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Dynamic Ensemble Bayesian Filter for Robust BCI Control of a Human with Tetraplegia

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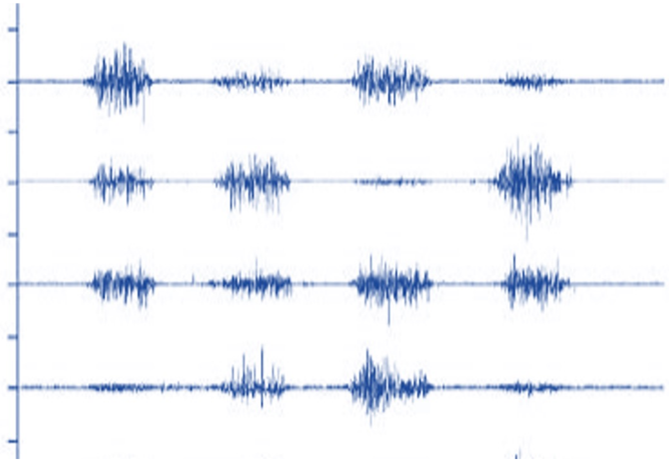
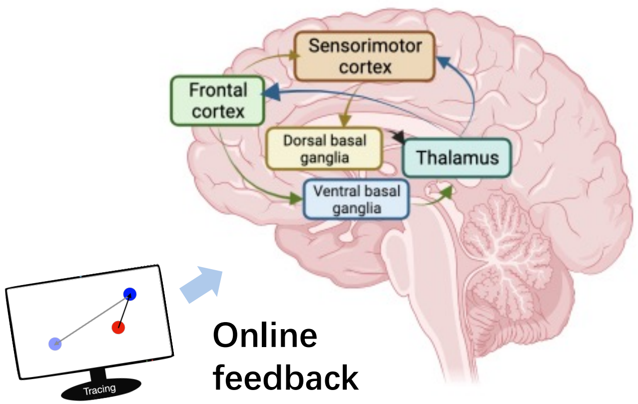
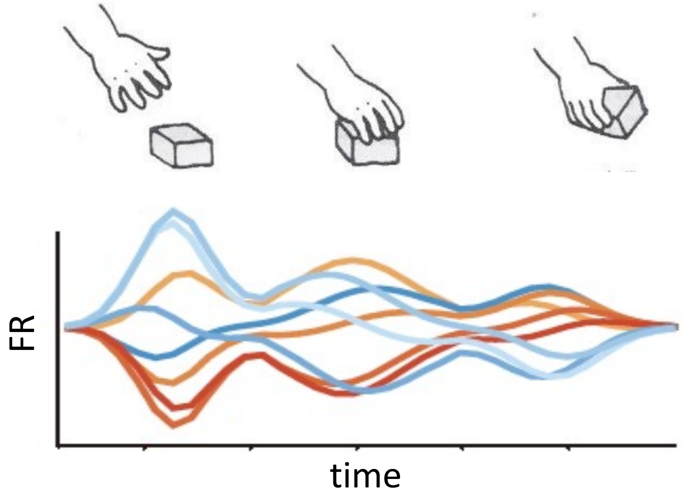
The **Robustness** of BCI control is an important problem

Challenge: the variability in neural signals

Noises	Dynamic Neural Pathways	Neural Functional Changes







External or Biological

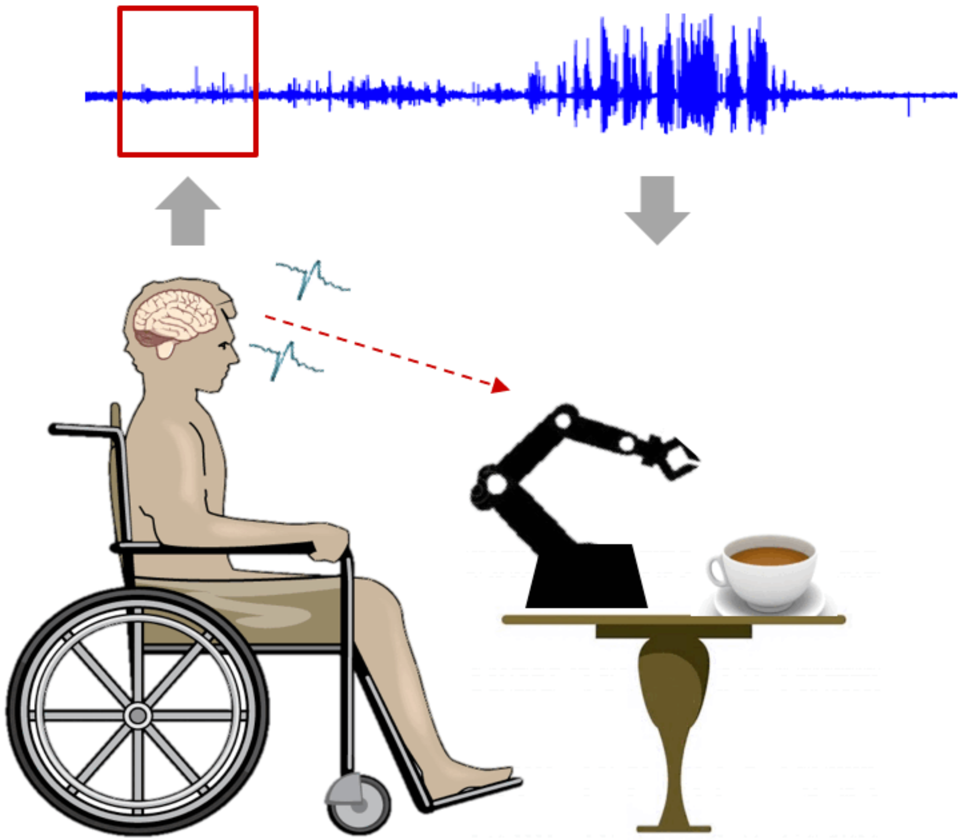
Neural function changes when control speed changes or error occurs *[Shenoy et al., 2017; Schwartz et al., 2018].*

Static decoders makes inaccurate predictions

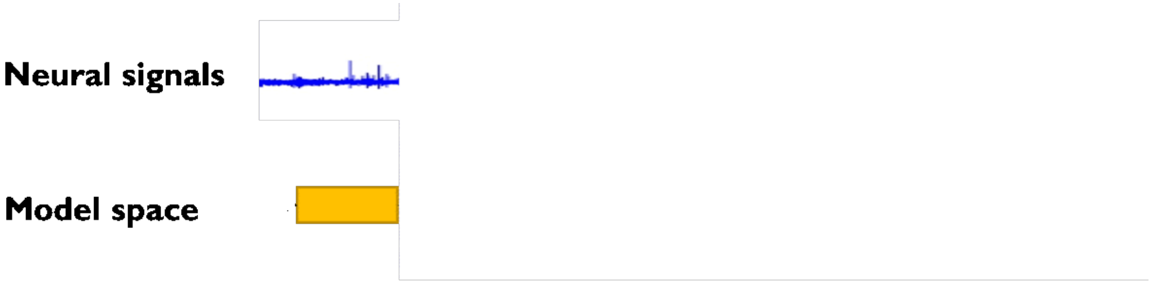
Variability in neural signals

Static neural decoders

Instabilities in BCI control



Dynamic neural decoders to cope with neural variability

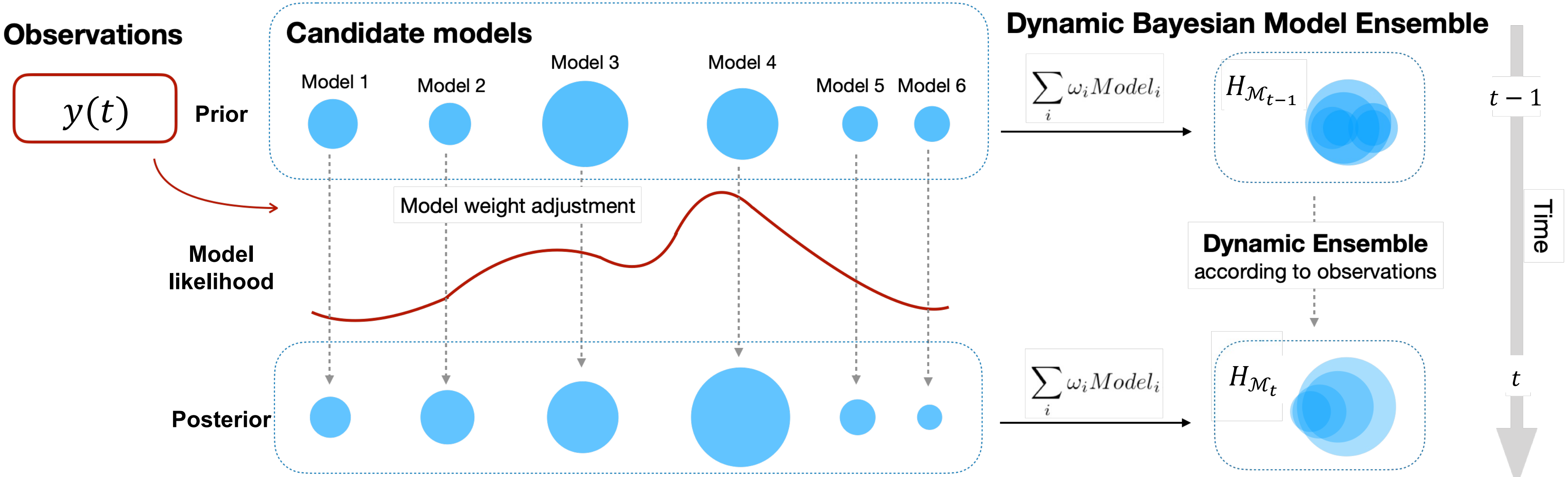


Variability in neural signals

Dynamic neural decoders

But how???

The Dynamic Ensemble Bayesian Filter model (DyEnsemble)

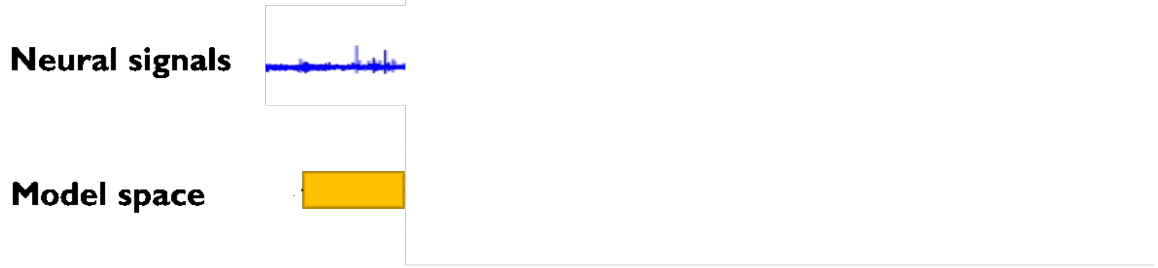


Model weights estimation with Bayesian model averaging :

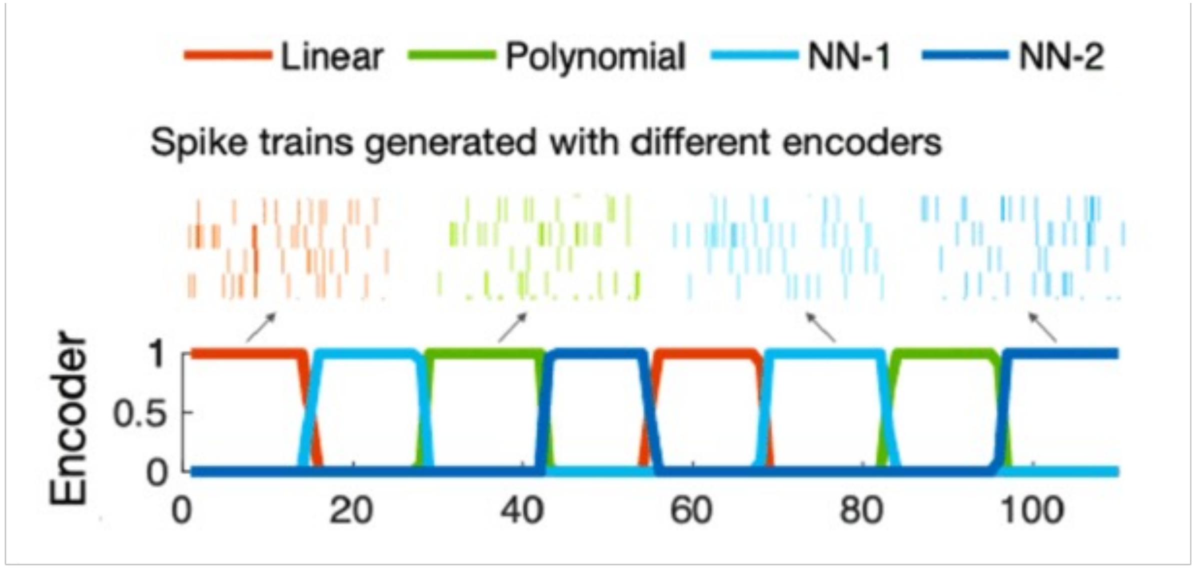
State-space model with a dynamic observation fu

$$p(\mathcal{H}_{\mathcal{M}_t} = m_k|\boldsymbol{y}_{0:t}) = \frac{p(\mathcal{H}_{\mathcal{M}_t} = m_k|\boldsymbol{y}_{0:t-1})p_k(\boldsymbol{y}_t|\boldsymbol{y}_{0:t-1})}{\sum_{j=1}^{q} p(\mathcal{H}_{\mathcal{M}_t} = m_j|\boldsymbol{y}_{0:t-1})p_j(\boldsymbol{y}_t|\boldsymbol{y}_{0:t-1})}$$

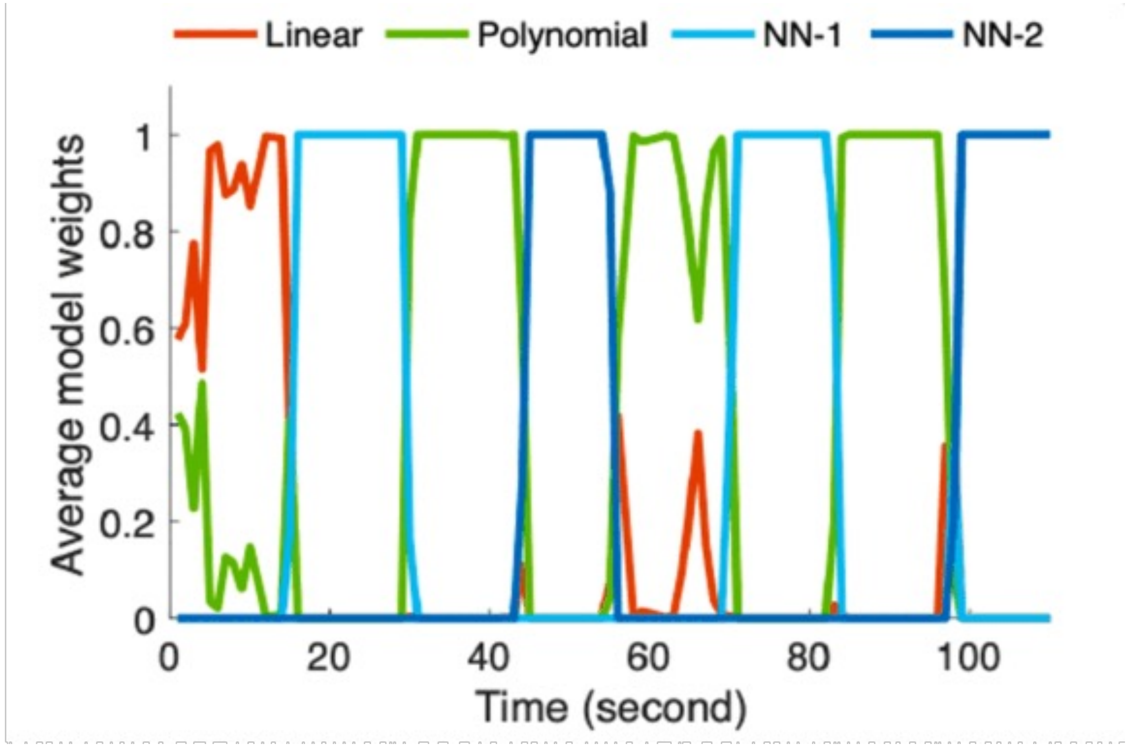
Enabling model switching with changes in signals.



Simulation performance

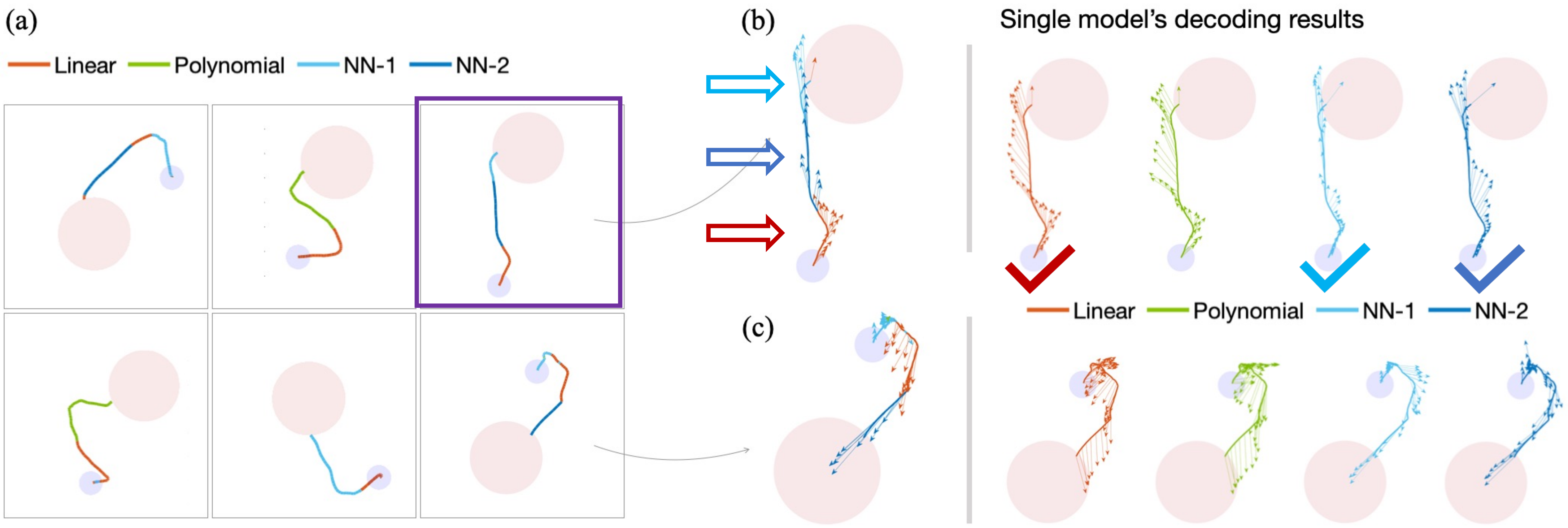


- Simulated neural signals with encoding model changes in time



- DyEnsemble **correctly assigns** model weights in simulations

Visualization of online BCI control



DyEnsemble **switches** to the '**optimal**' model for each time slot to achieve more accurate online control

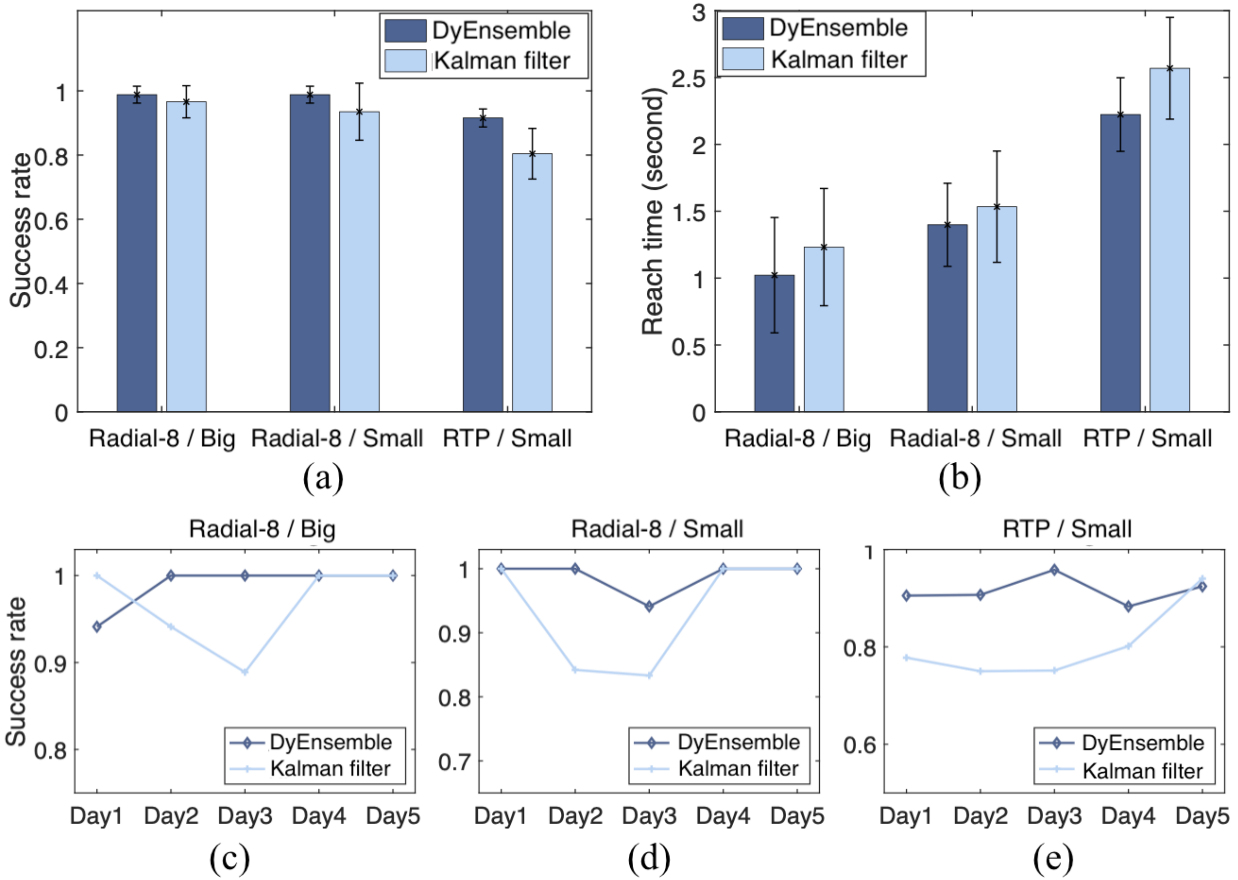
Online performance comparison with KF

Improve the accuracy

max **13.9%**

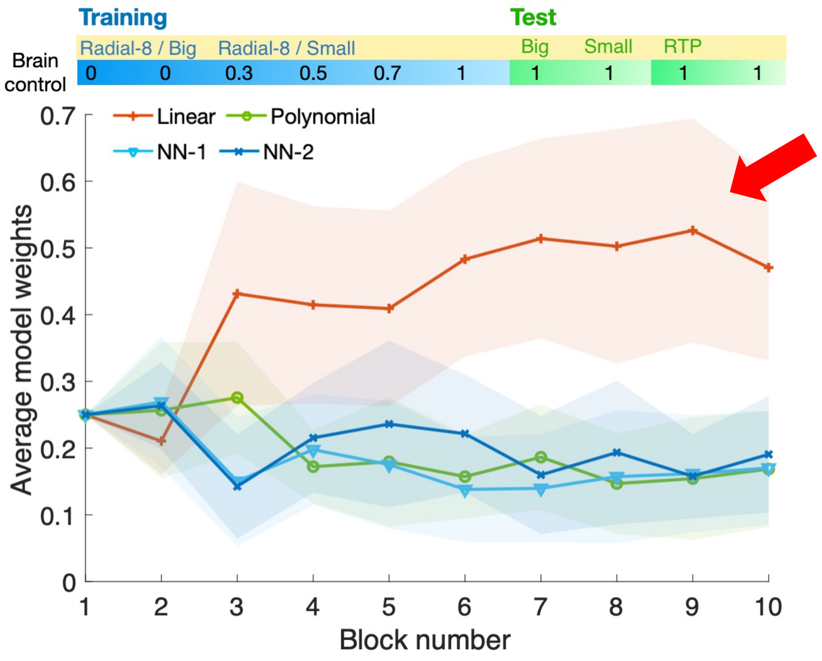
Improve the stability

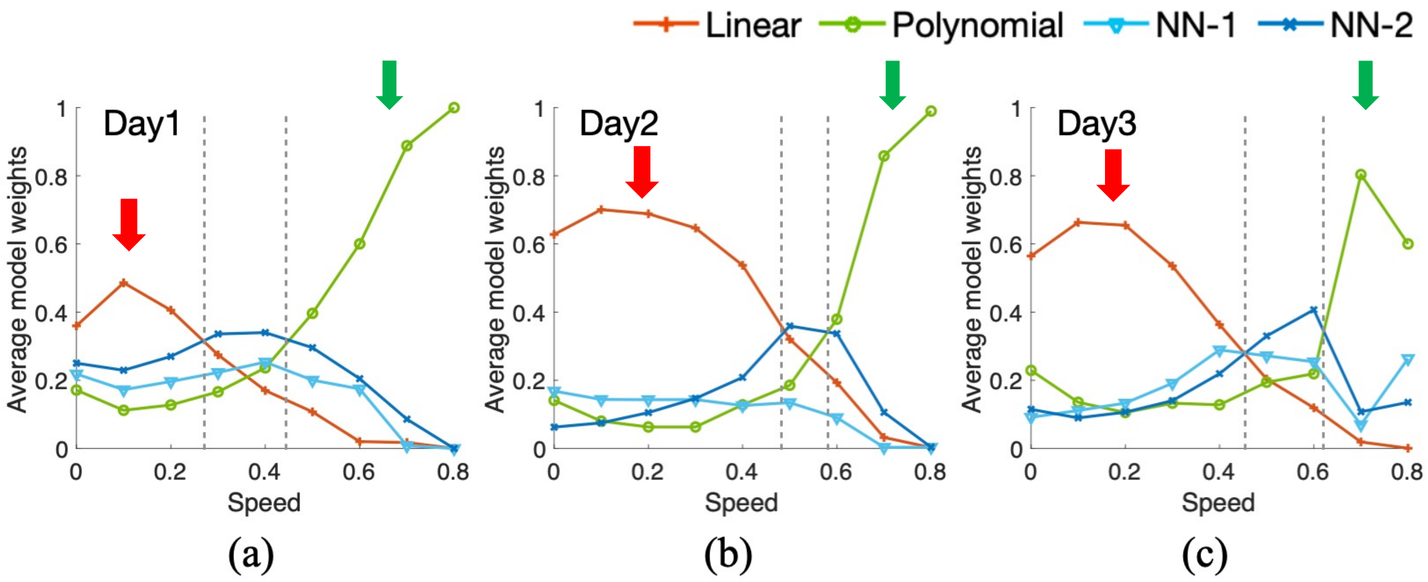
max **91%**



DyEnsemble significantly improves the control accuracy (increases the success rate by 13.9% in the random target pursuit task) and robustness (performs more stably over different experiment days).

Analysis of the dynamic ensemble process

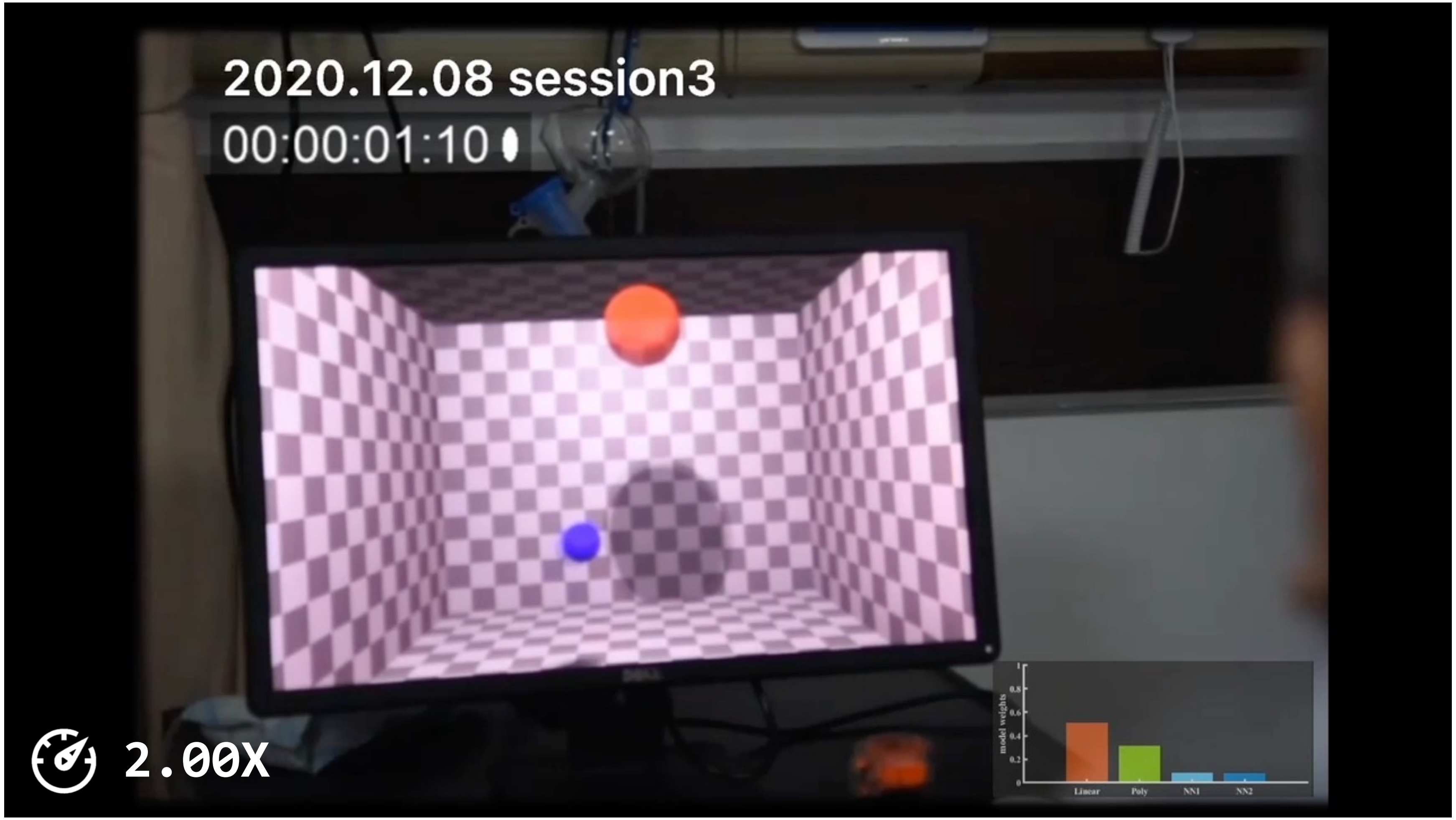




- Model ensemble changes during the closed-loop calibration, converging to a **linear dominant model** at full brain control stages.

- Linear models are favored at **low speeds**
- Polynomial models cover the **high speeds**.

Now Uncle Bobo can happily play his favorite mahjong with BCI !



Scan me to down load the papers:

Thanks!

Please find details in our papers:

[1] Dynamic Ensemble Bayesian Filter for Robust Control of a Human Brain-machine Interface, *Arxiv* 2022 (***Trans. BME*** *minor*)

[2] Dynamic Ensemble Modeling Approach to Nonstationary Neural Decoding in Brain-Computer Interfaces, ***NeurIPS*** 2019