Università degli Studi
di Cagliari, Italia

Department of Electrical
and Electronic Engineering

Pattern Recognition &
Application Lab

Electroencephalography signal processing based on textural features for monitoring the driver's state by a Brain-Computer Interface

Giulia Orrù, Marco Micheletto,
Fabio Terranova, Gian Luca Marcialis

Milan, 10 | 15 January 2021

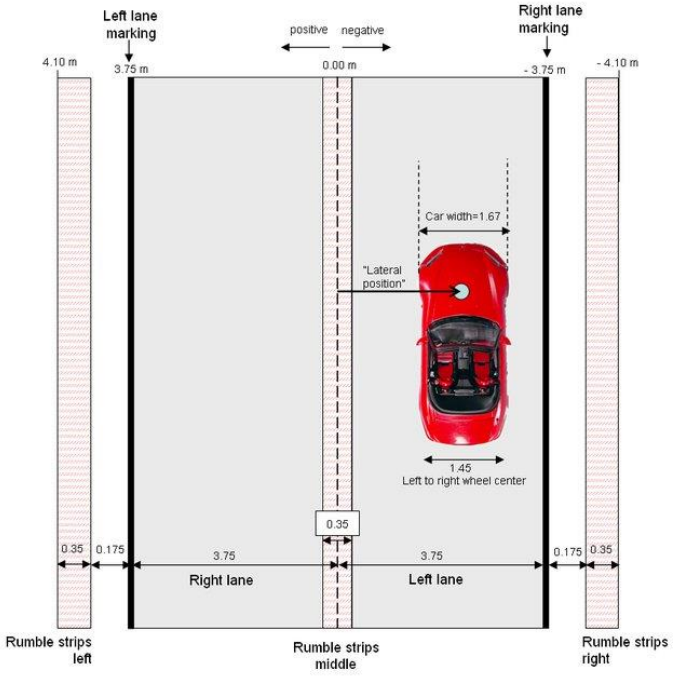
The importance of vigilance

- Vigilance plays an essential role in most human activities, especially in driving.

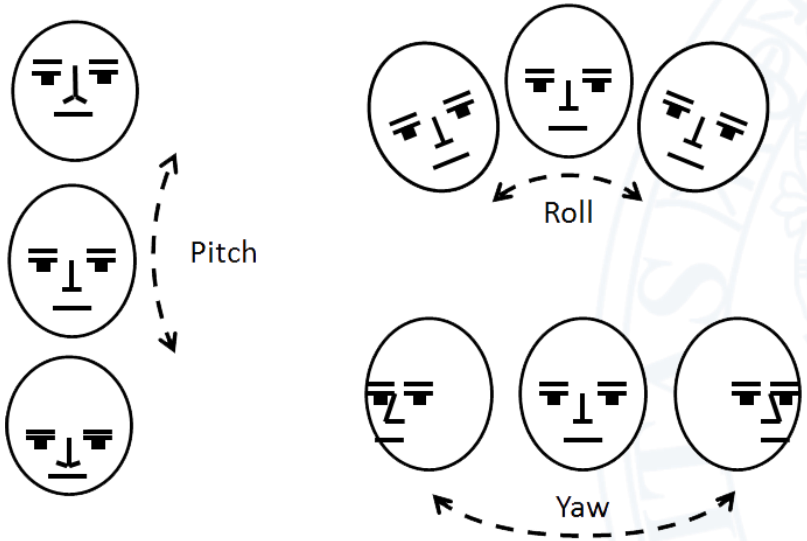
- A considerable percentage of road accidents has been caused by sleep and fatigue.

- Drowsiness detection could give a massive benefit in the prevention of both non-fatal and fatal crashes.

State of the art



Vehicle characteristics/ position

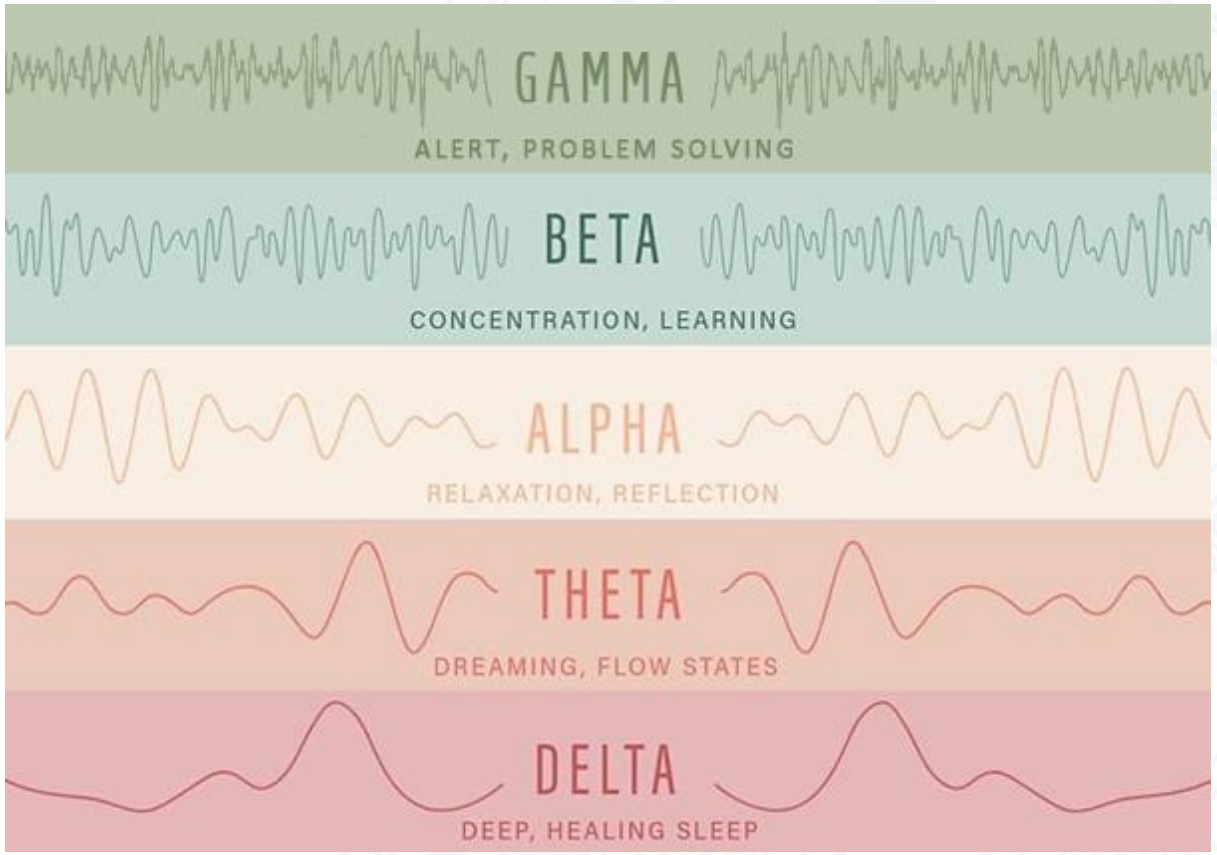


Driver eye/face monitoring

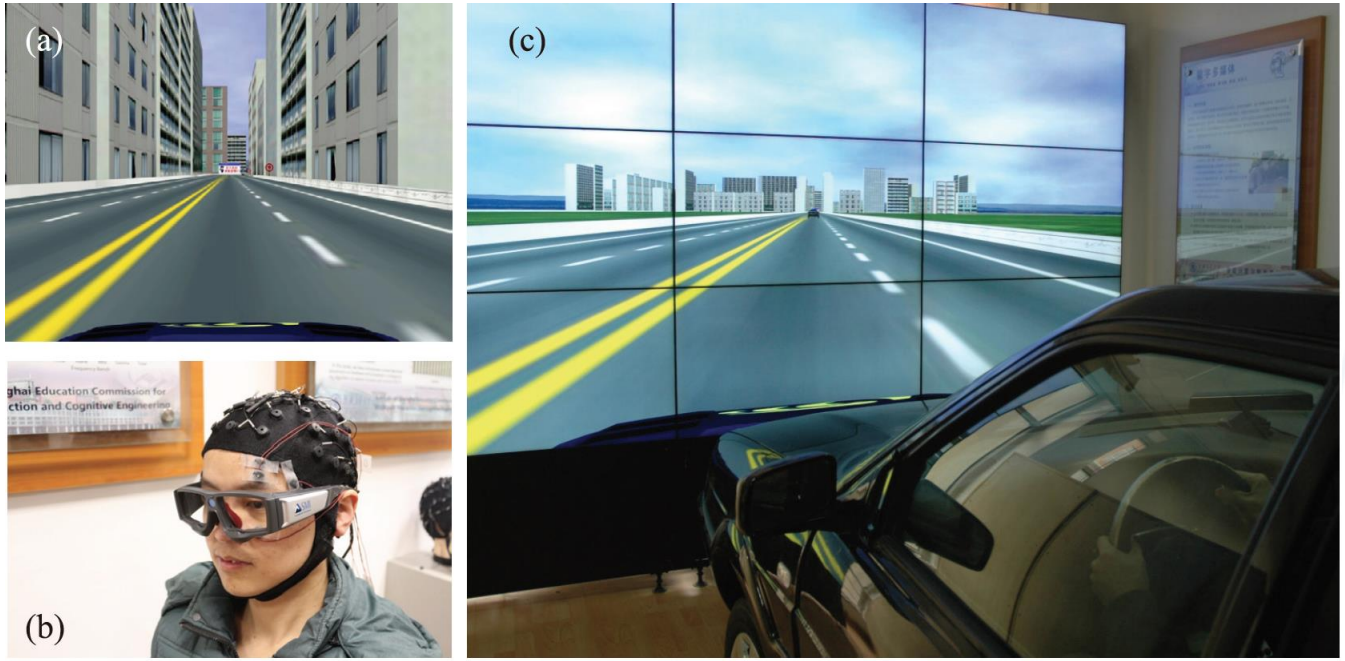
Physiological signals

Physiological signals: Electroencephalography (EEG)

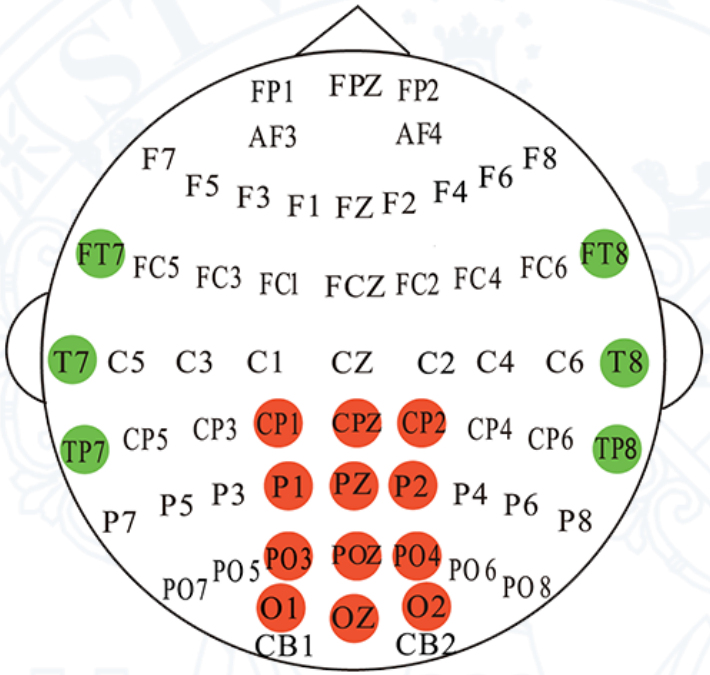
- Most promising drowsiness indicator.
- Many approaches based on analysis in frequency domain.
- Delta, theta, and alpha activity characterizes the EEG signal during driver fatigue



SEED-VIG data set



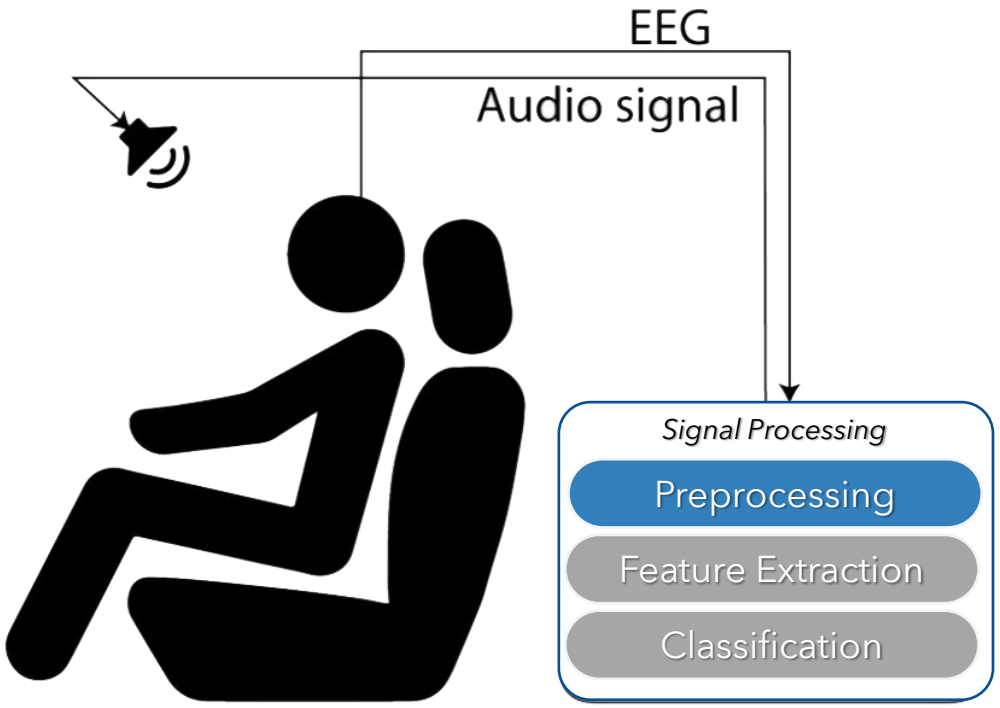
Experimental setup:
simulated driving scenario



Neuroscan system:
channels configuration

Wei-Long Zheng and **Bao-Liang Lu**, *A multimodal approach to estimating vigilance using EEG and forehead EOG*. Journal of Neural Engineering, 14(2): 026017, 2017.

Experimental protocol

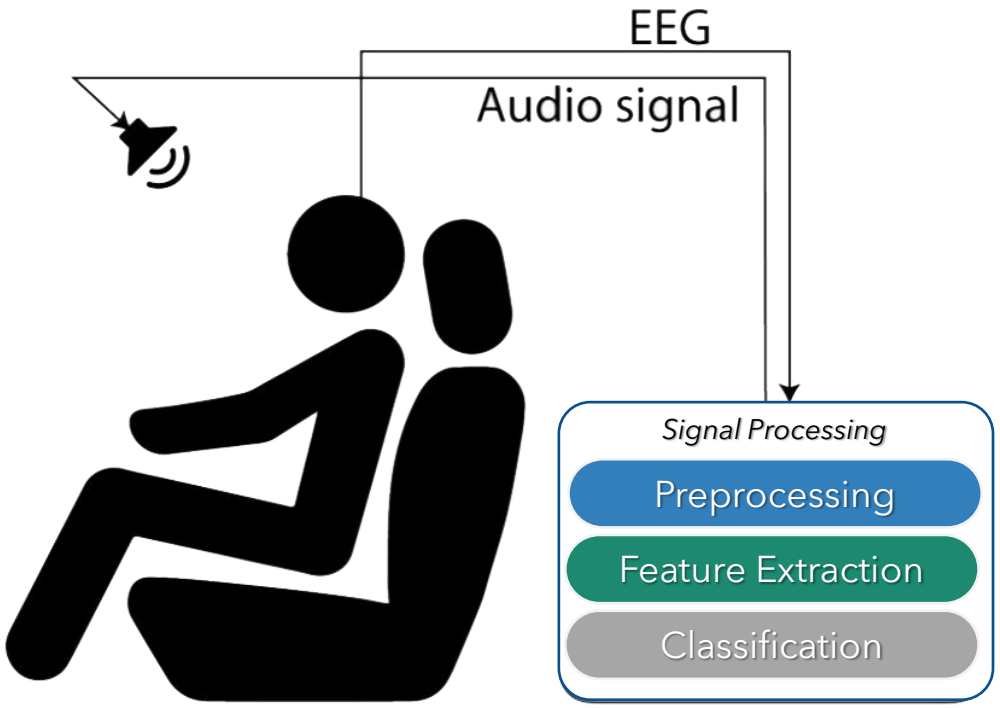


EEG-based **B**rain **C**omputer **I**nterface

Preprocessing

Butterworth bandpass filter

Experimental protocol



EEG-based **B**rain **C**omputer **I**nterface

Preprocessing

Butterworth bandpass filter

Feature Extraction

1D – Local Binary Pattern
(Proposed method)

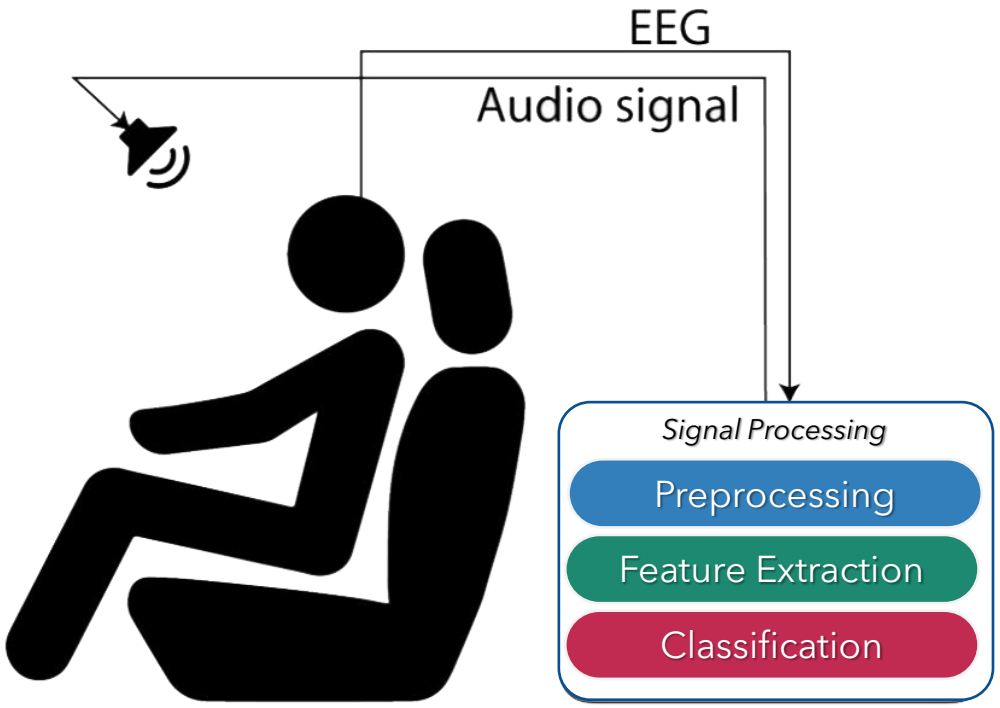
Feature Extraction: 1D-Local Binary Pattern

$$LBP^{1D}(x[i]) = \sum_{r=0}^{\frac{P}{2}-1} \{sgn\left(x\left[i+r-\frac{P}{2}\right]-x[i]\right)2^r + sgn(x[i+r+1]-x[i])\,2^{r+\frac{P}{2}}\} \quad (1)$$

$$sgn = \begin{cases} 0, & x < 0 \\ 1, & x \geq 0 \end{cases} \quad (2)$$

P represents the number of neighbouring samples thresholded against the centre one.

Experimental protocol



EEG-based **B**rain **C**omputer **I**nterface

Preprocessing

Butterworth bandpass filter

Feature Extraction

1D – Local Binary Pattern
(Proposed method)

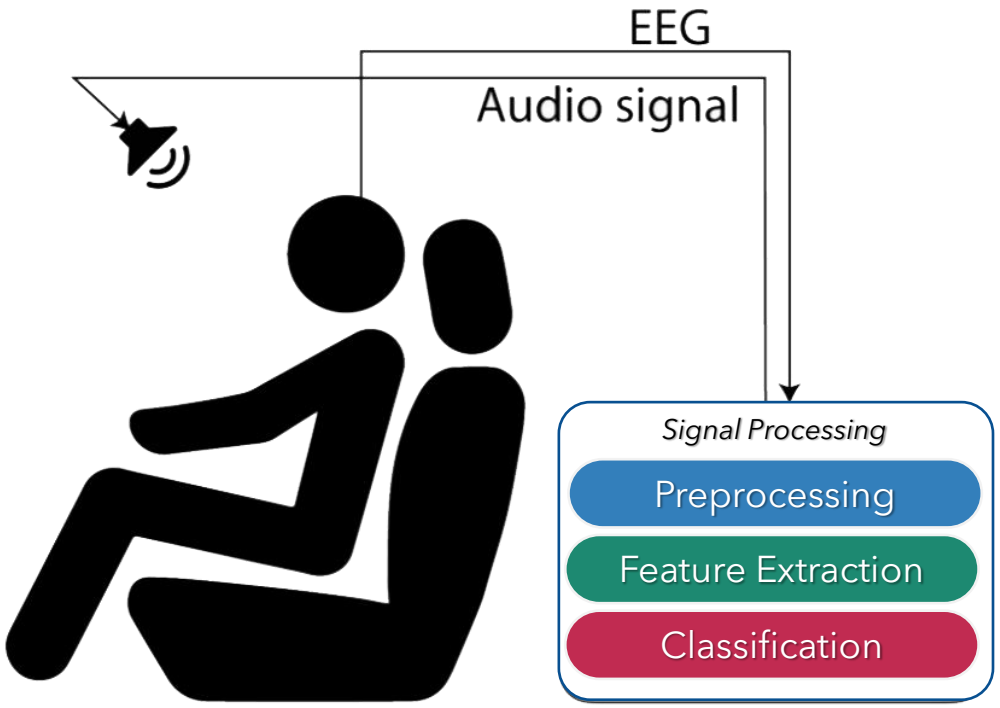
Classification

Support Vector Machine (SVM)

Linear | RBF kernel

Awake *Tired* *Drowsy*

Experimental protocol



EEG-based **B**rain **C**omputer **I**nterface

Preprocessing

Butterworth bandpass filter

Feature Extraction

1D – Local Binary Pattern
(Proposed method)

Differential Entropy
(Benchmark)

Classification

Support Vector Machine (SVM)

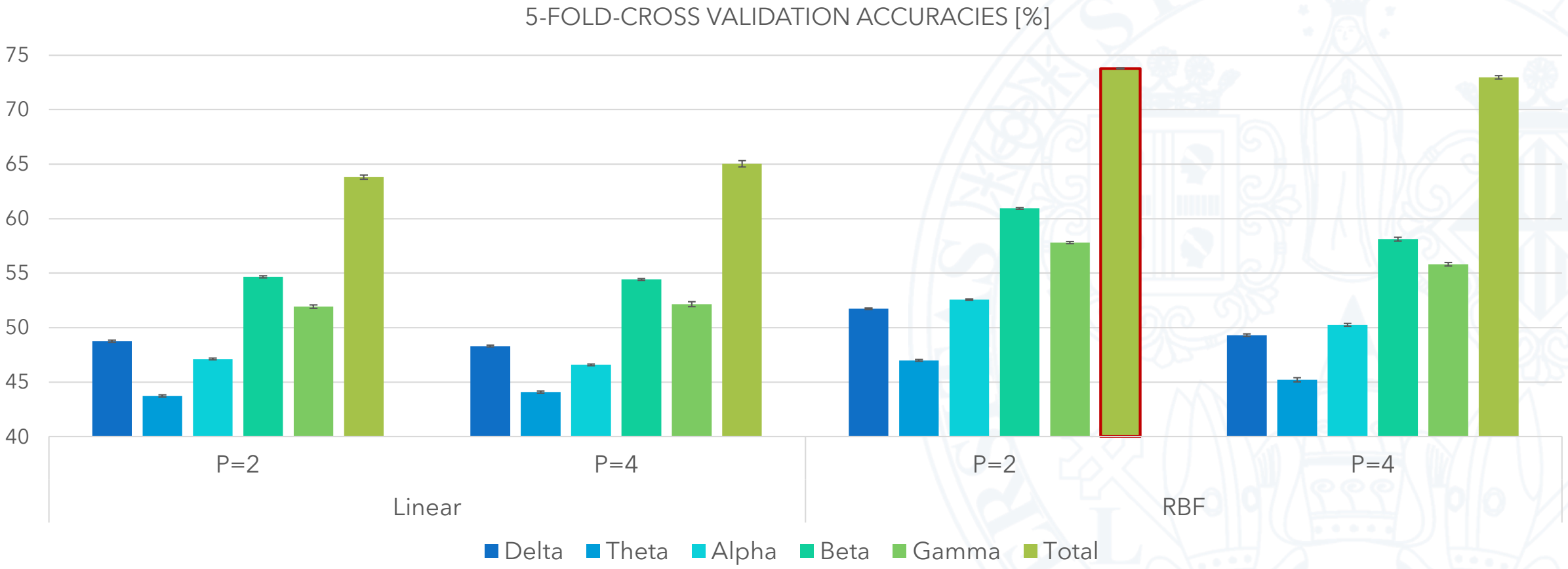
Linear

RBF kernel

Awake *Tired* *Drowsy*

Settings optimization: accuracy

best results highlighted



Generic user vs User-specific

Train dataset

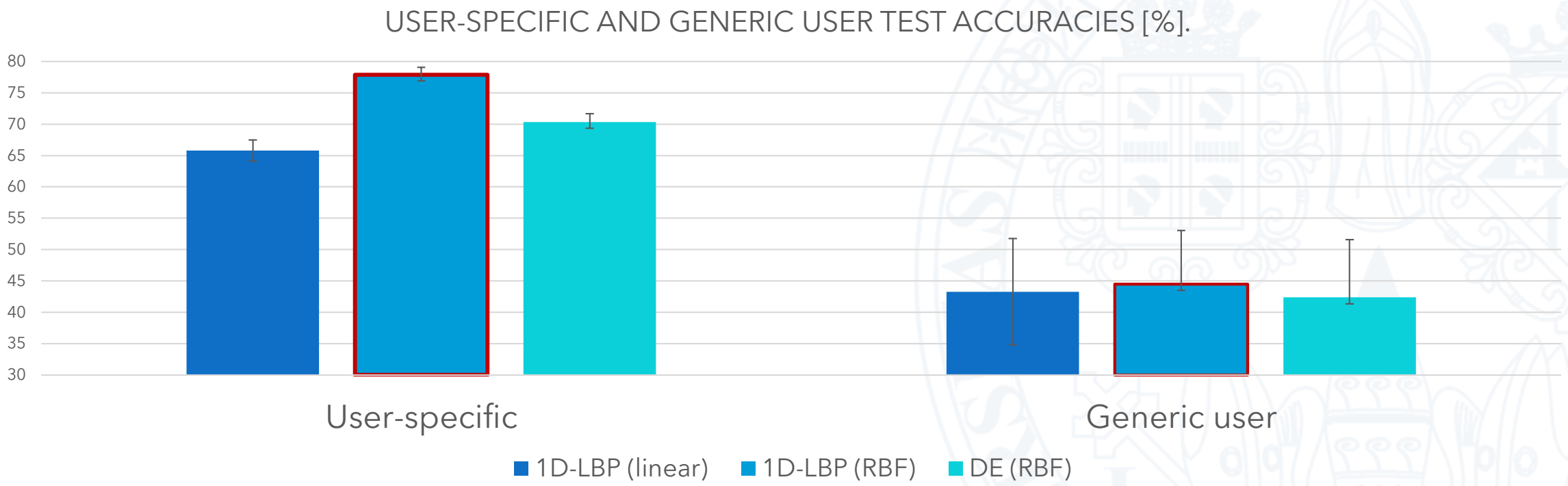
Test dataset

User-specific

Generic user

Settings optimization: accuracy

best results highlighted



New metrics for temporal response

Two distinct class transition considered:

$$Awake \rightarrow Tired\ (AT) \qquad Tired \rightarrow Drowsy\ (TD)$$

- $Hit\ rate = \frac{H_{AT}}{n_{AT}} + \frac{H_{TD}}{n_{TD}}$

  Ratio of successfully recognized class transitions (hits) to the total count of state changes.

- $0\text{ - }delay\ hit\ rate$

  Percentage of hits that happen on the first sample of the state change.

- $Mean\ hit\ delay = \frac{\sum_{i=0}^{n_{AT}} \Delta_i^{AT} + \sum_{i=0}^{n_{TD}} \Delta_i^{TD}}{n_{AT} + n_{TD}}$

  Mean of seconds of delay with which the response of the classifier correctly identifies a state change.

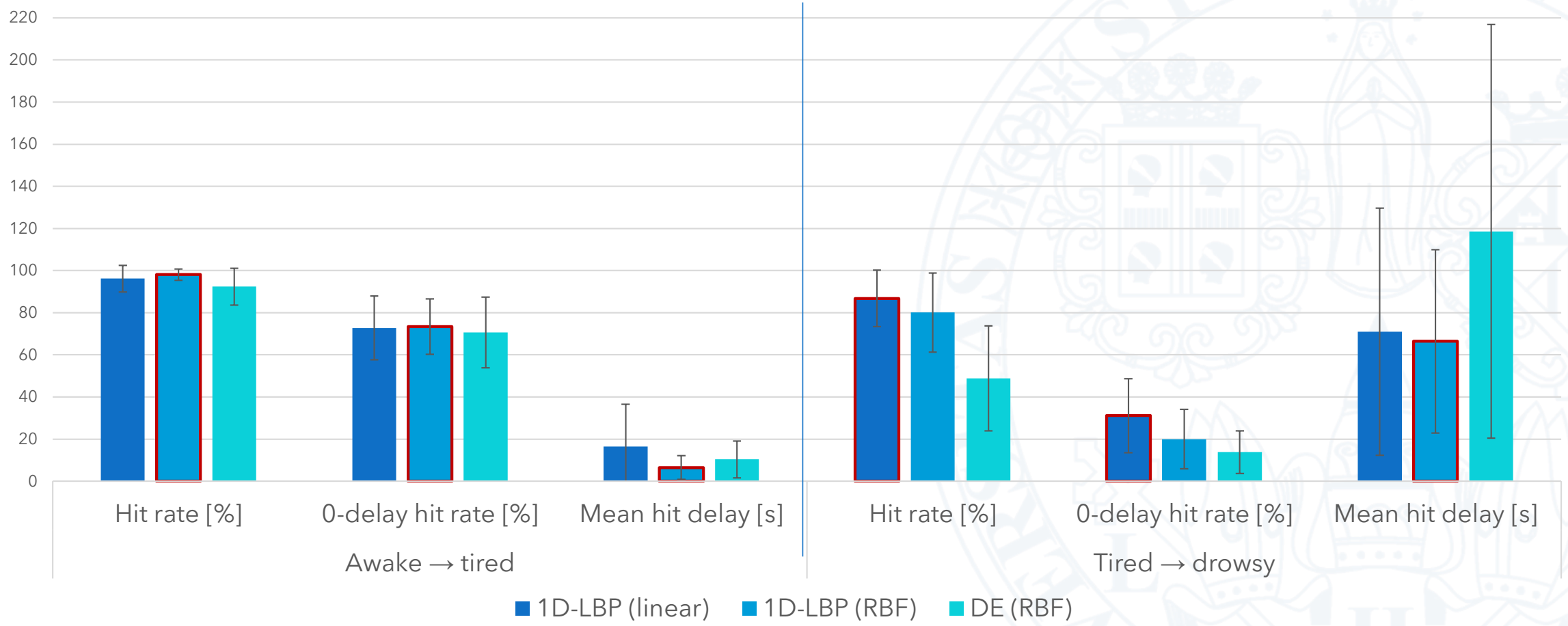
  $$\Delta^{xy} = t(hit)_{xy} - t(change)_{xy}$$

- $False\ hit\ rate = \frac{FN_{(awake)}}{FN_{(awake)} + TP_{(awake)}}$

  Rate of misclassified "awake" samples.

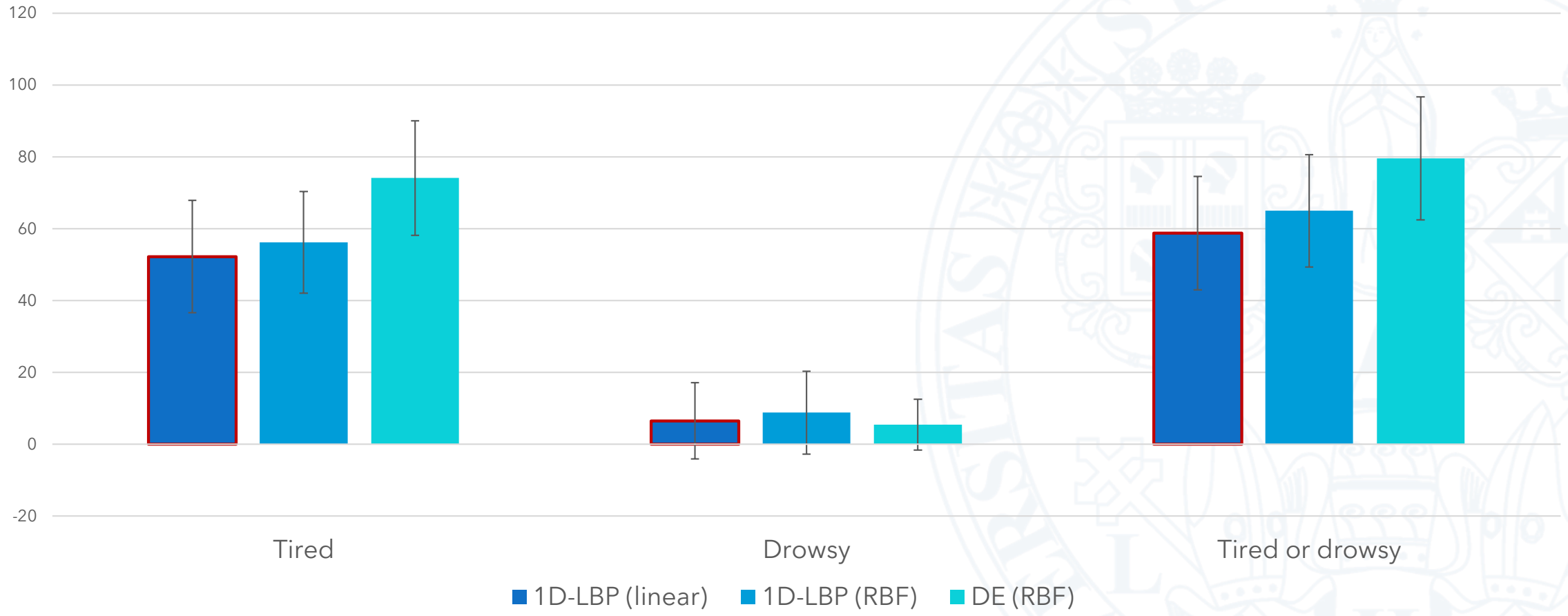
Results: hit rate, 0-delay hit rate and mean hit delay

best results highlighted



Results: False hit rate

best results highlighted



Conclusions

- 1D-LBP first application to driver's state monitoring.
- Introduction of novel performance parameters for the transition's detection and the related time delay.
- Strong effectiveness of the proposed method in detecting the awake-to-tired transitions (only 6 s of delay and the best hit rate).
- Overall performance is not yet good enough to develop a BCI for assessing the driver's vigilance in real environments.

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