Inteligencia Artificial y Biometría para una Educación Personalizada

2DO FORO DE INVESTIGACIÓN EDUCATIVA EN AGUASCALIENTES: Investigar para Mejorar

22 Mayo, 2025

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Background

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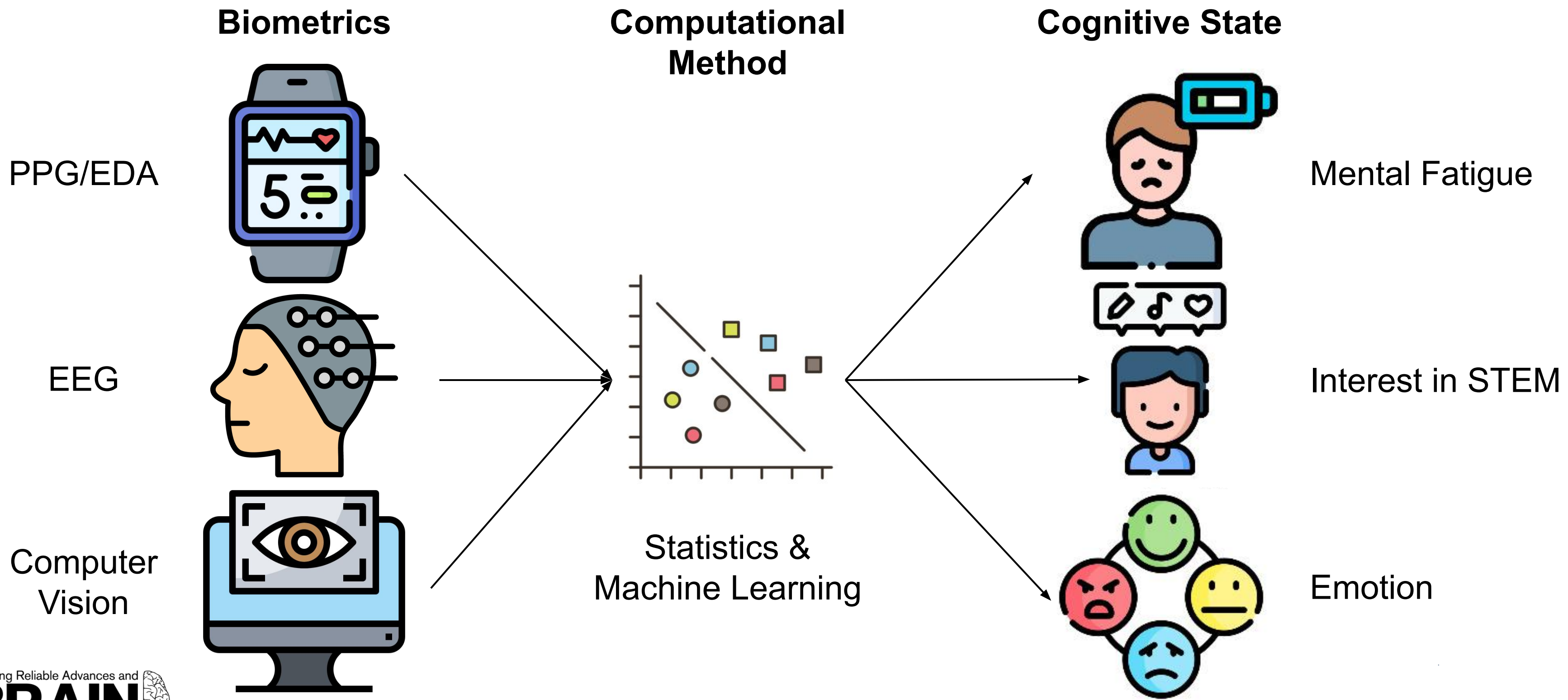
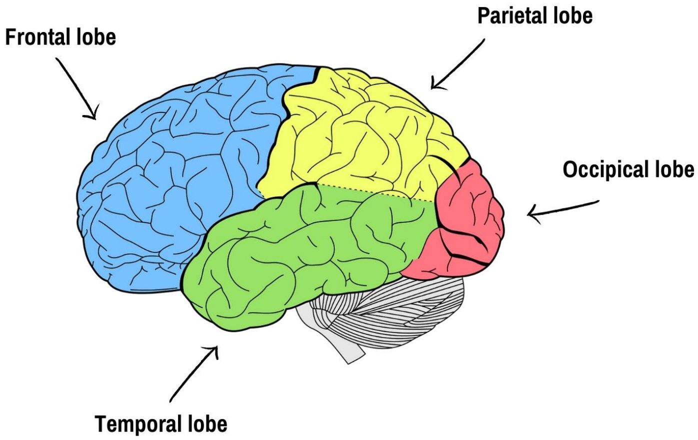
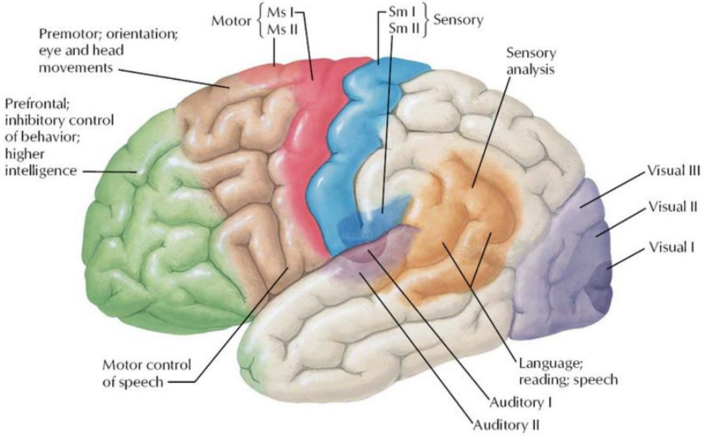
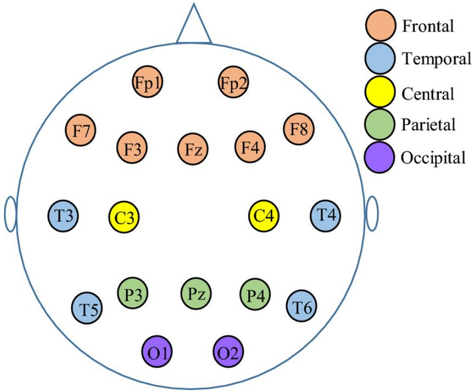


Building Reliable Advances and BRAIN Innovations in Neurotechnology







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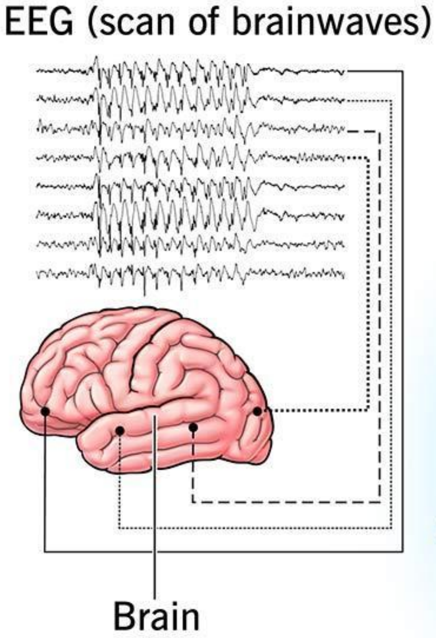

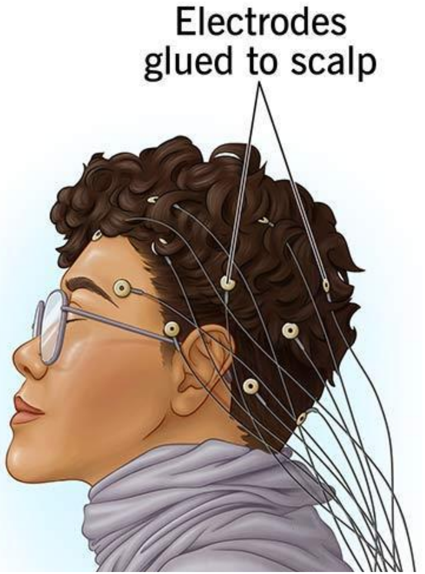

Building Reliable Advances and
BRAIN
Innovations in Neurotechnology

Biometric devices

EEG

Enophones (4)

ALAS

LiveAmp (8)

Talent Detection

OpenBCI (8)

NeuroH, ALAS

PPG/EDA

Empatica E4

ALAS, Talent Detection, Neurohumanities

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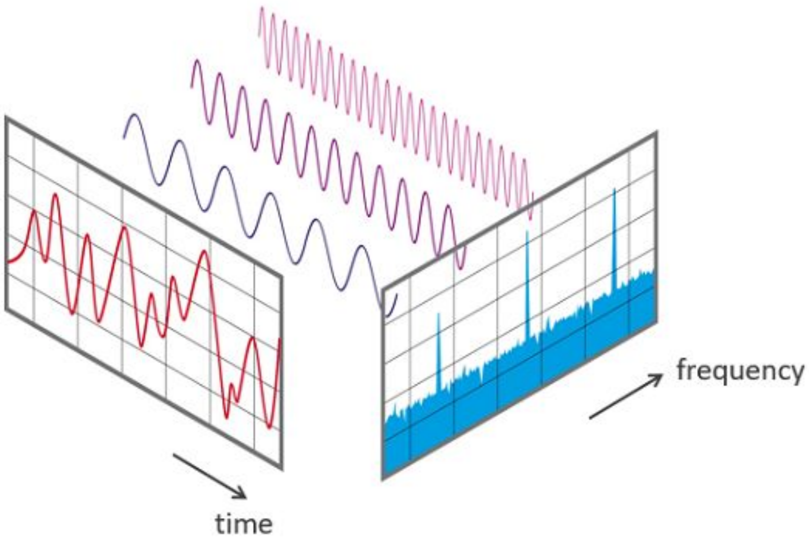
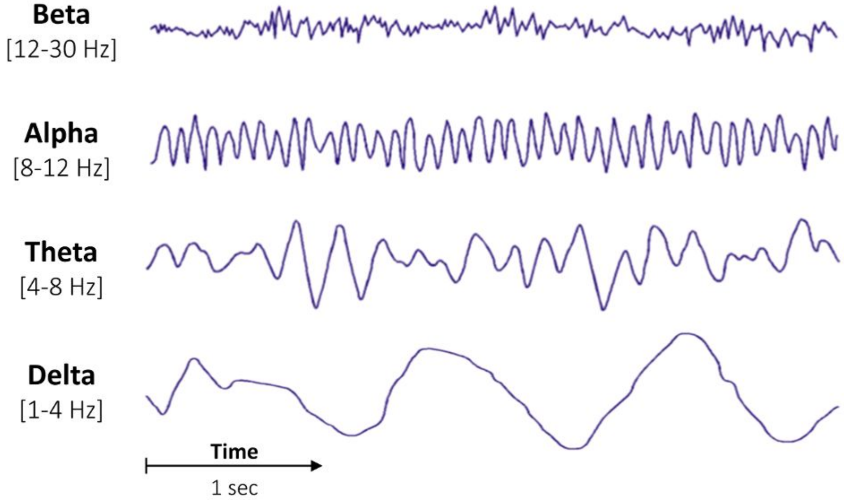
EEG frequency analysis (Fourier)





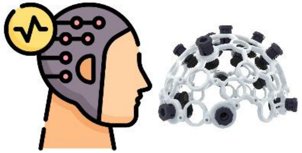
Active thinking

Attention

Sleeping

Deep Sleep

Projects Overview

Project	Device	Prediction	Interface	Publisher
Advanced Learner Assistance System	 4-channel Enophone	 Mental fatigue		IEEE MDPI
Talent Detection	 8-channel LiveAmp	 Interest in STEM		IEEE ELSEVIER
Neurohumanities Lab	 8-channel OpenBCI	 Emotion		frontiers

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Advanced Learner Assistance System (ALAS)

Recent Results

Advanced Learner Assistance System's (ALAS) Recent Results

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***Abstract*—This work presents a real-time biofeedback tool that employs wearables and the Internet of Things with educational applications to improve students' learning and retention. We aimed to create a web platform using the Internet of Things (IoT) and Machine Learning (ML) architecture to predict students' performance, analyze mental fatigue, and provide real-time quantitative biofeedback to identify the best learning modality. Thus, the main goal was to develop a system that allows students to learn and improve their projects. We integrated the analysis of real-time biometric signals, machine learning algorithms, and web services as we observed their behavior under different learning modalities, seeking to improve cognitive performance. For this, 23 volunteers filled out the ten-question Fatigue Assessment Scale questionnaire about mental fatigue, validated with the P300 waves acquired during auditory-oddball (AO) tests. Synchronized data acquisition was achieved using Enophones and an E4 wristband. To develop predictive models, we collected the biometric data and incorporated it into an ML algorithm to visualize students' performance in real time. The system can accommodate other wearable systems with new features in further experiments. Thus, we believe this current**

Currently, educational institutions are transforming to adapt to actual social demands through innovative technologies so that learning processes are more efficient and attractive for students, teachers, and society [6].

Obtaining biometric data from students provides the opportunity to address learning-related problems, through stress and anxiety monitoring, optimizing the educational environment and allowing data-based decision making [6].

Much research has been conducted using single biometric devices to gather relevant cognitive information and validate its effectiveness in predicting stress, mental fatigue, and attention to a given task [7]. Their features might be used in an interactive IoT environment to support constant monitoring, and improve students' learning experience.

Research on biometric wearables show their reliability: For example, the Empatica E4 wristband detects convulsive seizures [3]. Regarding cognition, electroencephalography

Motivation

- **Challenge:** There is a lack of reliable, generalizable, and fast mental fatigue assessment tools.
- **Solution:** ML + Biometrics (EEG, PPG/EDA) to predict mental fatigue through a fast test (4-minute AO for P300 wave)

Data collection

- 23 undergraduate students (19.8 +- 2 years; M = 14, F = 10)
- 10-question self-assessment questionnaire: Fatigue Assessment Scale (FAS)
  - No fatigue (1-21), substantial fatigue (22-35), and extreme fatigue (36-50)
- 4-min auditory-oddball (AO) for **P300 wave**
- Combined EEG + PPG/EDA features

Encoded name	Combined function
F_i–I	$\frac{1}{F_i}$
F_i–L	$\ln\|F_i + 1\|$
F_i–M–F_j	$F_i \cdot F_j$
F_i–D–F_j	$\frac{F_i}{F_j+\varepsilon}$

Fatigue Assessment Scale (FAS)

The following ten statements refer to how you usually feel. Per statement you can choose one out of five answer categories, varying from Never to Always.
Please circle the answer to each question that is applicable to you. Please give an answer to each question, even if you do not have any complaints at the moment.
1 = Never, 2 = Sometimes (about monthly or less); 3 = Regularly (about a few times a month); 4 = Often (about weekly) and 5 = Always (about every day).

	Never	Sometimes	Regularly	Often	Always
1. I am bothered by fatigue	1	2	3	4	5
2. I get tired very quickly	1	2	3	4	5
3. I don't do much during the day	1	2	3	4	5
4. I have enough energy for everyday life	1	2	3	4	5
5. Physically, I feel exhausted	1	2	3	4	5
6. I have problems to start things	1	2	3	4	5
7. I have problems to think clearly	1	2	3	4	5
8. I feel no desire to do anything	1	2	3	4	5
9. Mentally, I feel exhausted	1	2	3	4	5
10. When I am doing something, I can concentrate quite well	1	2	3	4	5

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Model performance and feature importance

FAS Classes	Precision	Recall	F1-Score	Accuracy	R^2
EEG Features ($n = 11$)					
2	0.92	0.91	0.91	0.91	0.56
3	0.55	0.64	0.55	0.64	
EEG & ECG Features ($n = 10$)					
2	0.87	0.80	0.80	0.80	0.48
3	0.67	0.60	0.57	0.60	

Device	Feature	Feature Importance
EEG	Alpha_A2-D-Alpha_A1	0.319703
	Alpha_A2-D-Alpha_C4	0.153771
	Gamma_A1	0.113352
	Gamma_A1-I	0.056444
	Theta_A1-D-Theta_C3	0.044882
	Alpha_A1-D-Alpha_A2	0.039322
	Gamma_A1-L	0.030554
	Theta_A2-D-Theta_C3	0.017749
	Gamma_A1-D-Gamma_A2	0.016955
	Beta_A2-D-Beta_A1	0.013921
EEG & Empatica	Alpha_C3-D-EDA_Kurtosis	0.081134
	Beta_A1-D-Beta_A2	0.053186
	Beta_A2-D-Beta_A1	0.042182
	EDA_Minimum-M-Gamma_A1	0.034817
	Delta_A1-D-BVP_Mean	0.034447
	Alpha_A1-D-Delta_C4	0.034355
	Gamma_A1-M-EDA_Median	0.033587
	Alpha_A1-D-Alpha_A2	0.029386
	Delta_A1-M-BVP_CoefficientVariation	0.028752
	Gamma_A2-D-Temp_Mean	0.021396

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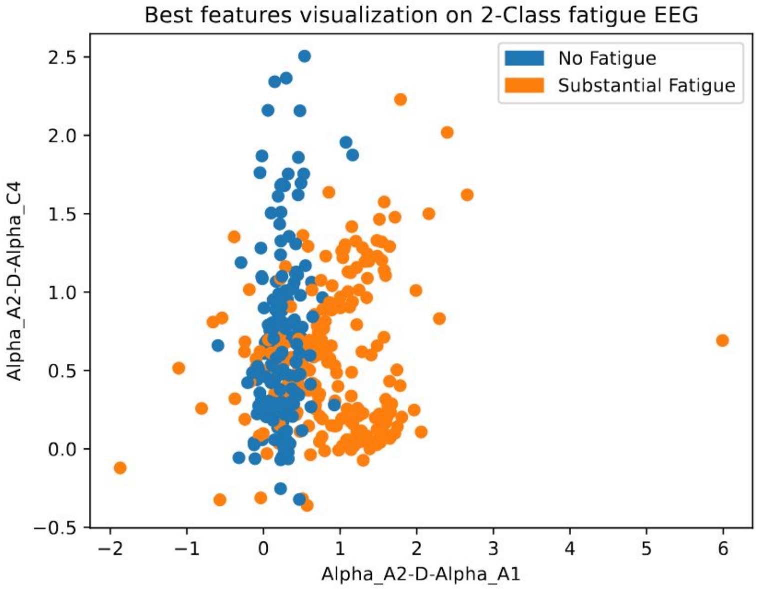
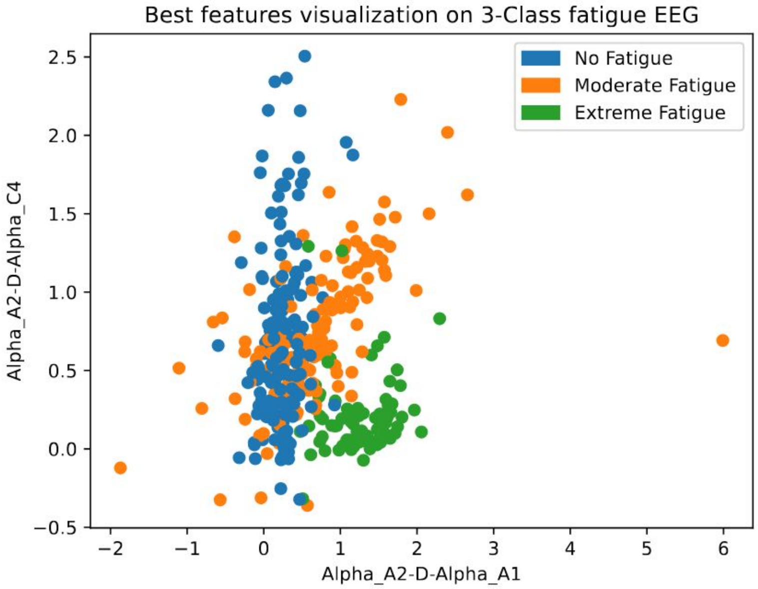
Results



(a) Best two features, using 2-Class level of FAS score.



(b) Best two features, using 3-Class level of FAS score.

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Evaluation of a Fast Test Based on Biometric Signals

to Assess Mental Fatigue at the Workplace–A Pilot Study


International Journal of *Environmental Research and Public Health*

MDPI

Article

Evaluation of a Fast Test Based on Biometric Signals to Assess Mental Fatigue at the Workplace—A Pilot Study

Mauricio A. Ramírez-Moreno [1], Patricio Carrillo-Tijerina [1], Milton Osiel Candela-Leal [1], Myriam Alanis-Espinosa [1], Juan Carlos Tudón-Martínez [2], Armando Roman-Flores [1], Ricardo A. Ramírez-Mendoza [1] and Jorge de J. Lozoya-Santos [1,*]

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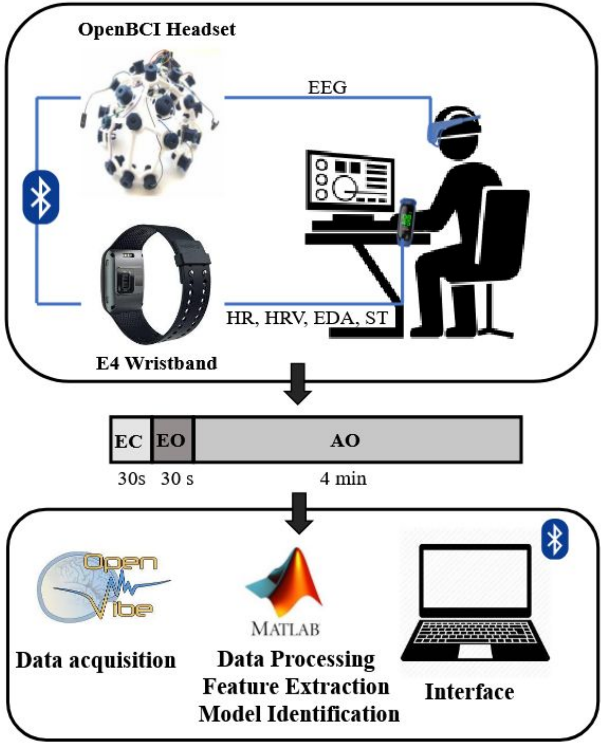
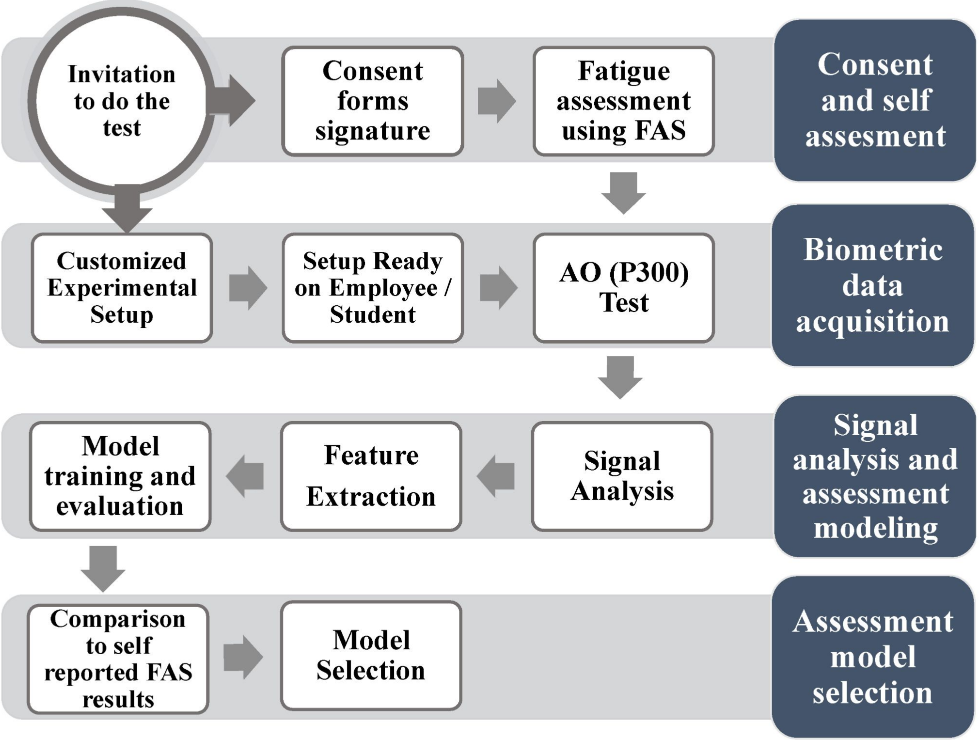
Abstract: Non-pathological mental fatigue is a recurring, but undesirable condition among people in the fields of office work, industry, and education. This type of mental fatigue can often lead to negative outcomes, such as performance reduction and cognitive impairment in education; loss of focus and burnout syndrome in office work; and accidents leading to injuries or death in the transportation and manufacturing industries. Reliable mental fatigue assessment tools are promising in the improvement of performance, mental health and safety of students and workers, and at the same time, in the reduction of risks, accidents and the associated economic loss (e.g., medical fees and equipment reparations). The analysis of biometric (brain, cardiac, skin conductance) signals has proven to be effective in discerning different stages of mental fatigue; however, many of the reported studies in the literature involve the use of long fatigue-inducing tests and subject-specific models in their methodologies. Recent trends in the modeling of mental fatigue suggest the usage of non subject-specific (general) classifiers and a time reduction of calibration procedures and experimental setups. In this study, the evaluation of a fast and short-calibration mental fatigue assessment tool based on biometric signals and inter-subject modeling, using multiple linear regression, is presented. The proposed tool does not require fatigue-inducing tests, which allows fast setup and implementation. Electroencephalography, photopletismography, electrodermal activity, and skin temperature from 17 subjects were recorded, using an OpenBCI helmet and an Empatica E4 wristband. Correlations to self-reported mental fatigue levels (using the fatigue assessment scale) were calculated to find the best mental fatigue predictors. Three-class mental fatigue models were evaluated, and the best

MDPI

Data collection





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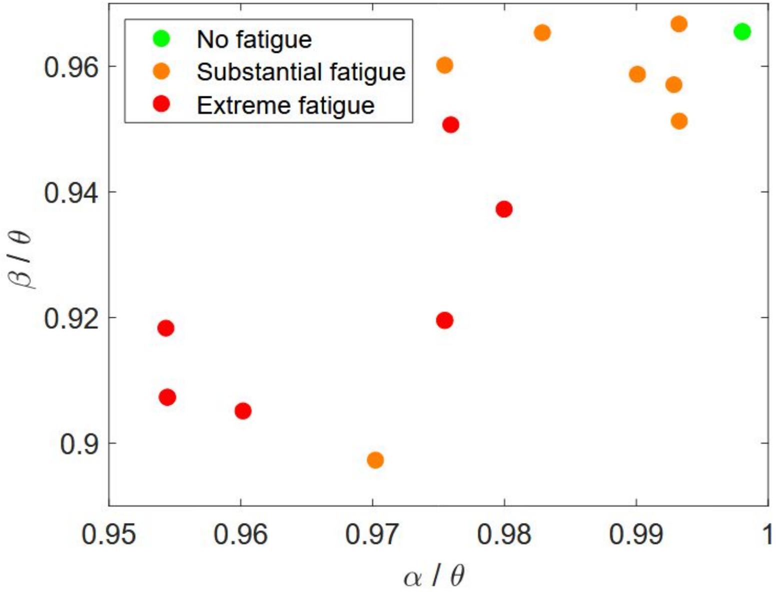
Results



Feature	p-Value	r	Feature	p-Value	r
β/θ (C3)	0.0003	−0.8252	δ/β (O1)	0.0145	0.6357
θ/β (C3)	0.0003	0.8242	α/δ (O1)	0.0148	−0.6343
α/θ (O2)	0.0011	−0.7777	γ/θ (C3)	0.0157	−0.6299
θ/α (O2)	0.0011	0.7760	β/δ (O2)	0.0160	−0.6287
θ/α (C3)	0.0059	0.6941	δ/α (O1)	0.0166	0.6262
α/θ (C3)	0.0060	−0.6927	θ/γ (O2)	0.0172	0.6235
γ/δ (O1)	0.0064	−0.6894	δ/γ (O2)	0.0172	0.6235
δ/γ (O1)	0.0071	0.6829	γ/δ (FP1)	0.0177	−0.6213
γ/β (O1)	0.0084	−0.6727	δ/β (O2)	0.0182	0.6193
β/γ (O1)	0.0086	0.67091	β/δ (C3)	0.0204	−0.6106
β/θ (O2)	0.0011	−0.6545	θ/γ (C3)	0.0205	0.6101
θ/β (O2)	0.0128	0.6445	δ/γ (FP1)	0.0211	0.6080
β/δ (O1)	0.0139	−0.6389	β/γ (P8)	0.0268	0.5886
γ/δ (O2)	0.0140	−0.6386	Latency (C3)	0.0268	0.5884
γ/θ (O2)	0.0145	−0.6358	δ/β (C3)	0.0285	0.5833

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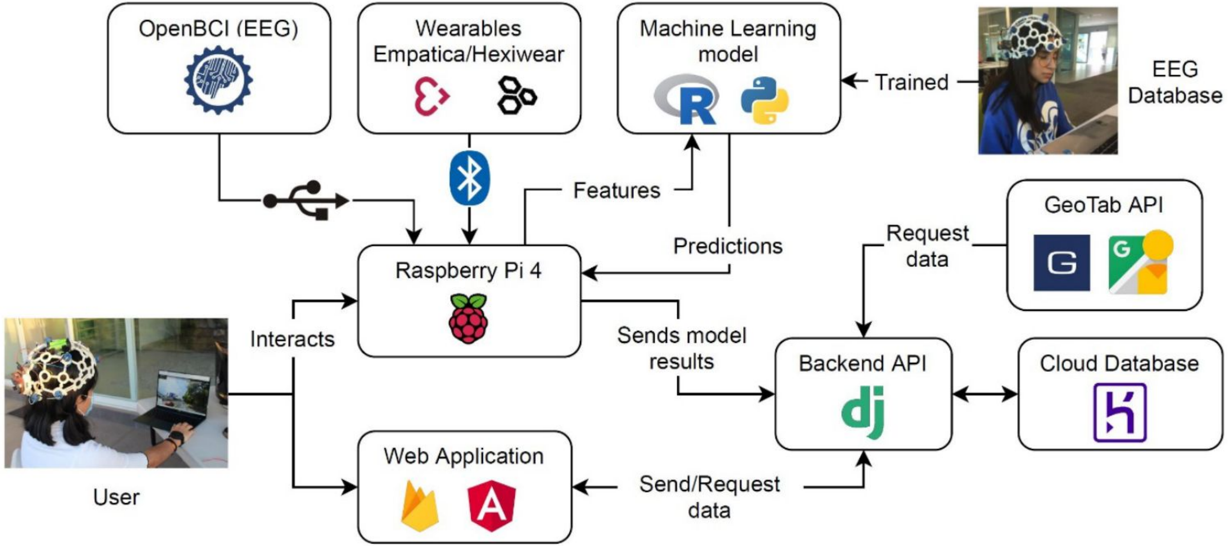
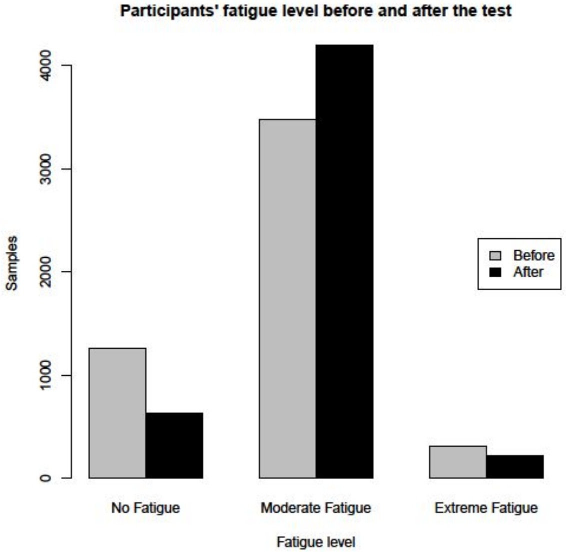
Further validation

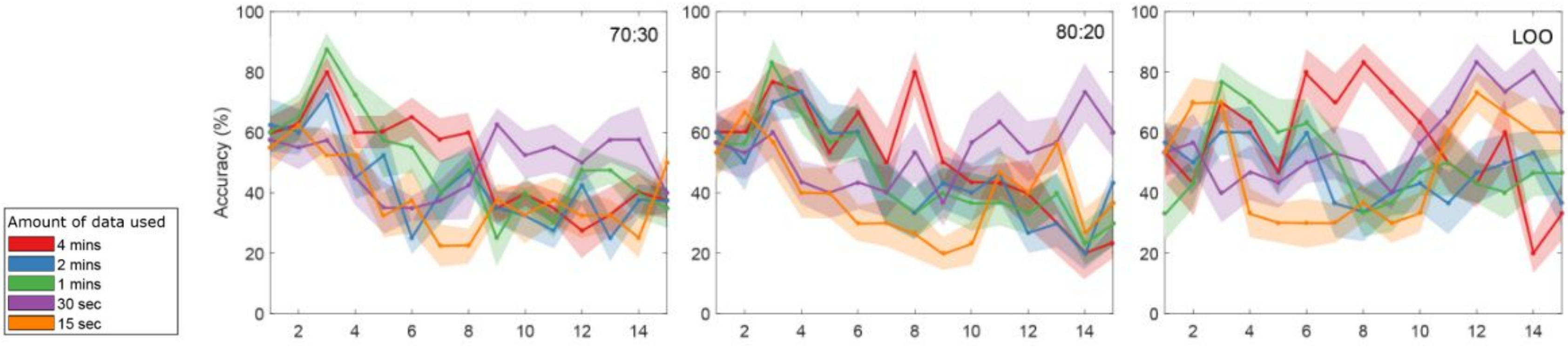




Candela-Leal et al. (2021) 6th *International Conference on Industrial Engineering and Operations Management*

Conclusion

- Despite subject-specific differences in mental fatigue, a reliable ML model is feasible
  - Normalization and feature engineering improved prediction
    - Further tested using cross-validation and biometric-based insights
- **Fast real-time fatigue assessment models are essential for optimal performance**



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Detecting Change in Engineering Interest in Children

Through Machine Learning using Biometric Signals

Detecting Change in Engineering Interest in Children through Machine Learning using Biometric Signals

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Abstract—**Promoting interest in Science, Technology, Engineering, and Mathematics (STEM) is a worldwide priority. Thus, accurate measures of professional interest, an aspect of**

between professional interest and personality [4]. Moreover, in the past three decades, physiological data has successfully estimated psychological variables, including personality

IEEE

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Motivation

- **Challenge:** Psychometric tests are prone to human bias and do not offer real-time insights.
- **Solution:** ML + Biometrics (EEG, PPG/EDA, CV) to predict STEM interest while taking courses.

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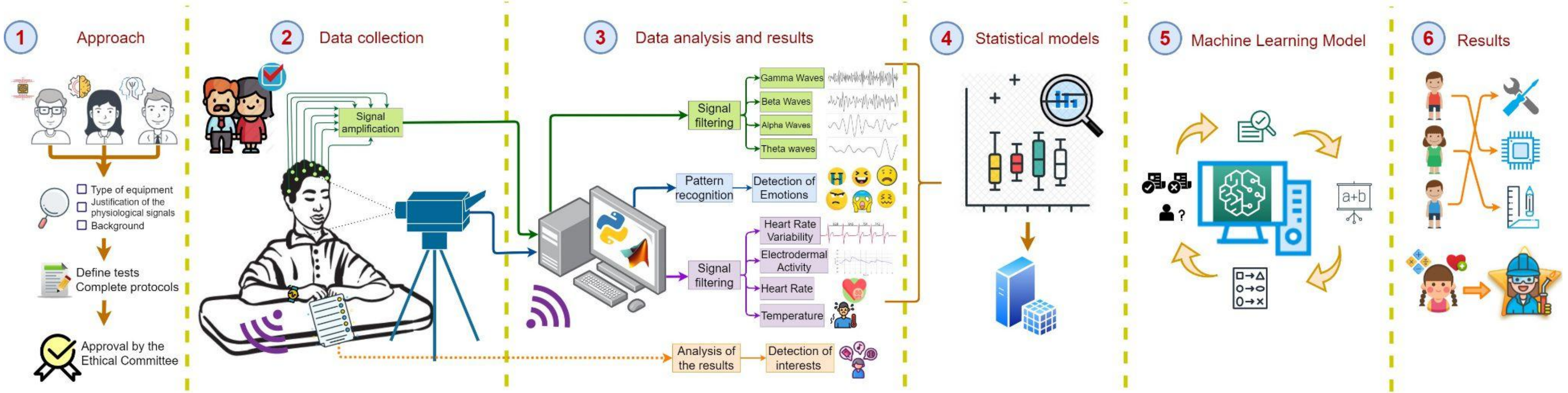
Methodology



Res Sci Educ
DOI 10.1007/s11165-013-9389-3

The Development of the STEM Career Interest Survey (STEM-CIS)

Meredith W. Kier · Margaret R. Blanchard ·
Jason W. Osborne · Jennifer L. Albert

Building Reliable Advances and BRAIN Innovations in Neurotechnology

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Data collection

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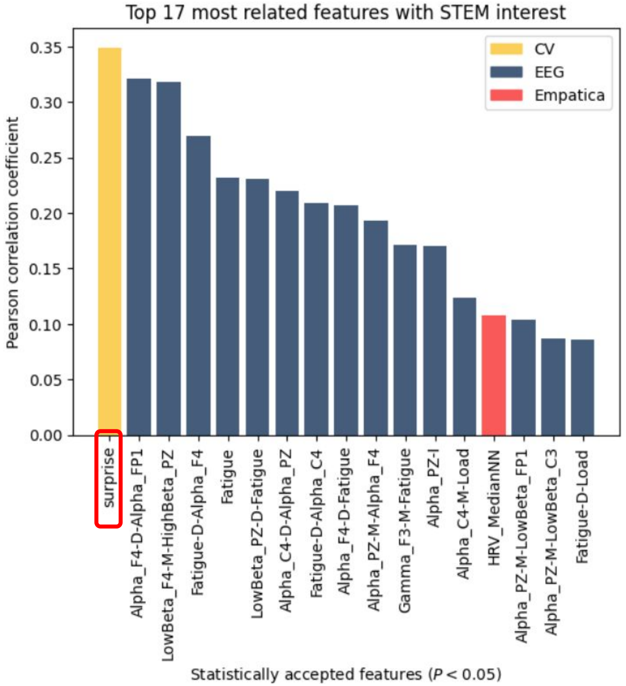
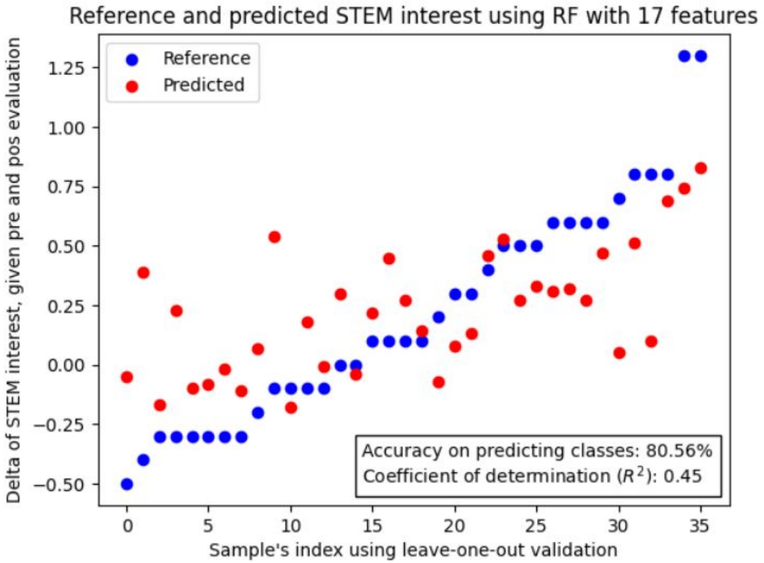
ML analysis





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Neural Signatures of STEM Learning and Interest in Youth

Contents lists available at ScienceDirect

Acta Psychologica

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Neural signatures of STEM learning and interest in youth

Milton O. Candela-Leal [a], Myriam Alanis-Espinosa [b], Jorge Murrieta-González [c], Jorge de-J. Lozoya-Santos [a], Mauricio A. Ramírez-Moreno [a,*]

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ARTICLE INFO

Keywords:
Brain activity
Children
EEG
STEM education
Educational neuroscience
Functional connectivity
Power spectral density

ABSTRACT

Understanding the neural mechanisms underlying interest in Science, Technology, Engineering, and Mathematics (STEM) and learning is crucial for fostering creativity and problem-solving skills, key drivers of technological and educational growth. Traditional methods of assessing STEM interest are often limited by cultural and human biases, highlighting the need for more objective approaches. This study utilizes Electroencephalography (EEG) to identify neural markers linked to STEM interest and course-specific cognitive demands in young learners enrolled in a specialized private STEM program, including courses such as 3D Design, Programming, and Robotics. Specifically, Power Spectral Density (PSD) and Functional Connectivity (FC) were analyzed within theta, alpha, and beta frequency bands, which are associated with performance monitoring, creativity, and executive functioning. The findings reveal a significant negative correlation between STEM interest and brain activity in the frontal (F3, F4) and prefrontal regions (FP1, FP2) in the theta ($r = -0.44$, $p = 0.2732$; $r = -0.77$, $p = 0.0268$; $r = -0.84$, $p = 0.0096$; $r = -0.62$, $p = 0.0990$) and beta bands ($r = 0.43$, $p = 0.2843$; $r = -0.56$, $p = 0.1524$; $r = -0.83$, $p = 0.0110$; $r = -0.75$, $p = 0.0328$), indicating engagement in working memory and executive processing. Additionally, course-specific brain activity patterns reveal that Robotics is characterized by denser long-range FC networks, associated with problem-solving, while 3D Design exhibits more sparse yet efficient networks, indicative of creative ideation. A consistent beta band FC pattern between central and left-frontal areas reflects cognitive synchronicity and lateralization. These findings contribute to understanding the neurocognitive markers involved in STEM interest and learning, offering a framework for assessing and fostering engagement in STEM education through objective, neuroscience-based approaches.

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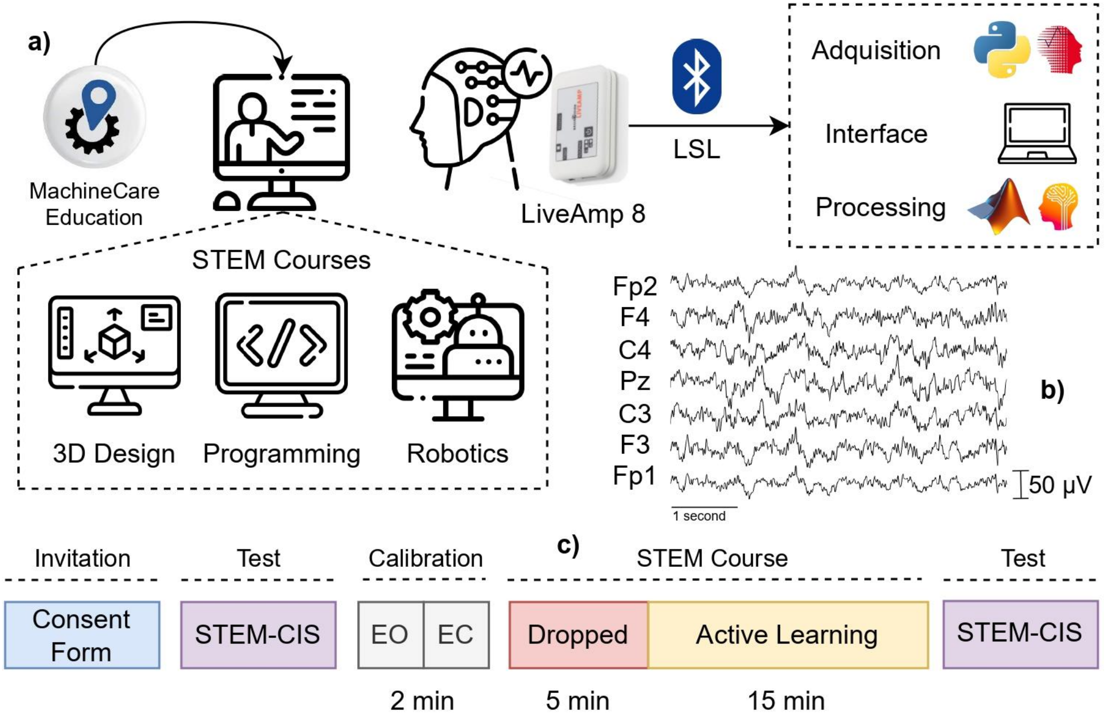
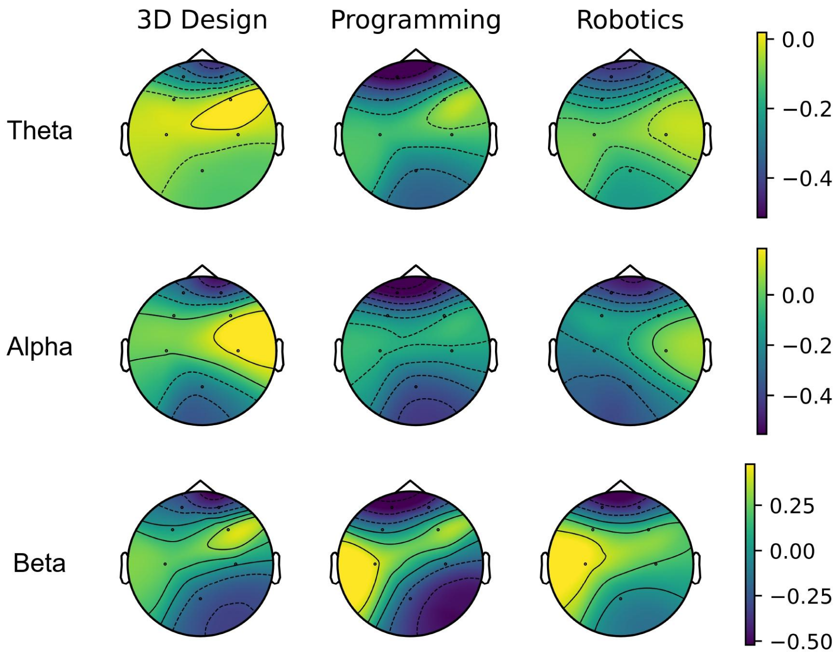
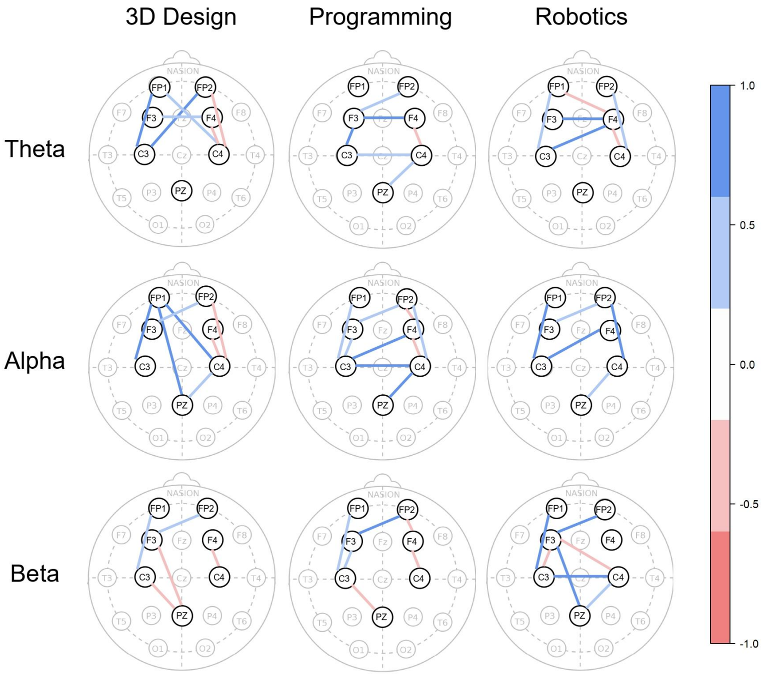
Methodology



Candela-Leal et al. (2025) *Acta Psychologica*

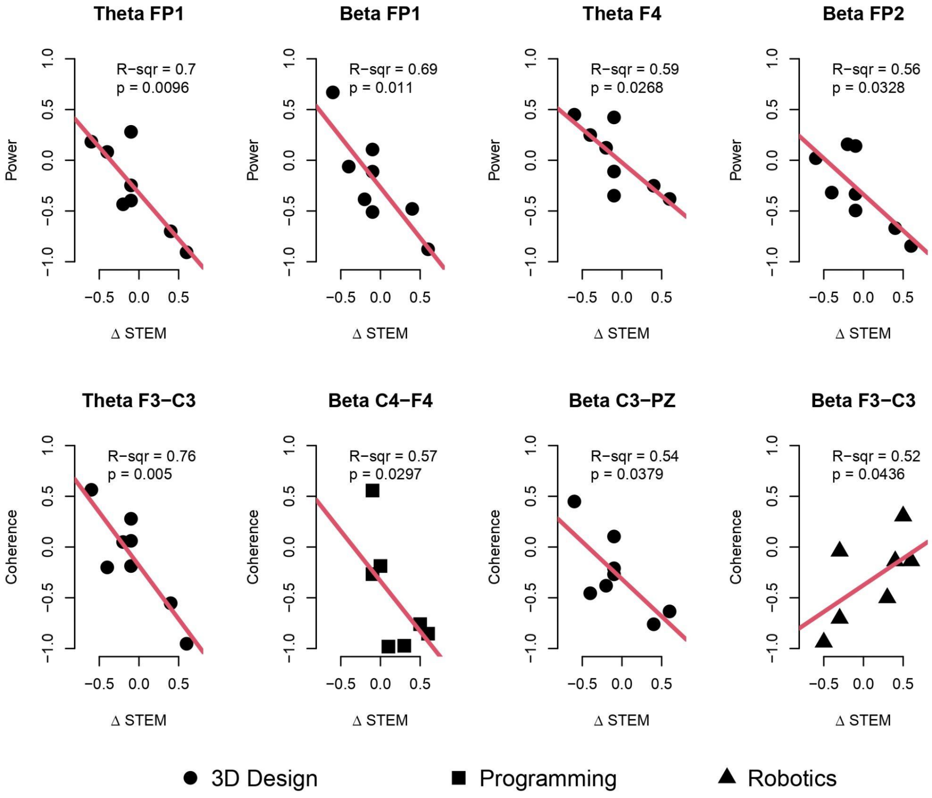
Brain activation patterns





Candela-Leal et al. (2025) *Acta Psychologica*

Regression analysis



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Conclusion

- Despite rising STEM interest, not all courses had the same impact
    - Course-specific differences regarding PSD and FC
        - Could improve learning by eliciting creativity or executive function
- **Adaptive teaching strategies are essential for optimizing learning**

Part. #	3D Design	Programming	Robotics	$\bar{x}$
01	-0.1	0.1	0.6	0.20
03	-0.6	-0.1	-0.5	-0.40
04	-0.1	0.3	0	0.06
06	-0.1	-0.9	-0.3	-0.43
09	0.6	0.5	0.4	0.50
10	-0.2	-0.1	0.5	0.06
11	0.4	0.6	1.3	0.76
13	-0.4	0.3	-0.3	-0.13
Σ	-0.5	0.7	1.7	0.62

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Perspectives from Principal Component Analysis and Tree-based Algorithms

frontiers | Frontiers in Human Neuroscience

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Real-time EEG-based emotion recognition for neurohumanities: perspectives from principal component analysis and tree-based algorithms

Miguel Alejandro Blanco-Ríos[1†], Milton Osiel Candela-Leal[1,2†], Cecilia Orozco-Romo[1], Paulina Remis-Serna[1], Carol Stefany Vélez-Saboyá[3], Jorge de Jesús Lozoya-Santos[1], Manuel Cebral-Loureda[3] and Mauricio Adolfo Ramírez-Moreno[1]*

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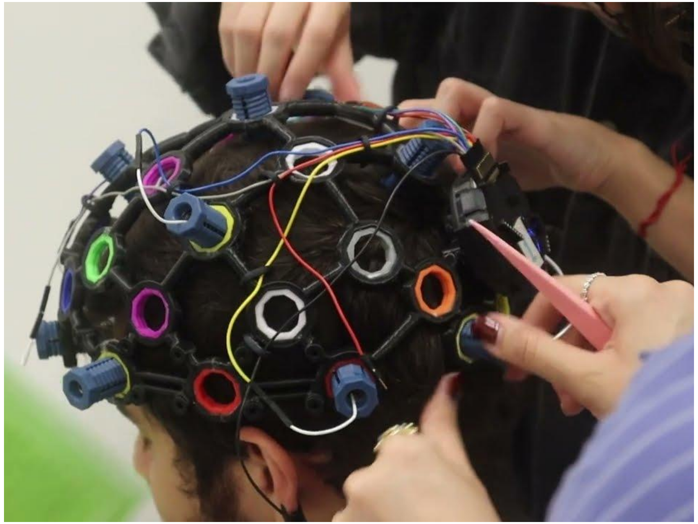
Within the field of Humanities, there is a recognized need for educational

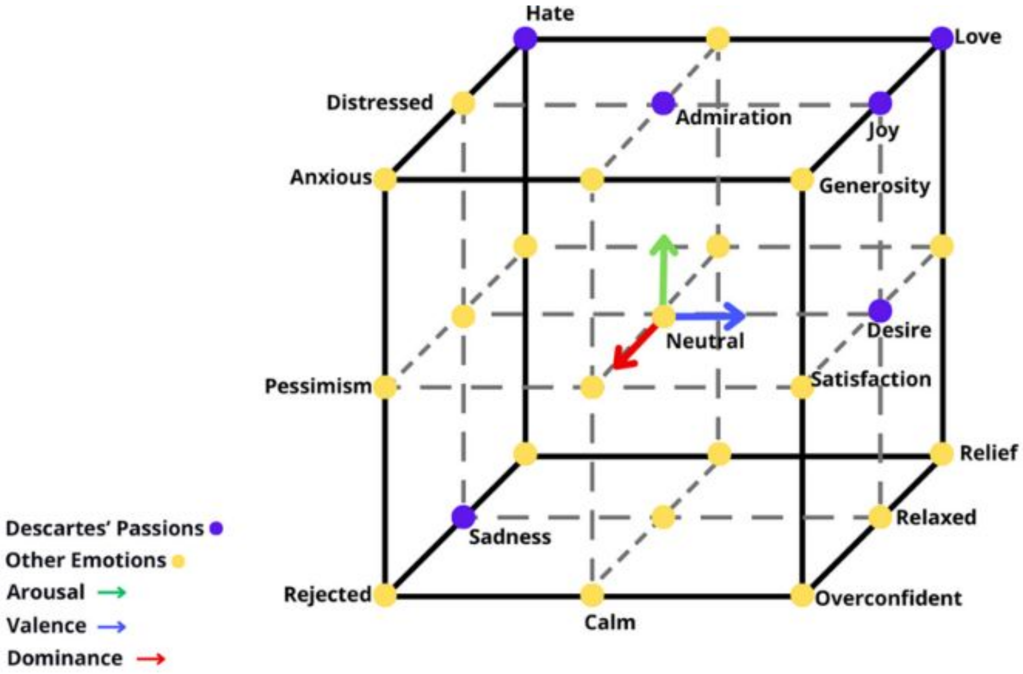
frontiers

Motivation

- **Challenge:** Humanities teaching methodologies has been slower compared to other fields.
- **Solution:** ML + EEG in real-time to predict emotion and create adaptive learning experience.



VAD emotion model



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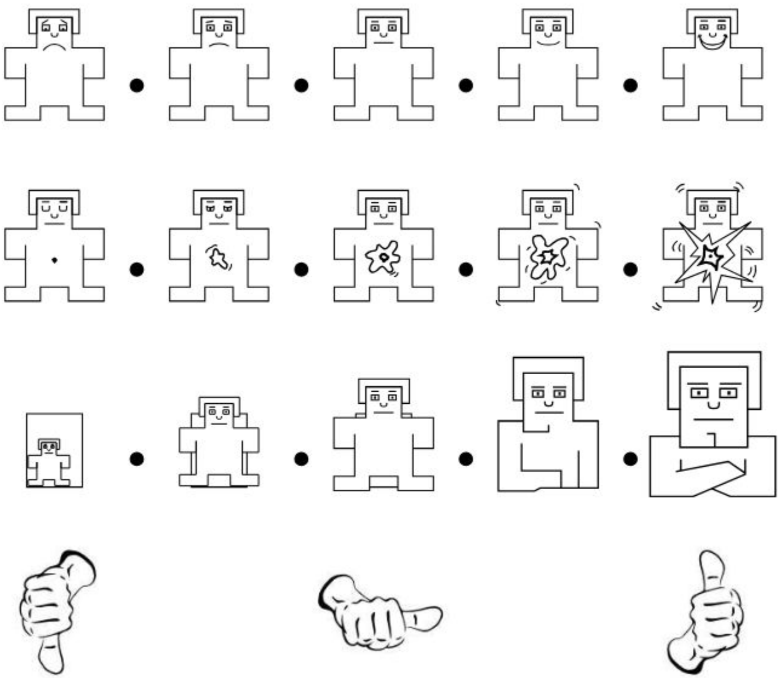
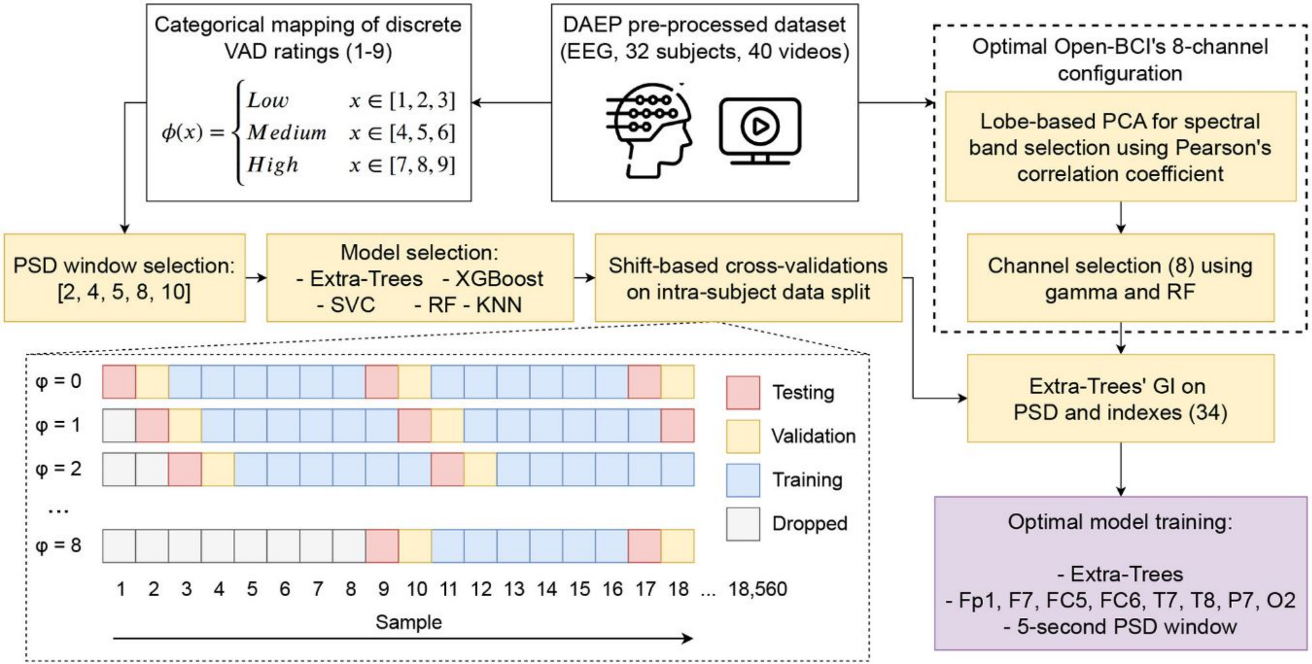
Self-Assessment Manikin (SAM)

- 1-9 Likert scale ratings
- **Valence:** Unpleasant (stressed) to happy (elated).
- **Arousal:** Uninterested (bored) to excited (alert).
- **Dominance:** Helpless (without control) to empowered (in control).



Koelstra et al. (2012) *IEEE Transactions on Affective Computing*

Methodology



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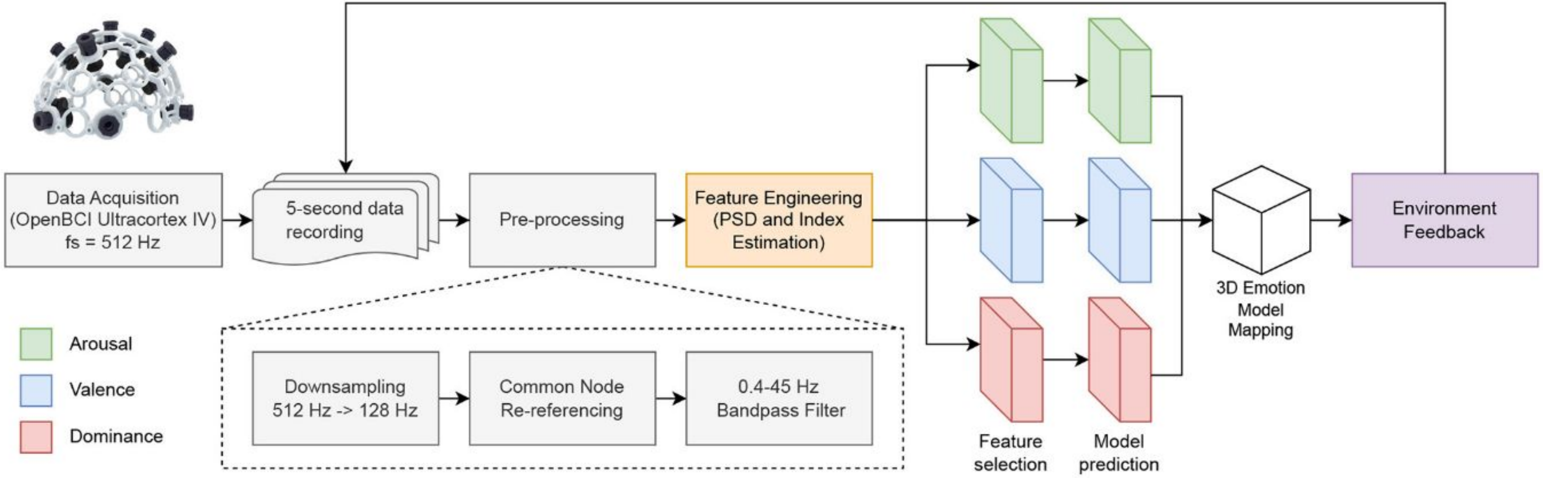
Flow diagram of real-time prediction



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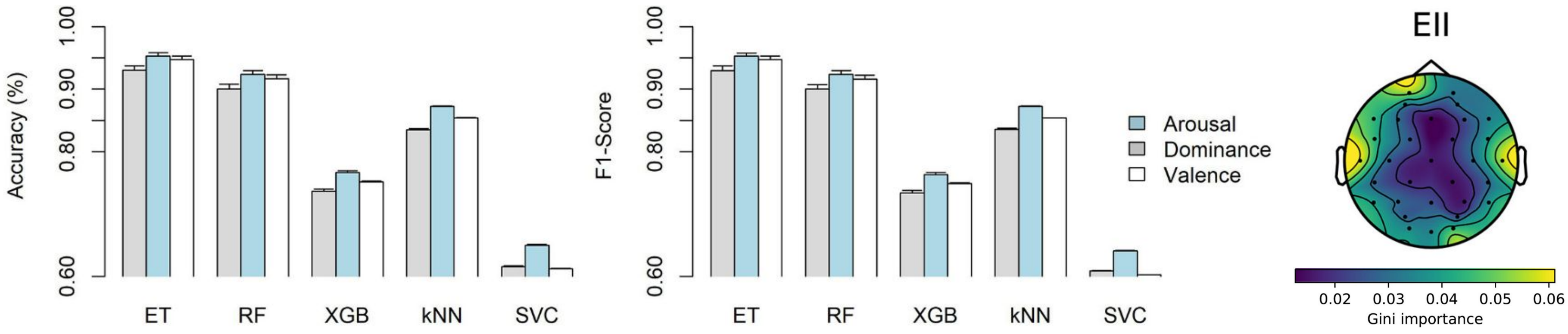
ML model selection & feature importance

- **ET**: Extra-Trees, **RF**: Random Forest, **XGB**: XGBoost
  kNN: k-Nearest Neighbors, **SVC**: Support Vector Classifier
- **EII**: Emotion Importance Index



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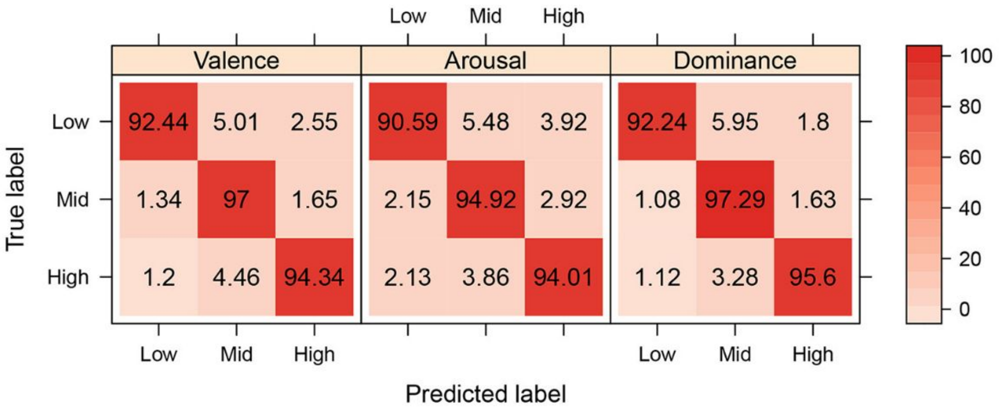
Conclusion

- 8-channel EEG real-time emotion recognition is feasible and accurate
    - VAD model is capable of mapping further emotions
        - Changing the current learning environment based on student’s state
- **Adaptive environments improves engagement and learning**



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Concluding remarks

- Cognitive states like mental fatigue, interest in STEM, and emotion can be decoded using EEG
- Both environmental conditions and educational content impact learning outcomes
- Personalized learning environments could optimize student performance and interest

Future directions:

- Longitudinal study to assess the impact of real-time biofeedback systems as educational tools

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Thanks

Any questions?

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