Why I believe machine learning in cognitive neuroscience is not a fad

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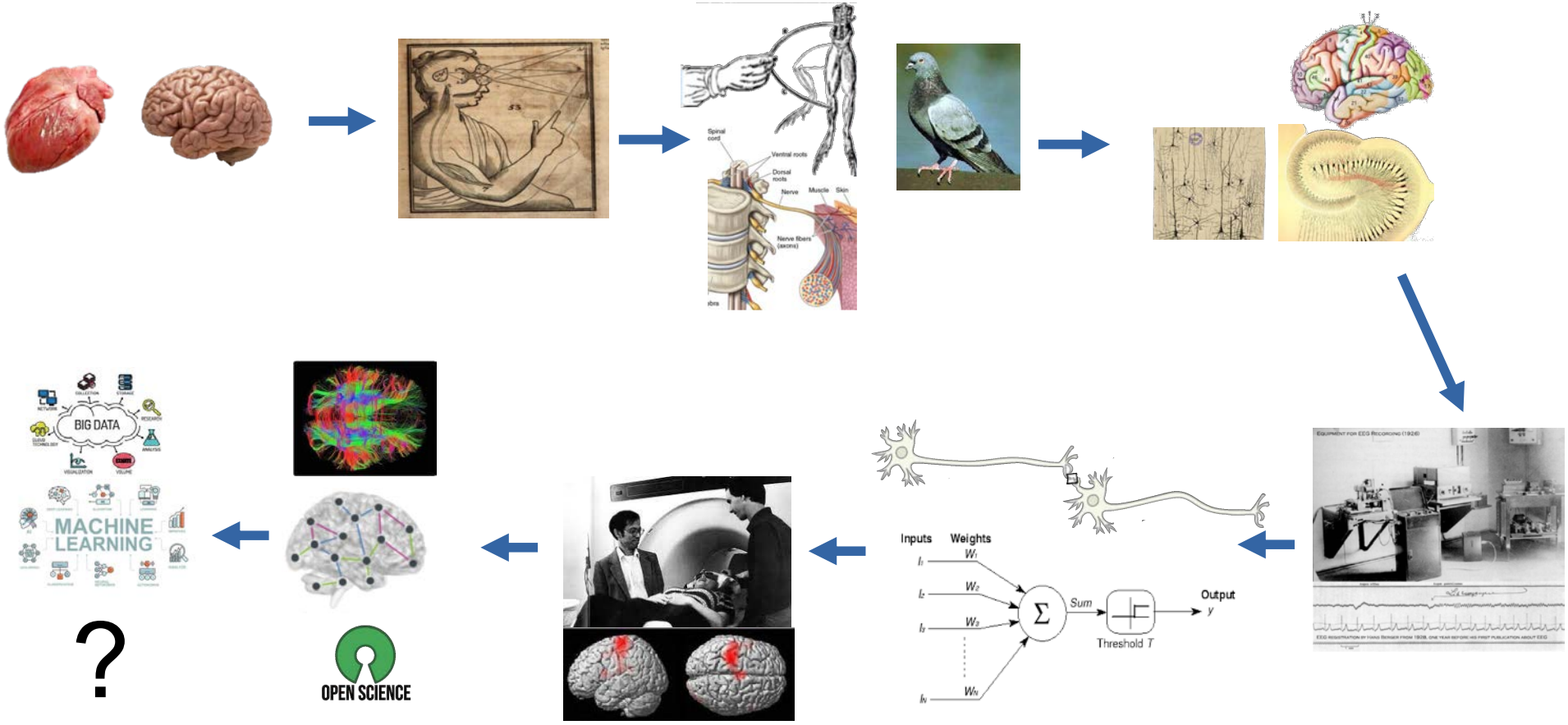
History of CogNeuro Methods



What is machine learning?

Unbiased & data-driven

Good for new areas of research

Why do we need ML in CogNeuro?

Prediction, decoding, generalization

Clinical implementations

Why should we be wary of ML?

[Sometimes] not theoretically driven

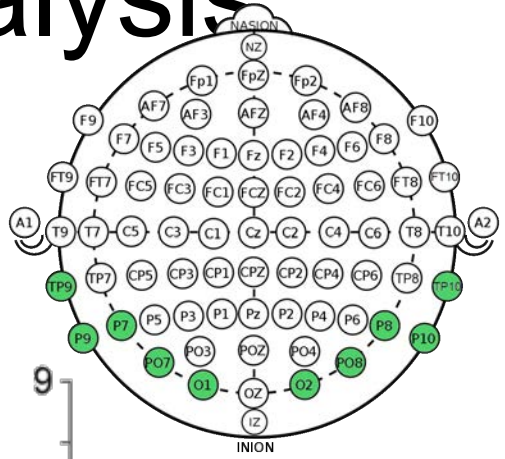
Easy and tempting to find patterns that are not theoretically relevant

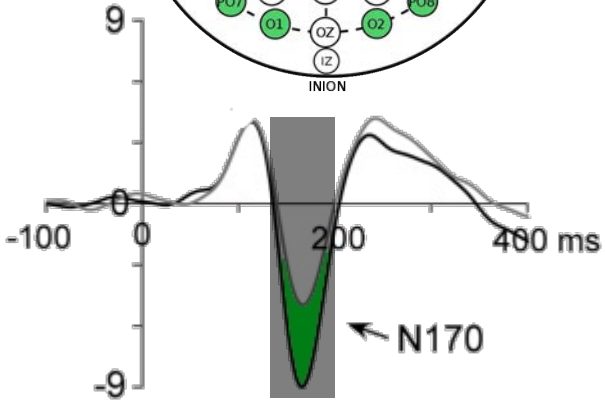
Fishing should stay as a hobby

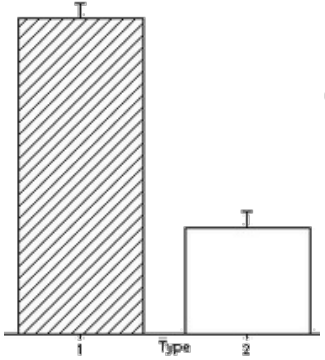
Mathematical/Numerical Cognition, Learning, and Development

Traditional EEG/ERP Analysis

- Determine electrode sites, time intervals, frequency bands/components etc. based on your hypotheses
- Take measurements
- Conduct parametric testing





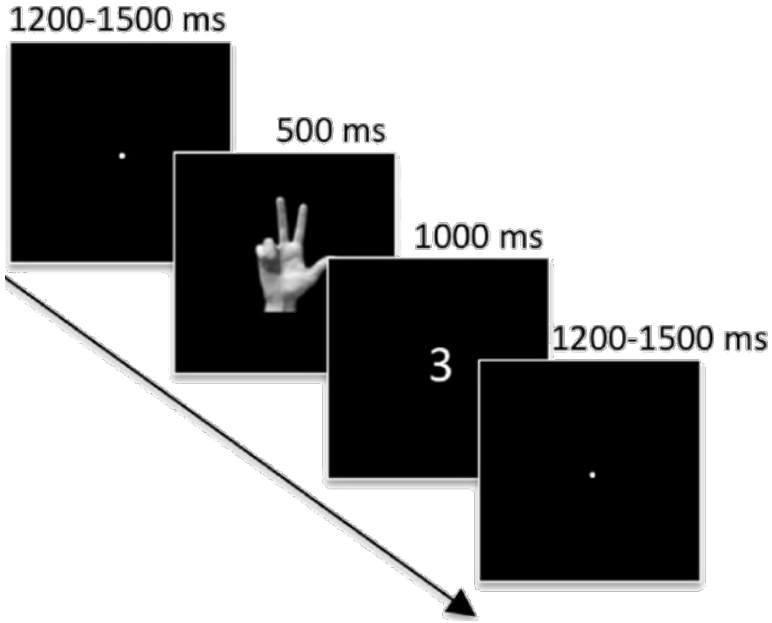


Machine Learning with EEG/ERP

- Little to no assumptions about electrode sites and time intervals
- Use of the entire scalp distribution and trial intervals
- Ideal for new domains

Preprocessing
Feature extraction and reduction
Model training and testing
Feature importance analysis
Interpretation

Traditional ERP Study



Montring (MO)

Counting (CO)

Non-canonical (NC)

Contents lists available at ScienceDirect

Neuroscience Letters

journal homepage: www.elsevier.com/locate/neulet

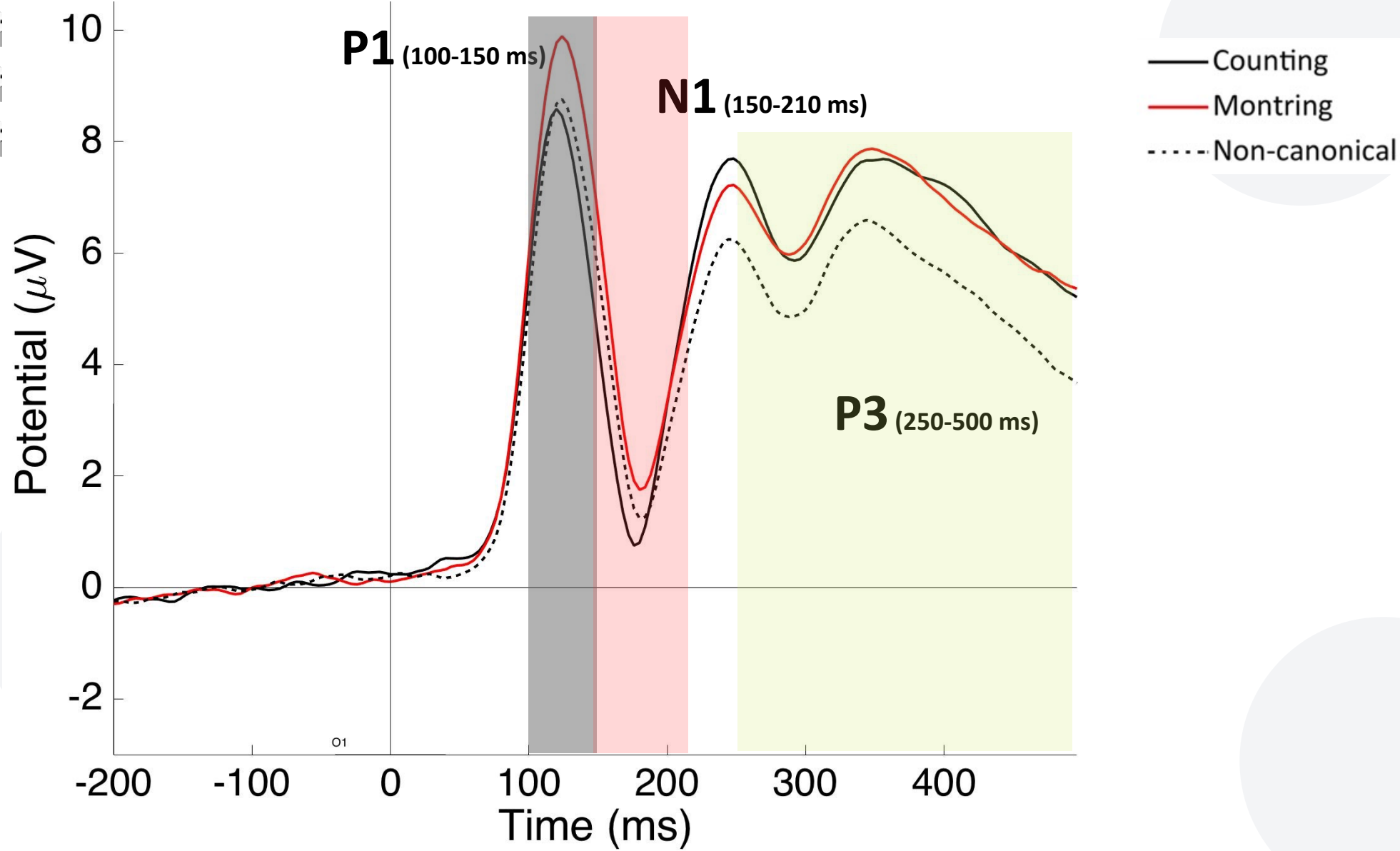
Research article

ERP differences in processing canonical and noncanonical finger-numeral configurations

Firat Soylu*, Brian Rivera, Mona Anchan, Nathaniel Shannon

Soylu, F., Rivera, B.*, Anchan, M.*, & Shannon, N.* (2019). ERP differences in processing canonical and noncanonical finger-numeral configurations. *Neuroscience Letters*, 705, 74–79.

Soylu, F. (2019). Public dataset: ERP differences in processing canonical and noncanonical finger-numeral configurations, *Harvard Dataverse*.


P1 (100-150 ms)
N1 (150-210 ms)
P3 (250-500 ms)
Counting
Montring
Non-canonical
Potential (μV)
Time (ms)
O1
10
8
6
4
2
0
-2
-200
-100
0
100
200
300
400

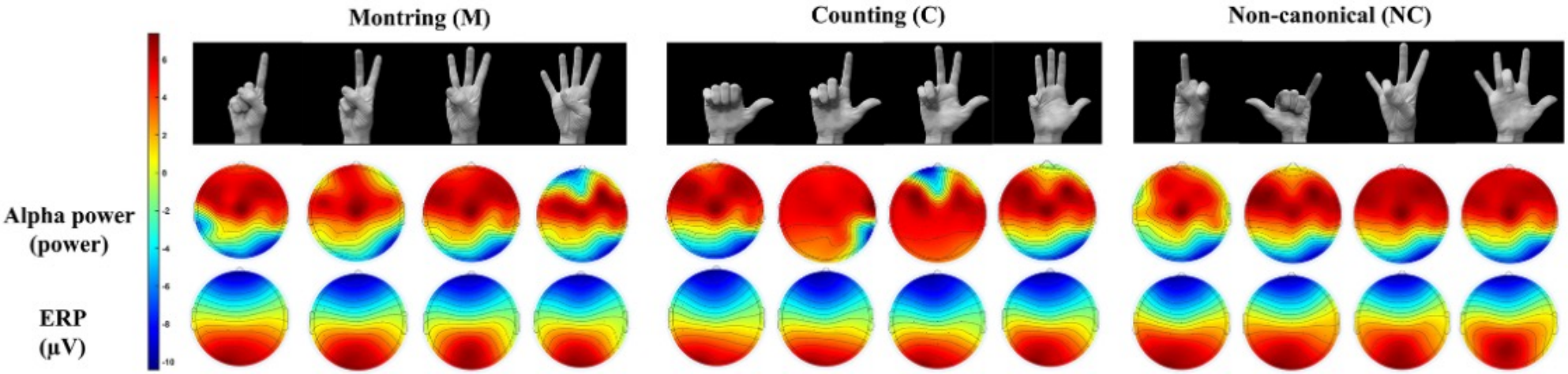
Decoding

Dr. Roya Salehzadeh
Lawrence Technological Uni.

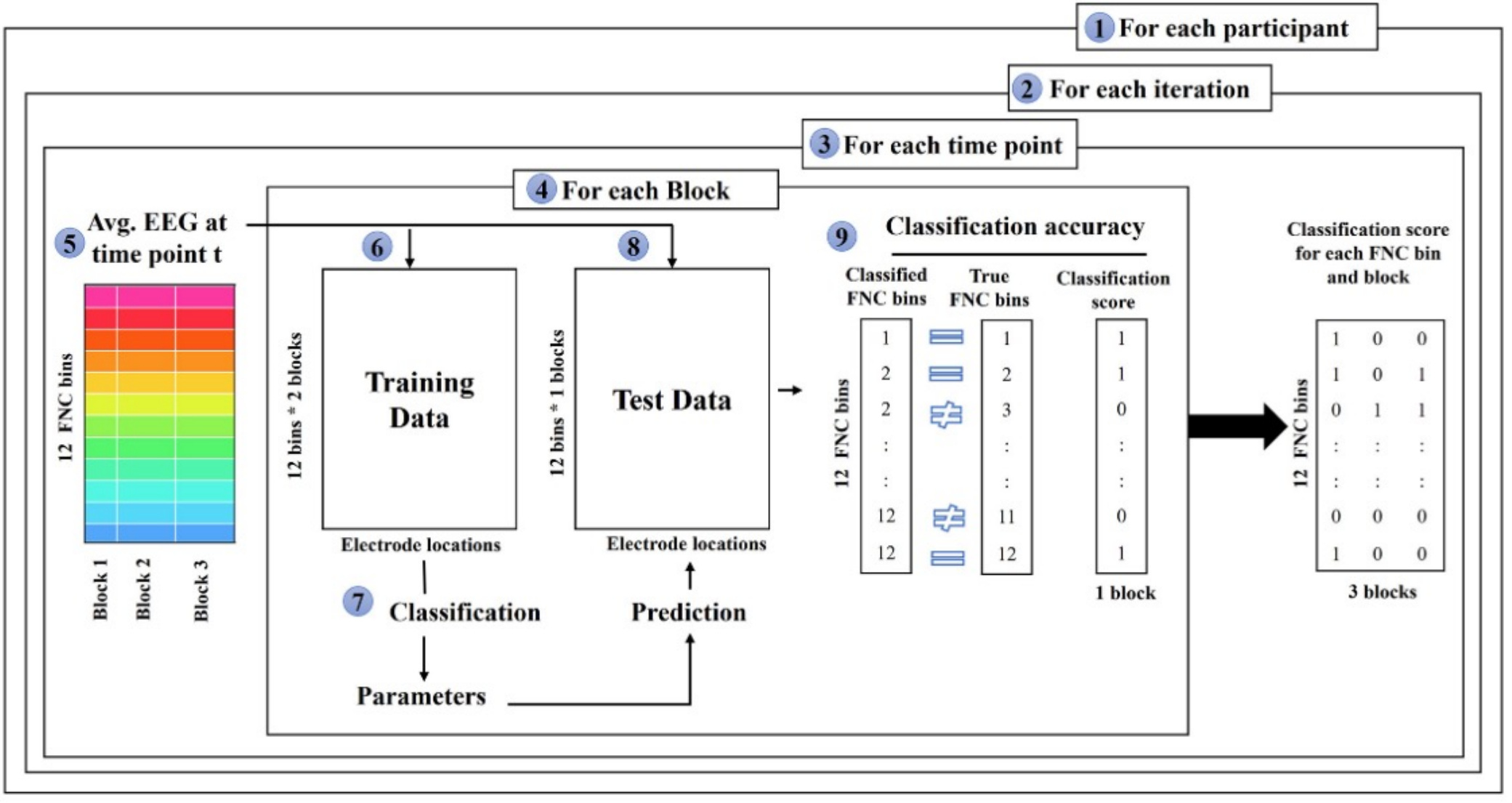
Dr. Brian Rivera
University of Nebraska-Lincoln

Journal of Numerical Cognition

EEG Decoding of Finger Numeral Configurations With Machine Learning

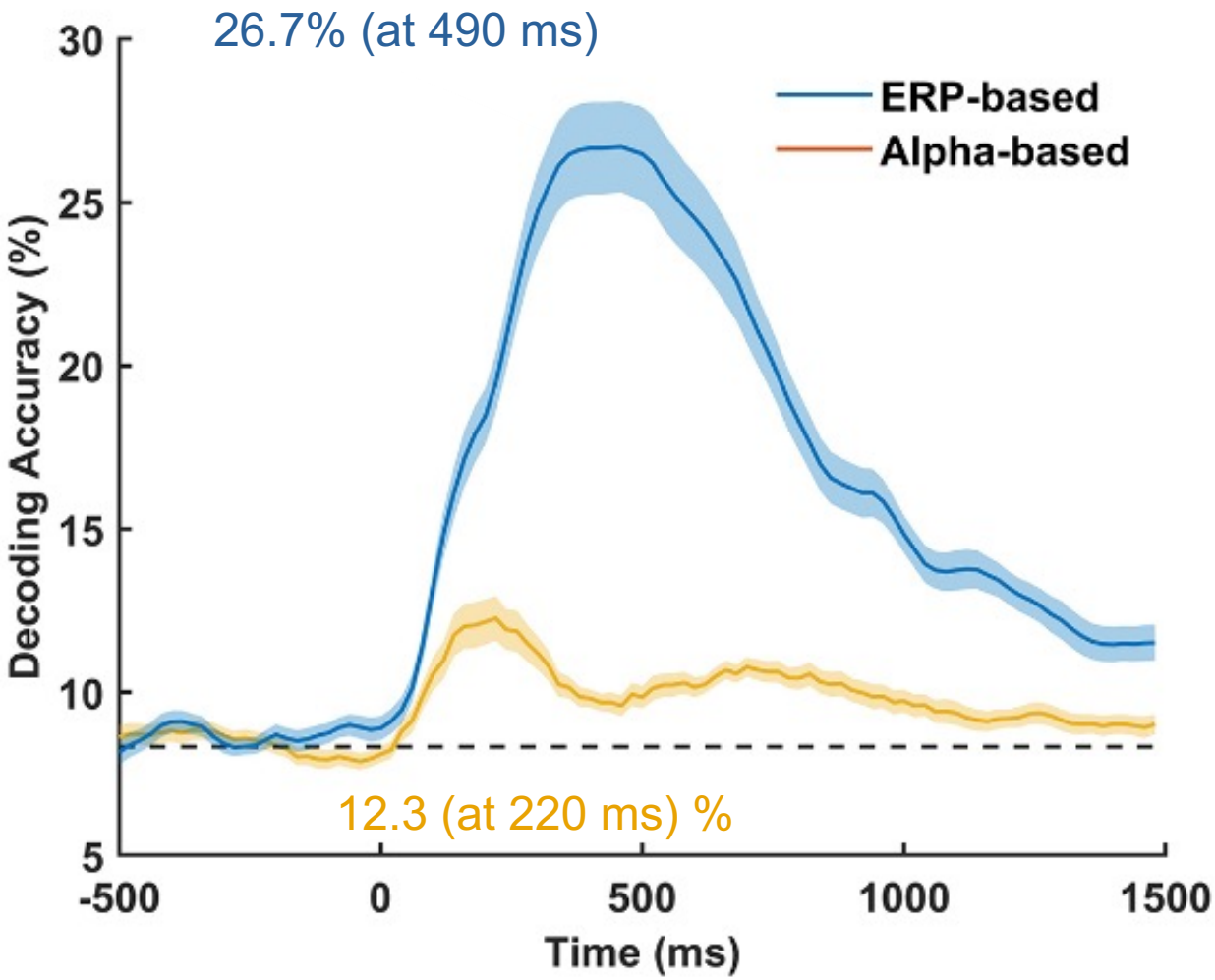


Salehzadeh, R.*, Rivera, B.*, Man, K., Jalili, N., & Soylu, F. (2023). EEG Decoding of Finger Numeral Configurations With Machine Learning. *Journal of Numerical Cognition*, 9(1), 206-221.



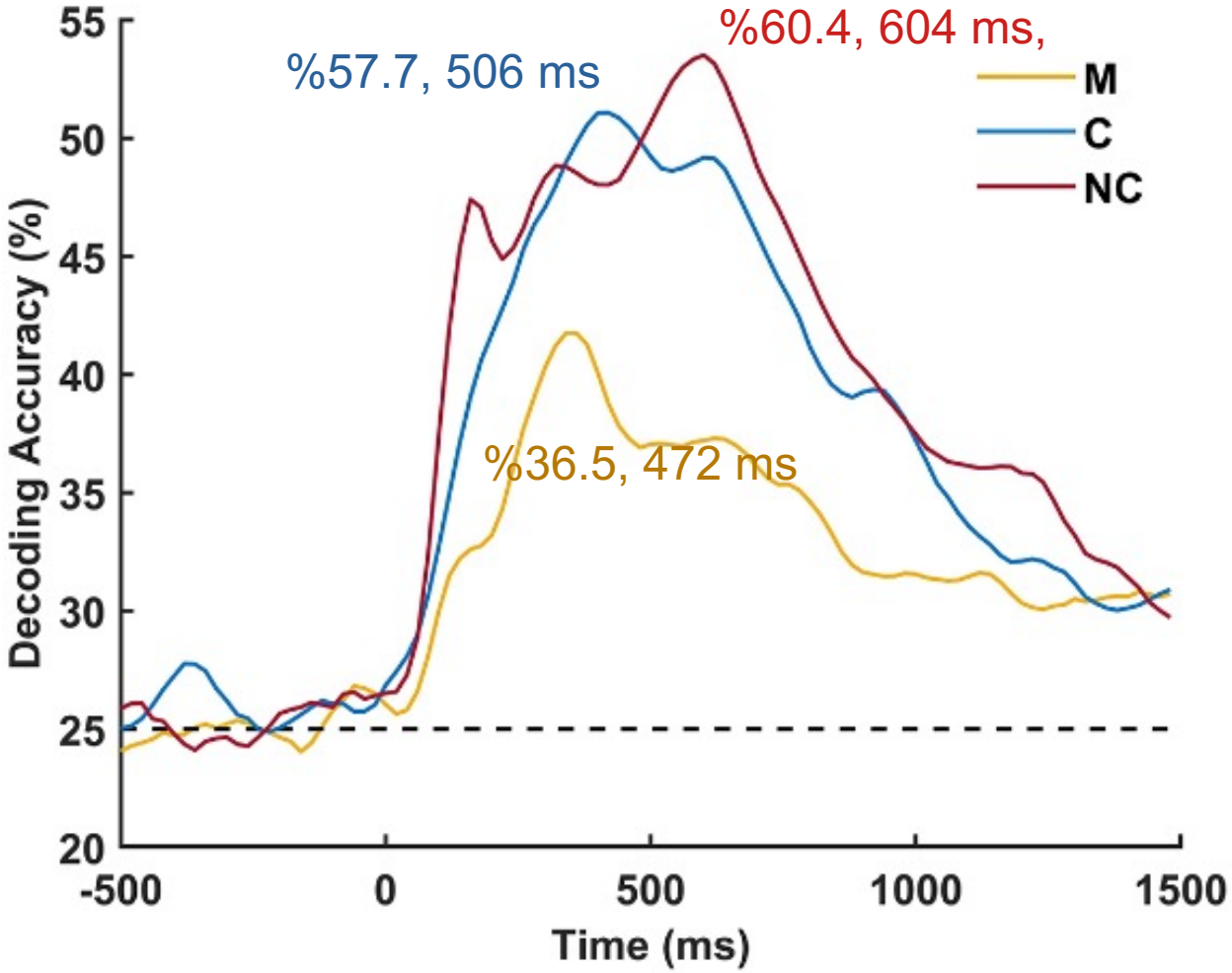
Bae & Luck (2019). Decoding motion direction using the topography of sustained ERPs and alpha oscillations. *NeuroImage*.

Mean Accuracy of Alpha-Based Decoding and ERP-Based Decoding Averaged Across All 12 FNCs



Note. The black horizontal line indicates the chance-level performance (1/12 ≈ 0.083≈ 8.3%). The shaded areas indicate ± 1 SEM.

Mean Accuracy of ERP-Based Decoding for Montring (M), Counting (C), and Noncanonical (NC) Configurations



Note. The black horizontal line indicates the chance-level performance (0.25 = 1/4).

The Percentage of Accurate Classifications for Each of the 4 FNCs

M

Stimuli (FNCs) \ Predicted Classes (FNCs)	M1	M2	M3	M4
M1	33.5%	23.3%	21.3%	21.9%
M2	22.7%	30.7%	24.0%	22.6%
M3	21.7%	23.7%	30.2%	24.4%
M4	22.1%	22.3%	24.4%	31.2%

C

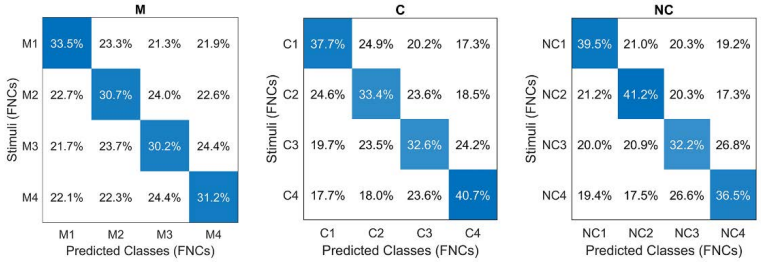
Stimuli (FNCs) \ Predicted Classes (FNCs)	C1	C2	C3	C4
C1	37.7%	24.9%	20.2%	17.3%
C2	24.6%	33.4%	23.6%	18.5%
C3	19.7%	23.5%	32.6%	24.2%
C4	17.7%	18.0%	23.6%	40.7%

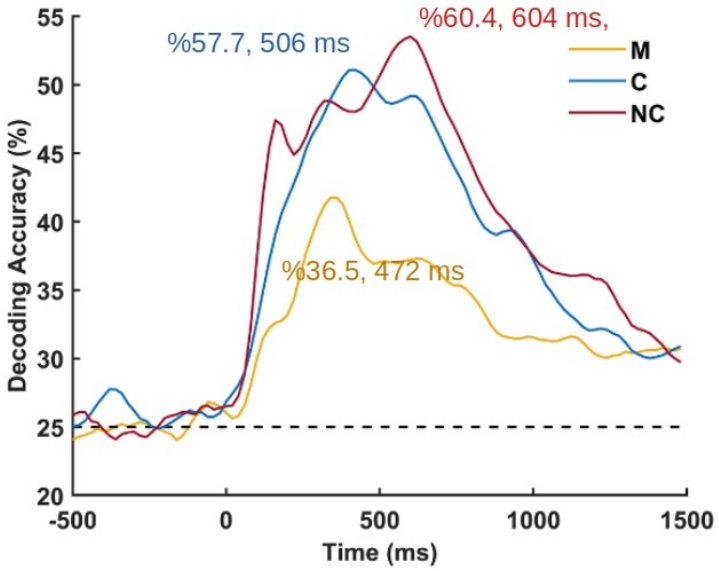
NC

Stimuli (FNCs) \ Predicted Classes (FNCs)	NC1	NC2	NC3	NC4
NC1	39.5%	21.0%	20.3%	19.2%
NC2	21.2%	41.2%	20.3%	17.3%
NC3	20.0%	20.9%	32.2%	26.8%
NC4	19.4%	17.5%	26.6%	36.5%

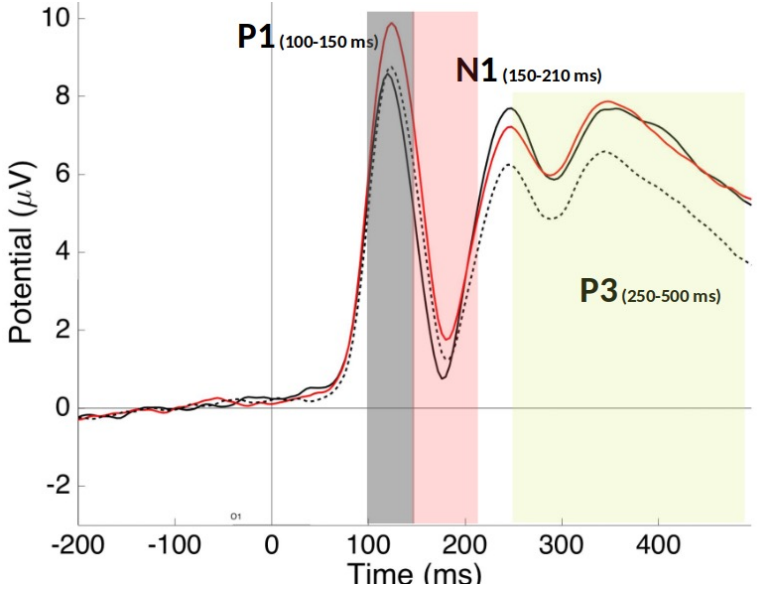
Comparison

Decoding





Traditional ERP



Decoding Performance of 6 ML Algorithms Compared

Biomedical Physics & Engineering Express

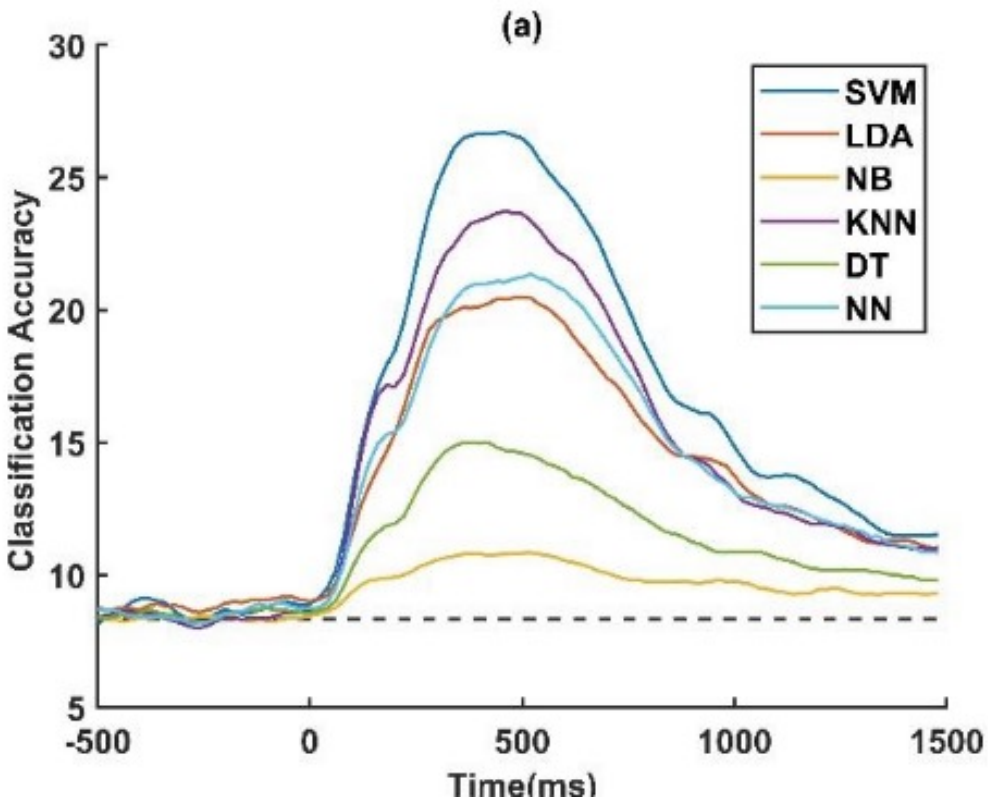
PAPER

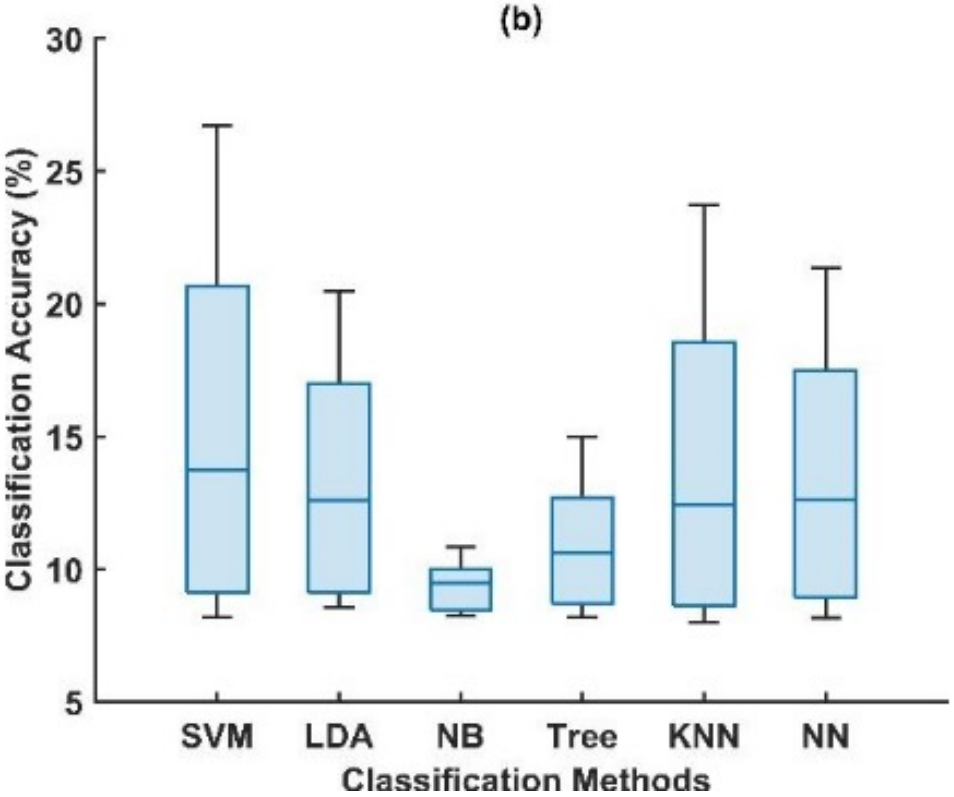
A comparative study of machine learning methods for classifying ERP scalp distribution

Roya Salehzadeh[1,*], Firat Soylu[2] and Nader Jalili[1]

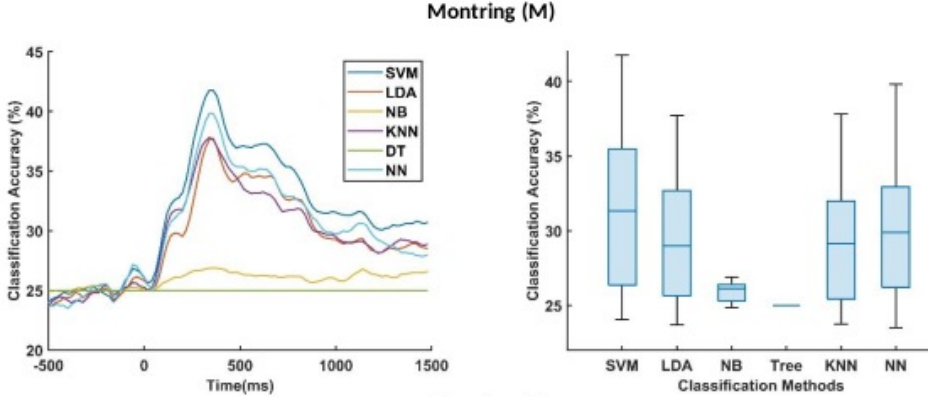
Classifier	MATLAB function	Detail
SVM	*fitcecoc()*	One. vs all, linear kernel
LDA	*fitcecoc()*	One. vs all, linear discriminar Kernel: normal
NB	*fitcecoc()*	One. vs all
KNN	*fitcecoc()*	One. vs all, k=12 for decodin all FNCs and K=4 fo category-specific decoding
DT	*fitcecoc()*	One. vs all
NN	*fitcnet()*	Input: [1,32], FC1: [10,32 FC2: [4,10] or [12, 10], outpu [1,1]

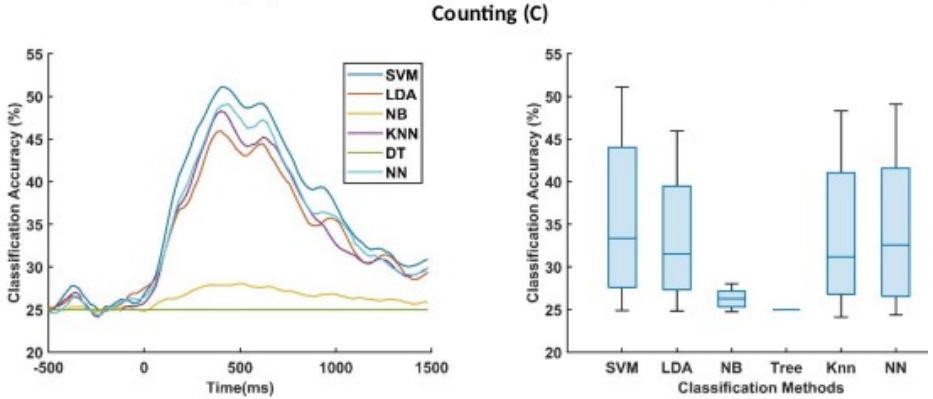
Salehzadeh, R., Soylu, F., & Jalili, N. (2023) A Comparative Study of Machine Learning Methods for Classifying ERP Scalp Distribution. *Biomedical Physics & Engineering Express*.

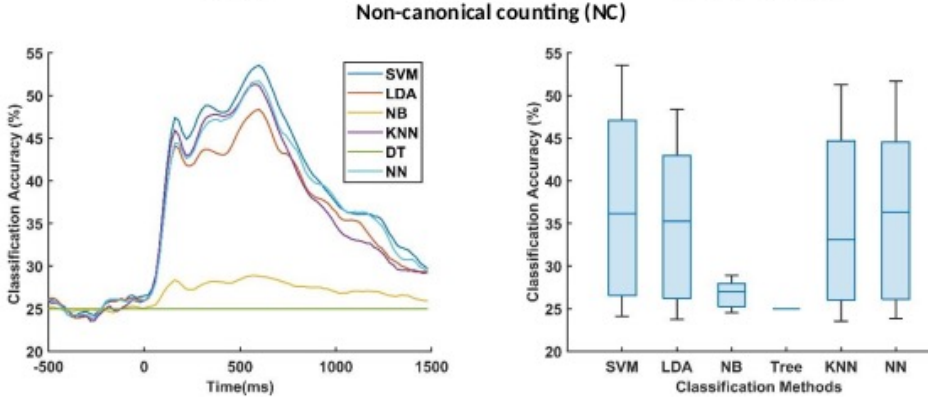

(a)
SVM
LDA
NB
KNN
DT
NN
Classification Accuracy
Time(ms)
30
25
20
15
10
5
-500
0
500
1000
1500


(b)
Classification Accuracy (%)
Classification Methods
SVM
LDA
NB
Tree
KNN
NN
30
25
20
15
10
5

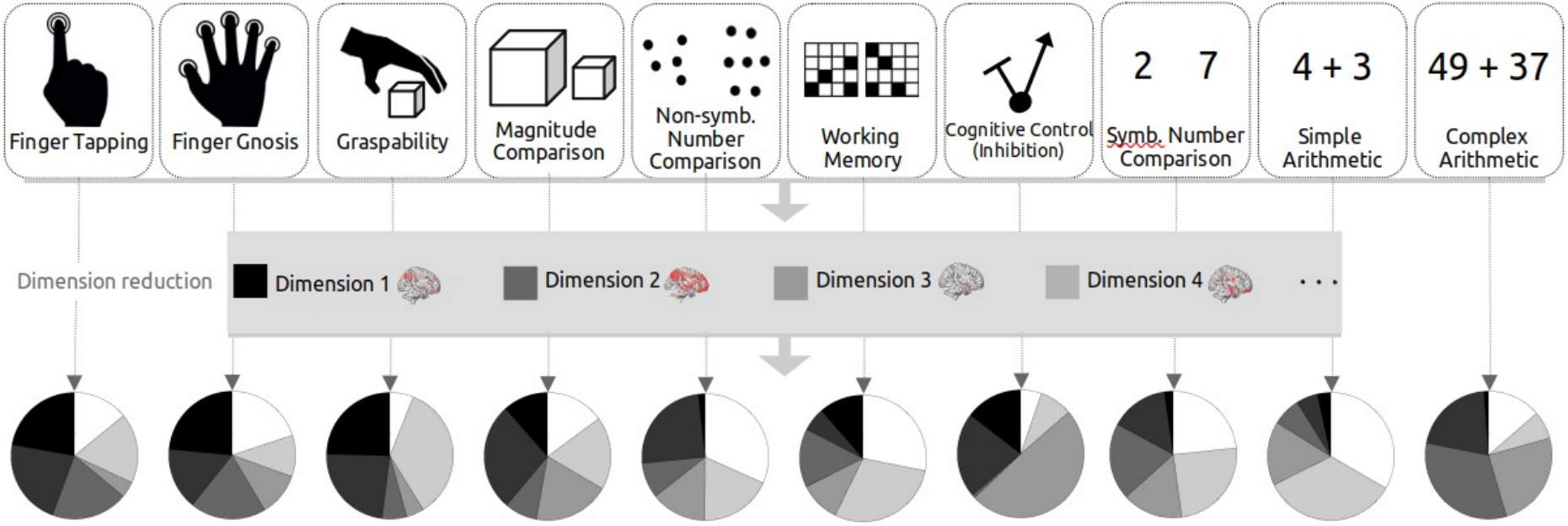
Category specific decoding



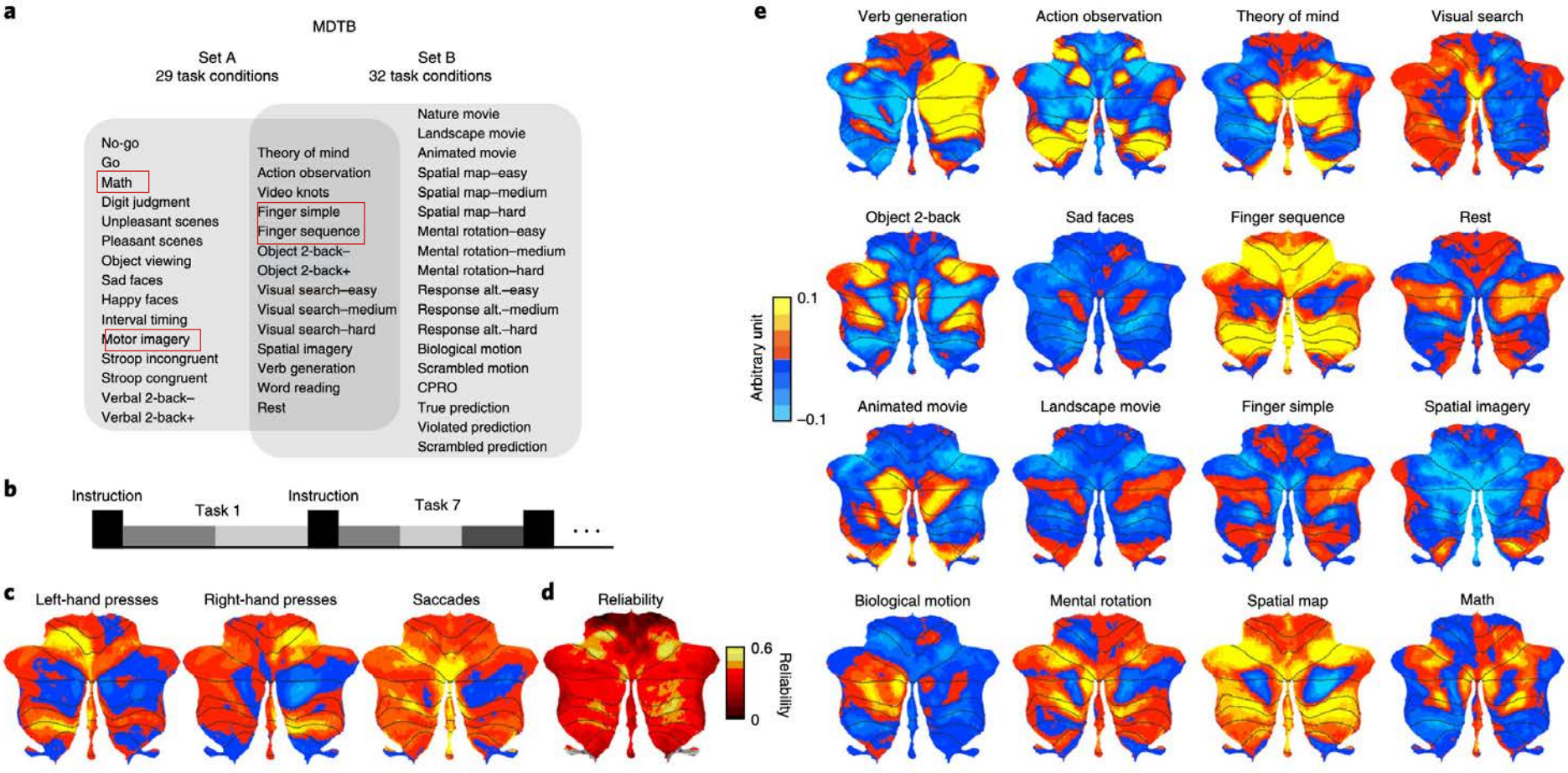




Current Projects



A New Ontology for Numerical Cognition: Integrating Evolutionary, Embodied, and Data Informatics Approaches (in press) *Acta Psychologica*



King, Hernandez-Castillo, Poldrack, Ivry, & Diedrichsen (2019). Functional boundaries in the human cerebellum revealed by a multi-domain task battery. *Nature Neuroscience*

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