Error-Related Brain Activity in ADHD: A Systematic Review and Meta-Analysis of Electroencephalography Markers of Cognitive Control Performance

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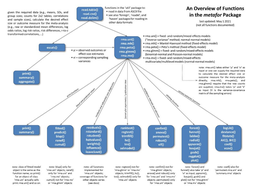
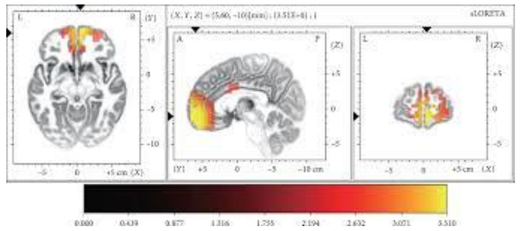
INTRODUCTION

Deviant cognitive control performance is heavily implicated in Attention-Deficit-Hyperactivity-Disorder (ADHD). It is also conjectured to be a potential diagnoser and differentiator between the Inattentive and Hyperactive-Impulsive ADHD types. Reliable measures have not been established due to the variation in published results. In this study, I have performed a systematic review and meta-analysis on EEG correlates of cognitive control monitoring as demonstrated in studies involving participants with ADHD performing tasks while under EEG monitoring.

OBJECTIVES

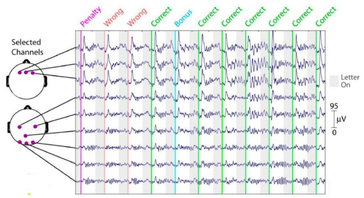
1. Find EEG waveform features with high statistical significance in Inattentive/Hyperactive ADHD Types
2. Find relevant information in other ways ADHD patients are differentiated(age, sex, etc.)to implicate future studies



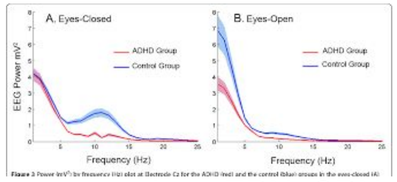


METHODOLOGY

Multiple databases including **PubMed, Scopus, Google Scholar, bioRxiv, medRxiv** were searched for eligible literature. A set of **125 studies** with **7248 participants** were shortlisted. To avoid extraneous variables, the sex ratio was maintained at 50:50, and the ages of subjects were equally varied.



Studies analyzed performance of Inattentive/Hyperactive and no ADHD patients on cognitive tasks.



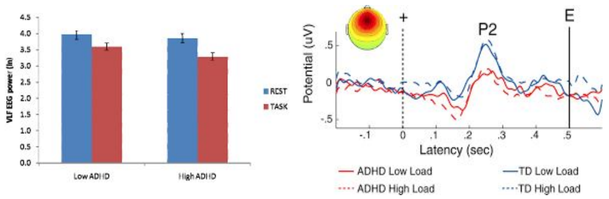
Measures such as ERN, CRN, Pe, and Pc, were tabled and analyzed using the Hedge's g standardized mean differences and Pandas.

Components	Fz	FCz	Cz	CPz	Pz
Go/No-Go ERN	-2.96 (5.23)	-3.32 (5.33)	-2.51 (4.94)	-0.90 (4.09)	-1.16 (4.21)
Go/No-Go CRN	2.49 (2.88)	3.43 (3.12)	3.86 (3.13)	1.50 (3.19)	2.11 (3.31)
Go/No-Go ΔERN	-5.45 (6.10)	-6.75 (5.96)	-6.37 (5.31)	-2.39 (4.60)	-3.28 (4.43)
Go/No-Go Pe	4.44 (8.11)	8.25 (8.37)	11.5 (7.83)	8.95 (8.41)	10.1 (7.98)
Go/No-Go Pe correct	8.95 (5.06)	9.31 (4.94)	6.80 (4.50)	-0.77 (5.79)	-0.02 (4.43)
Go/No-Go ΔPe	-4.50 (7.74)	-1.06 (8.41)	4.70 (8.31)	9.72 (8.88)	10.1 (7.88)
Flanker ERN	-1.29 (4.39)	-1.54 (4.91)	-1.31 (4.67)	0.36 (4.47)	0.18 (4.90)
Flanker CRN	0.71 (3.39)	0.21 (3.40)	0.96 (3.45)	1.24 (3.65)	1.30 (3.92)
Flanker ΔERN	-1.99 (4.82)	-1.75 (5.31)	-2.27 (5.18)	-0.88 (5.29)	-1.12 (5.14)
Flanker Pe	1.28 (8.02)	3.93 (7.64)	5.27 (7.39)	5.22 (7.34)	4.25 (8.00)
Flanker Pe correct	0.15 (5.32)	-2.39 (5.40)	-6.19 (6.01)	-9.71 (5.77)	-10.6 (5.73)
Flanker ΔPe	1.14 (8.73)	6.32 (8.49)	11.5 (9.46)	14.9 (9.14)	14.9 (9.64)

Jupyter Notebooks were utilized to table data and import manipulation libraries such as Pandas to plot and filter outliers (cleaning), and then to check-first hand stats such as cognitive standard deviation.

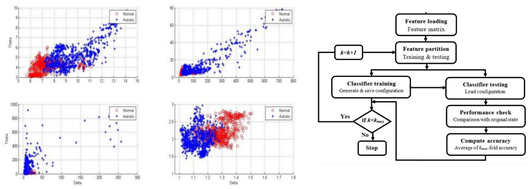
RESULTS

The ADHD-afflicted group showed reduced ERN values (Hedge's g=-0.58 [CIs: -0.76, -0.35]) and reduced Pe values (Hedge's g=-0.65 [CIs: -0.79, -0.44). The Hyperactive-Impulsive ADHD types (2574/7248 participants) showed an increased CRN (Hedge's g=0.68 [CIs: 0.71, 0.29]), while the Inattentive ADHD Types (4674/7248 participants) showed a slightly reduced CRN (Hedge's g=-0.25 [CIs: -0.31, -0.28].



CONCLUSIONS & DISCUSSION

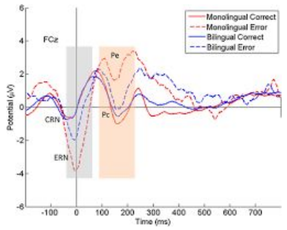
Results suggest that EEG Pattern Markers(especially Pe and CRN) can act as strong differentiators between the Hyperactive-Impulsive and Inattentive ADHD types.



In further development, deep learning classifiers can be built for ADHD types using EEG Markers as Features and statistical values as weights).

FEATURE OVERVIEW

ERN: Error-Related Negativity
CRN: Correct-Response Related Negativity
Pe: Perception of Error Amplitude
Pc: Perception of Correct-Response Amplitude



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Pranjali Awasthi is a 14-year-old researcher investigating the intersection of neuroscience and ML and its applications in diagnosis and transfer learning.

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This study was performed independently contributing to the open-source community.