
Meta-learning Reading Group

Filip Vercruyse (20 Nov 2019)

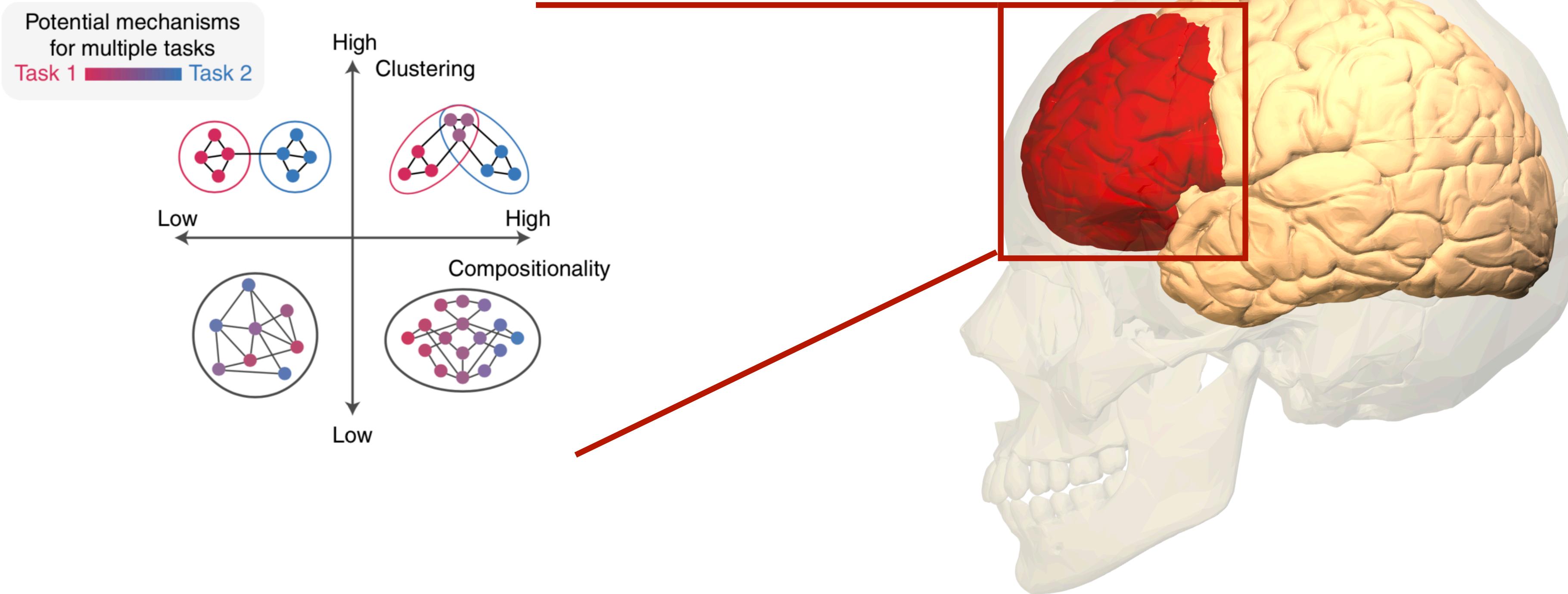
Article | Published: 14 January 2019

Task representations in neural networks trained to perform many cognitive tasks

Guangyu Robert Yang, Madhura R. Joglekar, H. Francis Song, William T. Newsome
& Xiao-Jing Wang 

Research question: How are multiple cognitive tasks represented in the prefrontal cortex

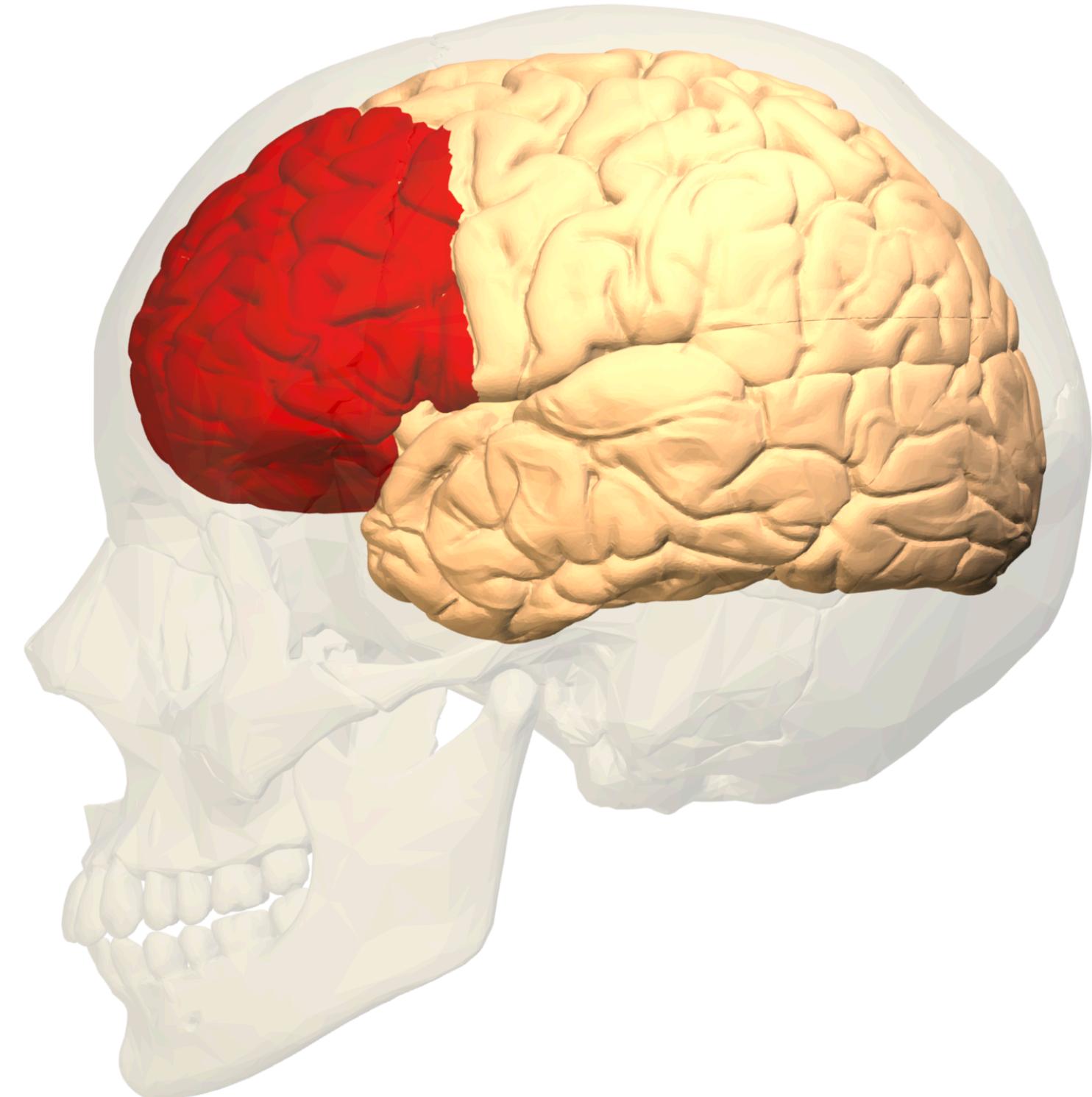
Neural representation and compositionality



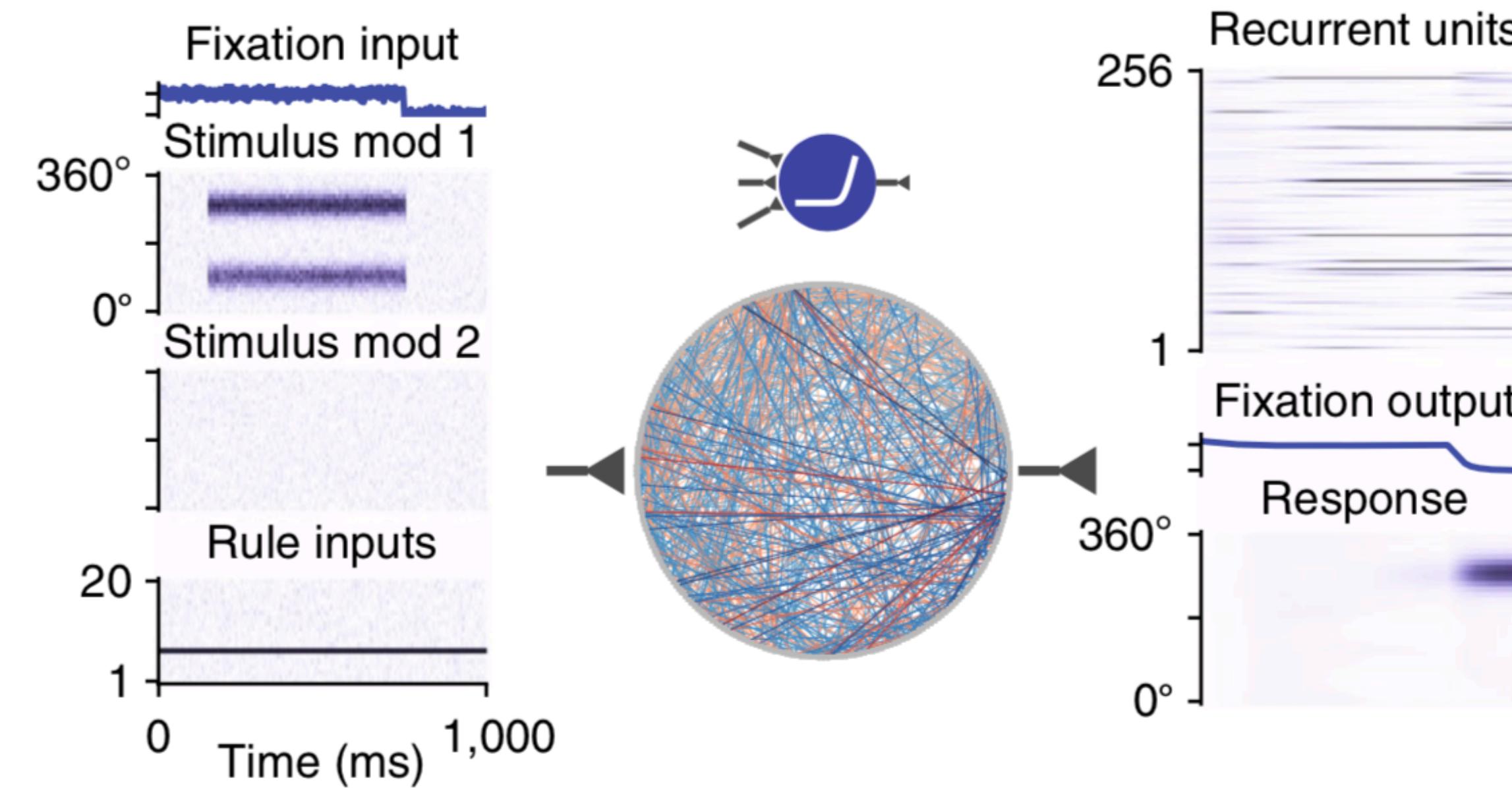
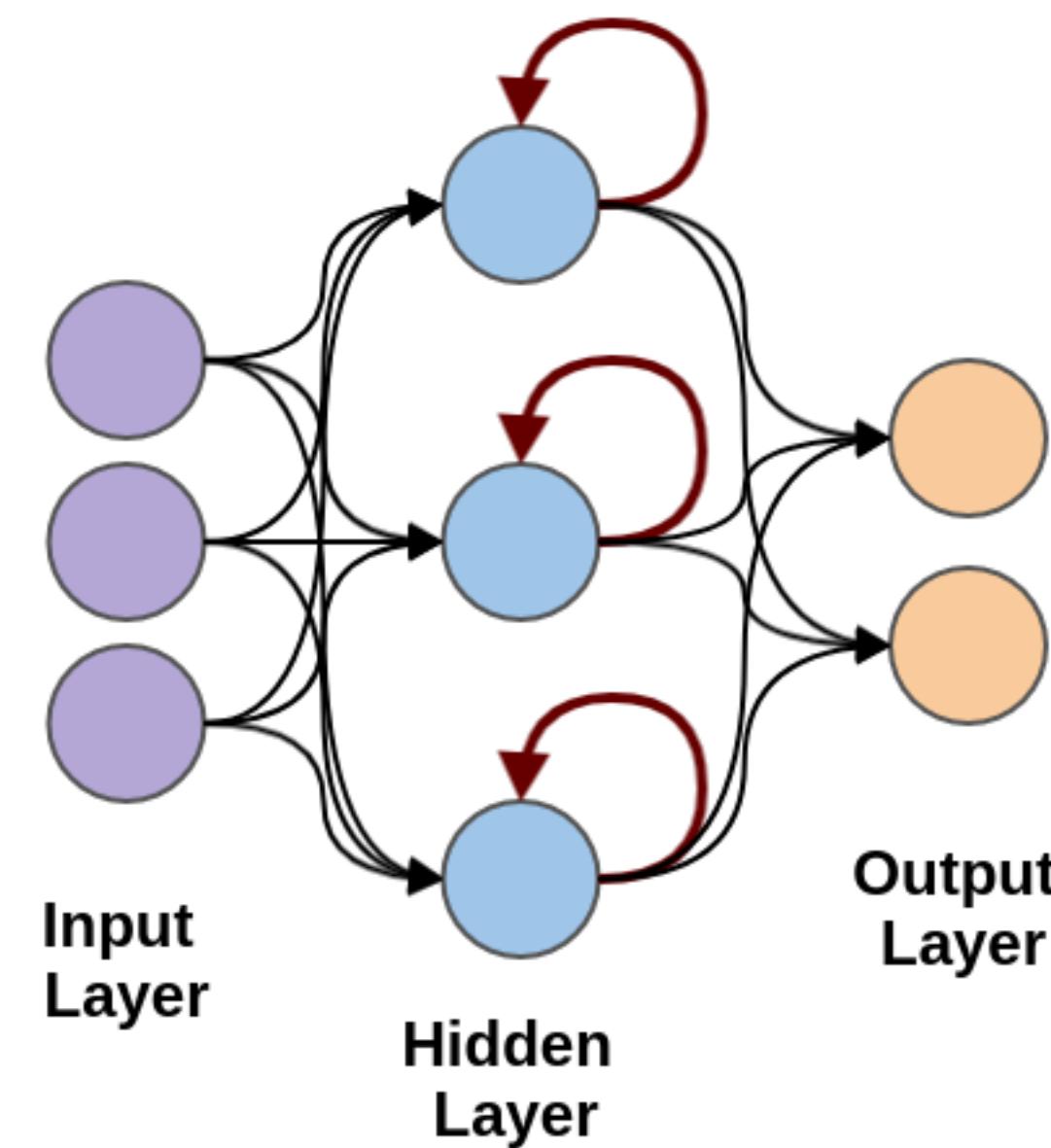
20 cognitive tasks that depend on working memory, decision making, categorisation and inhibitory control

Task families:

- **Go task family** (Go, RT Go and Dly Go)
- **Anti task family** (Anti, RT Anti and Dly Anti)
- **DM family**
- **Dly DM family** (Dly DM 1, Dly DM 2, Ctx Dly DM 1 and Ctx Dly DM 2)
- **Matching family** (DMS, DNMS, DMC, DNMC tasks)

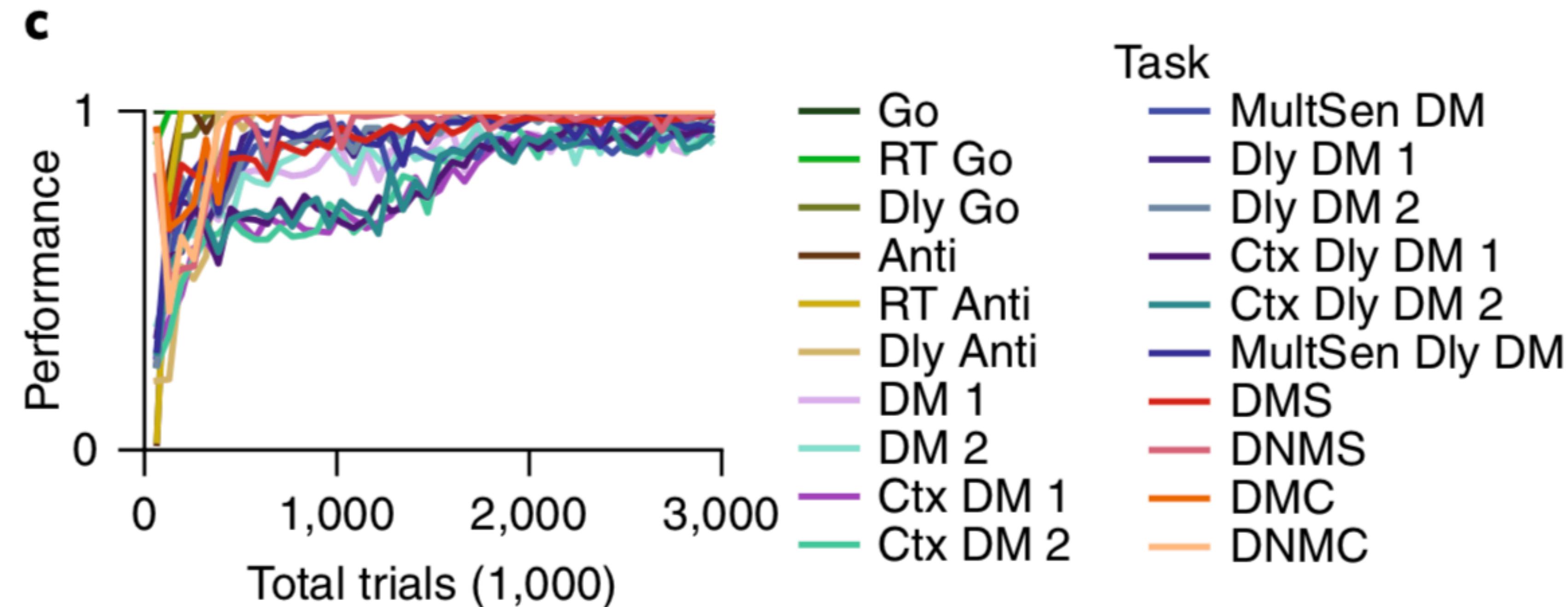


Method: Recurrent neural network - interleaved training

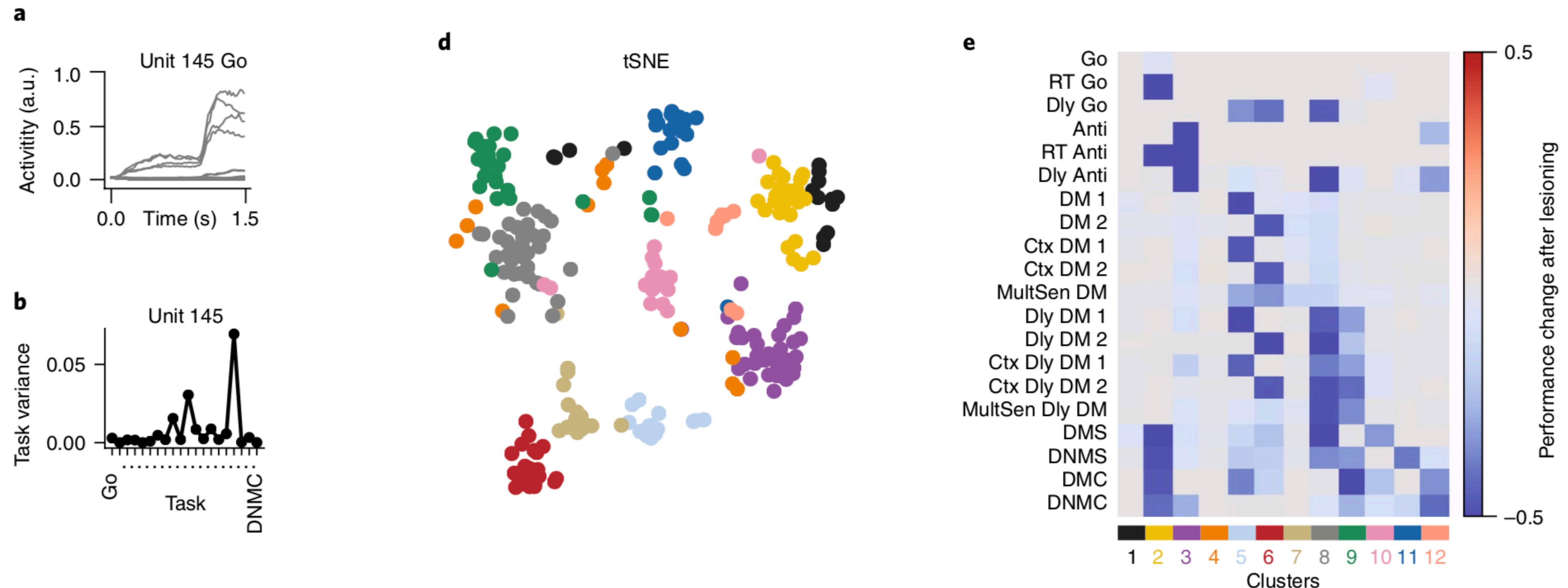


$$\tau \frac{d\mathbf{r}}{dt} = -\mathbf{r} + f(W^{\text{rec}}\mathbf{r} + W^{\text{in}}\mathbf{u} + \mathbf{b} + \sqrt{2\tau\sigma_{\text{rec}}^2}\xi)$$

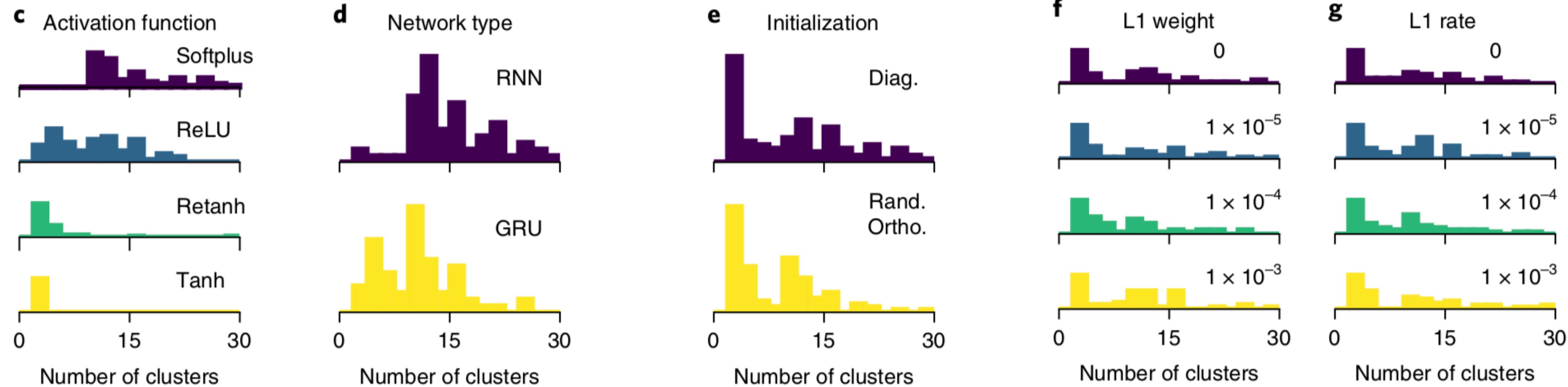
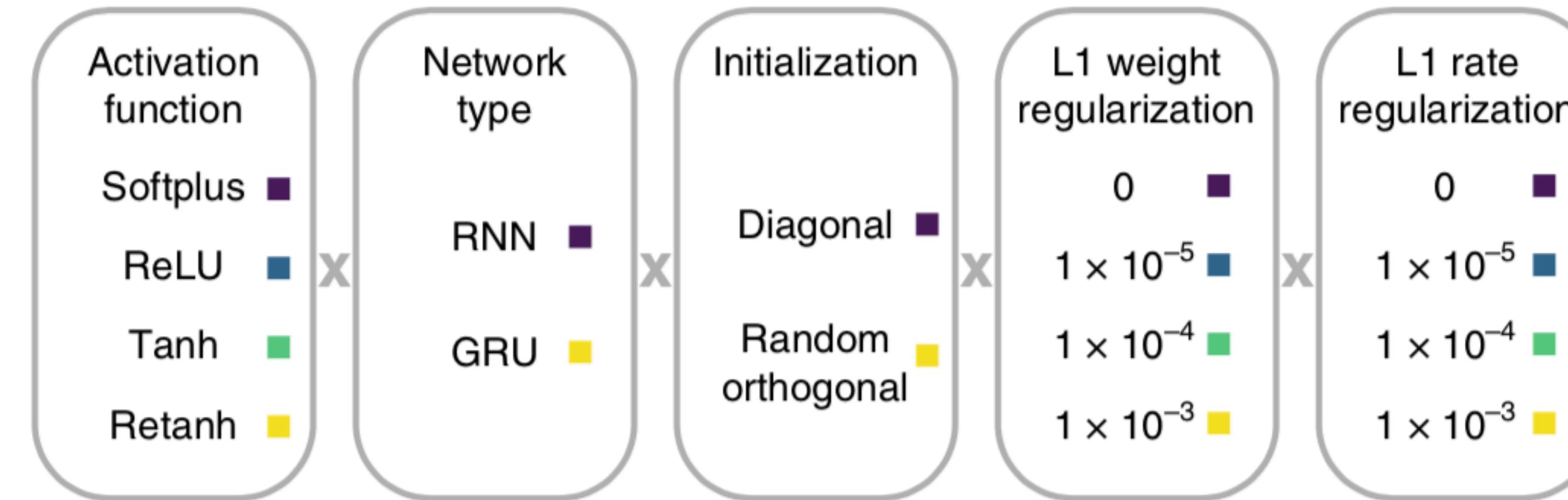
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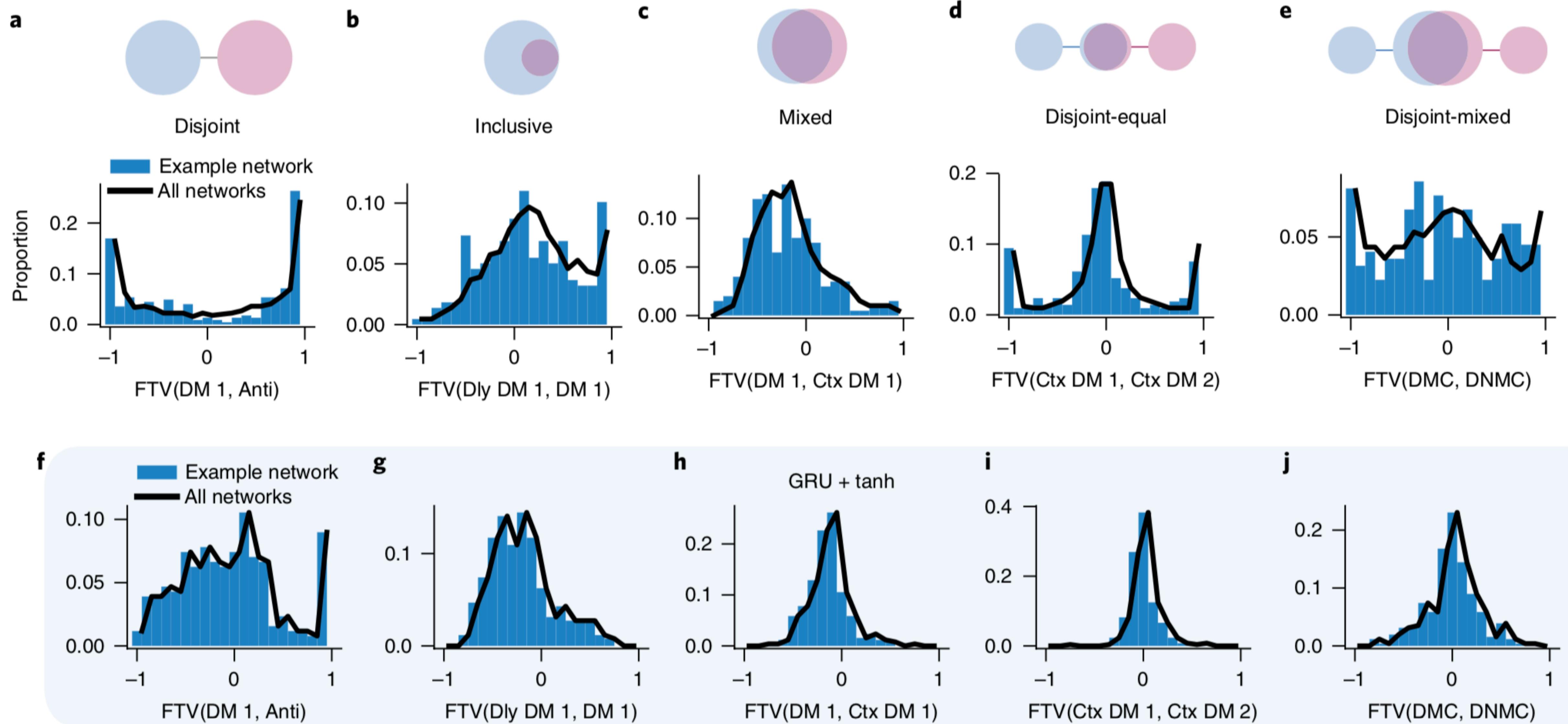
The emergence of functionally specialised clusters for task representation



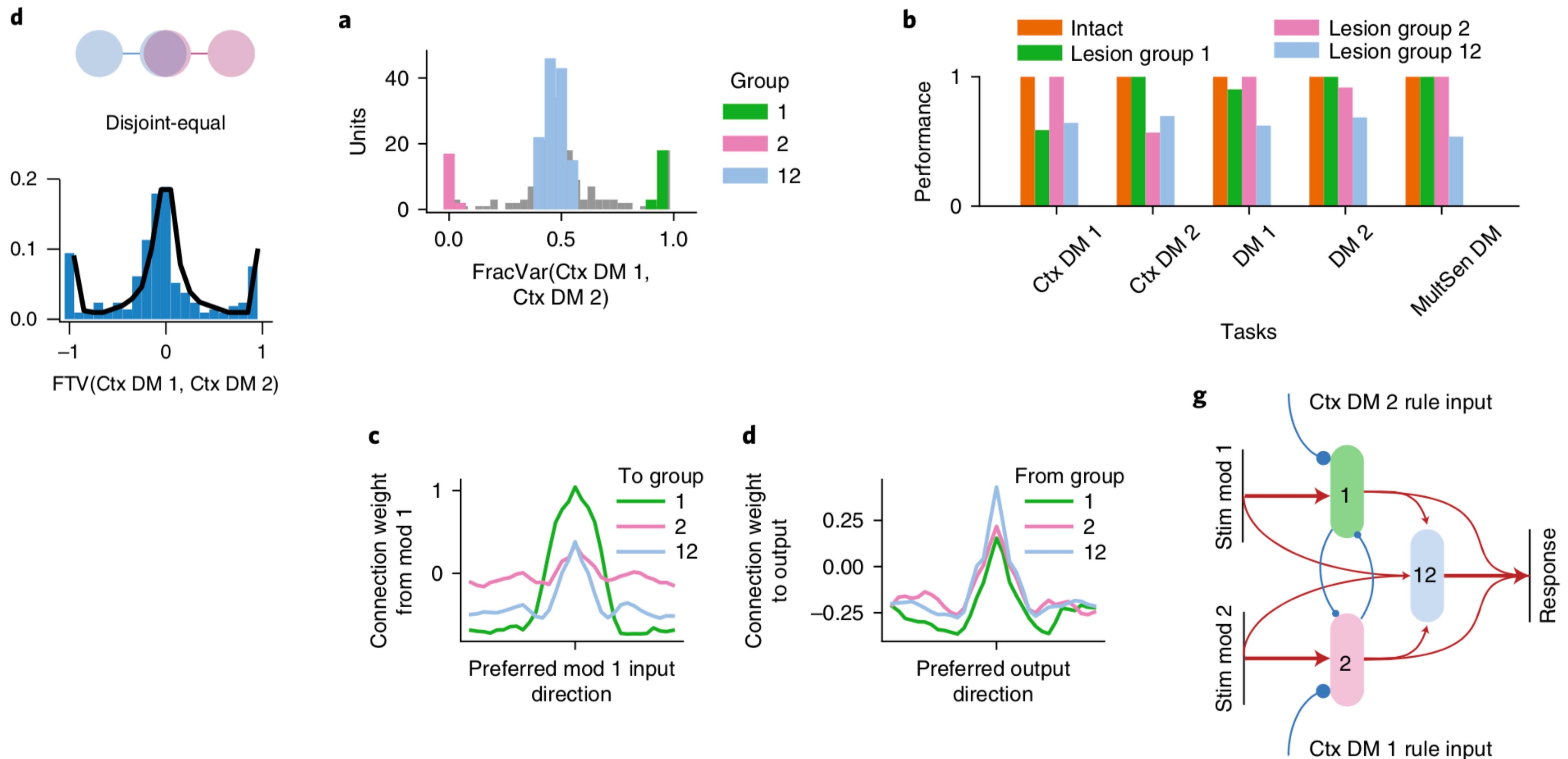
The activation function dictates whether clusters emerge in a network



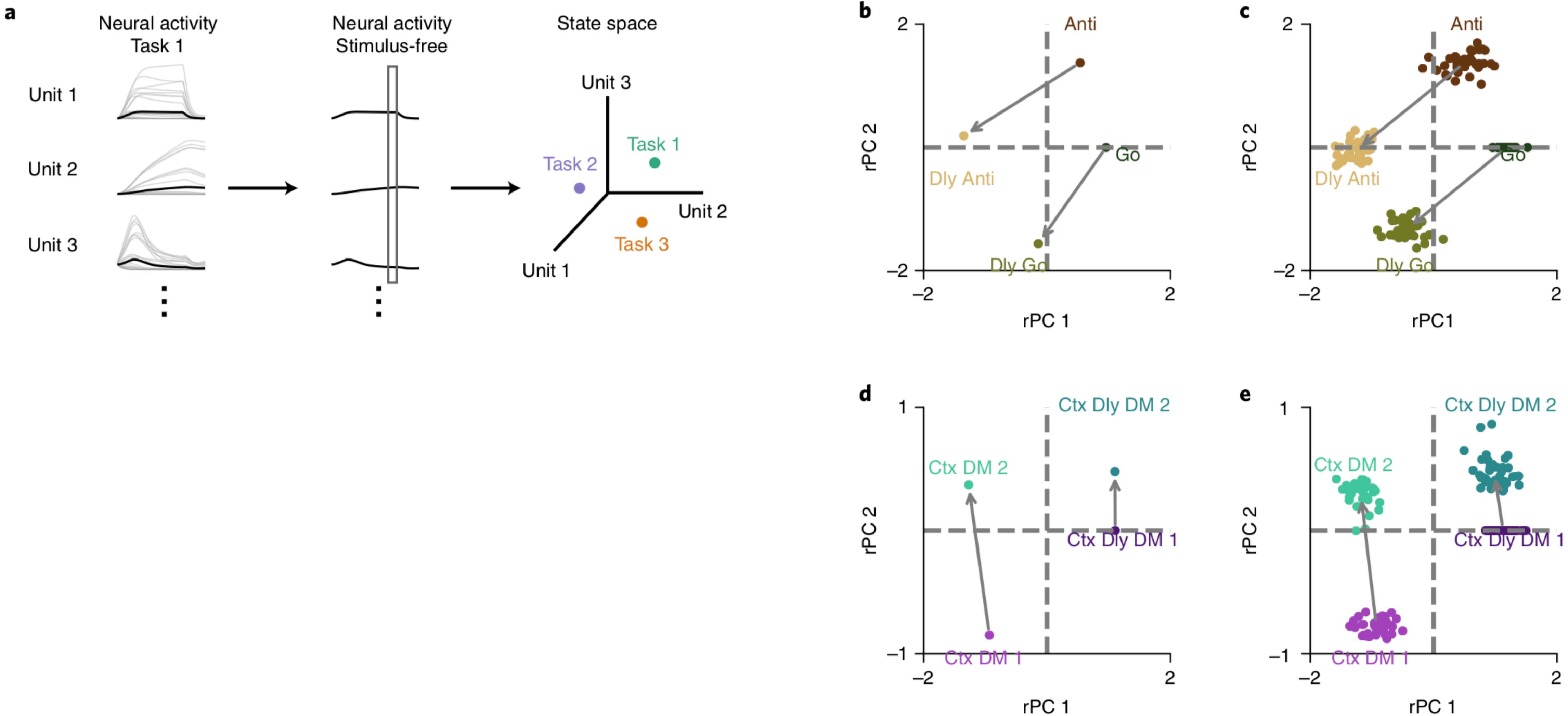
A diversity of neural relationships between pairs of tasks



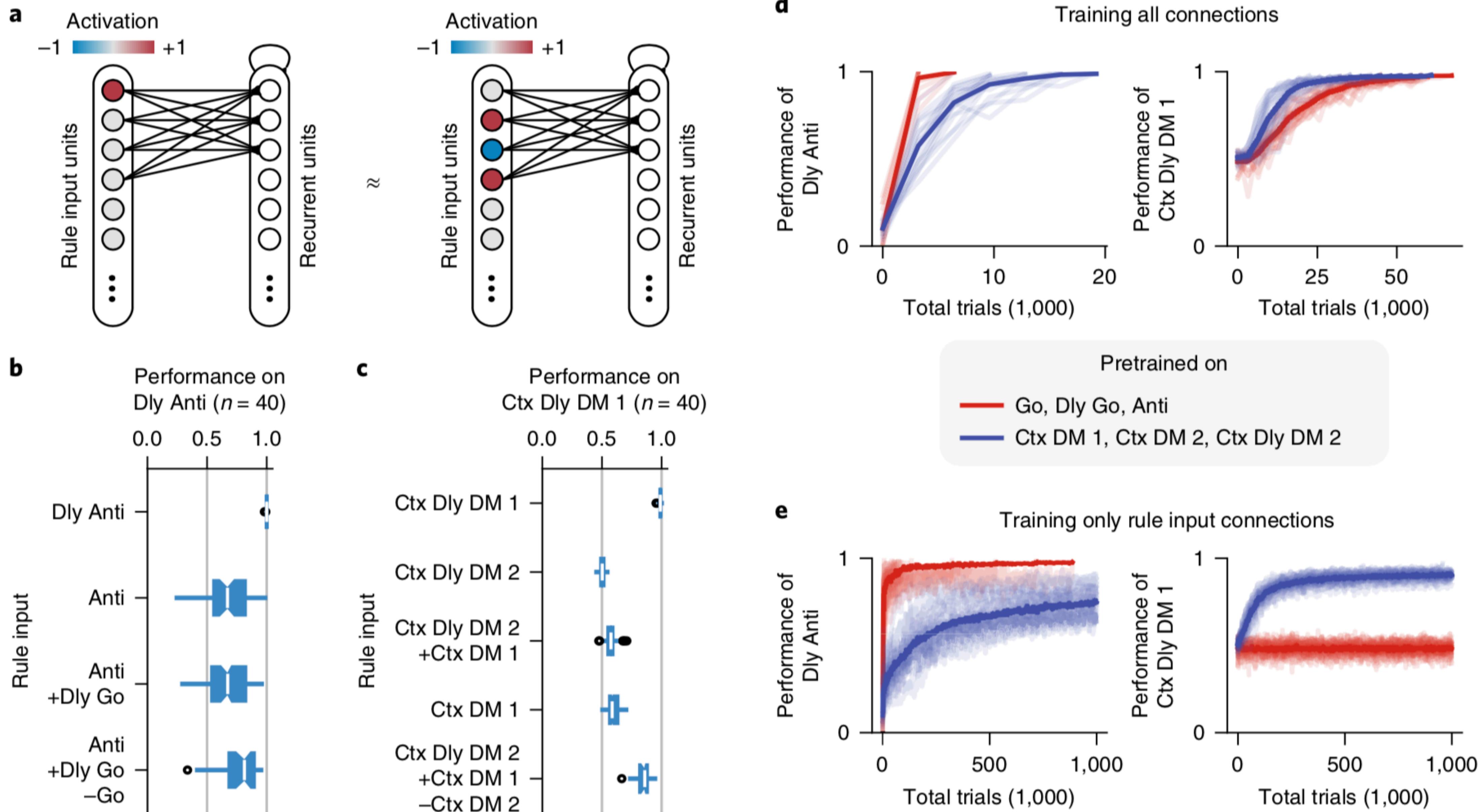
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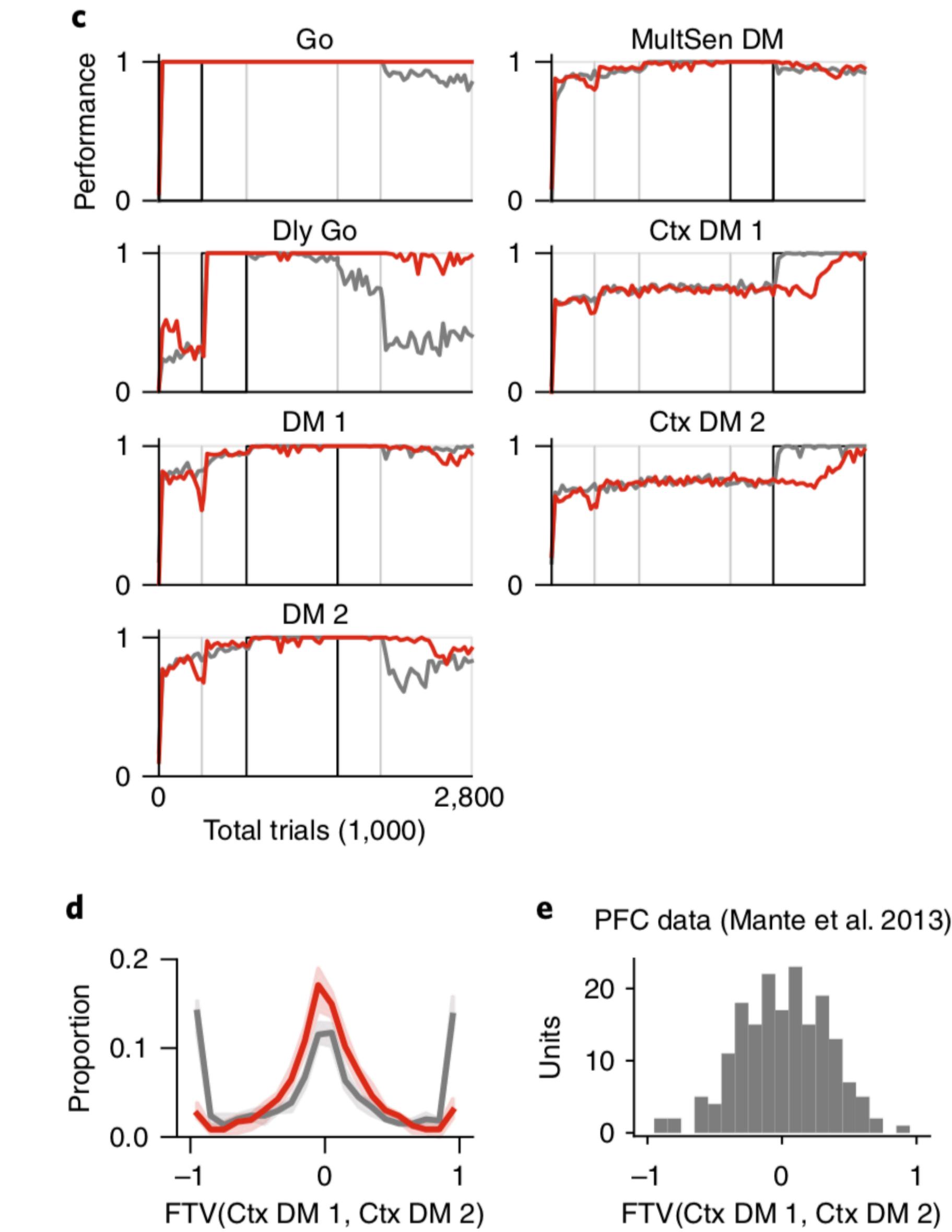
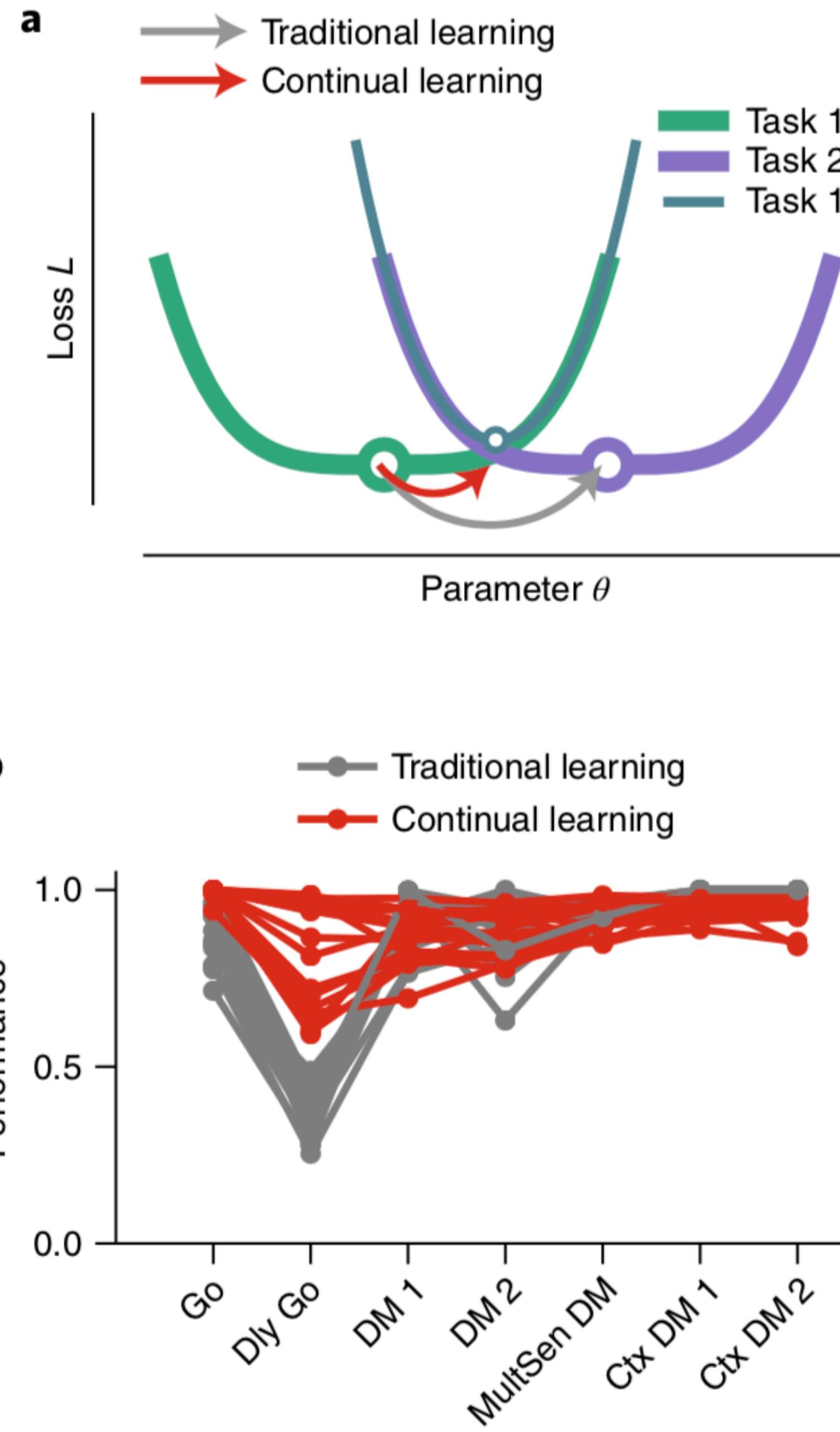
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Summary

- Successfully trained single RNNs to perform 20 cognitive tasks
- Emergent task representation is dependent on the activation function
- Non-saturating activation function (Softplus, ReLu) -> Clustering
- Compositional task representation emerges from training network models
- Certain tasks can be performed by combining instructions for other tasks
- Continual learning helps the performance on all task, but the neural representation is markedly different