

Deep learning for analysis of diffusion-MRI based white matter tractometry

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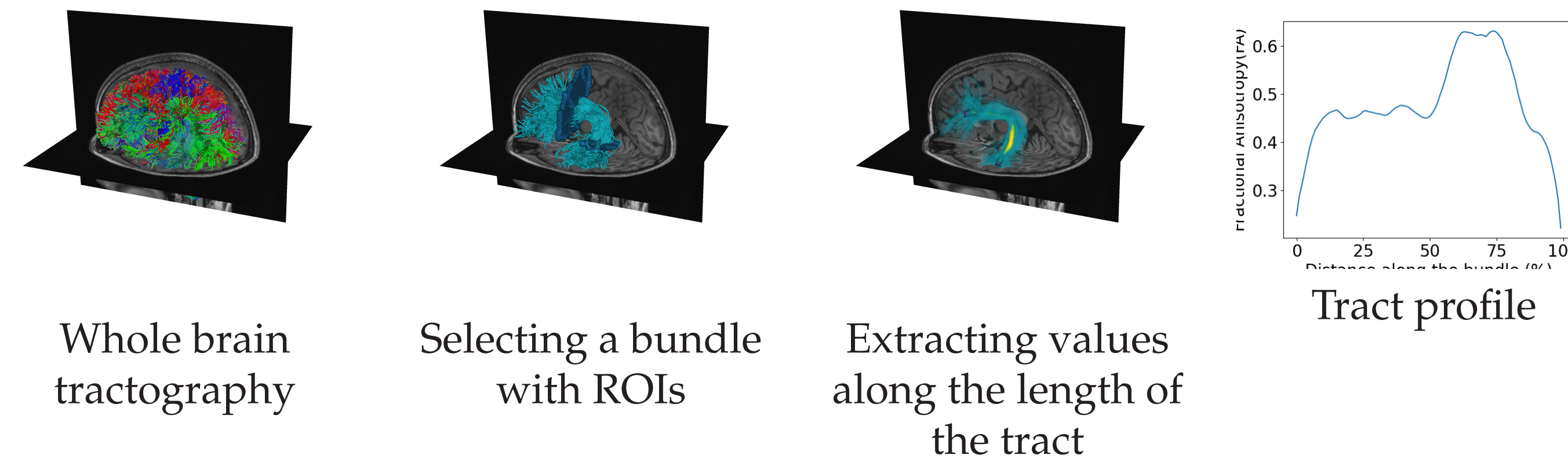
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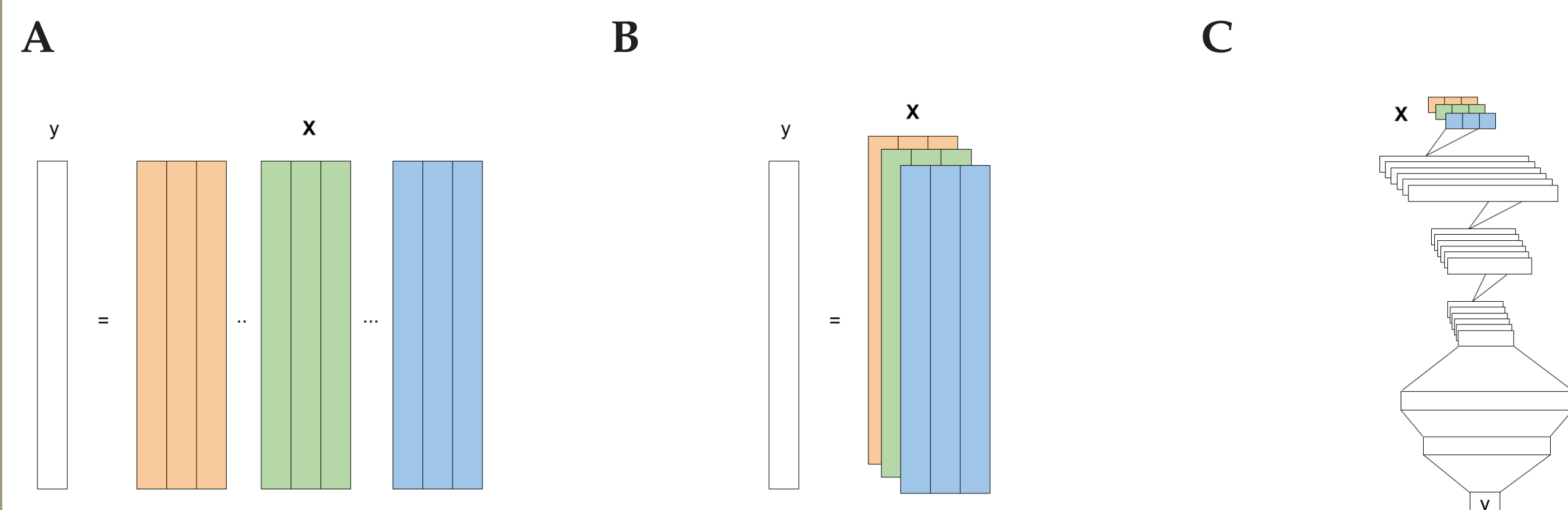
Introduction

- Tractometry uses diffusion MRI (dMRI) to quantify brain tissue properties within white matter connections *in vivo* [1].
- The Healthy Brain Network Processed Open Derivatives (HBN POD2) is a large (n>2,000) pediatric dMRI dataset that has been processed and automatically QC'd [2, 3].
- The pyAFQ software was used to create tract profiles for statistical analysis [4].
- In previous work, we demonstrated that regularized regression provides accurate predictions of individual age in HBN from tractometry data (WM-based “brain age”)[5].



Question: Would convolutional neural networks provide improvements in inferences from tractometry?

Methods



- (A) In a linear tractometry model, $y = \beta X$. (B) To move towards a convolutional neural networks, we stack the data from different tracts and metrics (FA, MD, MK) as different measurement “channels”. (C) Training samples are then passed to a network (here as schematic)
- We used the 1817 subjects from HBN POD2 that had passing QC scores and age information.
- A variety of convolutional neural networks were implemented in AFQ-Insight (<https://richiehalford.org/AFQ-Insight>)
- To evaluate the models, we set aside a test set of 20% of the subjects (363 subjects)
- To compare model dependence on training set size, we trained with variable train set sizes (100, 175, 350, 700, 1000, 1453 subjects)

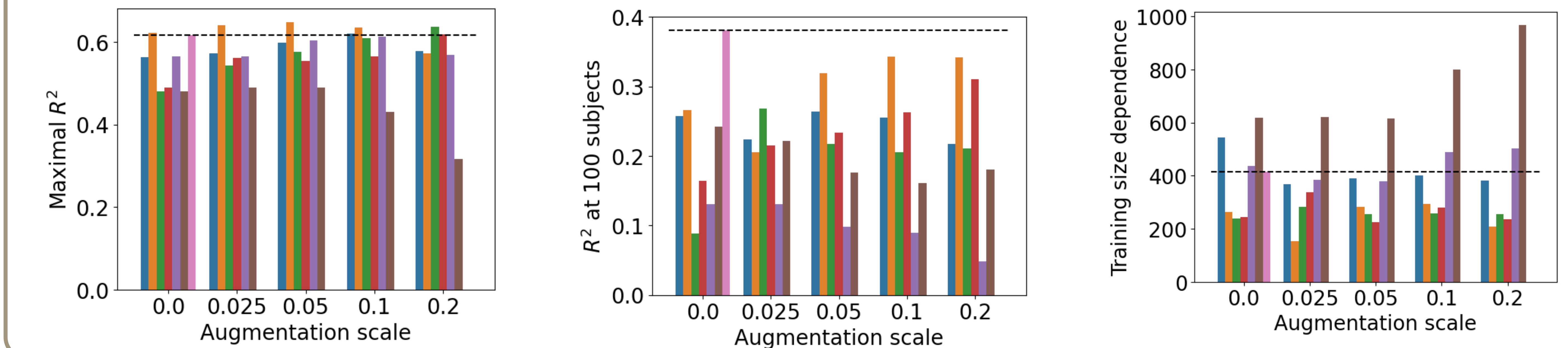
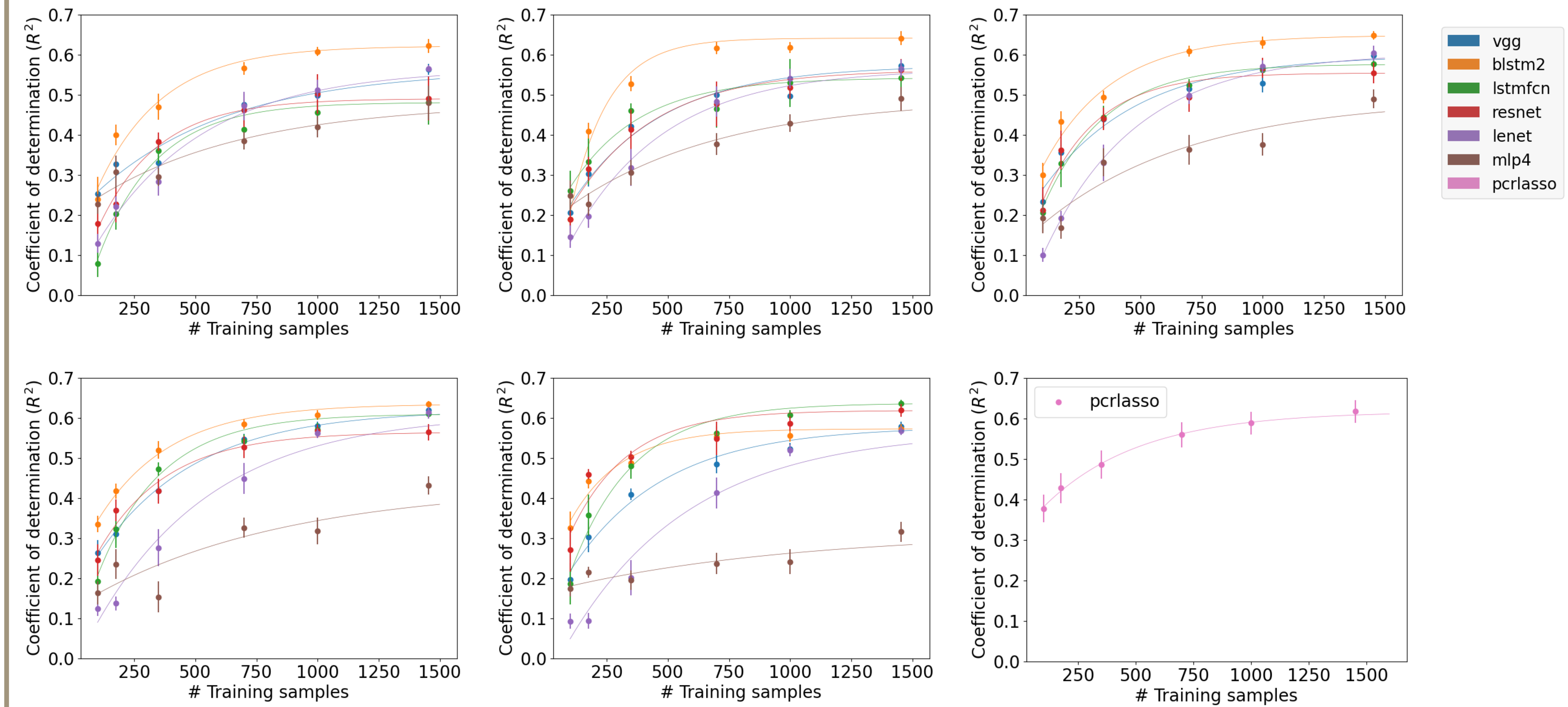
References

- [1] Jason D Yeatman, Robert F Dougherty, Nathaniel J Myall, Brian A Wandell, and Heidi M Feldman. Tract profiles of white matter properties: automating fiber-tract quantification. *PLoS One*, 7(11):e49790, November 2012.
- [2] Adam Richie-Halford, Matthew Cieslak, Lei Ai, Sendy Caffarra, Sydney Covitz, Alexandre R Franco, Iliana I Karipidis, John Kruper, Michael Milham, Bárbara Avelar-Pereira, Ethan Roy, Valerie J Sydnor, Jason D Yeatman, The Fibr Community Science Consortium, Theodore D Satterthwaite, and Ariel Rokem. An analysis-ready and quality controlled resource for pediatric brain white-matter research. *Scientific Data*, 9(1):1–27, October 2022.

Results

Model performance was quantified as the coefficient of determination, R^2

R^2 was modeled as: $\alpha - (\alpha - \beta)e^{-\frac{x - x_{min}}{\kappa}}$, where x is the number of training samples, α is R^2 at the maximal number of training samples, β is R^2 at the smallest number of training samples (x_{min}) and κ is a free parameter that denotes that number of training samples required to achieve R^2 that is 67% of the difference between β and α .



Conclusion and future work

- Neural network models (NNs) improve accuracy of tractometry analysis
- NNs are very data hungry
- Tuning and training these models is complicated and time-consuming
- Differences can be much more important in some cases (see poster # XXX)

Acknowledgments

