The Data Mentalist

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Introduction

Event Related Potential (ERP) based studies are pivotal in the diagnosis and comprehension of **disorders** linked to **visual perception**, as well as **atypical categorization** abilities [1,2] (autism, schizophrenia).
Discrete features derived from latencies and amplitudes of their components [4] are used describe these waves.

Proposal

A method based on **Functional Data Analysis** (FDA) [3] and the extraction of functional features from ERPs. Our aim is to extract a set of Principal Component Functions (PCF) that incorporates prominent features that **characterize the category of visual stimuli** a patient is receiving.

Pipeline

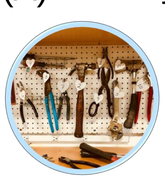
Dataset

- "Human electroencephalography recordings from 50 subjects for 22,248 images from 1,854 object concepts" [4].
- Rapid Serial Visual Presentation task
- Visual stimuli from THINGS [5].


Animal (A)


Body Part (B)


Vehicle (V)

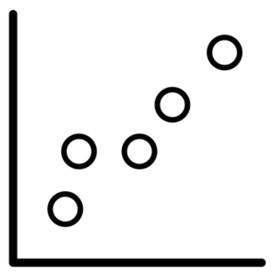

Tool (T)


Food (F)

Traditional Approach

Extraction of:
- Signed Area Amplitude (Area)
- 50% Peak Latency (Lat)

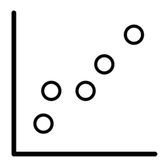
From P1, N1, N2, P3 components.



Functional Approach

1. Functional Basis Representation
2. Outlier Removal
3. Functional Principal Component Analysis (FPCA)
4. Kruskal-Wallis test on FPCA scores

Comparison


Area & Lat

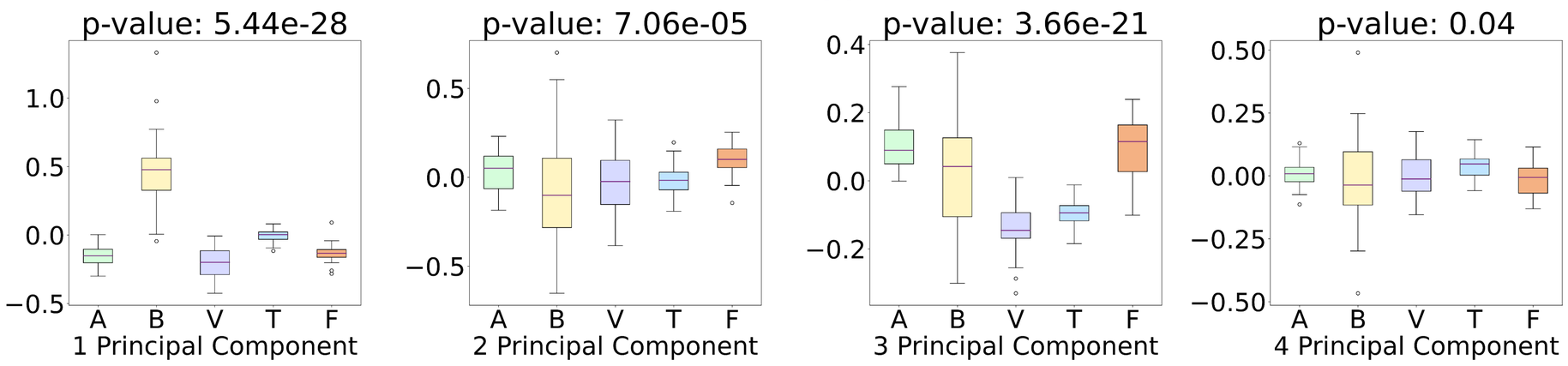
vs


FPCA scores

1. Linear Correlation Analysis (LCA) + Bonferroni Correction
2. Random Vector Machine (RVM) Classifier
3. Classification Performances

Results

Functional Approach



Boxplots of the categories' scores relative to PCFs and p-value of Kruskal-Wallis test.

Comparison – Performances

	Discrete Features	Functional Features
Accuracy	67.57%	**83.78%**
Precision	68.83%	**84.46%**
Recall	65.01%	**81.40%**
F1	64.40%	**82.16%**

Performances of RVM classifiers.

Comparison – LCA

PCF	Area P1	Lat P1	Area N1	Lat N1	Area N2	Lat N2	Area P3	Lat P3
1	••	•	•••	•••	•••	•		
2	••			•		•	•••	•
3	•	•	•			••		••
4	•		•				•	

LCA Results. The levels of significance are the following:
● → α < 0,05/32; ●● → α < e-10; ●●● → α < e-20

- **FPCA scores differ** between image categories.
- Discrete and functional features are **significantly correlated**.
- **Functional features outperform** traditional ones in all the classification parameters.

Conclusions

- The classification performance related to functional features **is better in all respects** than the discrete ones.
- PCFs capture **morphological aspects related to visual ERP categorization better** than traditional discrete measures.
- FDA-based analysis emerges as a **valid approach** to solve the image classification problem.

References

[1] Jeon, Y.-W. and Polich, J. (2003). Meta-analysis of P300 and schizophrenia: patients, paradigms, and practical implications. Psychophysiology 40, 684–701
[2] Webb, S. J., Dawson, G., Bernier, R., and Panagiotides, H. (2006). ERP evidence of atypical face processing in young children with autism. J Autism Dev Disord 36, 881–890.
[3] Ramsay, J., Silverman, B., Media, S. S., and Silverman, H. (2005). Functional Data Analysis. Springer Series in Statistics. Springer.
[4] Grootswagers, T., Zhou, I., Robinson, A. K., Hebart, M. N., and Carlson, T. A. (2022). Human EEG recordings for 1,854 concepts presented in rapid serial visual presentation streams. Scientific Data 9, 3.
[5] Hebart, M. N., Dickter, A. H., Kidder, A., Kwok, W. Y., Corriveau, A., Van Wicklin, C., and Baker, C. I. (2019). Things: A database of 1,854 object concepts and more than 26,000 naturalistic object images. PLOS ONE 14, 1–24