Reliability and subject specificity of personalized dynamical whole-brain models

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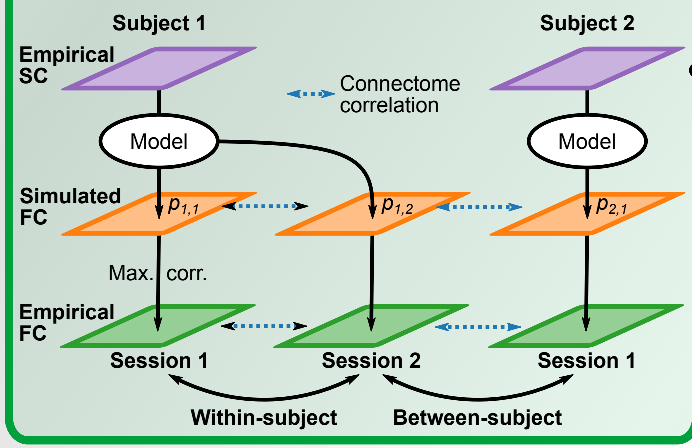
Main messages

- The reliability of whole-brain dynamical models ranges from "poor" to "good"
- The reliability and subject specificity of modeling results may exceed those of empirical data
- Model personalization has a positive influence on the reliability and subject specificity
- Parcellations have a much larger effect on modeling results than on empirical data

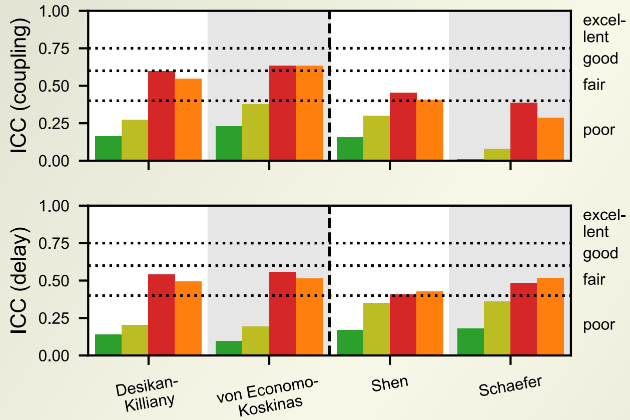
Method

- How **reliably and specifically** are personalized dynamical whole-brain models fitted to the empirical data? [1,2]
- Empirical SC and FC (4 sessions) of 200 subjects in HCP [3,4]
- Model parameters optimized for every individual FC
- **Reliability of model fit:** Intraclass correlation **(ICC)** of optimal model parameters and FC edges
- **Reliability of FC:** within-subject connectome correlation
- **Specificity** = within- — between-subject correlation
- **Variation of model complexity:** networks of linear [5], phase oscillators and neural mass models [6]
- **Variation of model personalization:** using varying amounts of subject-specific data for the phase oscillator

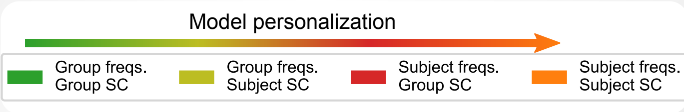


ICC (model personalization)

- Model parameters fitted with "poor" to "good" reliability
- Model personalization has positive influence on reliability
- Change of parcellation may alter results substantially

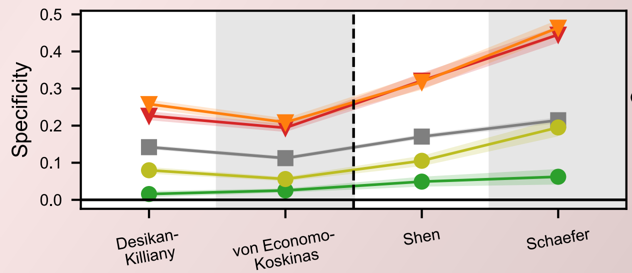


ICC of the optimal coupling (top) and delay (bottom) parameter for varying model personalizations [7-10]. The labels "poor", "fair", "good" and "excellent" are taken from [11].



FC subject specificity

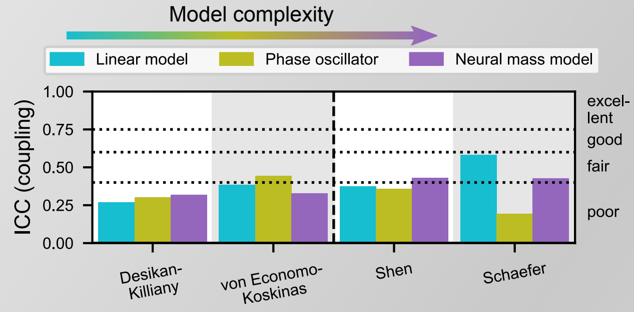
- Simulated FC can be more subject-specific than empirical FC
- Personalization positively affects subject specificity
- Effect of atlas larger for simulated than for empirical FC



Specificity indices calculated from the connectome correlations of the empirical FC (gray) and simulated FC for varying model personalizations and parcellations [7-10].

ICC (model complexity)

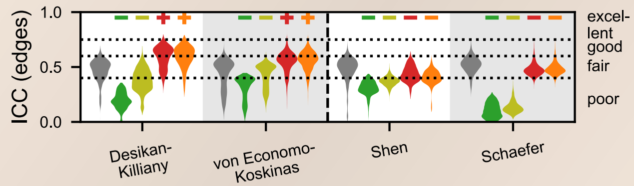
- Reduced variation across atlases for higher complexity
- Differences across complexities inconsistent across atlases



ICC of the optimal coupling model parameter for varying model complexities [7-10]. The reliability labels are taken from [11]. Latency of signal propagation (delay) was ignored.

ICC of FC edges

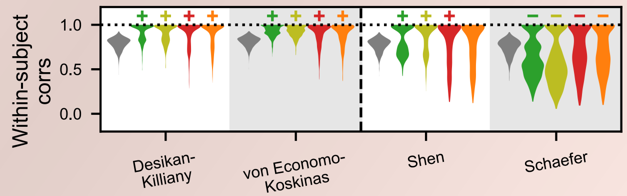
- ICC of edges may be higher for simulated than for empirical FC
- ICC of edges can be explained by ICC of parameters



Edge ICC distributions for the empirical (gray) and simulated FC. Pluses (minuses) indicate significant increases (decreases) for simulated FC relative to empirical FC.

FC reliability

- Reliability of simulated FC may exceed the empirical one
- Effect of atlas: potentially lower distributions with bimodalities



Within-subject connectome correlations [7-10]. Pluses (minuses) indicate significant increases (decreases) for the simulated FC relative to the empirical FC (gray).

References

(1) Honey et al. PNAS. 2009, 106(6), 2035-2040; **(2)** Bansal et al. Curr. Opin. Neurobiol. 2018, 52, 42-47; **(3)** Van Essen et al. NeuroImage. 2012, 62(4), 2222-2231; **(4)** Van Essen et al. NeuroImage. 2013, 80, 62-79; **(5)** Saggio et al. PLoS One. 2016, 11(8), e0157292; **(6)** Wilson et al. Biophys. J. 1972, 12(1), 1-24; **(7)** Desikan et al. NeuroImage. 2006, 31(3), 968-980; **(8)** Scholtens et al. NeuroImage. 2018, 170, 249-256; **(9)** Shen et al. NeuroImage. 2013, 82, 403-415; **(10)** Schaefer et al. Cereb. Cortex. 2018, 28(9), 3095-3114; **(11)** Cicchetti et al. Am. J. Ment. Defic. 1981, 86(2), 127-137

Acknowledgements

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