The Data Mentalist

My research in 5 minutes

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Mentalism: A Kind of Magic?

If we asked someone to choose an image randomly and look at it, would we be able to know what they are watching without the help of paranormal powers?

Aims

To extract relevant EEG features that allow us to predict what a person is watching

Aims

To achieve a deeper understanding of cognitive processes

State of the Art

How are EEGs studied in image categorization?

Event Related Potential - ERP

Small voltages generated by the brain in response to specific stimuli.
In our case the stimuli are visual

Discrete Statistical Quantities

Divide the ERP into time intervals covering its components and extract from them discrete quantities (maximum or fractional peak amplitude and latency, average amplitude, ...)

Statistical Analysis

ANOVA tests represent the main approach to investigate if the features extracted from different groups/conditions are significantly diverse

S. Luck, An Introduction to the Event-Related Potential Technique, second edition, ser. A Bradford Book. MIT Press, 2014.

Dataset

Human electroencephalography recordings from 50 subjects

Average of Occipital channels

THINGS: A database of 1,854 object concepts

5 image categories

50 EEG reponses to a rapid serial visual presentation of images

Standard 10/10 electrode placement

Tool

Animal

Vehicle

Body Part

Food

Grootswagers, Tijl and Zhou, Ivy and Robinson, Amanda and Hebart, Martin and Carlson, Thomas (2021). Human electroencephalography recordings from 50 subjects for 22,248 images from 1,854 object concepts. OpenNeuro. [Dataset] doi: doi:10.18112/openneuro.ds003825.v1.2.0

M. N. Hebart, A. H. Dickter, A. Kidder, W. Y. Kwok, A. Corriveau, C. Van Wicklin, and C. I. Baker, "Things: A database of 1,854 object concepts and more than 26,000 naturalistic object images," PLOS ONE, vol. 14, no. 10, pp.1–24, 10 2019

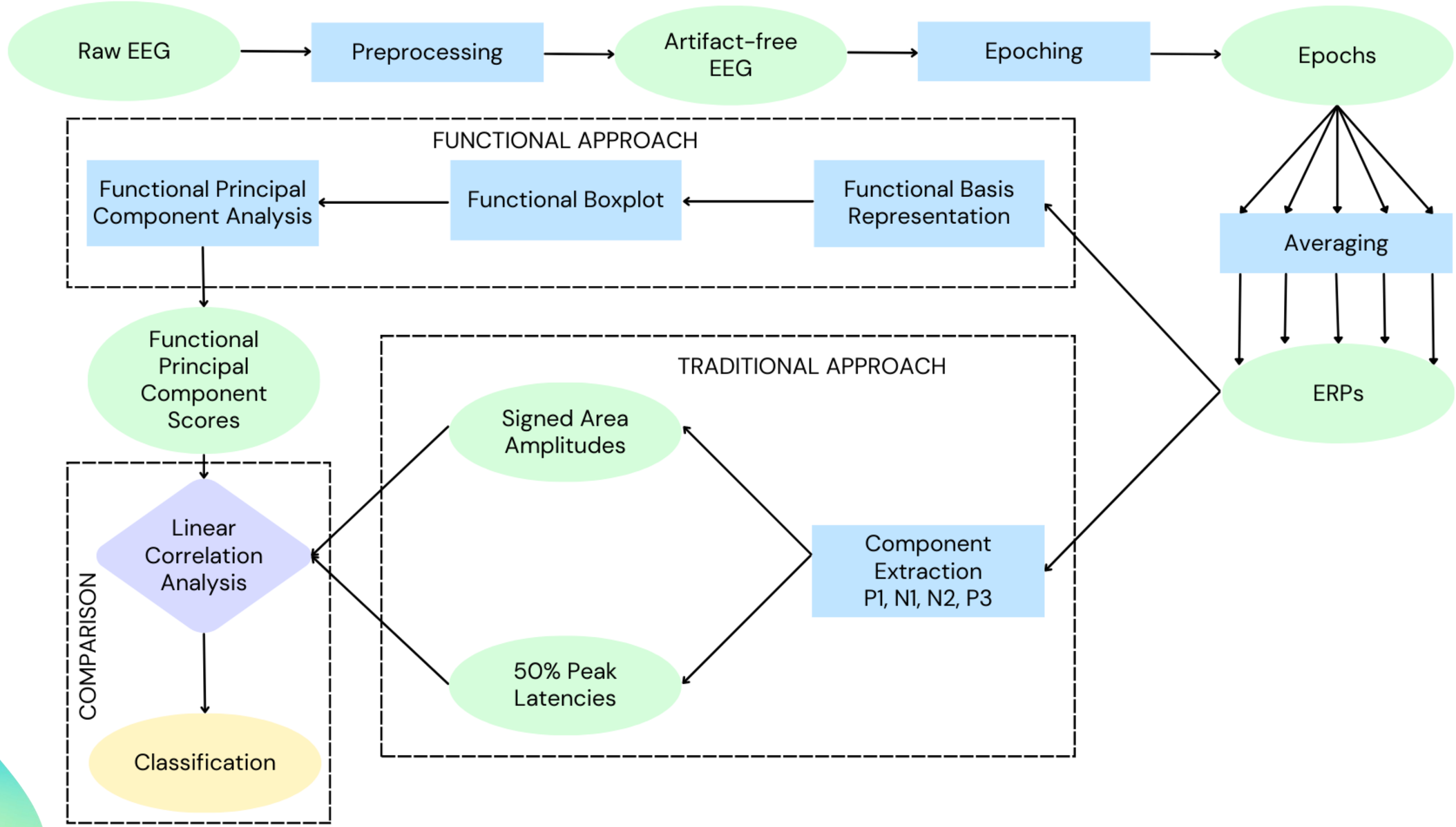
Every great magic trick consists of three parts or acts. The first part is called "The Pledge". The magician shows you something ordinary. [...]

The second act is called "The Turn". The magician takes the ordinary something and makes it do something extraordinary.
[...]

But you wouldn't clap yet. Because making something disappear isn't enough; you have to bring it back. That's why every magic trick has a third act, the hardest part, the part we call "The Prestige".

The Prestige, C. Nolan, 2006

The magic trick step-by-step



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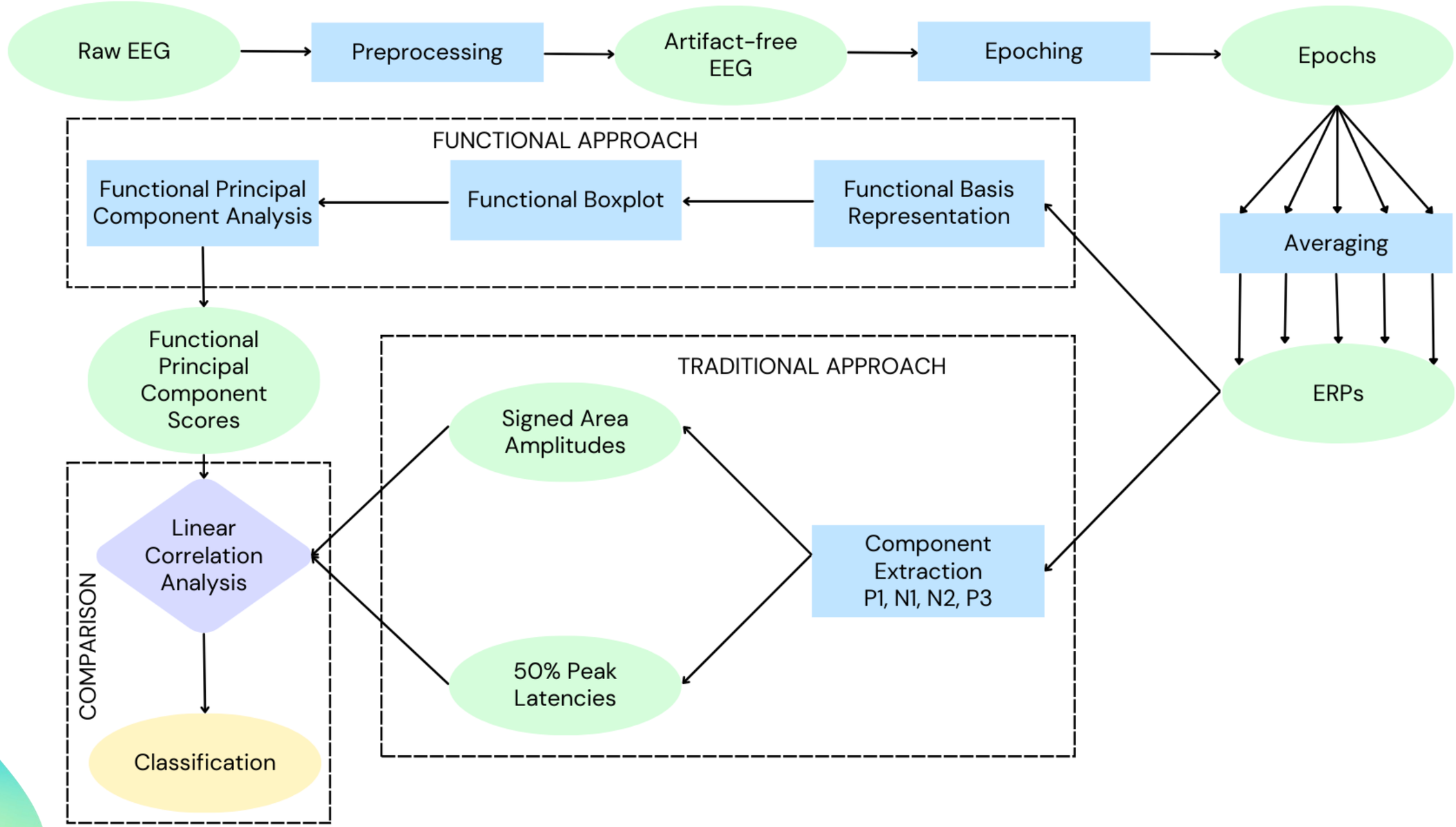
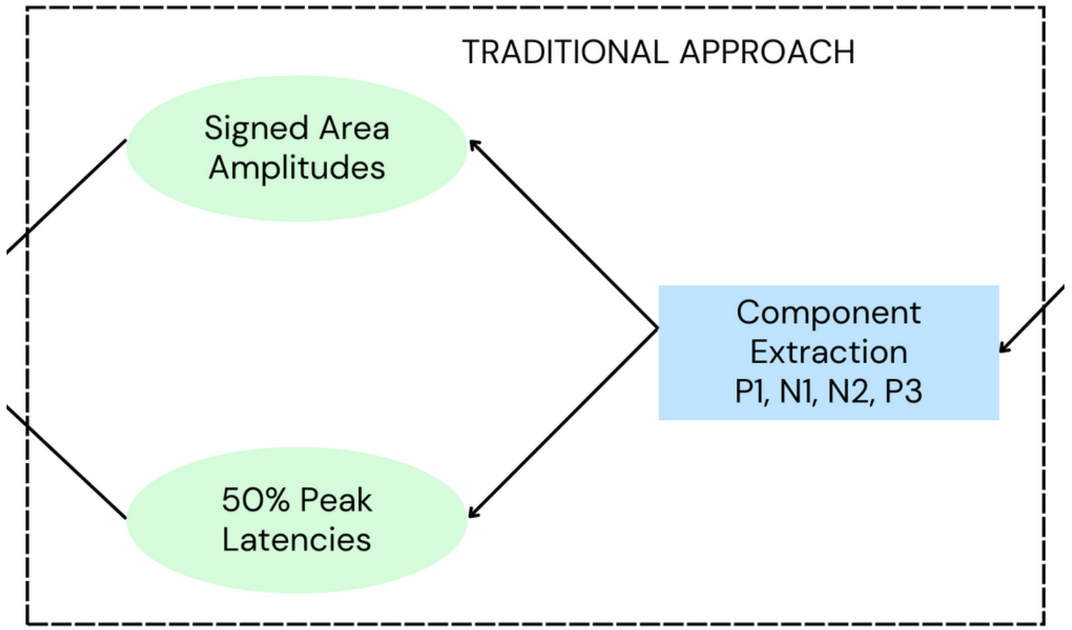


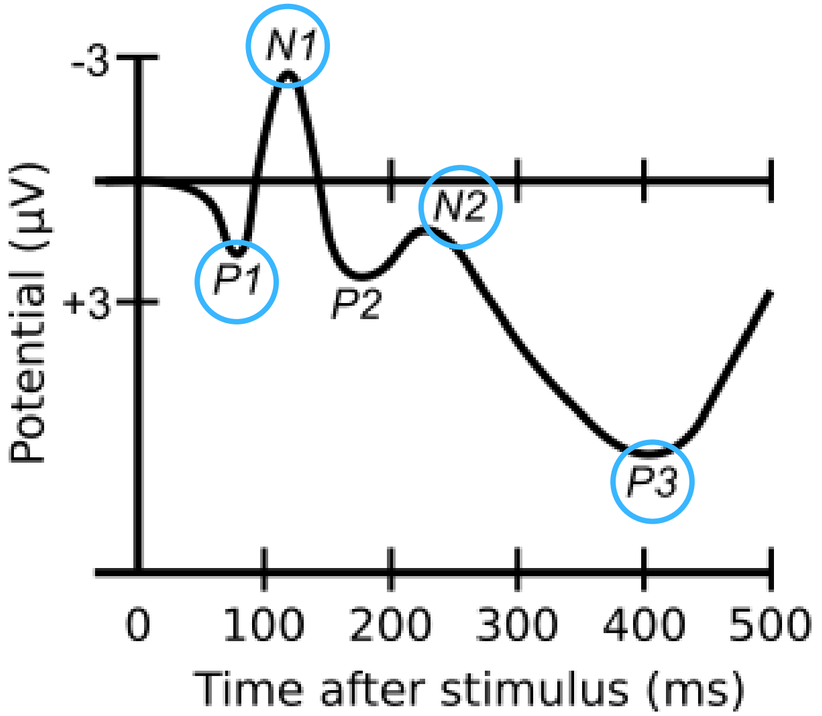
The *"Pledge"*


TRADITIONAL APPROACH
Signed Area Amplitudes
Component Extraction P1, N1, N2, P3
50% Peak Latencies

Discrete Features Extraction

We have to answer 2 questions:

- **Which components?**
- Which features?



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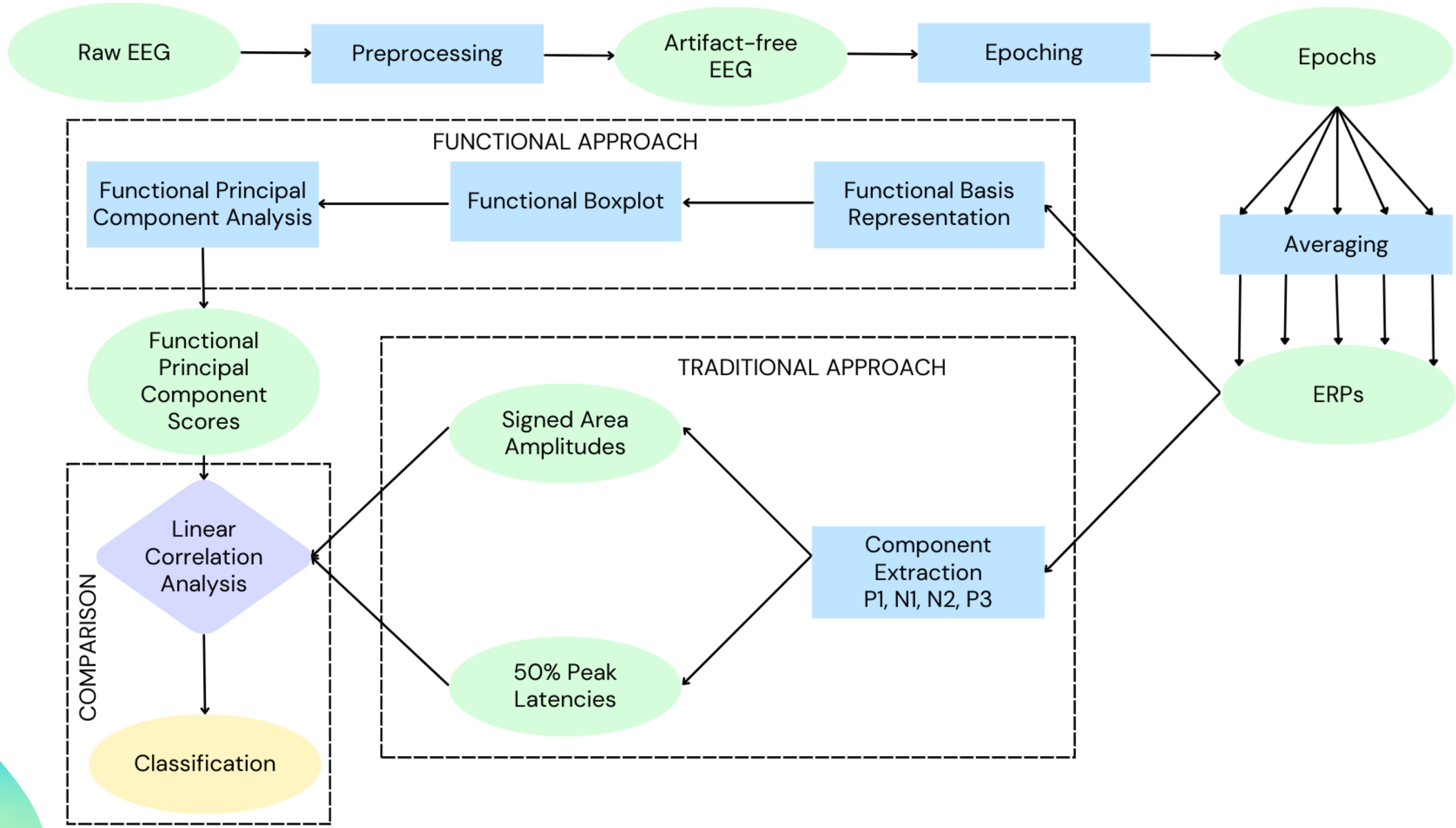
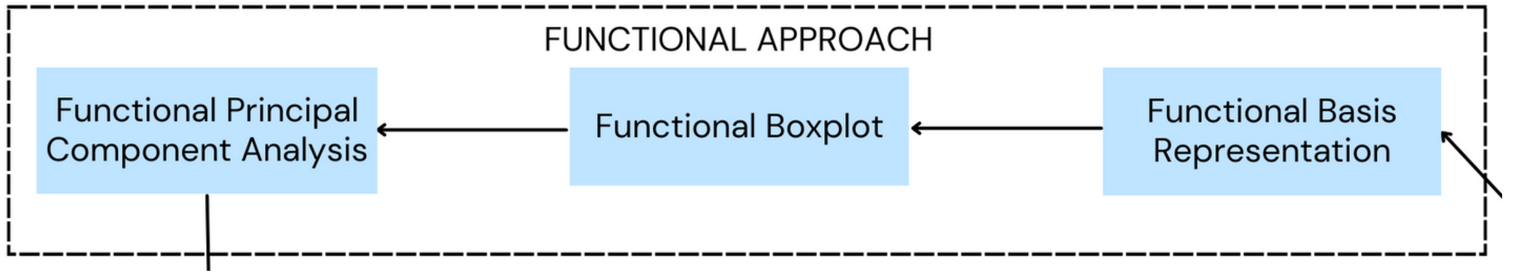
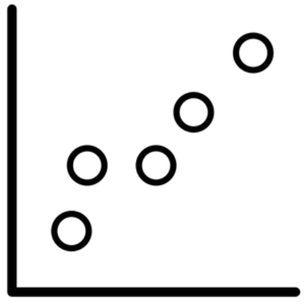


The *"Turn"*


FUNCTIONAL APPROACH
Functional Principal Component Analysis
Functional Boxplot
Functional Basis Representation

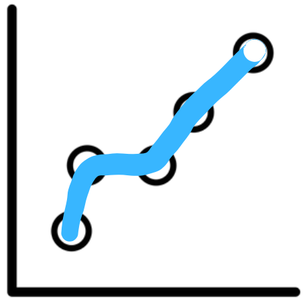
Functional Data Analysis

Functional Data Analysis grants us a family of statistical methods to analyze continuous curves rather than discrete measures



J. Ramsay, J. Ramsay, B. Silverman, S. S. Media, and H. Silverman, Functional Data Analysis, ser. Springer Series in Statistics. Springer, 2005.

Functional Data Analysis

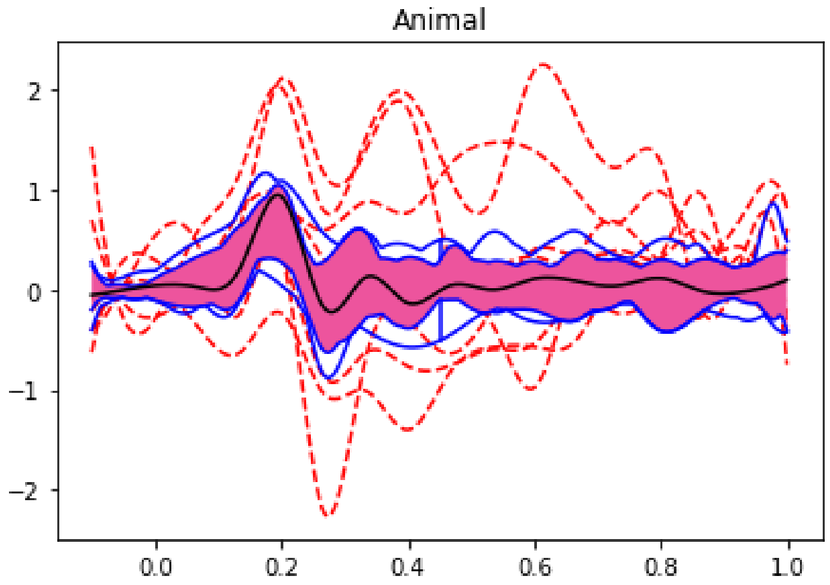


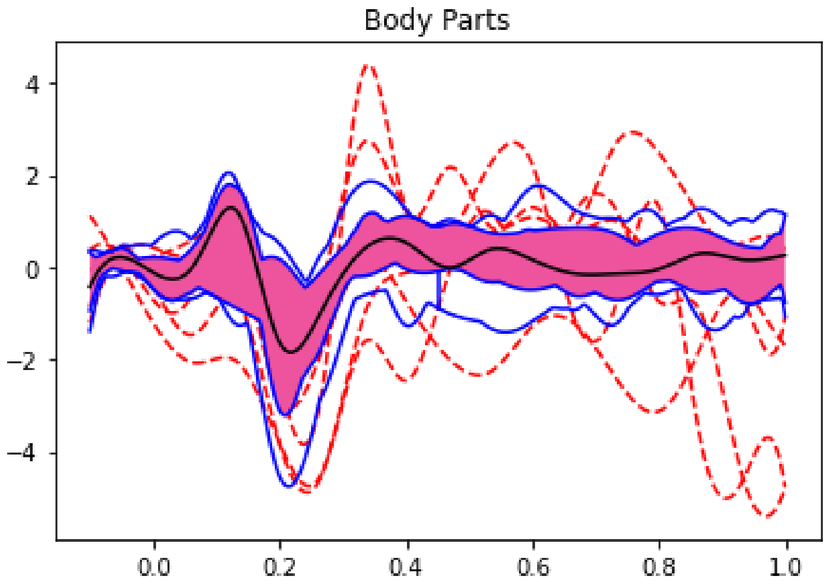
PROS:

- Evaluate ERP differences from a morphological level
- Extraction of functional features
- Take into account the shape of the component in its entirety

Functional Representation

We smooth the signals through a basis function representation to obtain functional objects and apply proper methods of FDA. We then implement Functional Boxplots to remove outliying ERPs

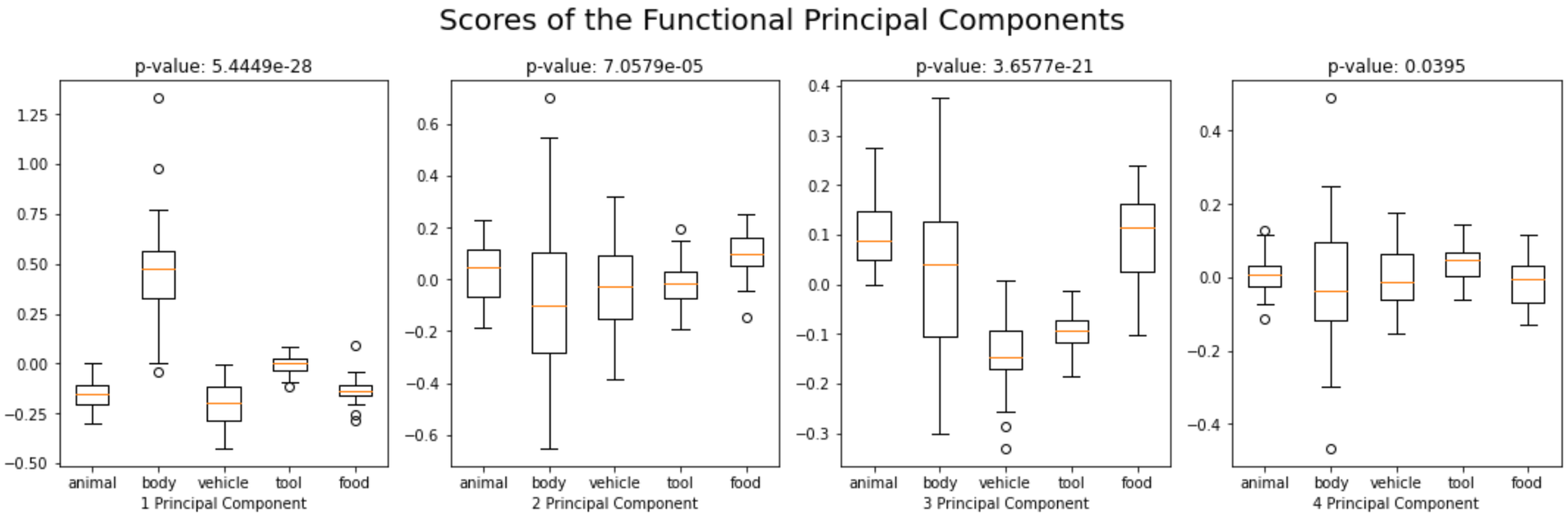




Functional Principal Component Analysis - FPCA

We extract 4 Principal Component Functions (PCF) that cumulatively explain 85% of the total variance of the data

The scores associated to each PCF vary significatively between the categories considered



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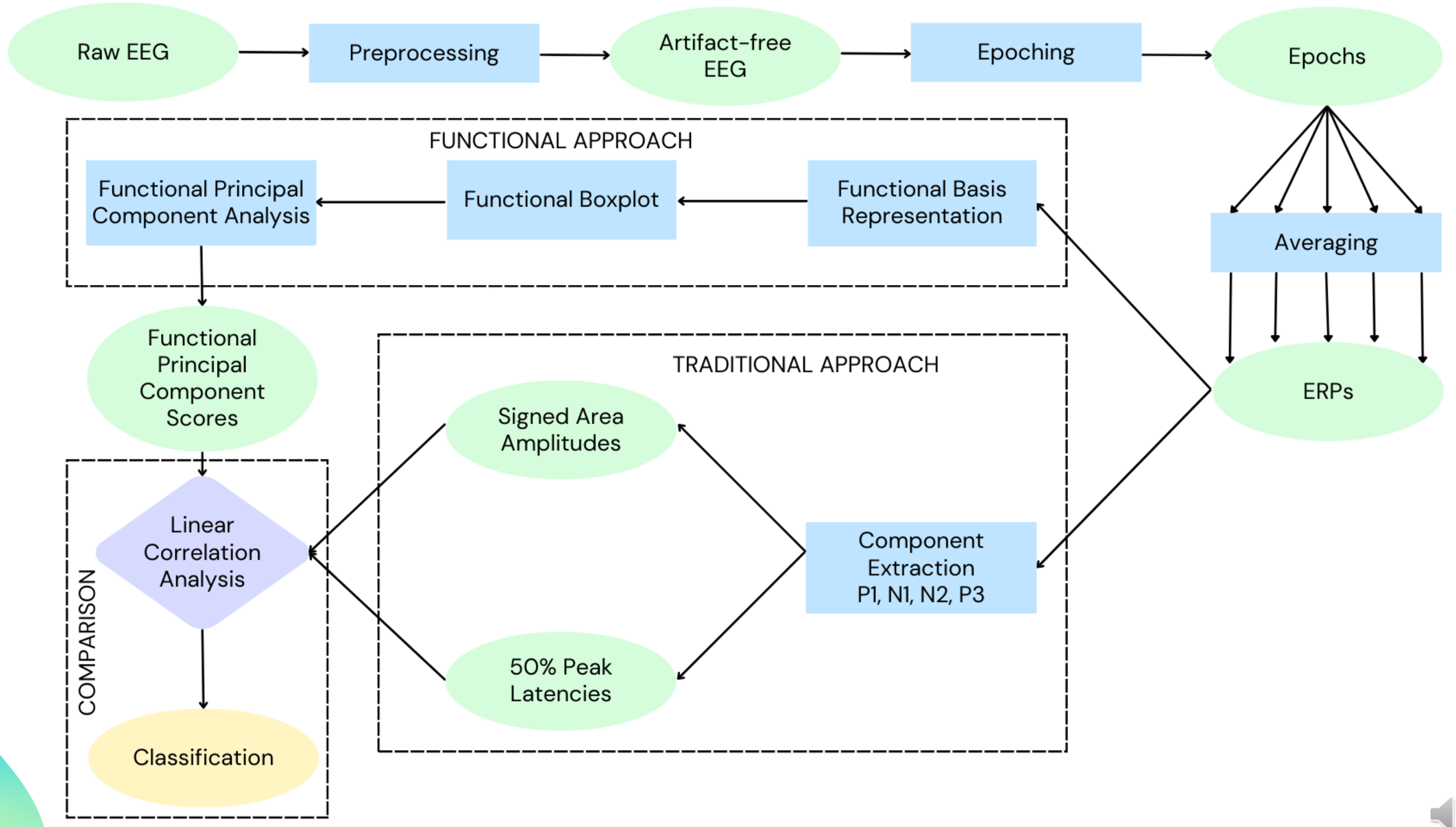

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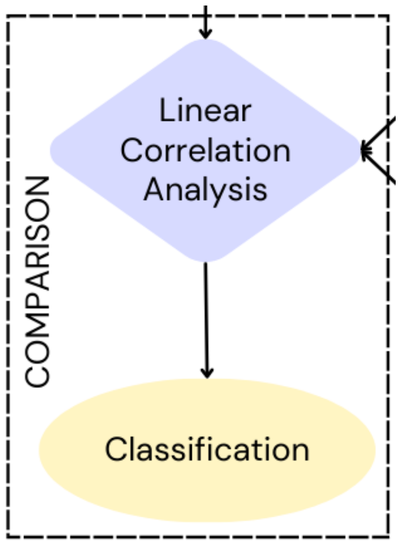

Comparison

To compare the approaches, we use two methods:

- **Linear Correlation Analysis** to investigate associations between discrete measures and PCFs' scores
- **Support Vector Machine** classifiers to study how differently functional and discrete features perform

HOCUS POCUS!

And now...

Let's bring everything back for the *"Prestige"*

Results: LCA

PCFs	Area P1	Latency P1	Area N1	Latency N1	Area N2	Latency N2	Area P3	Latency P3
1	**	*	***	***	***	*		
2	**			*		*	***	*
3	*	*	*			**		**
4	*		*				*	

* -> $\alpha < 0{,}05/32$
**-> $\alpha <$ e-10
**-> $\alpha <$ e-20

Results: Classification

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

Conclusions

- Principal Component Functions capture morphological aspects related to ERP categorization better than discrete measures
- Functional Data Analysis emerges as a valid approach to solve the image classification problem
- Everybody can be a mentalist, all they need is an EEG and a statistics book!

That's all folks!
Thank you for your attention

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To know more: https://github.com/jaclaz/FDA-on-visual-ERPs