Structural and Behavioral Correlates of Anhedonic Depression: A Voxel Based Morphometry Investigation

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Study Rationale

- Anhedonia is characterized by diminished pleasure, reduced reward motivation, and impairments in anticipating positive outcomes [1]
  - While transdiagnostic in nature, anhedonia is commonly associated with major depressive disorder and may predict treatment – resistance [2]
- Behaviorally, individuals experience deficits in goal-directed behavior and blunted reward evaluation [3]
- Anhedonia has been associated with dysfunctional dopaminergic reward pathways [4] and mixed findings regarding the structural alterations across the frontostriatal and limbic networks [5,6]
  - Therefore, the precise neuroanatomical alterations associated with anhedonia remain largely underreported

Hypothesized Regions of Interest

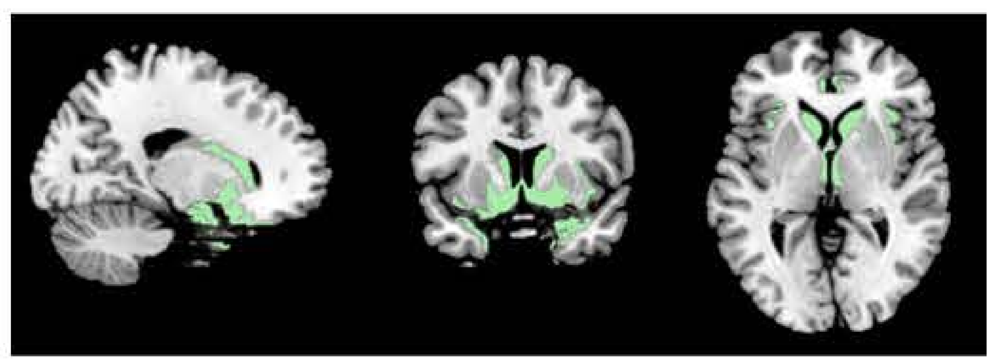


Figure 1. A 3D representation of hypothesized regions of interest where increased anhedonia severity results in decreased gray matter volume

Methods

- We acquired high-quality structural T1-MPRAGE images then participants completed the A-EEfRT task while undergoing functional imaging scanning protocols
- We aim to determine if there are distinct neuroanatomical regions associated with greater levels of anhedonia and distinguishable behavioral patterns between groups in a reward-based effort expenditure paradigm
- We hypothesized whole-brain Voxel Based Morphometry will a show distributed reduction grey matter volume
  - We predict secondary ROI analyses will show reduced grey matter volume particularly in regions such as the striatum, ventromedial prefrontal cortex, and anterior cingulate cortex
- Furthermore, we hypothesize high anhedonia groups will show deficits in goal-directed behavior indexed by reduced probability of selecting the hard option

MRI Background

Structural Image Acquisition

- Anatomical data was collected using a research-dedicated 3T Siemens Prisma Scanner
- A T1-MPRAGE, a 3D MRI sequence widely used for high-resolution structural imaging, was collected for each participant (N = 25) (11 Female; M = 20.59 years, SD = 1.42)

Figure 2. FSU Magnetic Resonance Imaging Facility (MRIF)

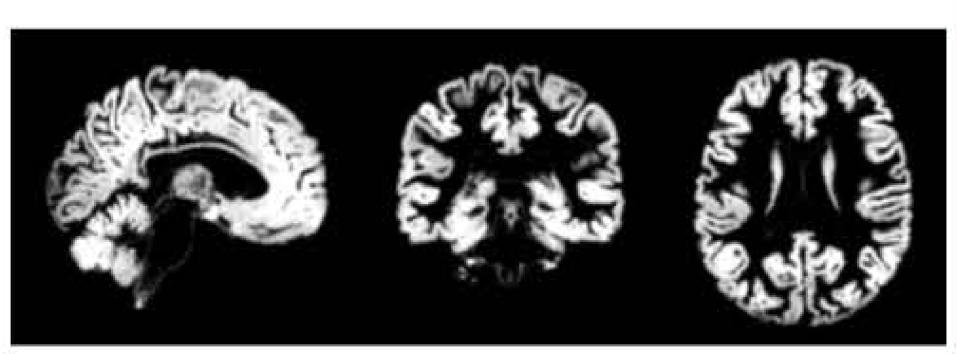


Figure 3. Representation of a T1-MPRAGE sequence that has been segmented to show grey matter (Sub068)

T1 Preprocessing Procedure

- All T1 images were preprocessed in SPM25 using standardized procedures
- Images were realigned to the anterior commissure, normalized into standard space (MNI), segmented based on tissue types, and smoothed

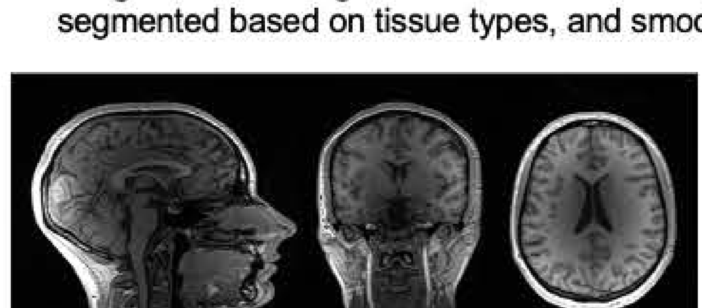


Figure 4. Raw T1-MPRAGE Image (Sub011)

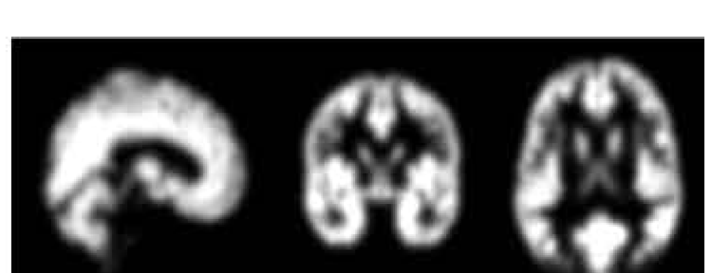
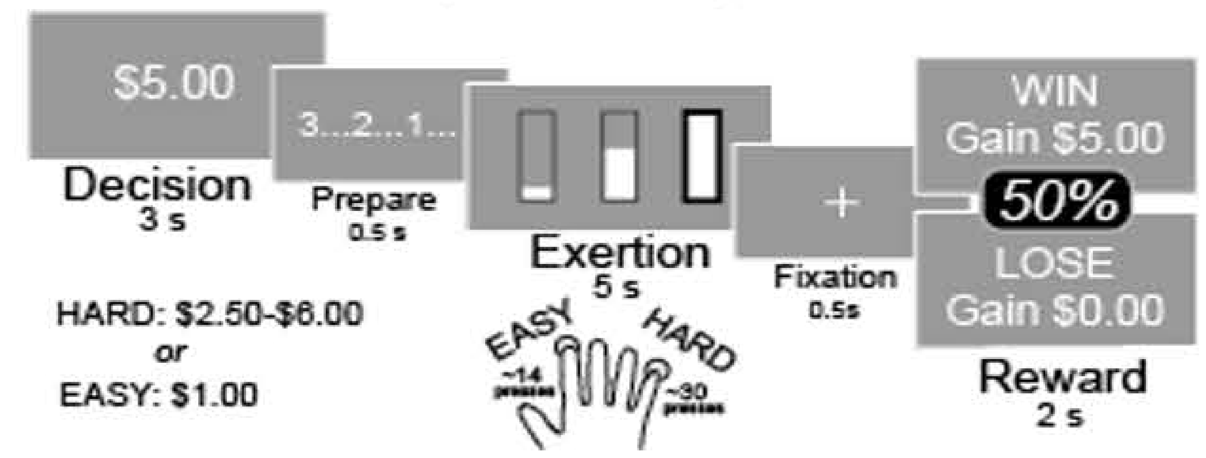


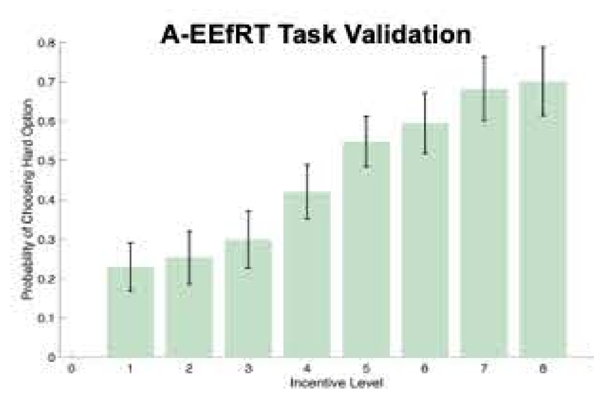
Figure 5. Complete preprocessed T1-MPRAGE (Sub011)

Adaptive Expenditure of Effort for Reward Task (A-EEfRT)



A-EEfRT Analysis

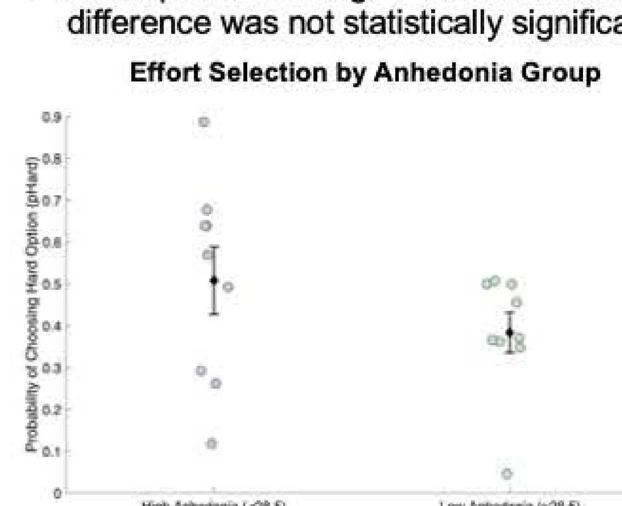
Behavior Results – Task Validation

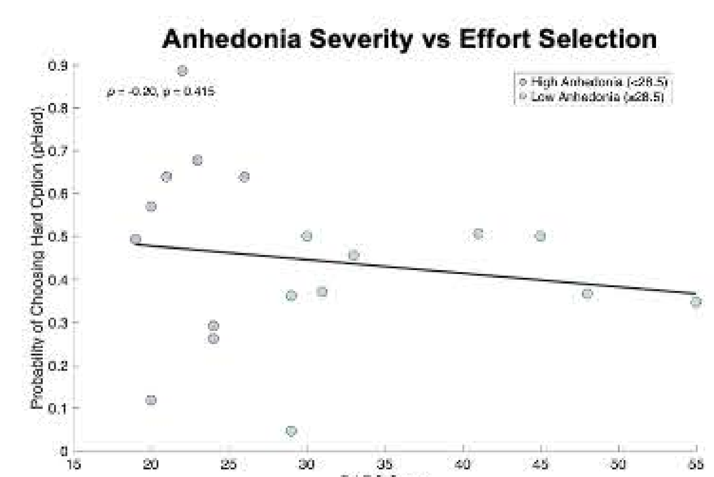


- Participants selected the high-effort option more frequently as incentive level increased, confirming that the A-EEfRT successfully captured reward-motivated effort ($F(1,17) = 89.53$, $p < .001$).
- Overall task performance indicated low failure rates (M = 0.10) and consistent response times (M = 0.95 s), suggesting participants remained engaged during effort-based decision making.

Symptom Correlations

- DARS scores were not correlated with hard-task choice probability, reward sensitivity, failure rate, or response time (all $p > .24$).
- Participants with higher anhedonia selected the hard option more frequently (d = 0.63), though this difference was not statistically significant.





Voxel Based Morphometry Results

- Voxel Based Morphometry (VBM) is a tool used to estimate structural brain changes between groups
  - Specifically, VBM tests differences in grey matter volume (GMV) in the whole brain
- Secondary analyses were run with small volume region-of-interest (ROI) sectioning based on hypothesized ROIs
  - Regions computed: Ventral striatum (and surrounding structures), orbitofrontal cortex, and anterior cingulate cortex

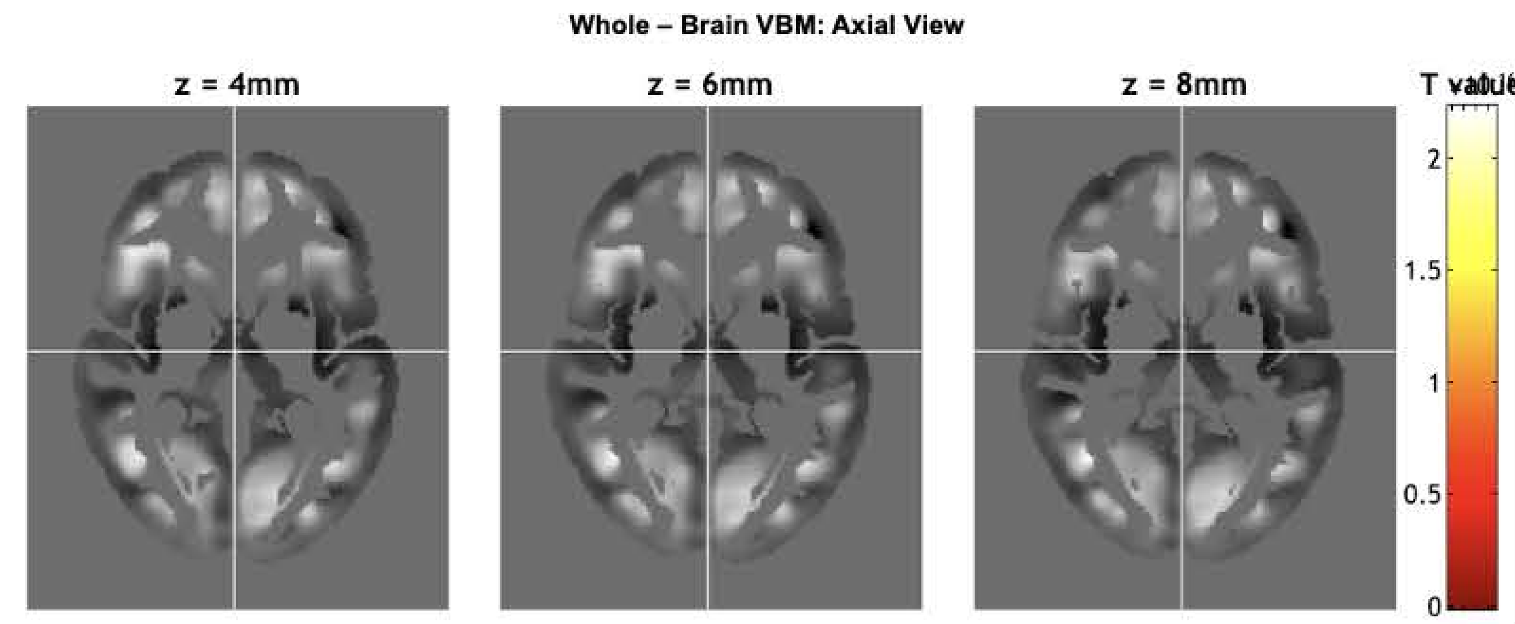
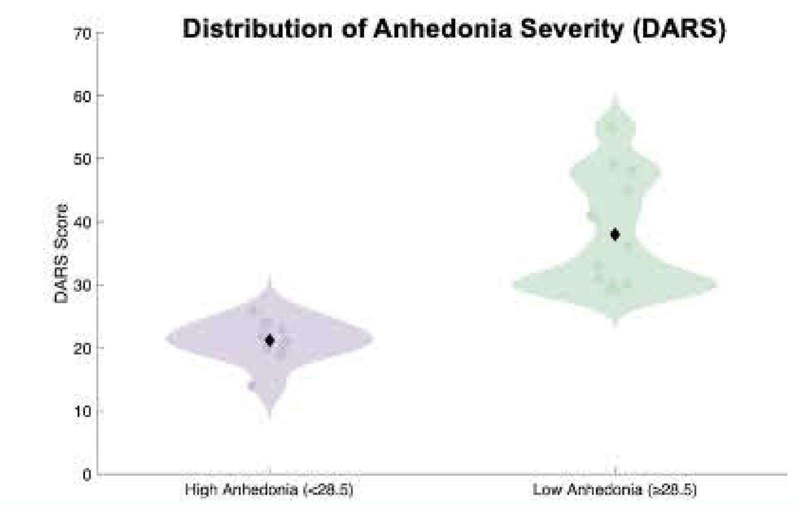


Figure 6. No evidence for whole-brain or ROI structural differences associated with anhedonia severity in this sample. No clusters survived thresholding ($p < .001$ uncorrected).

Anhedonia Group Dimensions

- The Dimensional Anhedonia Rating Scale (DARS) is a 17-item self report measure assessing pleasure, motivation, and effort across four domains (hobbies, food, social, and sensory)
- Using a 5-point Likert scale, lower scores indicate more severe anhedonia, while higher scores reflect greater reward experience

Figure 7. Participants were grouped using a cutoff of 28.5 to differentiate higher vs lower anhedonia. DARS scores ranged from 14–55 (M = 30.0, SD = 10.96)[7]



Conclusions

- Participants selected the high-effort option more frequently as reward magnitude increased, confirming that the task reliably measures reward-motivated effort
- Contrary to predictions, higher anhedonia scores were not significantly related to effort-based decision making or other behavioral metrics
- Participants with higher anhedonia demonstrated a moderate increase in hard-task choices, though this effect was not statistically significant and should be interpreted with caution
- Whole-brain and ROI VBM findings suggest that structural alterations linked to anhedonia may be more strongly reflected in functional neural dynamics rather than gray matter volume

Limitations

- The sample was relatively limited in symptom severity/range, which may have reduced sensitivity to detect associations with anhedonia
- Furthermore, VBM requires a robust sample size in detecting structural differences reliably
- While the A-EEfRT measured effort allocation, anhedonia may be more strongly reflected in other task metrics such as anticipation or valuation

Additional Information

Additional information (i.e. code) or questions can be directed to the primary author, Morgan Brown (mab23e@fsu.edu)

References

Future Directions

- We plan to analyze our high-density Electroencephalography (EEG) data through time frequency and phase amplitude coupling analyses to determine distinct oscillatory patterns during the A-EEfRT paradigm

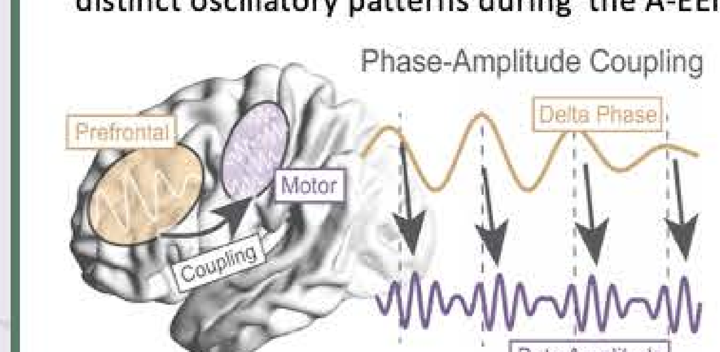


Figure 3. Previous research notes the role of frontal-midline delta waves coupling with beta waves in the motor cortex as the mechanism for translating reward-evaluation into goal-directed behavior

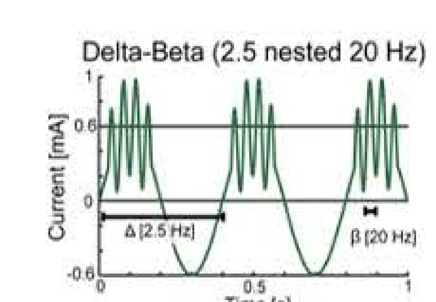


Figure 4. Representation of delta-beta cross-frequency transcranial alternating current stimulation (CF-tACS) pattern

- Additionally, we plan to assess how oscillatory dynamics were modulated via delta-beta CF-tACS introduced over a 5-day treatment paradigm while participants were received modified behavioral activation exercises

About the Lab

We are investigating the neural basis of cognitive control and its disruption in psychiatric illness. We use EEG and fMRI in combination with non-invasive brain stimulation (electric and magnetic) to understand how neural oscillations mechanistically support functional brain networks.

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Learn more at TheRiddleLab.org

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