Structure-Function Decoupling of Electrophysiological Brain Activity During Video-Watching

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Intro

Structure-function relationships in cognitive neuroscience have previously been studied using connectomics, for example by testing how brain anatomy (e.g. white matter connectivity) relates to spontaneous brain activity (i.e. functional connectivity)〔1, 2〕. This dependency of the functional signal on the anatomical structure is referred to as Structure-Function Coupling. Naturalistic stimuli such as videos offer the potential of richer conditions involving widespread brain networks spanning both cognitive and affective functions, such as multimodal integration, episodic memory, emotions, thus mimicking daily life situations. Stimuli eliciting strong shared neural responses provide an opportunity to study brain under a common window. In sum, we investigate structure-function coupling during highly correlated brain activity across subjects (n = 25) watching the same movie, using EEG and DWI data and used graph signal processing to quantify structural-functional decoupling patterns using Structural Decoupling Index (SDI).

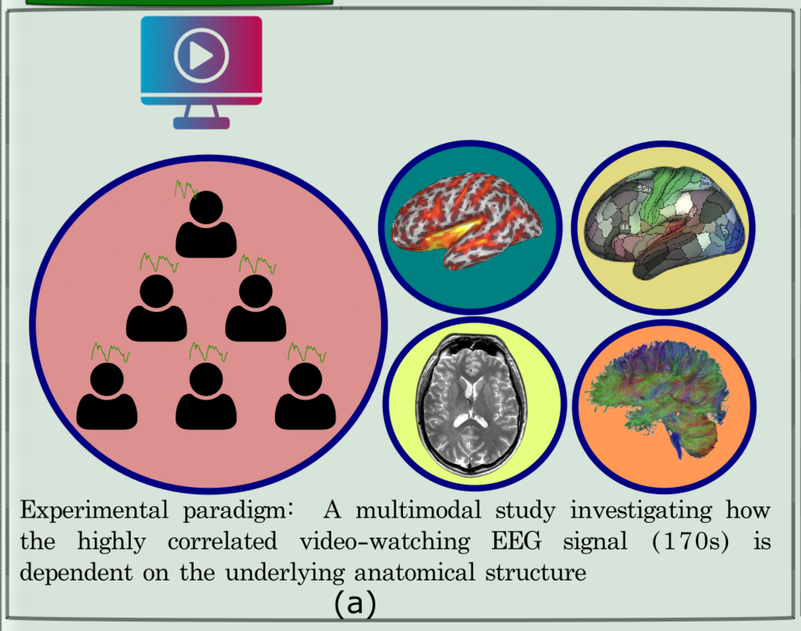
Aim

- Investigate structure-function coupling during video watching using inter-subject correlation (ISC).
- Exploit the advantages of two different modalities to study the structure-function relationships (EEG + anatomical connectome)

Dataset

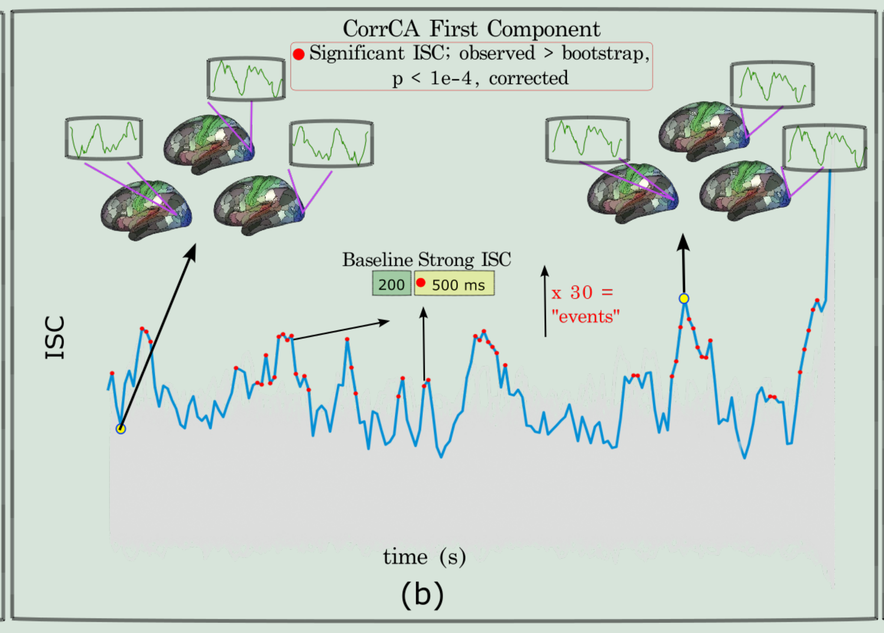
- Video-Watching EEG from Healthy Brain Network (HBN) 〔3〕; consensus structural graph from Human Connectome Project (HCP) 〔4〕
- Preprocessing and selection of subjects based on age, quality of EEG as in 〔5〕

Methods

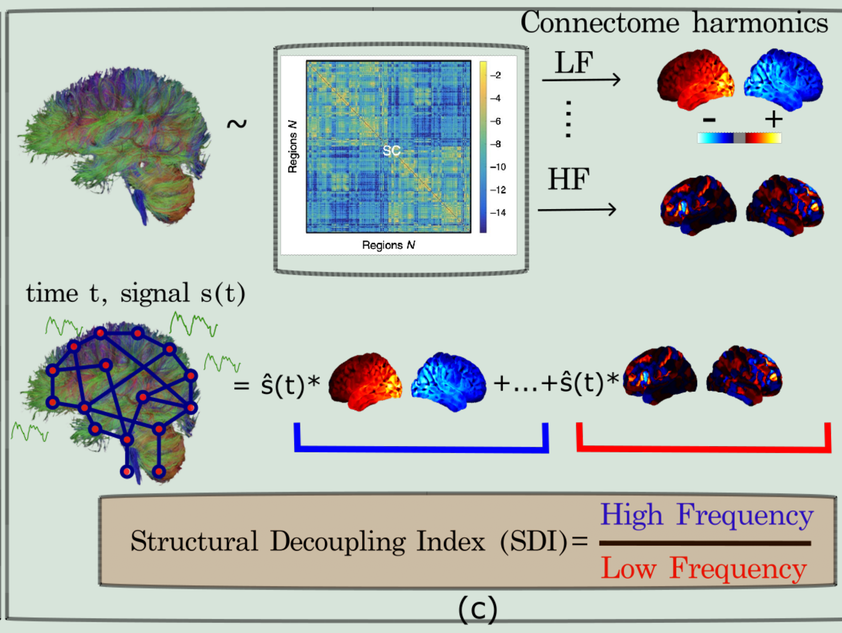


Experimental paradigm: A multimodal study investigating how the highly correlated video-watching EEG signal (170s) is dependent on the underlying anatomical structure

(a)

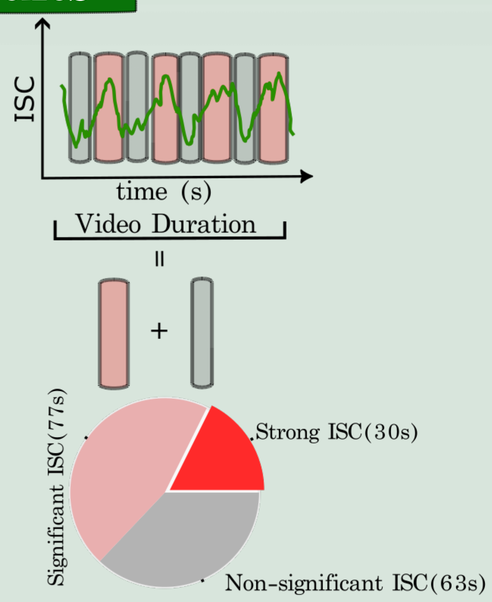


(b)

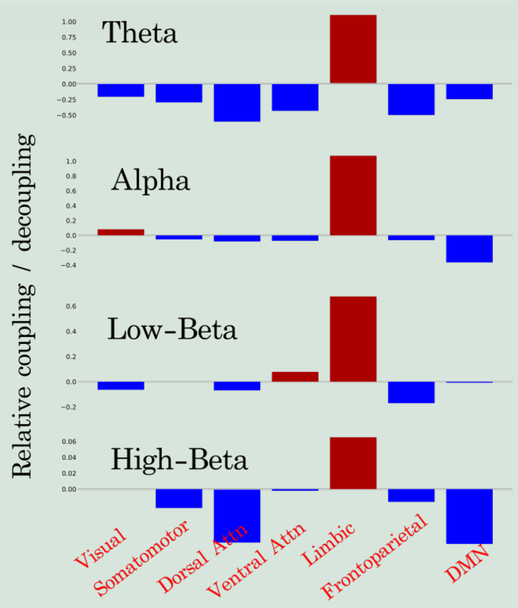


(c)

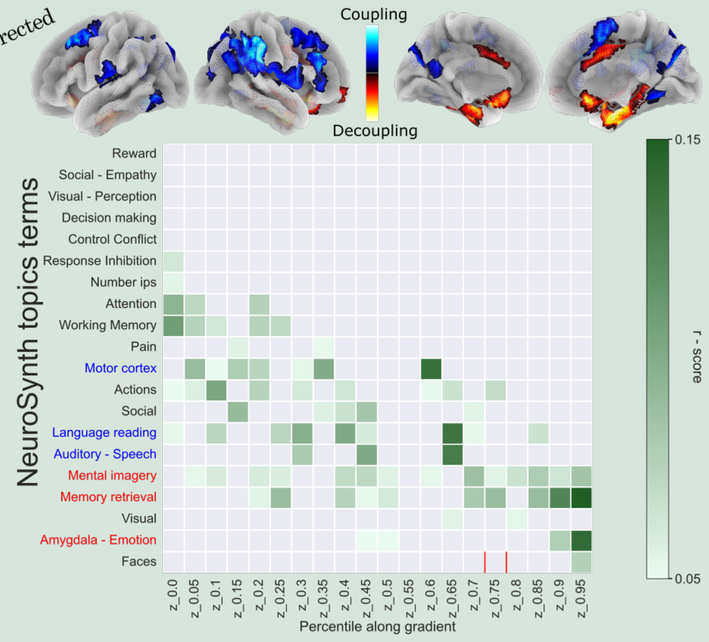
Results



(a) Depicting how the video stimulus is eliciting shared neural responses



(b) Relative change in coupling in 7 Yeo networks 〔6〕 during Strong ISC versus baseline



(c) Spatial map of SDI for Theta band; decoding results of Meta analysis of the top 5% SDI

Discussion

- Strong ISC during 17% of the video, suggesting not all of the stimulus elicits strongly stimilar neural responses across subjects.
- Panel (b) indicates relative change in Structure-Function coupling during Strong ISC versus baseline. Low frequency EEG signals are decoupled from structure in ventral regions. Meta-analytic search with NiMare / Neurosynth (Panel (c), bottom) shows similar patterns of the top 5% of the SDI (higher decoupling) with previous studies related to Emotions - Amygdala, Memory retrieval and processing faces.
- EEG signals in the theta band are coupled with a spatial pattern similar to previous fMRI studies involving language, motor and auditory functions.
- Our results are comparable with previous results in resting-state fMRI 〔1〕, suggesting that inter-correlated EEG activity during video watching has a similar pattern of decoupling with anatomical connectivity as spontaneous hemodynamics.

Perspectives

1) Use subject-specific graphs preserving individual variability to study the coupling at individual level; 2) Explore how the functional signal, evoked by exogenous (also endogeneous) sources, dynamically uses the structure; 3) Use physiological measures such as pupil dilation to enhance the understanding of the behavioral relevance; 4) Include, beside analysing the recorded activity, the first-person perspective via retrospective questionnaires recording the subjective experience felt watching the video

References

1. Preti, M. G., & Van De Ville, D. (2019). Decoupling of brain function from structure reveals regional behavioral specialization in humans. Nature communications, 10(1), 4747.
2. Suárez, L. E., Markello, R. D., Betzel, R. F., & Misic, B. (2020). Linking structure and function in macroscale brain networks. Trends in cognitive sciences, 24(4), 302-315.
3. https://healthybrainnetwork.org
4. https://www.humanconnectomeproject.org
5. Nentwich, M., Ai, L., Madsen, J., Telesford, Q. K., Haufe, S., Milham, M. P., & Parra, L. C. (2020). Functional connectivity of EEG is subject-specific, associated with phenotype, and different from fMRI. NeuroImage, 218, 117001.
6. Yeo, B. T., Krienen, F. M., Sepulcre, J., Sabuncu, M. R., Lashkari, D., Hollinshead, M., ... & Buckner, R. L. (2011). The organization of the human cerebral cortex estimated by intrinsic functional connectivity. Journal of neurophysiology.