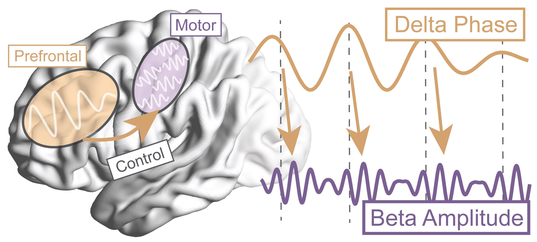
Causal role of delta-beta coupling for goal-directed behavior in anhedonia

Amy Le, Saige Elyse Whitaker, Lauren E. Jackson, Justin Riddle, Ph.D.

Department of Psychology, Florida State University

Introduction

- Major Depressive Disorder (MDD) has become more prevalent in modern society now than before. It is characterized by persistently low or depressed mood, and a lack of interest, enjoyment, or pleasure in one's life, also known as anhedonia [1]
- Delta waves (2-4Hz) in the prefrontal cortex and beta waves (15-30Hz) in the motor cortex, show increased cross-frequency coupling (a metric of coordinated activity) during goal-directed behavior [2]
- Studies found that reward-based decision-making tasks unmask behavioral pathology in anhedonia, which this study will further explore through brain imaging techniques of EEG and fMRI [5]
- An emerging line of evidence suggests that there is a correlation between increased levels of anhedonia symptoms and a decrease in goal-directed behavior and delta-beta coupling [3].



Original figure by Justin Riddle. The goal-directed behavior pathway from the prefrontal cortex to the motor cortex is associated with, respectively, delta and beta oscillations

Objective

- We aim to examine a novel, potential treatment paradigm to decrease anhedonia symptoms by administering noninvasive brain stimulation to restore the reduced prefrontal-to-motor control system by increasing the synchronization of delta and beta neural oscillations

Hypotheses

- Restoration of coupling between the prefrontal and motor cortex will be achieved by five consecutive days of transcranial alternating current stimulation (tACS) to synchronize delta-beta brain waves.
- We also hypothesize that stimulation will decrease symptoms of anhedonia.

Methods

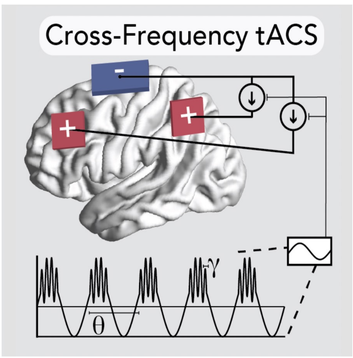
- A sample size of 48 adults, ages 18-65, with a current diagnosis of MDD from the DSM-V(MINI), and high levels of anhedonia
- Participants will complete computer-based tasks during their f**unctional Magnetic Resonance imaging (fMRI) and electroencephalography (EEG)** session where scans will quantify the brain's activity, or active areas, while participants complete reward-based decision-making tasks
- Participants will also complete action-planning and goal-setting worksheets during tACS, which participants will later reflect on the success or failure of plans and further reconstruct the plans, adapted from principles of behavioral activation therapy worksheets (BA)

Electroencephalogram (EEG)

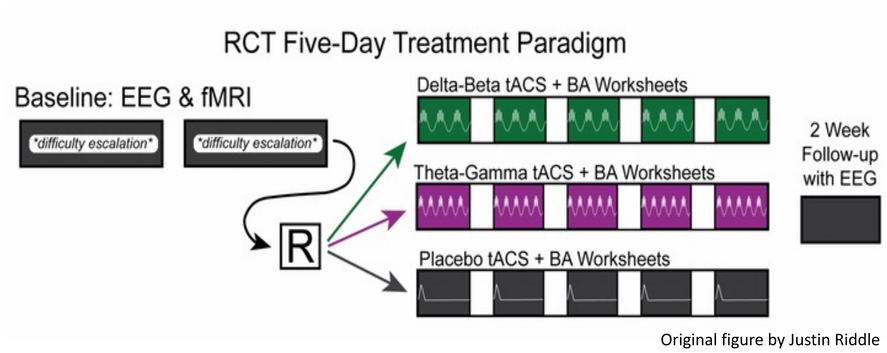
- A method to record the brain's electrical activity with 96 electrodes attached to a cap fitted to the participant's scalp. Gel will be administered to help record the brain electrical activity through waveform

Transcranial Alternating Current Stimulation (tACS)

- This non-invasive brain stimulation method is being used to mimic the brain's endogenous delta-beta waves in the prefrontal and motor cortex. The induced delta-beta electrical fields by tACS will modulate the natural waves in these brain areas. tACS has been administered previously as a novel treatment for major depressive disorder [4]



Study Design

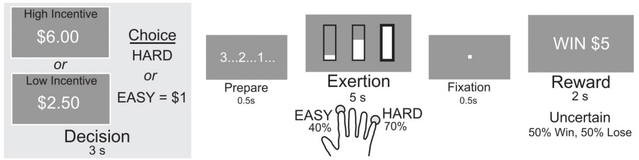


Original figure by Justin Riddle

1st	2nd	3rd	4th - 6th	7th	8th
Virtual clinical assessment for consent, Qualtrics assessments, and to determine eligibility.	Complete reward-based decision-making tasks (S-EEfRT, D-EEfRT, C-EEfRT) during the fMRI session.	Complete the initial worksheet for identifying personal goals and the three versions of the reward-based decision-making task before the tACS stimulation. Evaluate how their actions align with their values and make practical plans to achieve these goals during an action-planning and goal-setting worksheet during stimulation.	Perform three reward-based decision-making tasks while receiving 40 minutes of tACS stimulation.	Complete the initial worksheet for identifying personal goals and the three versions of the reward-based decision-making task before the tACS stimulation. Evaluate how their actions align with their values and make practical plans to achieve these goals during an action-planning and goal-setting worksheet during stimulation.	Participants return for an in-person session that includes self-report clinical assessments. EEG is applied and participants complete the three different versions of the reward-based decision-making task

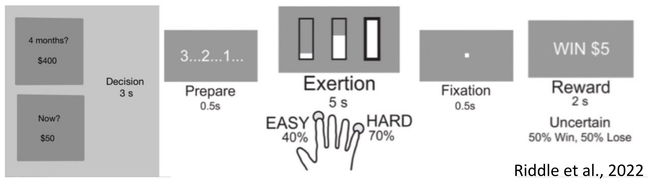
Computer-based Tasks

- **S-EEfRT** (Streamline version of Expenditure of Effort for Reward Task) – Participants are presented with a decision between easy task with minimal physical exertion to wing $1 or a hard task with greater physical exertion to win a larger amount of money



Riddle et al., 2022

- **D-EEfRT** (Delayed discounting version of EEfRT) - instead of easy or hard, participants are presented with an amount of time for which they must wait to receive a higher reward or can choose to receive an immediate reward of lower value



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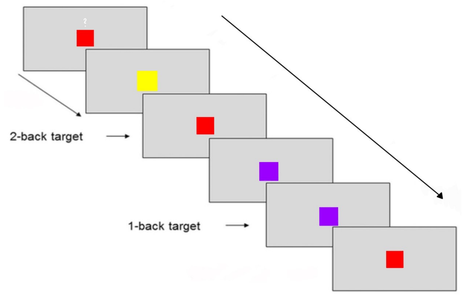
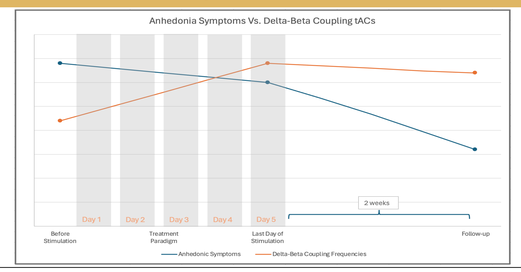
- **C-EEfRT** (Cognitive version of EEfRT) – This task is similar to S-EEfRT, however, instead of physical exertion, a working memory N-back task is performed



Vékony et al., 2018

Anticipated Results



If we obtain the expected results between cross-frequency coupling and goal-directed behavior, we can conclude that increasing delta-beta coupling has a positive correlation with an increase in goal-directed behavior which is associated with a lower level of anhedonia in participants

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