyond that expected due to spatial autocorrelation. The somatomotor, dorsal attention, salience, and default mode networks, and the left control network also exhibit high probability of presenting homogeneous reliability. Most of the subcortical areas and the left cerebellum feature high homogeneity as well.
- Fig. 2: The same observations made for ICC_{CVR} can be extended to ICC_{lag} (except for the right dorsal attention network and left cerebellum).
- Parcels from all atlases show significant specificity, indicating that the three architectures taken into account here could explain equally well the observed patterns in ICCCVR and ICClag. This could indicate that CVR and its lag could share specific individual characteristics with other cerebral features (e.g. functional networks [10,11]). Moreover, given that functional areas are vascularised by sections of the carotid arteries, our observation that both atlases present similarly specific reliability corroborates the presence of an important link between vascular physiology and functional networks [12].

Bibliography

1. Kastrup A et al (1998), Stroke; 2. Lipp I et al (2015), Neuroimage; 3. Moia S et al (2021), Neuroimage;
4. Bright MG & Murphy K (2013), Neuroimage; 5. Moia S et al (2021), OpenNeuro; 6. Burt JB et al (2020), Neuroimage;
7. Yeo BTT et al (2011), J Neurophysiol; 8. Mutsaerts HJMM et al (2015), PLoS One; 9. Fischl B et al (2002), Neuron;
10. Finn ES et al (2015), Nature Neurosci; 11. Gratton C et al (2018), Neuron; 12. Bright MG et al (2020) Neuroimage.

Methods

- We leveraged a precision functional mapping dataset of BH tasks [4], acquired in seven subjects over ten sessions, using optimally-combined multi-echo BOLD fMRI [5]. Subjects were instructed through visual cues.
- We used the maps of the voxelwise reliability of CVR and lag metrics (ICC_{CVR} and ICC_{lag}, respectively) of the optimally-combined analysis adapted from [3] (Figure 3).
- We generated 1000 whole-brain surrogate datasets of the voxelwise ICC_{CVR} and ICC_{lag} maps, maintaining spatial autocorrelation properties [6].
- We used three different atlases, one based on functional networks [7], one based on vascular anatomy (arterial flow territories) [8], and one based on anatomical subcortical and cerebellar parcellation [9] to extract within-parcel variance of the ICC values from the original ICC maps and from all surrogates maps, scaling them by the variance of all brain voxels.
- Finally, for each ROI we assessed the probability of the ICC variance being lower in the original data than in the surrogate null data, that would indicate a better match with the intrinsic organisation of the data.

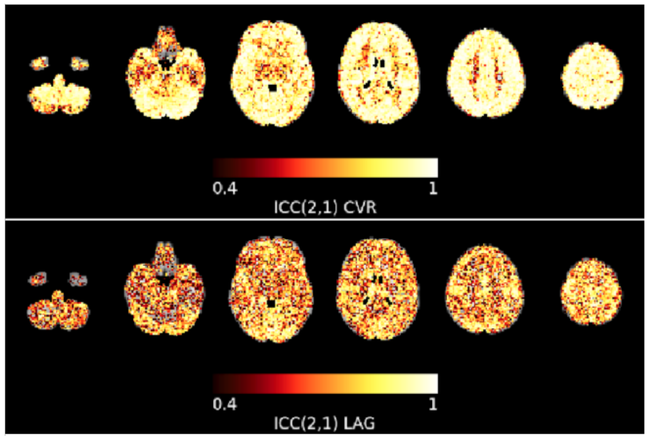


Figure 3. ICC_{CVR} and ICC_{lag} maps, adapted from Figure 9 in [] for the optimally-combined (OC-MPR) approach used in this work.

Acknowledgements

Research supported by the Eunice Kennedy Shriver National Institute of Child Health and Human Development of the National Institutes of Health under award number K12HD073945, the European Union's Horizon 2020 research and innovation program (Marie Skłodowska-Curie grant agreement No. 713673), a fellowship from La Caixa Foundation (ID 100010434, fellowship code LCF/BQ/IN17/11620063), the Spanish Ministry of Economy and Competitiveness (Ramon y Cajal Fellowship, RYC-2017- 21845), the Spanish State Research Agency (BCBL "Severo Ochoa" excellence accreditation, SEV- 2015-490), the Basque Government (BERC 2018-2021 and PIBA_2019_104), the Spanish Ministry of Science, Innovation and Universities (MICINN; FJCI-2017-31814)