Theta/Beta Ratio Frequency Band Analysis in Electroencephalography and its ability to Evaluate Cognitive Control in Youth with Epilepsy

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RATIONALE

BACKGROUND

Epilepsy occurs in 1.2% of the US population, resulting in an estimated 3.4 million people with epilepsy nationwide. Of those with epilepsy, about 3 million are adults and about 470,000 are children.[1]

Epilepsy is defined as a condition of recurrent, unprovoked seizures, and frequently co-exists with other neurodevelopmental or psychiatric disorders, such as attention deficit hyperactivity disorder (ADHD), depression, and anxiety.[2]

COGNITIVE CONTROL

Cognitive control, which involves successful inhibition of attention in the presence of distracting information, has been shown to be important for successful regulation of both non-affective and affective information.

Epilepsy and its treatments have been shown to affect cognitive processes including memory, attention, and executive functions, which can adversely impact many areas of life, such as education, employment opportunities, and social relationships.[2]

Cognitive control deficits not only diminish quality of life but may also elevate the risk of accidents or injuries.

Evaluation of cognitive control, including inhibitory control and working memory, can be used to predict post-surgical outcomes and for development of safety measures that can be implemented during seizures.

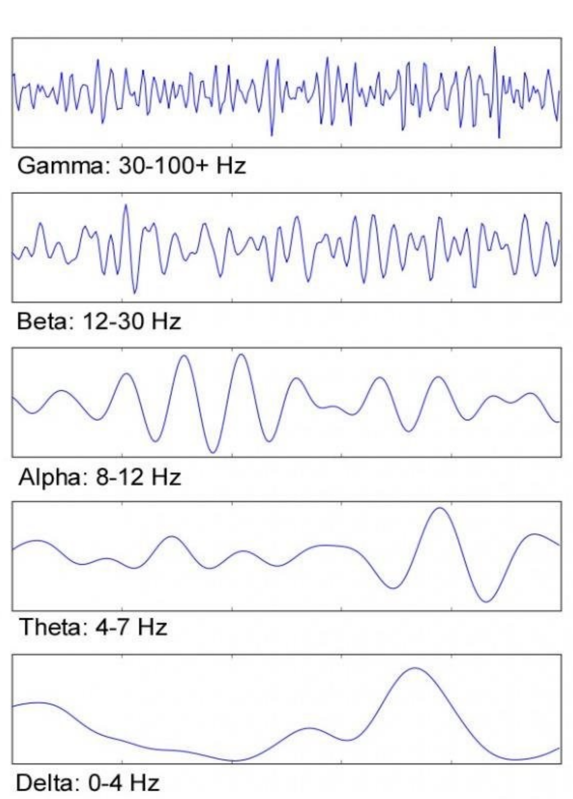
ELECTROENCEPHALOGRAPHY

Electroencephalography (EEG) is used as a primary tool for **diagnosing** and **monitoring** epilepsy, and can assist in the evaluation of cognitive processes, including cognitive control.

Specifically, frequency band analysis offers insights into neural activity associated with various cognitive processes, such as analysis of theta and beta oscillations, which can isolate different aspects of cognitive control processes from epileptiform discharges.

FREQUENCY BANDS

Theta waves are associated with **drowsiness** and early stages of sleep. Abnormalities in theta activity may be observed in some types of epilepsy, particularly during the transition between wakefulness and sleep.[3,4,5] **Theta oscillations** occur when individuals make **conflict-based decisions**.



Beta waves are associated with **active, alert**, and focused mental states. In epilepsy, abnormal beta wave activity can play a role in the manifestation and progression of seizures.

Increased beta **activity** may be observed but may also be a normal response to certain stimuli.[3,4,5] In some cases, there may be an **increase in beta wave activity** during interictal periods (the periods between seizures). The abnormal elevation in beta wave activity may be localized to specific brain regions or involve a greater number of areas in the brain.[3,4,5]

GOALS

1: Characterize theta-beta band activity in epilepsy using task-based EEG data, and 2: Determine if this brain activity correlates with various aspects of cognitive control (e.g., inhibition, regulation), psychological traits (i.e., personality) and mental health symptoms (e.g., depression, anxiety)

HYPOTHESES

Theta-beta ratio will be able to predict cognitive control performance in youth with epilepsy. Adolescents with EPI will have longer reaction times and poorer accuracy than TD controls for both tasks. Task performance will be significantly associated with level of depressive symptom severity, anxiety level, and anhedonia level. Individuals with EPI will have a greater theta/beta ratio than TD controls.

METHODS

PARTICIPANTS

Participants will be recruited from Cook Children's Medical Center as part of a larger study examining biomarkers.

Ages range from 10-20, with TD participants varying from EPI participants by no more than 3 years. The current study is a secondary analysis.

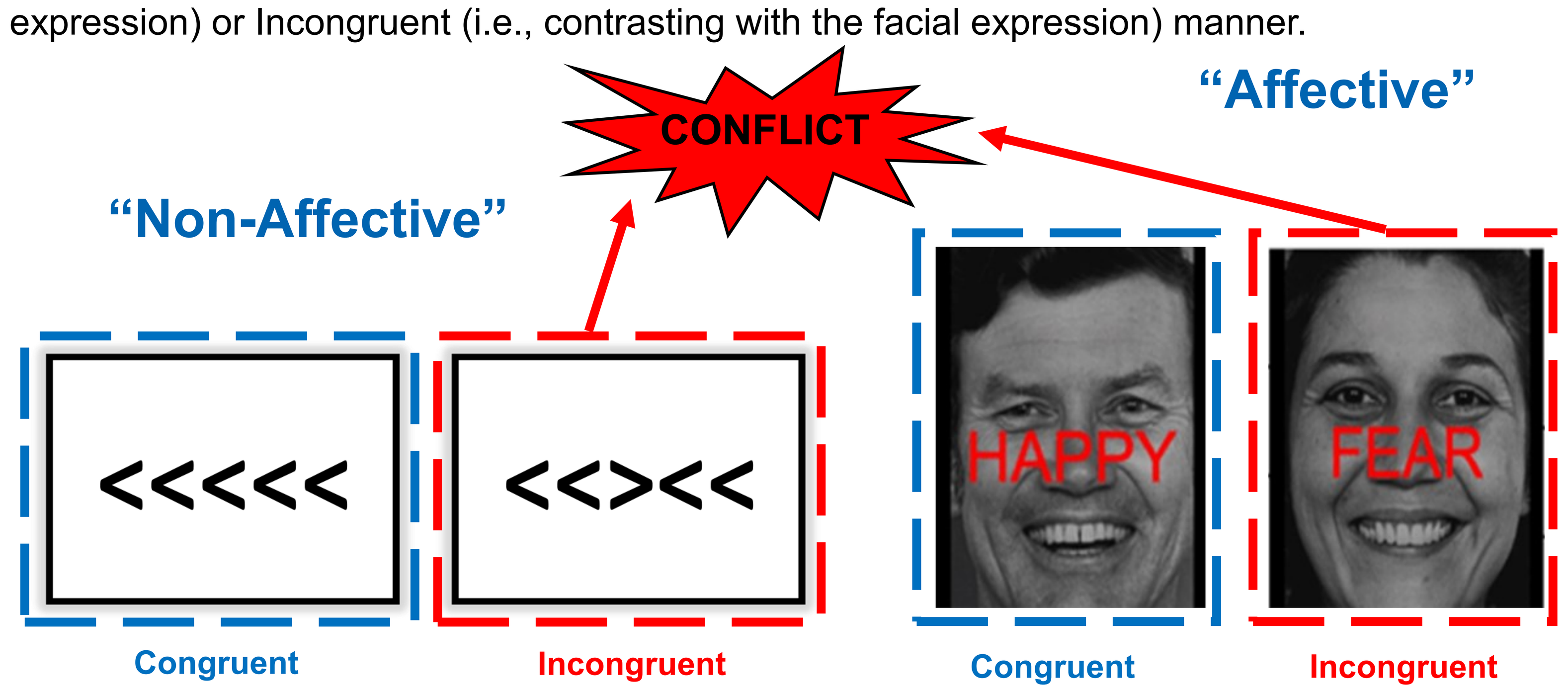
ASSESSMENTS

Assessment Name	Abbreviation	Outcome Measure
Patient Health Questionnaire-9 Item	PHQ-9	Depression Severity
Generalized Anxiety Disorder-7 Item	GAD-7	Anxiety Level
Dimensional Anhedonia Rating Scale	DARS	Anhedonia Level

COGNITIVE TASKS

The **Flanker Interference task** assesses cognitive control via inhibition. In this task, participants are presented with a series of arrows to which they respond to the center arrow's direction that is flanked by congruently or incongruently facing arrows.

The **Emotional Face-Word Stroop** task involves presentation of either Happy or Fearful faces, with the word "HAPPY" or "FEAR" displayed across the face in a Congruent (i.e., consistent with the facial expression) or Incongruent (i.e., contrasting with the facial expression) manner.



ELECTROENCEPHALOGRAPHY

MEG is a neuroimaging technique that allows measurement of the magnetic activity generated by the human brain. HD-EEG is a neuroimaging technique that measures the electrical potential on the scalp with an array of electrodes placed on the scalp.

MEG and HD-EEG will be used to measure resting and active brain states. The MEG/HD-EEG markers in this study can be divided into two groups.

Participants will first undergo resting (10 min) and task-based (45 min) recordings. The total time estimate for completion of preparation and recordings is approximately 1.5 hours.

DATA PROCESSING & STATISTICAL ANALYSES

Characterization of **theta/beta ratio** activity will be done with programs in Brainstorm and MATLAB software.

Accuracy and reaction times for **emotional reactivity to conflict** will be calculated by subtracting Congruent (C) from Incongruent (I) trial performance (I-C) for overall and emotion-specific (Happy and Fear faces) measures.

Depression severity will be calculated by taking the summary score for the self-reported Patient Health Questionnaire-9 Item (PHQ-9). **Anxiety level** will be calculated by taking the summary score for the self-reported Generalized Anxiety Disorder 7 Item (GAD-7). **Anhedonia level** will be calculated by taking the summary score for the Dimensional Anhedonia Rating Scale (DARS).

A series of **independent samples t-tests** will be used to compare each accuracy and reaction time measure between the TD and EPI groups. **Pearson's-r correlations** will be conducted between performance scores and depression severity.

PREDICTED OUTCOMES

FLANKER INTERFERENCE TASK

PERFORMANCE

- Individuals with epilepsy will show slower response times than typically developing controls.

CLINICAL CORRELATIONS

- Significant associations will be observed between overall reaction time and depressive symptom severity.
- Higher levels of depressive symptom severity will be related to slower response times on the task.
- Significant associations will be observed between overall reaction time and anxiety symptom severity.
- Higher levels of anxiety will be related to faster response times on the task.
- Significant associations will be observed between overall reaction time and level of anhedonia.
- Higher levels of anhedonia will be related to slower response times on the task.

EMOTIONAL FACE-WORD STROOP TASK

PERFORMANCE

- Individuals with epilepsy and typically developing controls will show typical reaction time slowing for incongruent relative to congruent trials.

CLINICAL CORRELATIONS

- Significant associations will be found between the Emotional Face-Word Stroop and depressive symptom severity, anxiety symptom severity, and/or level of anhedonia, in the total sample.

ELECTROENCEPHALOGRAPHY

CLINICAL CORRELATIONS

- Significant differences will be observed between typically developing controls and individuals with epilepsy.
- Individuals with epilepsy will have a greater theta/beta ratio than typically developing controls.

ADDITIONAL DIRECTIONS

- Additional testing with a **larger** sample is needed to further examine group differences in affective and non-affective cognitive control between individuals with epilepsy and typically developing healthy controls, as well as the potential effect of depression on various cognitive control processes, **anhedonia**, and **anxiety**.
- Future investigations characterizing specific performance and clinical relationships based on **epilepsy subtype** are needed to understand where focal and generalized epilepsies may differ.
- Understanding the impact of **epilepsy**, **depression**, **anxiety**, and **anhedonia** on **affective** and **non-affective cognitive control domains** may ultimately guide development of interventions to improve cognitive control processes and related **outcomes** in adolescents with these disorders.

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FUNDING

The Jordan Elizabeth Harris Foundation

The Jane and John Justin Neurosciences Foundation

Discover 2024