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No Free Lunch from Deep Learning in Neuroscience: A Case Study through Models of the Entorhinal-Hippocampal Circuit

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Research in Neuroscience, as in many scientific disciplines, is undergoing a renaissance based on deep learning. Unique to Neuroscience, deep learning models can be used not only as a tool but interpreted as models of the brain. The central claims of recent deep learning-based models of brain circuits are that they shed light on fundamental functions being optimized or make novel predictions about neural phenomena. We show, through the case-study of grid cells in the entorhinal-hippocampal circuit, that one may get neither. We rigorously examine the claims of deep learning models of grid cells using large-scale hyperparameter sweeps and theory-driven experimentation, and demonstrate that the results of such models are more strongly driven by particular, non-fundamental, and post-hoc implementation choices than fundamental truths about neural circuits or the loss function(s) they might optimize. We discuss why these models cannot be expected to produce accurate models of the brain without the addition of substantial amounts of inductive bias, an informal No Free Lunch result for Neuroscience.

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