Using open data and code to investigate brain-behaviour relationships

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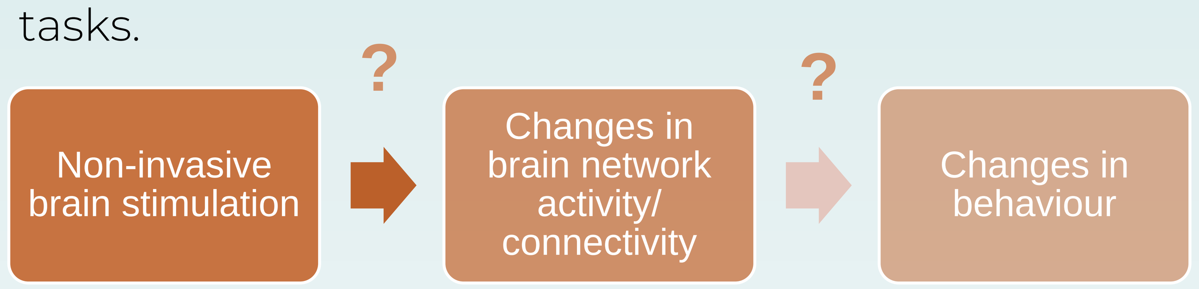
Introduction

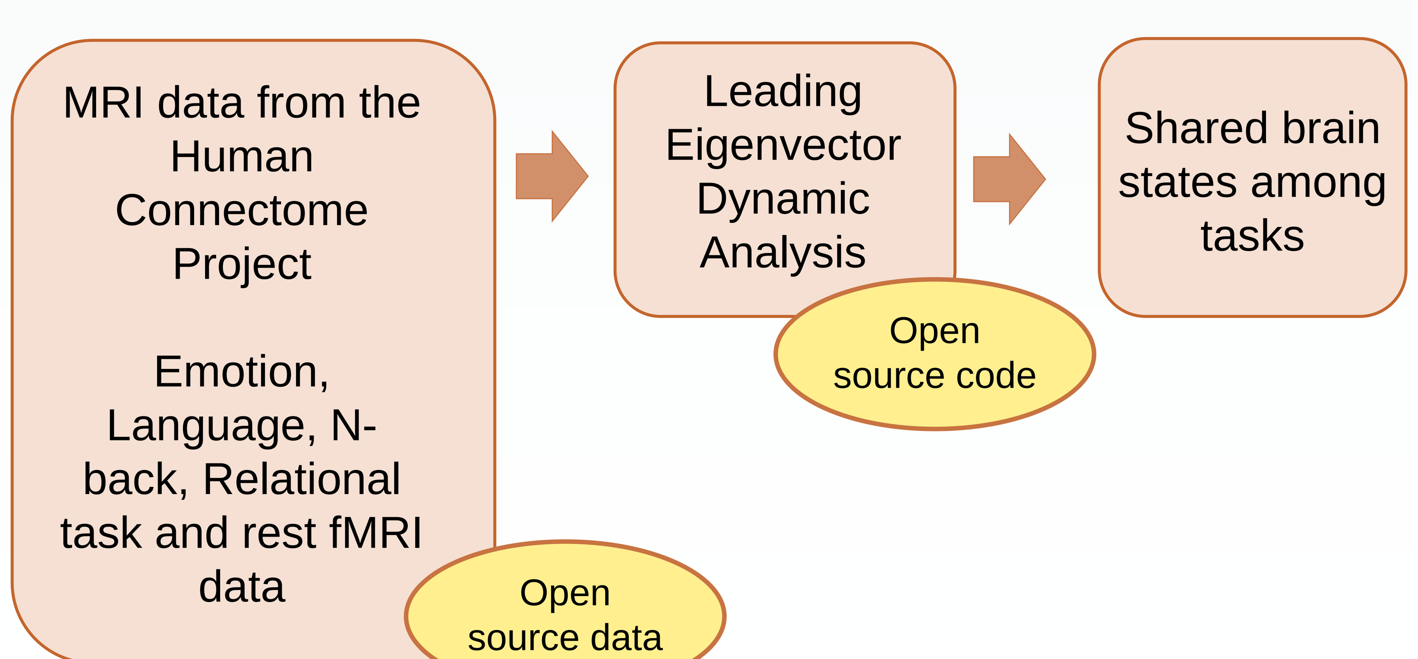
Neuromodulation uses sound, electricity, or magnetism to change how the brain works, with the aim of changing behaviour. However, current neuromodulation technology cannot reach its full potential until there is a mechanistic understanding of how stimulation influences brain network dynamics, and as a result, behaviour. Moreover, neuroimaging studies are often underpowered (median n=25), resulting in inflated effects and non-replicable results [1]. Utilising open data (n=187) and code, I have developed a pipeline that identifies recurrent patterns of brain network connectivity and their dynamics, as well as measures of complexity. I have assessed how these metrics relate to behaviour across a diverse set of cognitive tasks.



Open Research Practice

My study utilises validated open-source data and code; likewise, any additions to the LEiDA pipeline will be made available on GitHub. Any papers from this study will be made open access. Further recommendations to increase the openness and replicability of any part of this study are welcome. Collaboration, big data, and open access code are crucial tools needed to understand our brain and effectively utilise neuromodulation for clinical and research purposes.

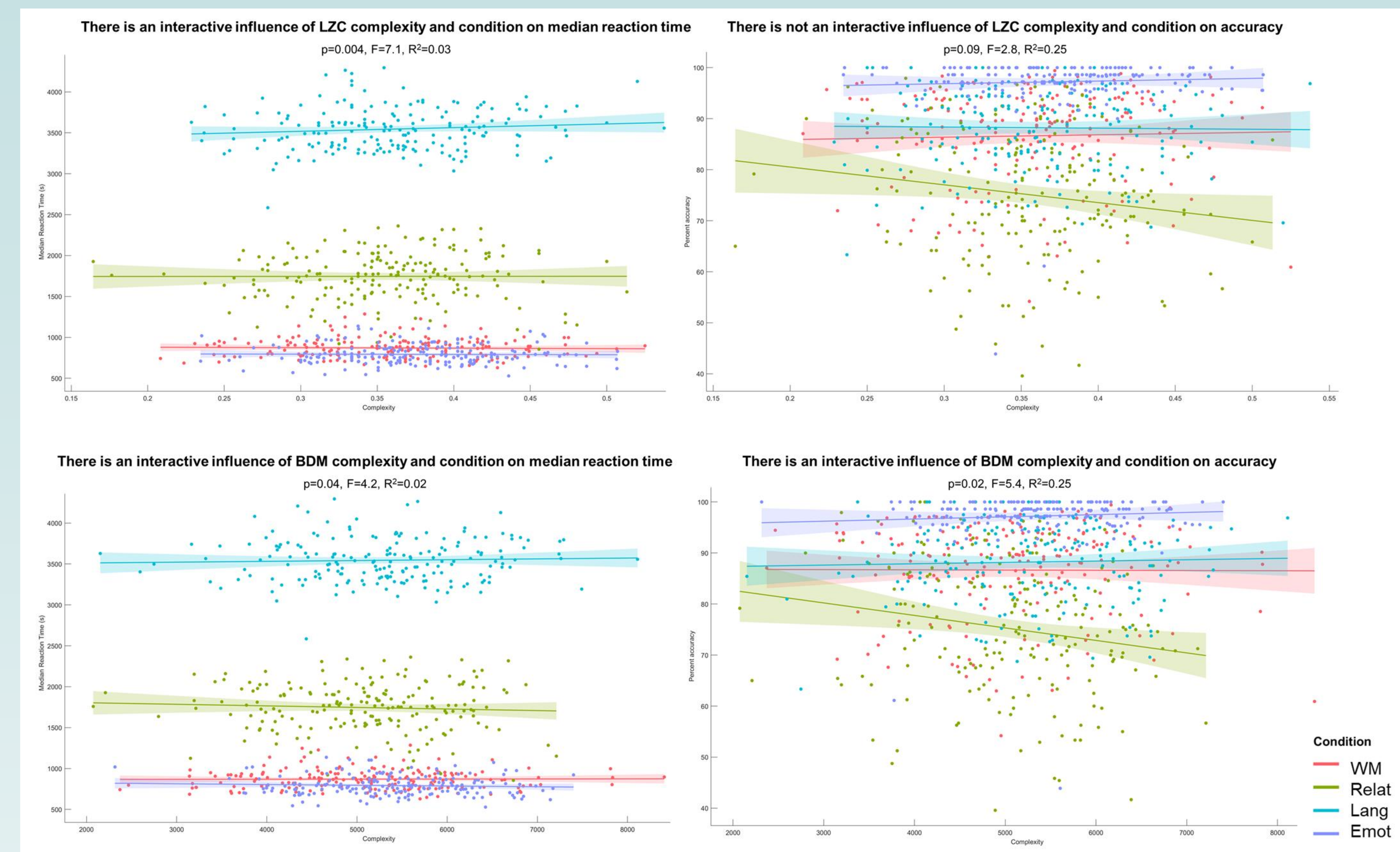
Determining the recurrent, phase-based connectivity states among conditions



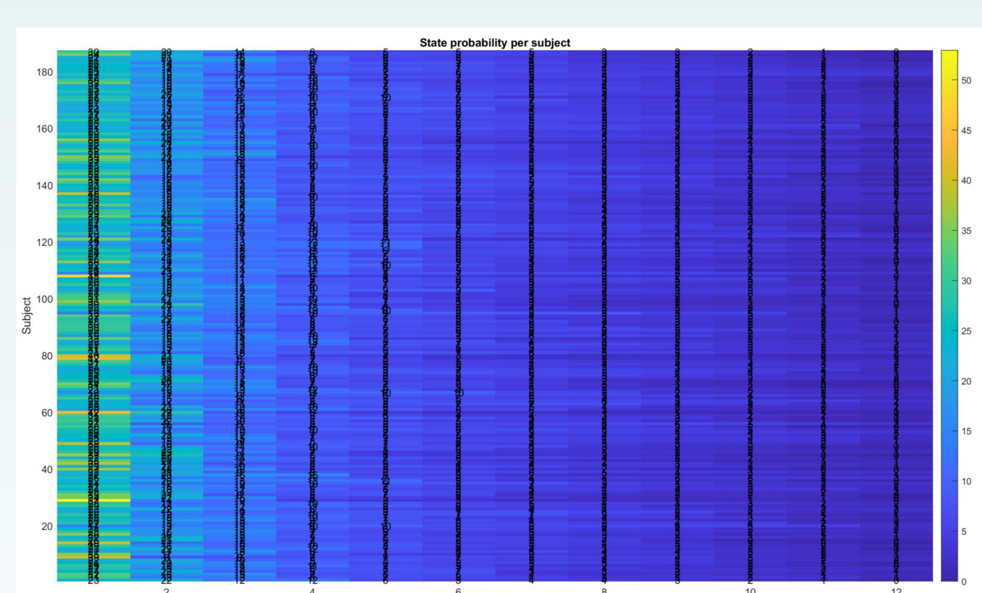
Methodology

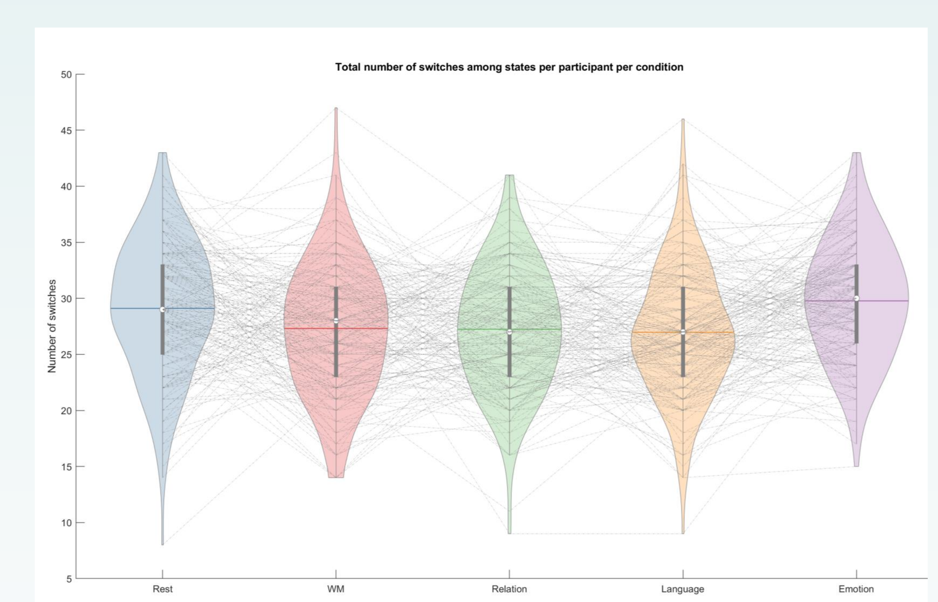
The Human Connectome Project (HCP) is an open, high-quality functional magnetic resonance imaging (fMRI) dataset of 1200 young adults resting or completing tasks [2]. Using a subset of 200 participants, we have used open-source code for Leading Eigenvector Dynamic Analysis (LEiDA) [3] to identify the shared connectivity states within and between experimental conditions. We have made several additions to the LEiDA pipeline, including Lempel Ziv (LZC, statistical) and Block Decomposition Methods (BDM, algorithmic) complexity metrics. Complexity is a measure of entropy and provides clues about the predictability of the brain's dynamics at both the regional and whole-brain level. Finally, we compare these metrics to each other and behavioural performance metrics to assess which brain metrics, if any, are predictive of task performance.

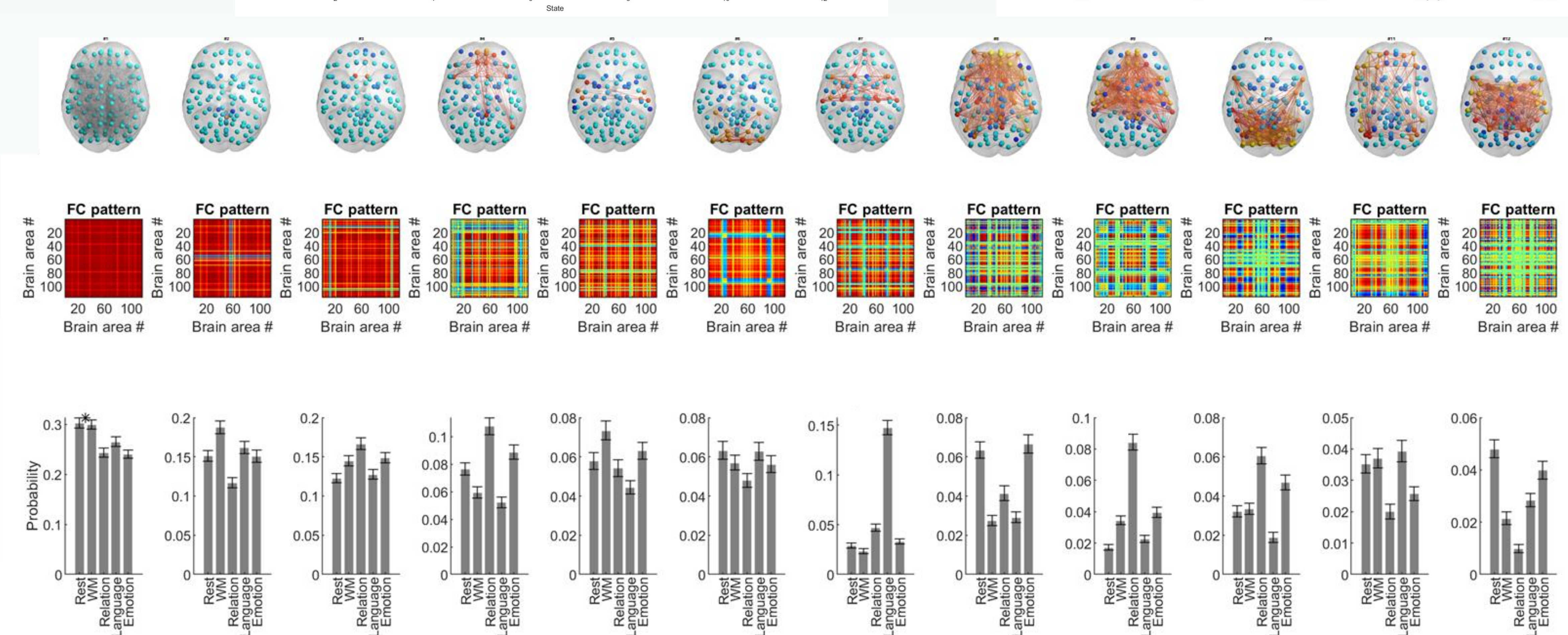
Relationship between complexity and behaviour



Metrics used to compute differences in state behaviour among conditions







Conclusion

Though most metrics of network dynamics (number of switches per subject, lifetime and probability per state, directed transitions) are not significantly different between conditions, there are significant main and interactive effects of complexity and condition on behavior. We are now testing these relationships using brain states unique to each task. If the complexity-behavior relationship is robust and replicable, complexity may be an ideal target for neuromodulation.

References

[1] Marek, Scott, et al. Nature (2022)
[2] Van Essen, David C., et al. Neuroimage (2013)
[3] Cabral, Joana, et al. Scientific reports (2017)