Human Motor Cortex Encodes Complex Handwriting Through a Sequence of Stable Neural States

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1 INTRODUCTION

Problem : How the human **motor cortex** orchestrates **sophisticated fine movements** ?

Character 脑 (brain) — Radical 月 亟 — Stroke — Trajectory

Behavioral Decomposition !

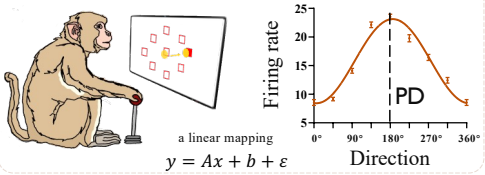
Neural Decomposition ?

- Is it a state-dependent process ?
- What is the primitive units ?
- How each unit is encoded in MC ?

Fundamental Knowledge : 【Georgopoulos et al., 1982 / 1986】

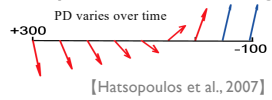
Neurons encode movement commands through cosine tuning curves.

Directional Tuning Model



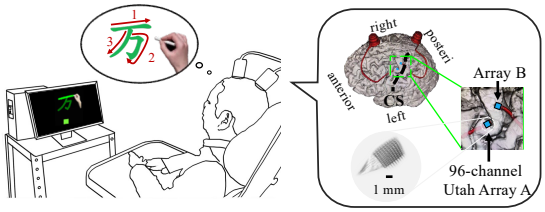
Challenges :

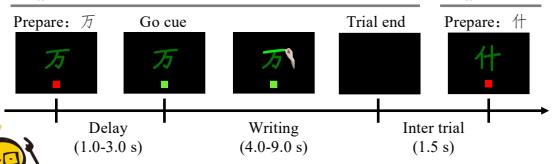
I. Inaccurate predictions.
II. Unexplained activities.
III. Dynamic neural tunings.



【Hatsopoulos et al., 2007】

2 CLINICAL EVIDENCE

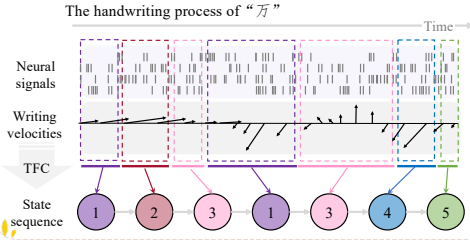




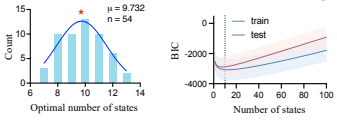
The handwriting process is state-dependent.

3 IDENTIFY STABLE STATES & LEARN ENCODING MODELS (WHEN TRAINING)

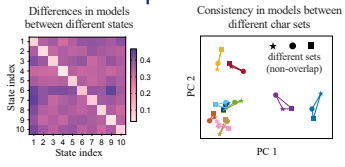
State-dependent Directional Tuning Model



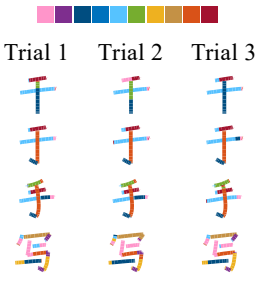
✓ **A small num of states is enough.**



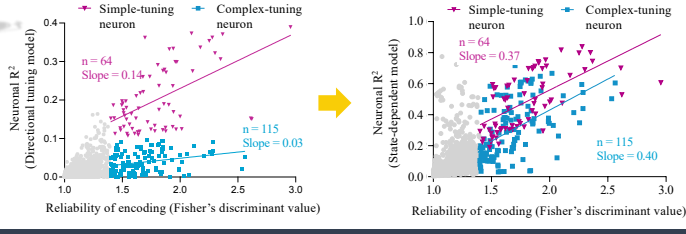
✓ **Models are specific & consistent.**



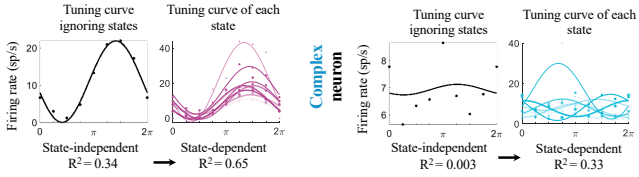
TFC segmentation



State-dependent model better explains neural activities !

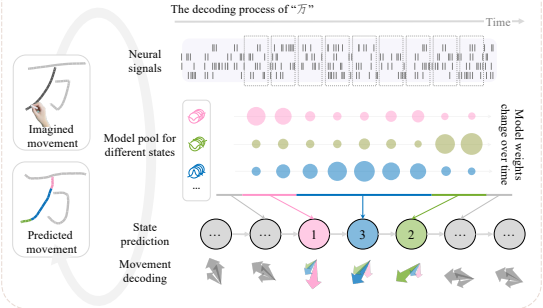


✓ **2 types of neurons : simple(stable PDs) & complex(distinct PDs)**



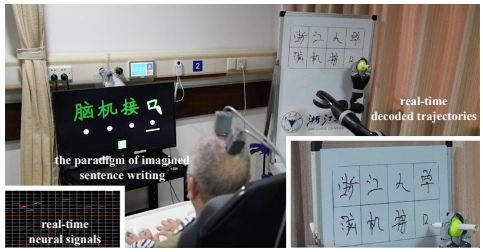
4 PREDICT STATES & DECODE TRAJECTORIES (WHEN TESTING)

State-dependent Decoder



State-independent decoder

State-dependent decoder



5 HIGHLIGHTS

- ✓**We propose :** a state-dependent encoder & a state-dependent decoder.
- ✓**We find :** MC programs the writing of complicated characters by sequencing a small set of stable states.
- ✓**We get :** 229% more explained neural activities & 69% higher decoding performance.

Please find details in our papers:

[1] Human Motor Cortex Encodes Complex Handwriting Through a Sequence of Stable Neural States, ***Nature Human Behaviour*** *2024* (under review)

[2] Dynamic Ensemble Bayesian Filter for Robust Control of a Human Brain-machine Interface, ***Trans. BME*** *2022*

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