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Decoding Cognitive Performance

From Chess Puzzles to STEM Classrooms

Cognitive Neuroscience minor - Tecnológico de Monterrey
19 September, 2024

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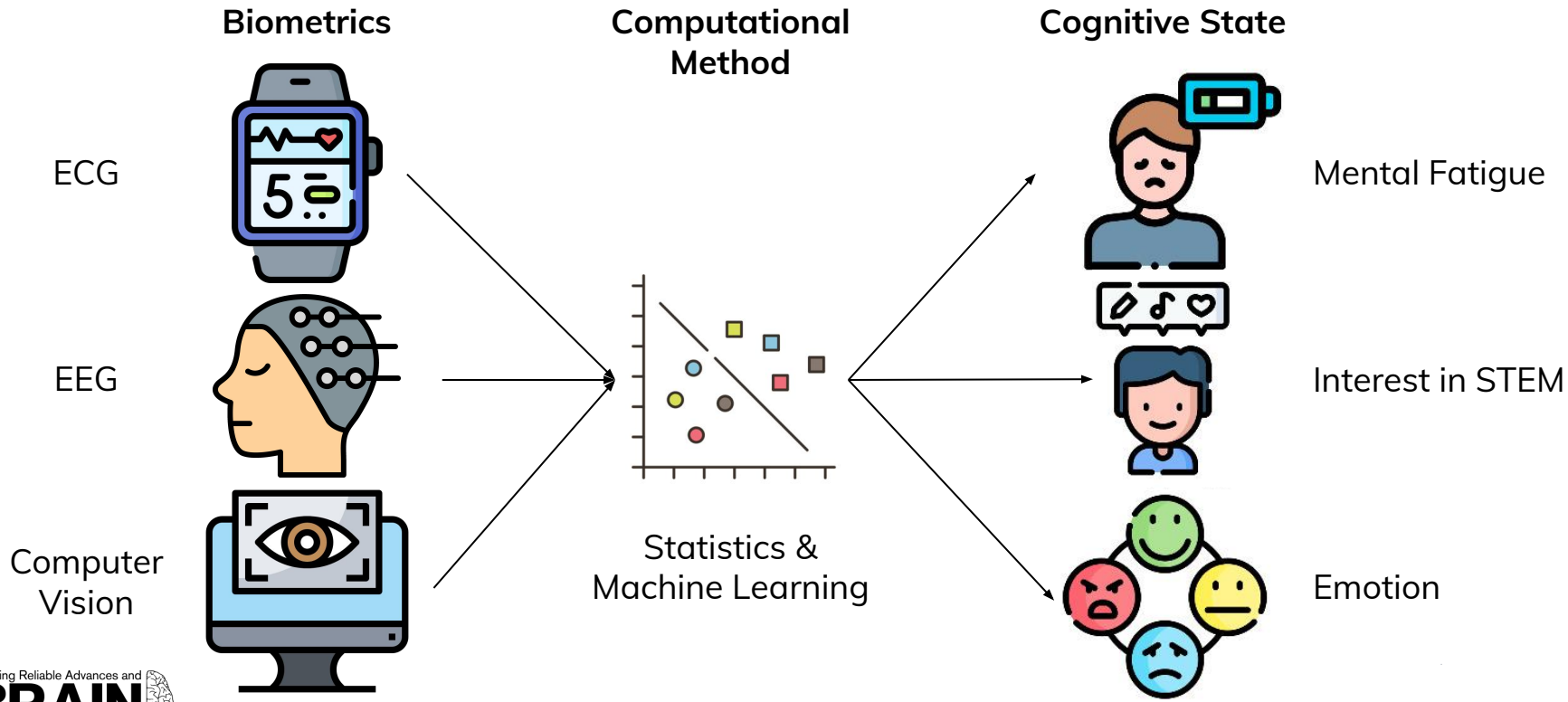
Building Reliable Advances and BRAIN Innovations in Neurotechnology

MACHINECARE EDUCATION

Overview


Biometrics
Computational Method
Cognitive State
ECG
EEG
Computer Vision
Statistics & Machine Learning
Mental Fatigue
Interest in STEM
Emotion

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Biometric devices

EEG

ECG (BVP, EDA, IBI)

Enophones (4)

ALAS

LiveAmp (8)

Talent Detection

OpenBCI (8)

Neurohumanities

Unicorn (8)

Chess Load

Empatica E4

ALAS, **Talent Detection**, Neurohumanities

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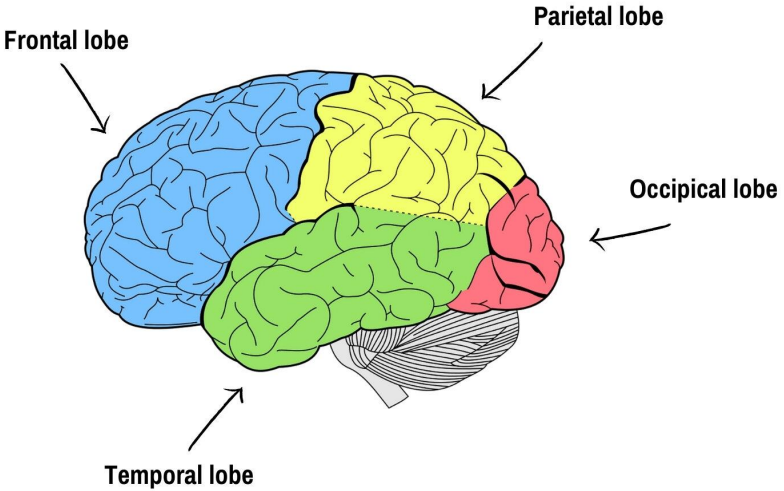
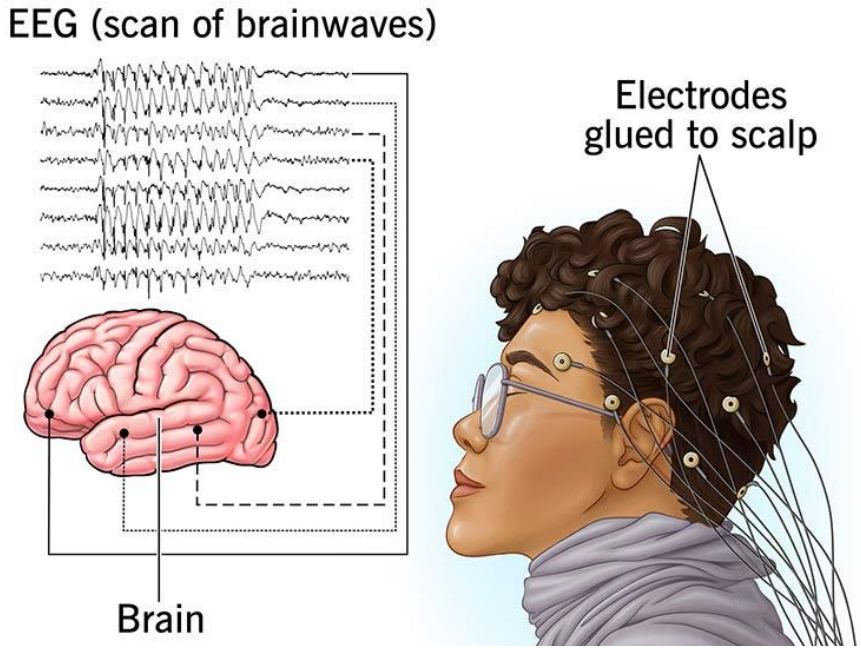
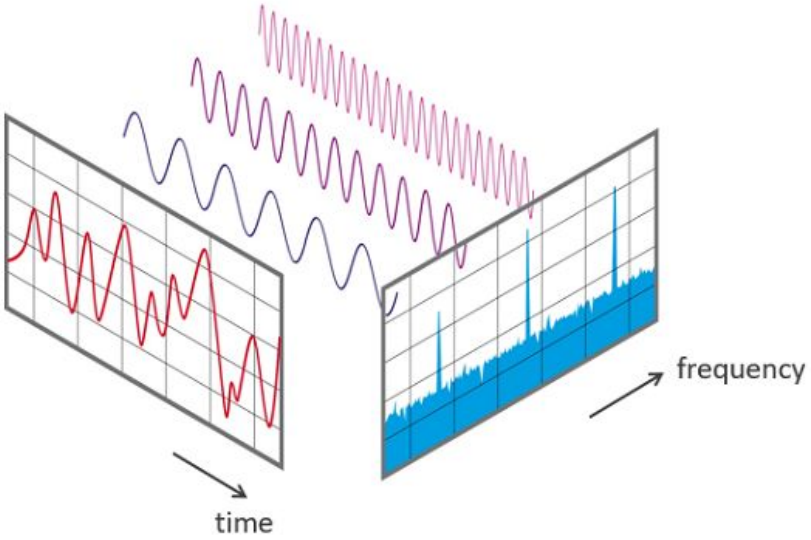
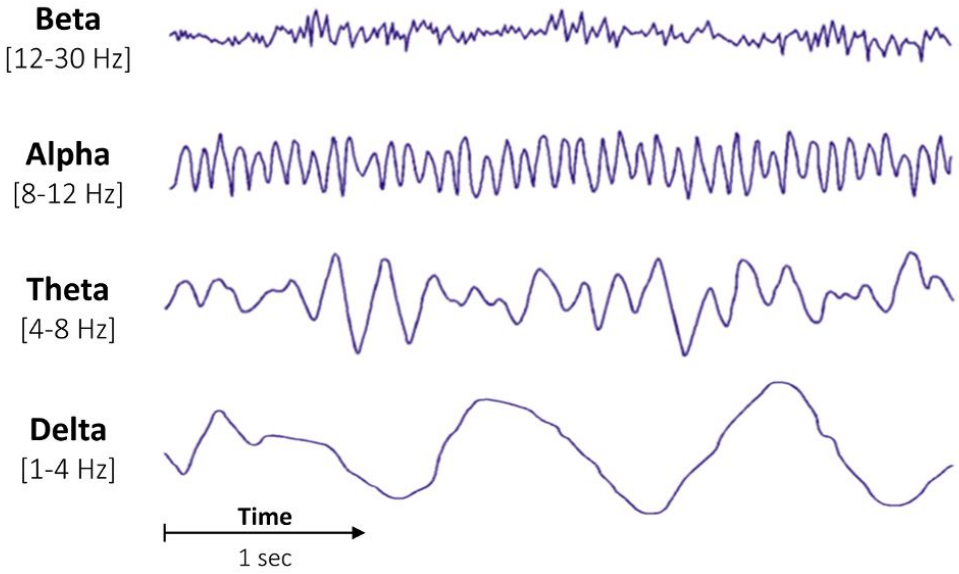
Brain signal?



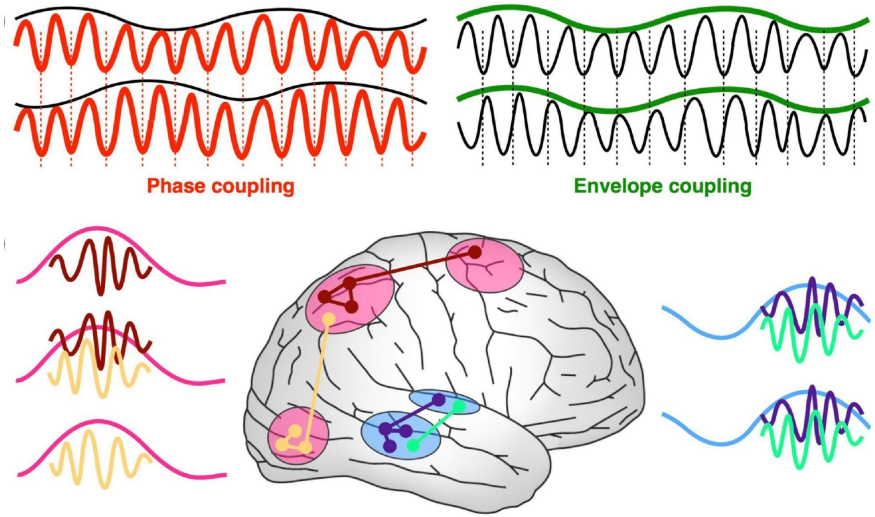


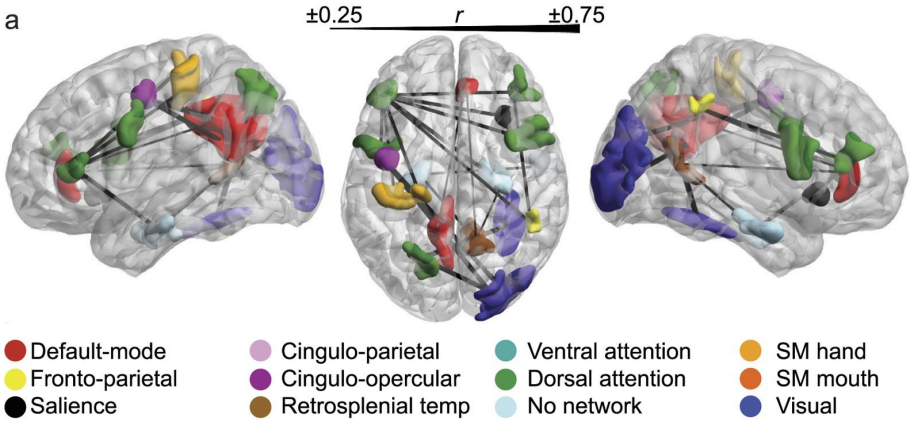
EEG frequency analysis (Fourier)





EEG functional connectivity analysis





Engel, AK. & Gerloff, C. *Trends Cogn Sci* (2022)
Hearne, LJ. et al. *Sci Rep* (2016)

Projects

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Detecting Change in Engineering Interest in Children

Through Machine Learning using Biometric Signals

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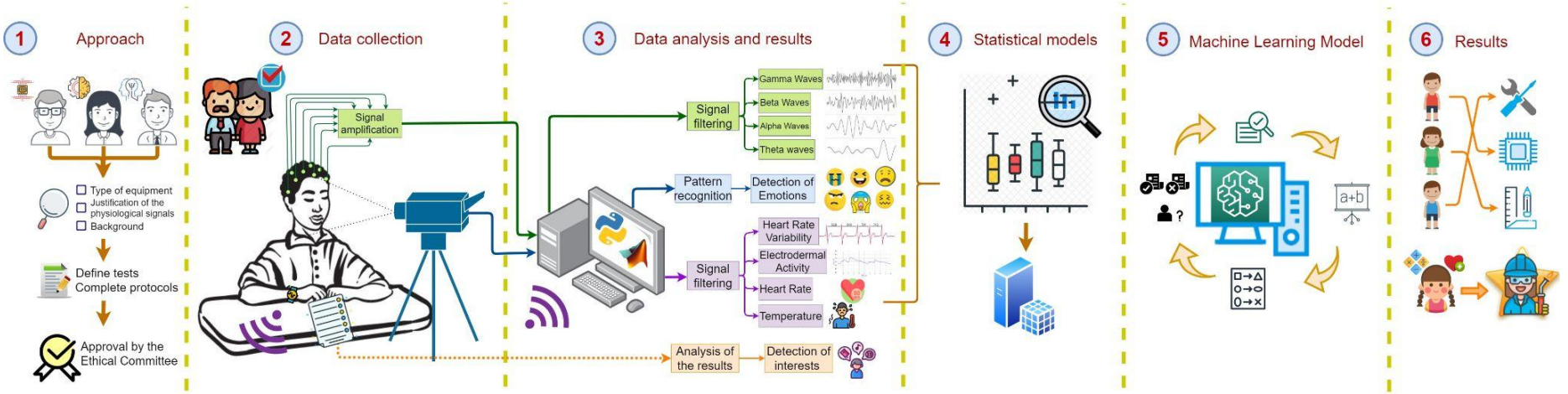
Motivation

Methodology



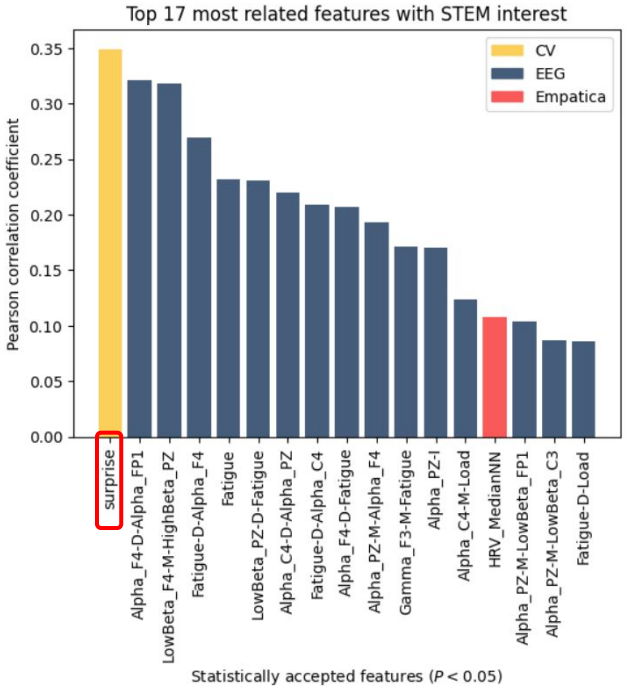
Res Sci Educ
DOI 10.1007/s11165-013-9389-3

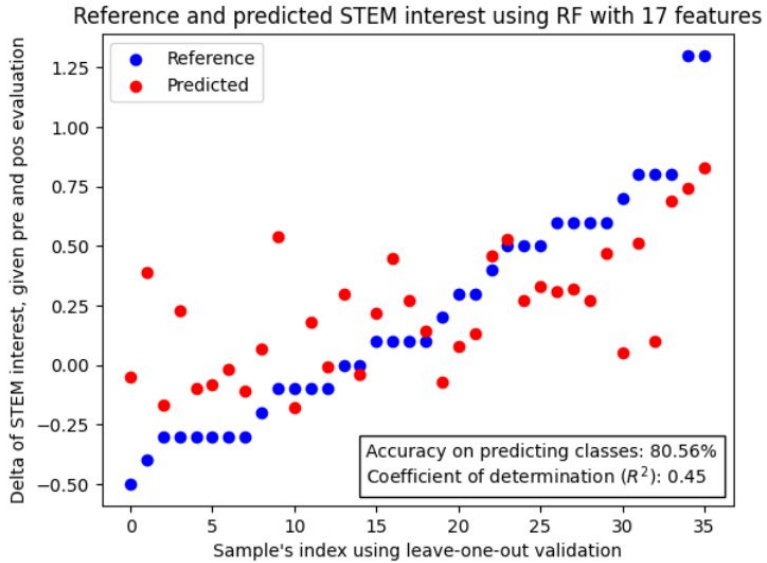
The Development of the STEM Career Interest Survey (STEM-CIS)

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

Data collection

ML analysis





Olivas-Martínez, G. et al. *1st IFE-WS* (2021)

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Neurocognitive Insights into STEM Learning

An Integrated EEG Analysis of Bandpower and Functional Connectivity among Youth

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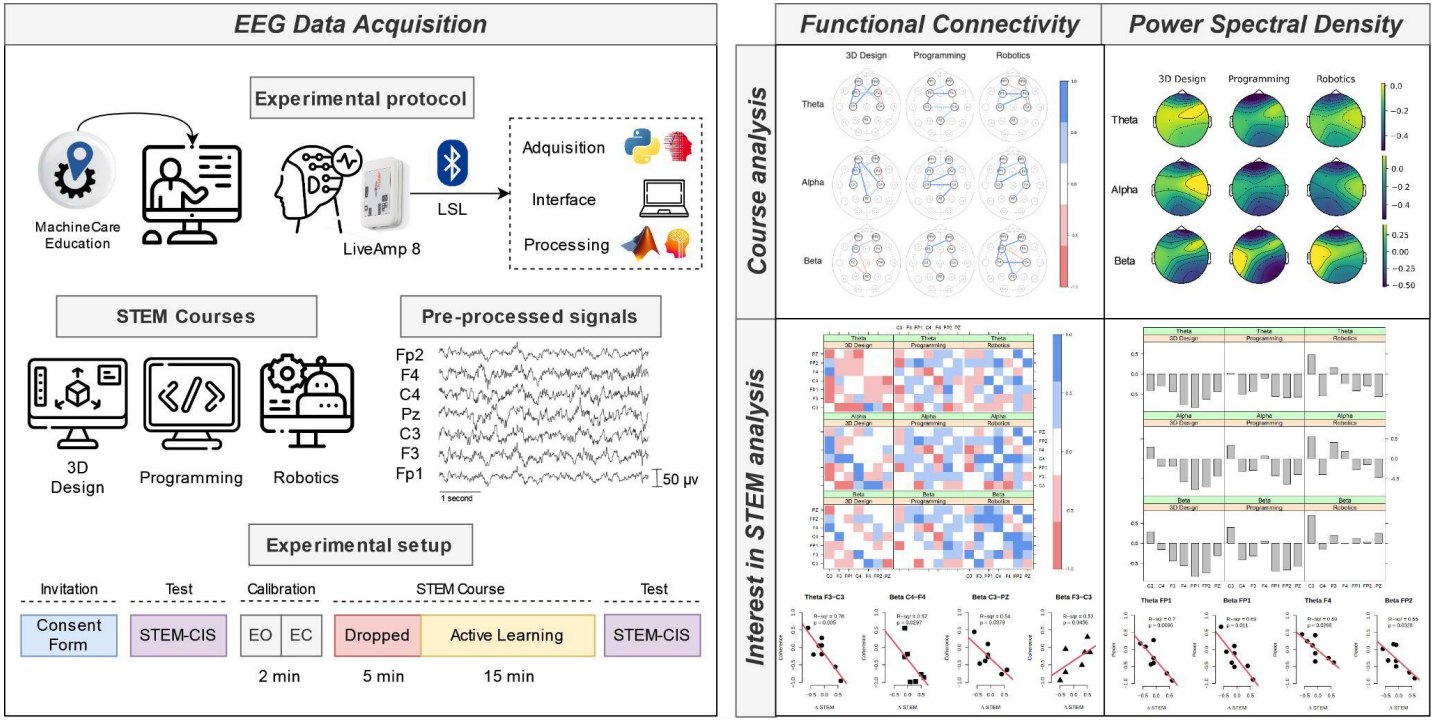
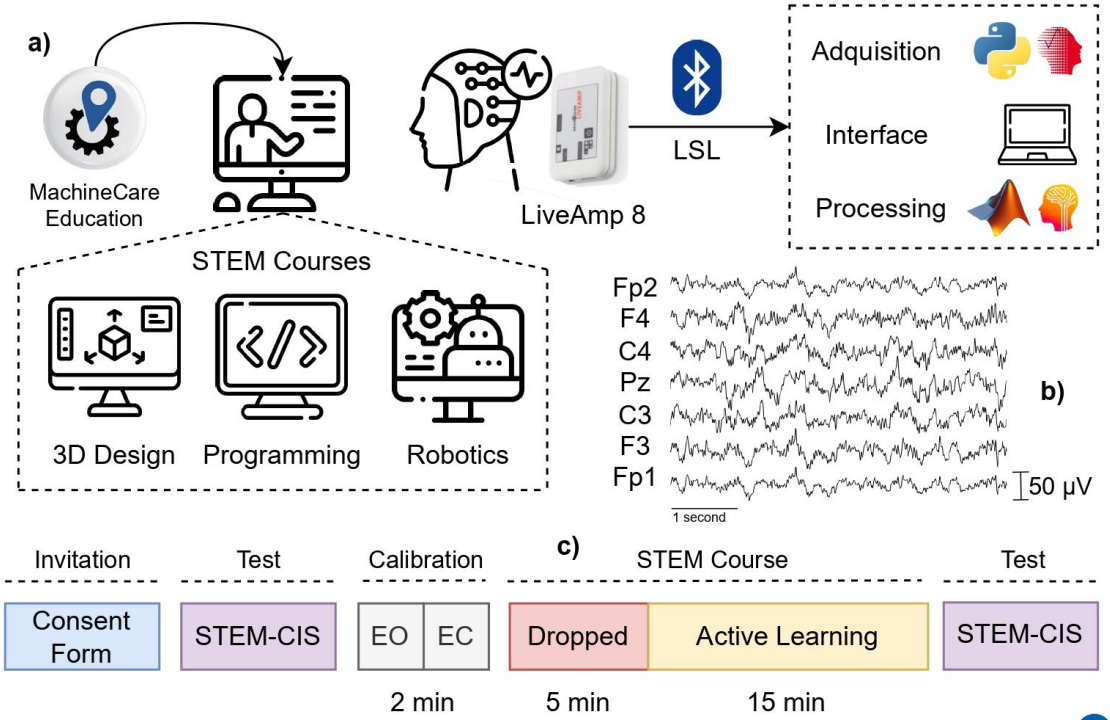
Graphical Abstract

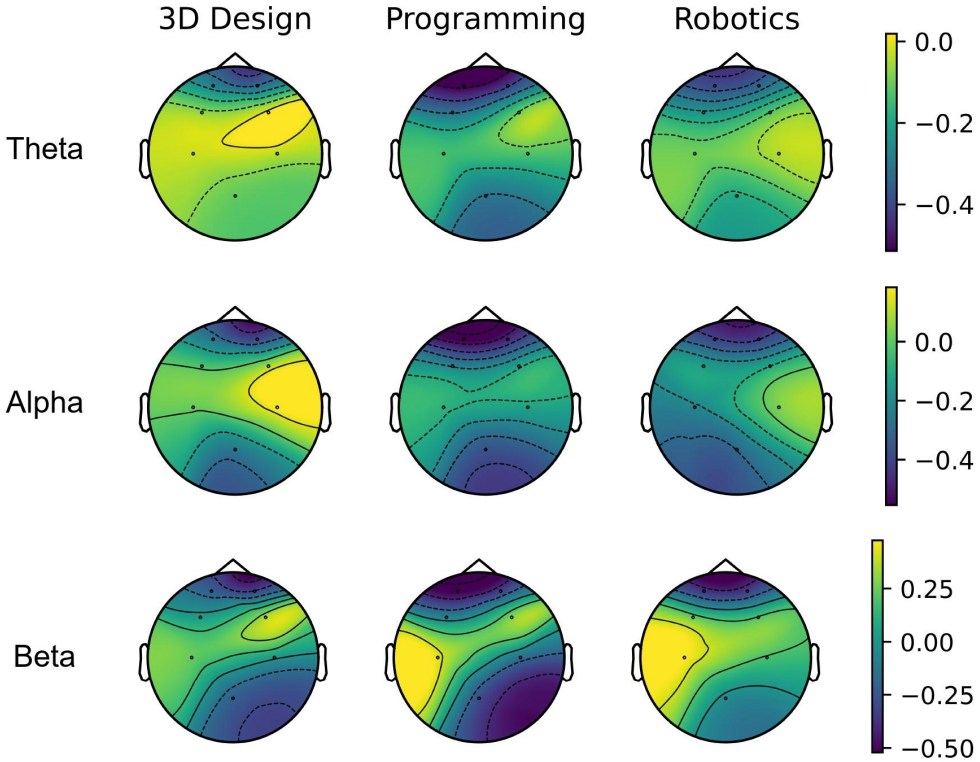


Candela-Leal, MO. et al. (*submitted*)

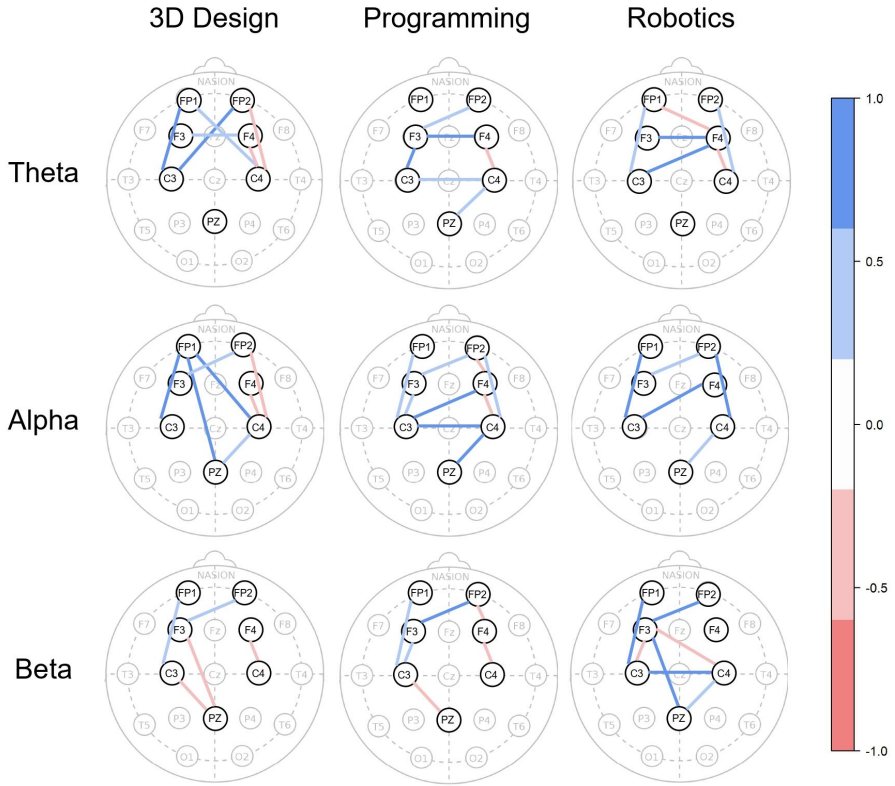
Methodology



Brain activation patterns



Functional connectivity analysis



Correlations with interest in STEM

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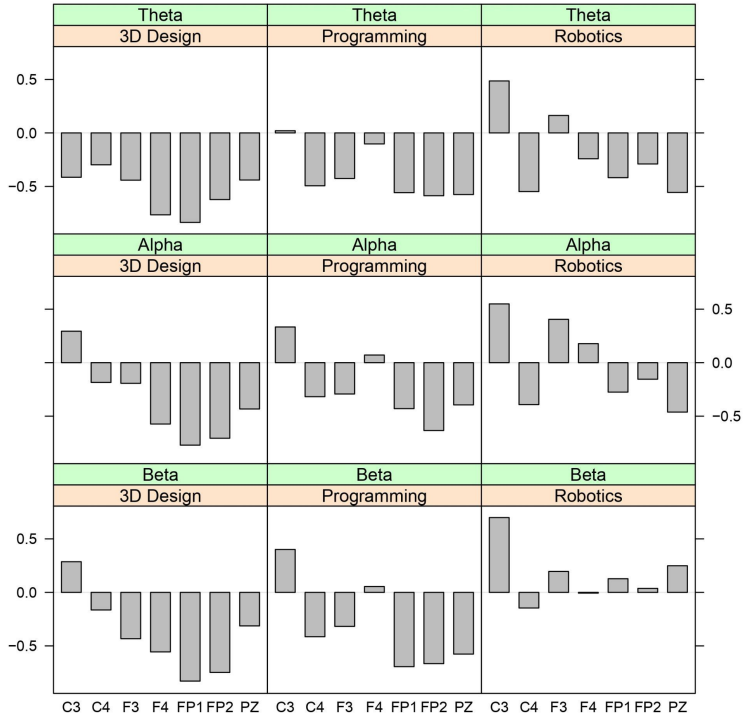

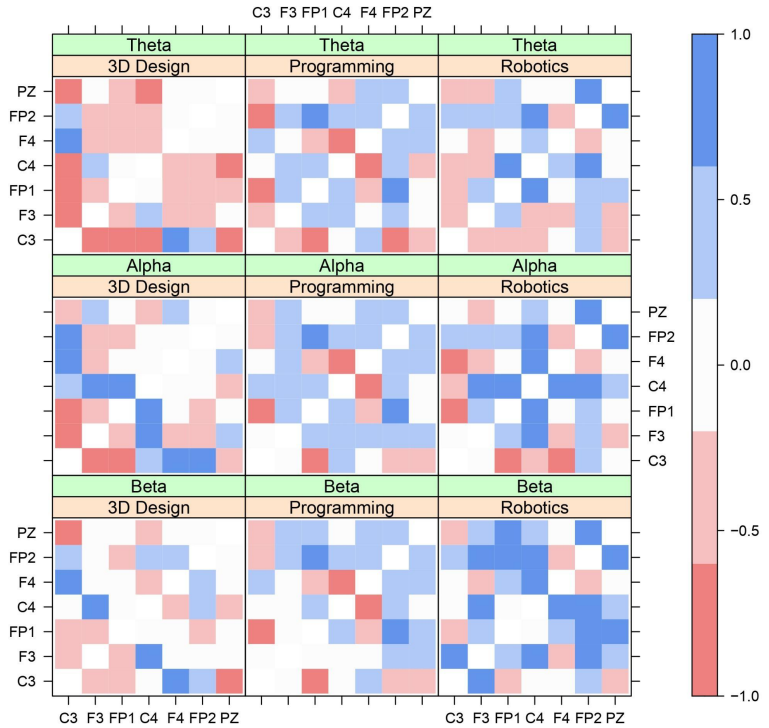

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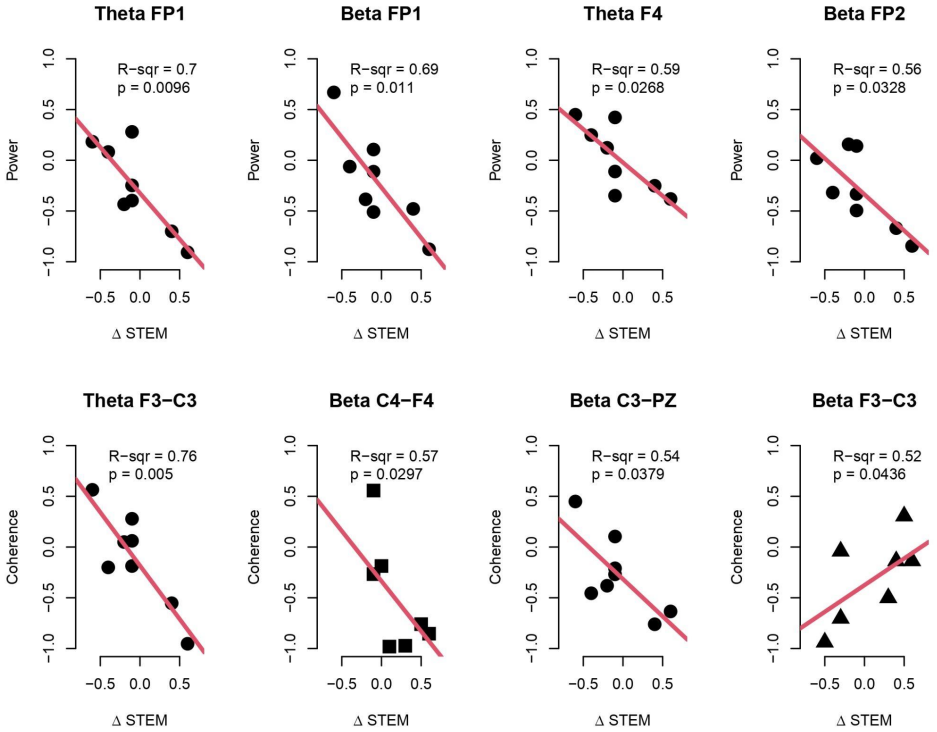
Regression analysis



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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Environmental Noise Impact on Cognitive Performance

A Chess EEG Study

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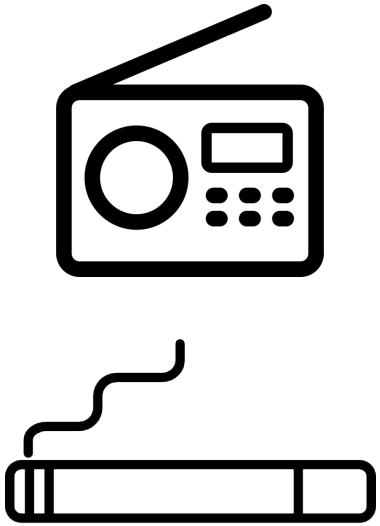
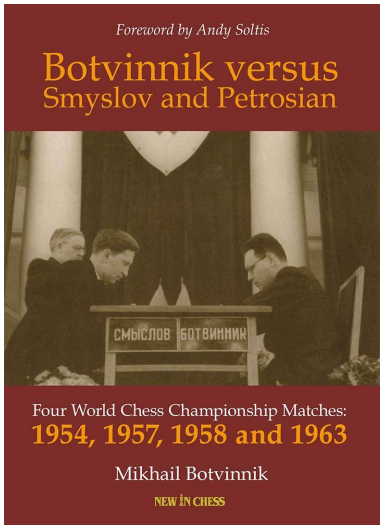
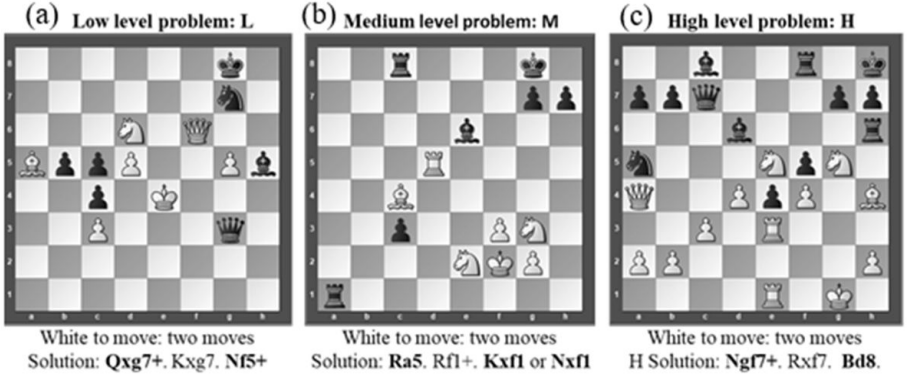
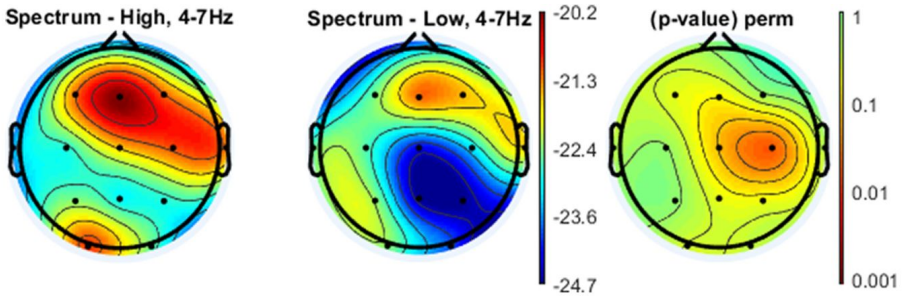
Motivation




Foreword by Andy Soltis
Botvinnik versus
Smyslov and Petrosian
СМЫСЛОВ
БОТВИННИК
Four World Chess Championship Matches:
1954, 1957, 1958 and 1963
Mikhail Botvinnik
NEW IN CHESS

Chess + EEG findings

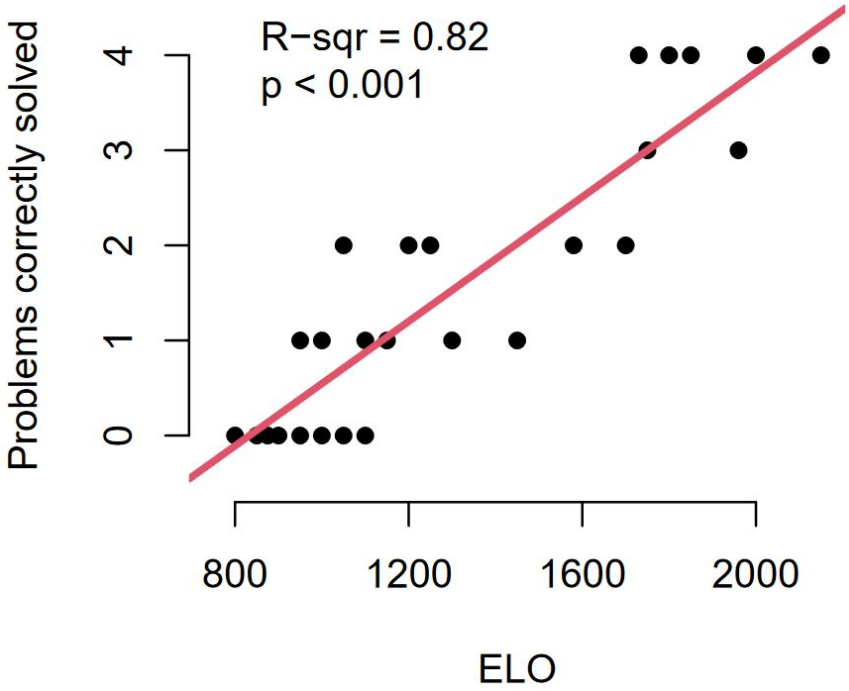




Pereira, T. et al. *Sensors* (2020)
Fuentes-García, JP. et al. *Physiol Behav* (2019)

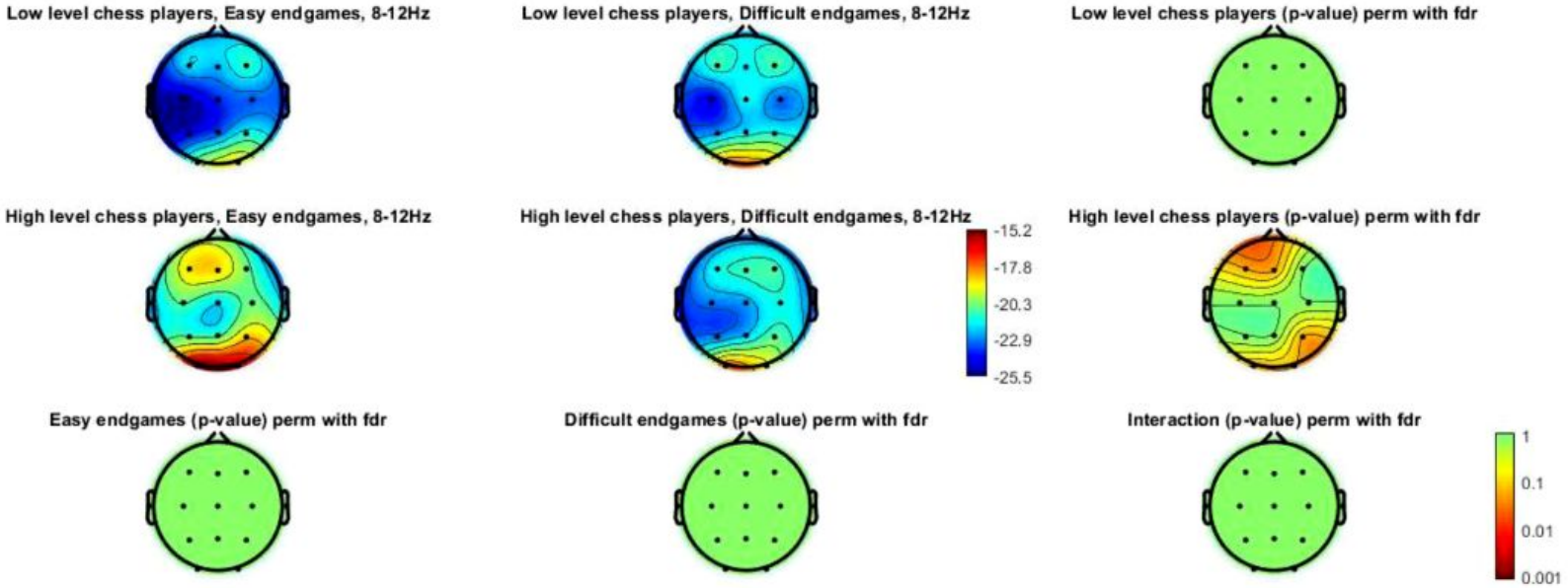
ELO

- Chess level quantitatively through the ELO rating system
  - Developed by Arpad ELO [1] and used by FIDE
- Estimates the relative skill in competitor-versus-competitor games [2] (higher is better).



[1] Elo, A & Sloan, S. *Ishi Press International* (2008)
[2] Di Fatta, G. et al. *IEEE CIDM* (2009)

Chess + EEG findings



Villafina, S. et al. *Physiol Behav* (2021)

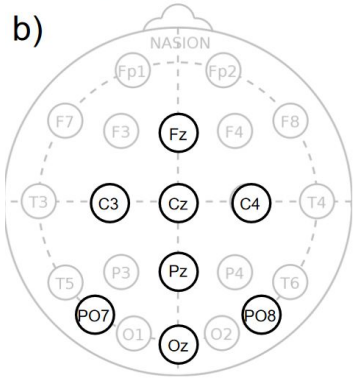
Data collection

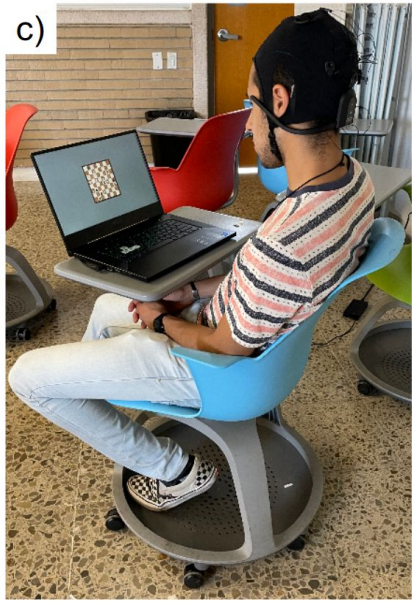
a) 8-electrode Unicorn Hybrid Black

b) Channels employed
   - Frontal: Fz
   - Central: C3, Cz, C4
   - Parietal: Pz
   - Parieto-occipital: PO7, PO8
   - Occipital: Oz

c) Experimental setup

- Ambient Noise (AN) = 40 dB
- White Noise (WN) = 65 dB





Chess puzzles

Low-level problems: L1 and L2

White to move: Two moves
L1 Solution: **Rxe5**, Rxe5, **Kf7+**

White to move: Two moves
L2 Solution: **Qxg7+**, Kxg7, **Nf5+**

High-level problems: H1 and H2

White to move: Two moves
H1 Solution: **Rxh3+**, Kxh3, **Qh1+**

White to move: Two moves
H2 Solution: **Ra5**, Rf1+, **Nxf1**

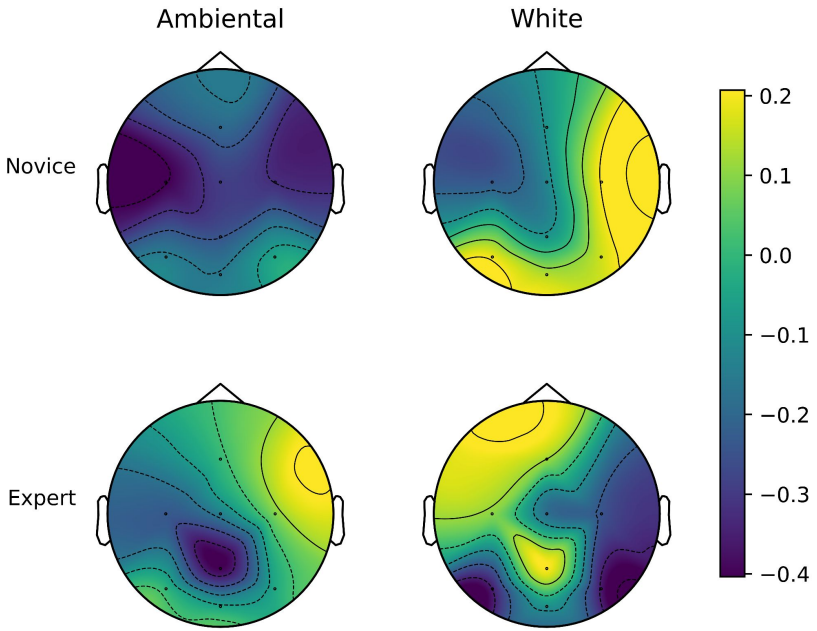
Brain activation patterns (Theta)

Novices

- Fatigue-related band
  - Barely activated in AN
  - Greatly activated in WN at the right-hemisphere (C4)

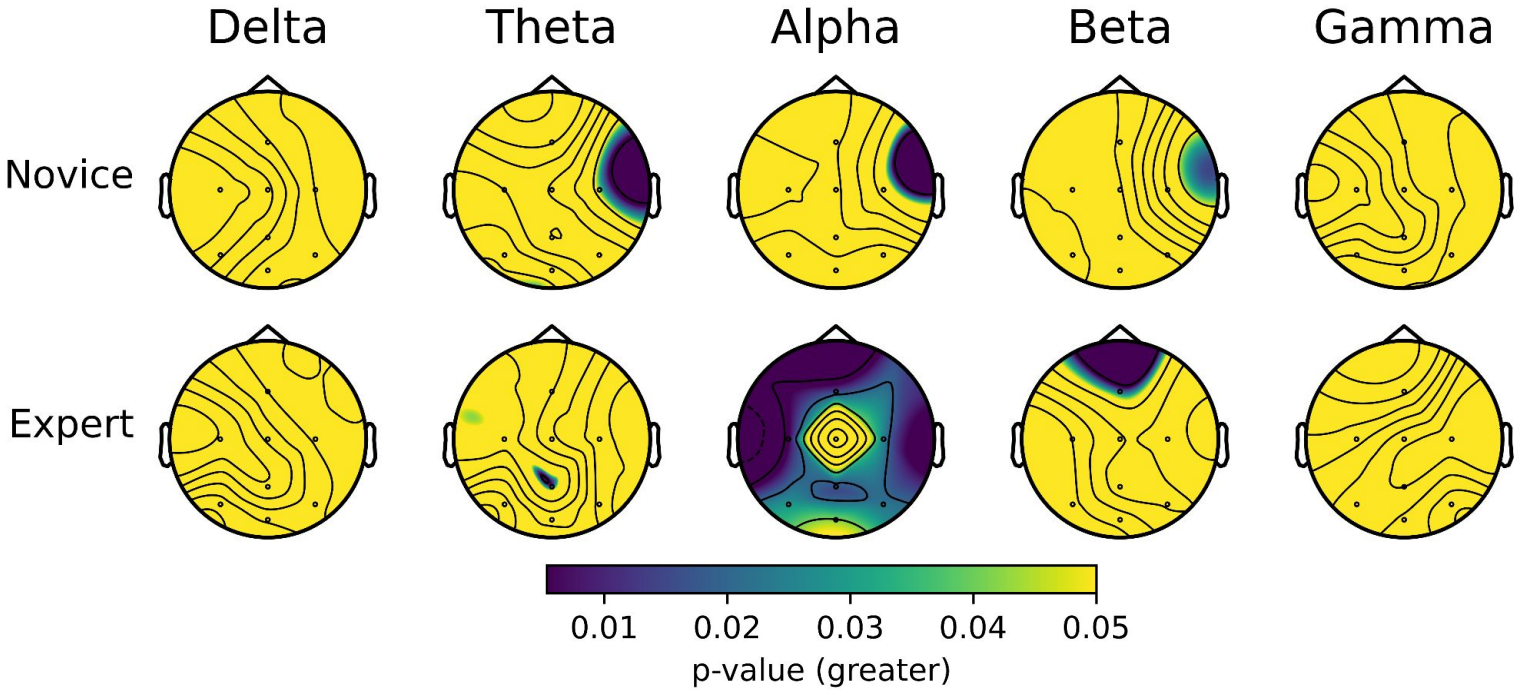
Experts

- Weak differences between AN-WN
  - Except for parietal lobe (Pz)



Candela-Leal, MO. et al. (*submitted*)

Spatial differences with WN



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Estimating Task Completion Time at Chess Problem-solving

Using Single-channel EEG

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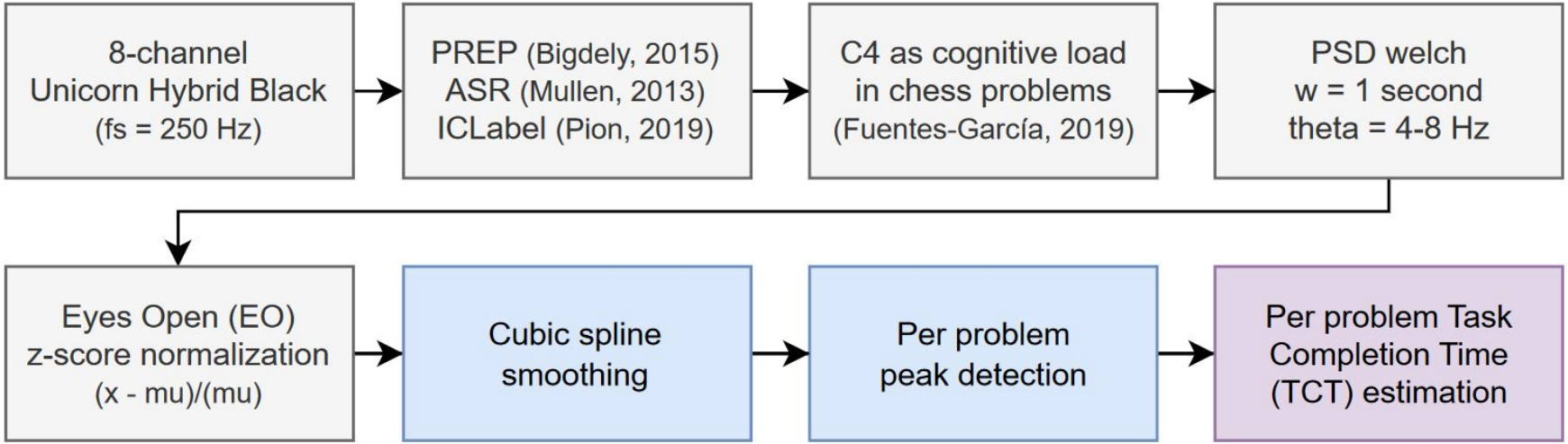
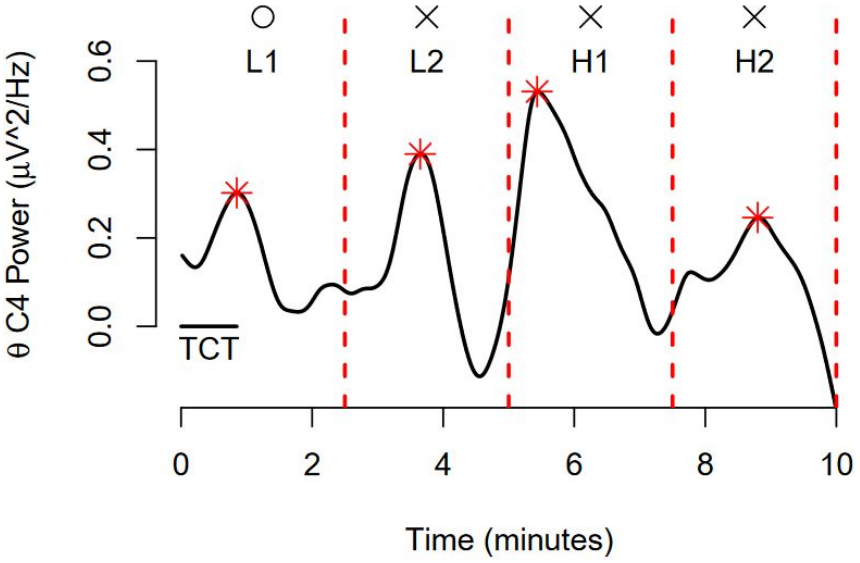
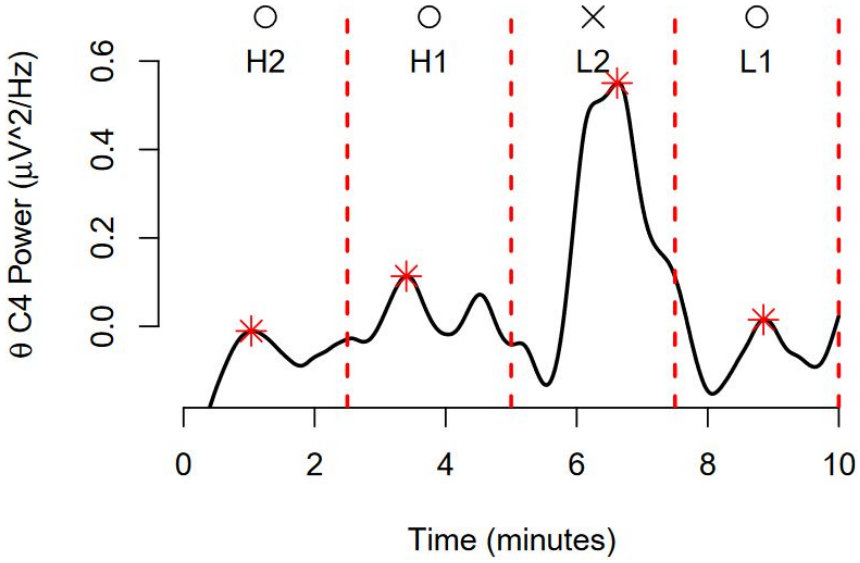
Methodology



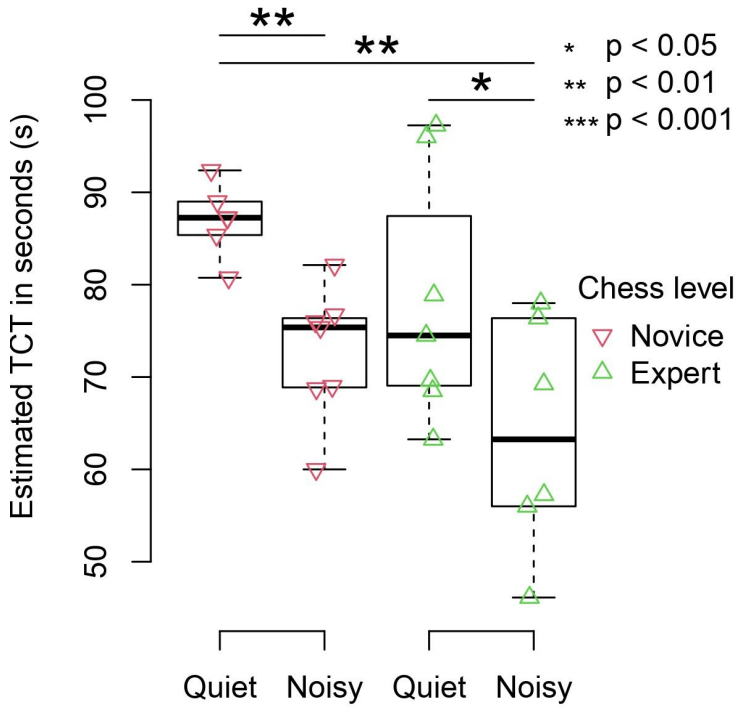
What if we plot theta C4? -> TCT

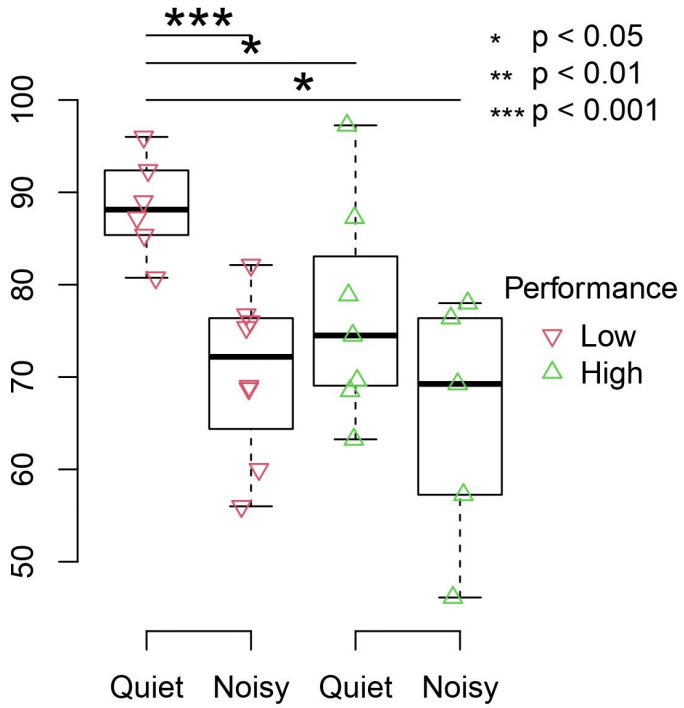




Candela-Leal, MO. et al. (*submitted*)

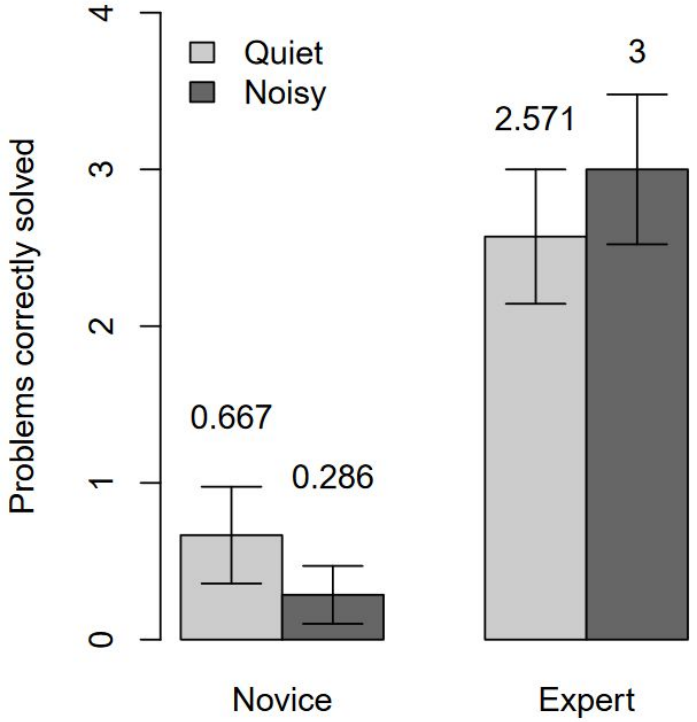
Novices' TCT affected by WN





Conclusion

- Even though performance between AN and WN were not as different
  - Task Completion Time and theta (fatigue) was increased
    - With greater extent in novices and low performing players
- **Challenging environments hinder learning in the absence of mastery**

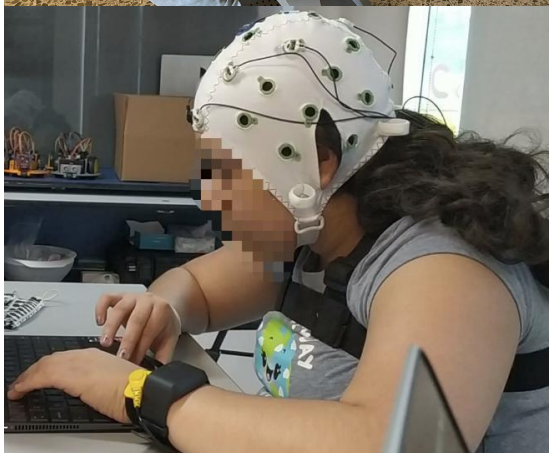


Concluding remarks

- Cognitive states like interest in STEM, load, and engagement can be measured using EEG
- Both environmental conditions and educational content impact learning outcomes
- Personalized learning environments could optimize student performance and interest

Future directions:

- Explore EEG in other learning environments
- Add real-time biofeedback to educational tools



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Thanks

Any questions?

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