Challenges and impacts of spatial smoothing on high-resolution structural connectomes

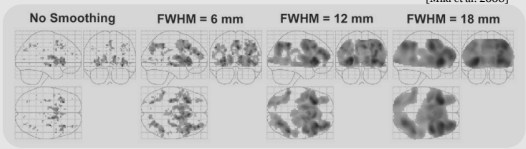
Sina Mansour L. [a], Caio Seguin [b], Vanessa Cropley [b], Robert E. Smith [c], Andrew Zalesky [a,b]

a. Department of Biomedical Engineering, The University of Melbourne, Australia
b. Melbourne Neuropsychiatry Centre, The University of Melbourne, Australia
c. Florey Institute of Neuroscience and Mental Health, Melbourne, Australia

Introduction

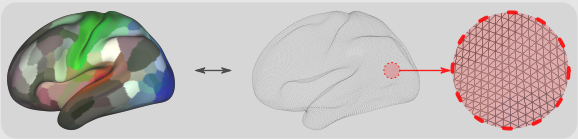
Spatial smoothing is a well-recognized preprocessing step that is commonly implemented in a wide range of neuroimaging modalities (fMRI, EEG, fNIRS, PET, etc.). This step is undertaken to increase the signal to noise ratio at the expense of spatial specificity [1].

[Mikl et al. 2008]



Structural connectivity (SC) is not normally smoothed because most SC maps are constructed at the resolution of brain atlases comprising broad areal parcels.

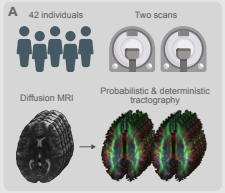
Recent studies highlight the benefits of investigating SC higher spatial resolutions:
- High-resolution SC (HRSC) accurately captures intricate neural connections [2]
- HRSC detects local modularities in brain networks [3]
- HRCS perform better in neural fingerprinting and predicting behavior [4]



High-resolution connectomes are susceptible to:
- image registration misalignment, tractography artifacts and noise

This can reduce connectome accuracy and test-retest reliability.
We investigate a network analogue of image smoothing to address these key challenges and investigate the impacts of smoothing on connectome reliability and individual identifiability of SC maps at different resolutions.

Study design



Diffusion images sourced from the Human Connectome Project:

- 42 individuals with repeat scans

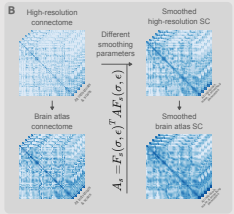
- Deterministic & probabilistic tractography

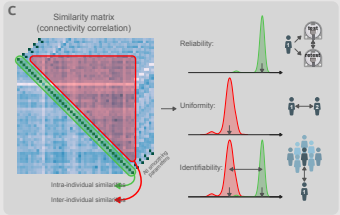
HRSC mapped at the resolution of cortical vertices

Connectivity-based spatial smoothing performed

- truncated bivariate Gaussian kernel

All SC maps also downsampled to atlas resolution





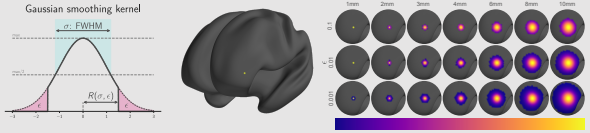
Different smoothing parameters compared based on:

- Raliability (robustness)
- Identifiability (individualised)

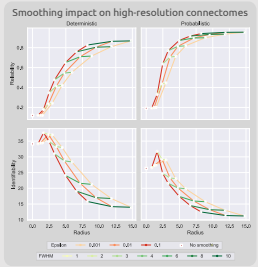
Other important considerations:

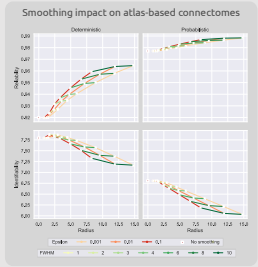
- Computation & storage burden

Results



Both High-resolution and atlas SC maps are impacted by smoothing.
- Stronger & wider smoothing increases reliability.
- Moderate smoothing improves identifiability (2mm FWHM)
- Extensive smoothing reduces individual identifiability (>6mm FWHM)
- Deterministic SC performed better at identification
- Probabilistic SC was comparatively more reliable





Concluding remarks:
- Smoothing is crucial for high-resolution SC (2-6 mm FWHM recommended)
- Smoothing can benefit atlas-resolution SC (4-8 mm FWHM recommended)
- Deterministic SC requires stronger smoothing compared to probabilistic

1. Mikl, Michal, et al. "Effects of spatial smoothing on fMRI group inferences." *Magnetic resonance imaging* 26.4 (2008): 490-503.
2. Besson, Pierre, et al. "Whole-brain high-resolution structural connectome: inter-subject validation and application to the anatomical segmentation of the striatum." *Brain topography* 30.3 (2017): 291-302.
3. Taylor, Peter N., Yujiang Wang, and Marcus Kaiser. "Within brain area tractography suggests local modularity using high resolution connectomics." *Scientific reports* 7.1 (2017): 1-9.
4. Mansour L., Sina, et al. "High-resolution connectomic fingerprints: Mapping neural identity and behavior." *NeuroImage* 229 (2021): 117695.

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