Intrinsic Brain Activity, via Resting-State EEG, and Executive Functioning Abilities in Children with and without Autism Spectrum Disorder (ASD): The GENDAAR Study

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Background

Autism Spectrum Disorder (ASD) is a neurodevelopmental disorder characterized by social communicative impairments and restricted, repetitive behaviors (APA 2013).

- Children with ASD often have impairments in executive functioning (EF), a broad term for cognitive processes including working memory, planning, impulse control, inhibition, and mental flexibility
- Previous research has supported an executive functioning theory that has found direct links between executive functioning problems and restrictive, repetitive behaviors in children with ASD
- Intrinsic brain activity, measured by Resting-State Electroencephalography (RS-EEG), particularly activation of the beta (12-30 Hz), alpha (8-12 Hz), and theta (4-8 Hz) bands, has been shown to reflect memory and inhibition. Specifically, alpha power is associated with cognitive inhibition, beta power is associated with active task engagement, and theta power is related to memory processes (Wang, 2013)
- Prior RS-EEG research has found links between reduced theta and beta activation and increased alpha activation in children with ASD.

This study asked the following questions and hypothesized :

1. How will the whole-head alpha, beta, and theta activity levels compare for ASD and TD participants?
   Hypothesis: ASD participants will have higher theta and beta power and lower alpha power in comparison to TD participants
2. How will the theta-beta ratio differ for ASD and TD participants?
   Hypothesis: ASD participants will have a higher theta-beta ratio than TD participants
3. How will EF abilities in participants correlate with alpha, beta, and theta activity levels?
   Hypothesis: There is a negative correlation with alpha power and EF and a positive correlation with beta power and EF

Methods

Participants and Measures

109 participants with a confirmed diagnosis of ASD and 108 participants with typical development (TD) ages 8 to 17 (M=12.6, SD=2.88) with IQ in the average to above average range were included in this study.

Table 1: Details on the measures used in this study.

Area of Interest	Measure	Details
Intrinsic Brain Activity	Resting State EEG Alpha, Beta, and Theta Band Power	An EGI 128 channel Net Amps 300 system with HydroCel nets was used to collect EEG data. The EEG data was recorded at a 500 Hz sampling rate, referenced to a vertex electrode, and impedances were kept below 50 KΩ
Executive Function	Behavior Rating of Executive Function (BRIEF; Gioia, 2002)	A parent/teacher questionnaire that assesses executive functioning abilities. 8 clinical scales are measured to form 2 broader indexes: Behavior Regulation and Metacognition, and an overall score: the Global Executive Composite (GEC). Higher GEC scores indicate low EF abilities and lower GEC scores indicate high EF abilities

Table 2: Participants were separated by ASD diagnosis. Mean scores across two EF subindices and the GEC are noted.

Group	N	Behavioral Regulation Score	Metacognition Score	Global Executive Composite	Age in Years
ASD	109	M = 67.00 SD = 11.437	M = 68.76 SD = 11.139	M = 69.12 SD = 10.632	M = 12.28 SD = 2.834
TD	108	M = 42.12 SD = 4.991	M = 45.03 SD = 8.407	M = 43.30 SD = 6.814	M = 12.995 SD = 2.885

Results

Question 1: Whole-head alpha, beta, and theta activity levels

A series of independent sample t-tests for were run comparing ASD and TD participants on whole-head alpha, beta, and theta levels.

Table 3: Differences in alpha band activity for ASD and TD participants

Group	N	Alpha Levels	SD	p value	Confidence Interval of Difference
ASD	109	7.460	5.624	0.173	-2.609 to 0.471
TD	108	8.529	5.884		

Table 4: Differences in beta band activity for ASD and TD participants

Group	N	Beta Levels	SD	p value	Confidence Interval of Difference
ASD	109	6.136	4.167	0.328	-0.516 to 1.536
TD	108	5.626	3.466		

Table 5: Differences in theta band activity for ASD and TD participants

Group	N	Theta Levels	SD	p value	Confidence Interval of Difference
ASD	109	8.851	6.306	0.660	-1.120 to 1.886
TD	108	8.506	5.150		

- There were no significant differences in whole head RS-EEG levels in the alpha, beta, and theta bands between ASD and TD participants
- No significant differences were found after running an additional series of ANOVA tests comparing RS-EEG levels in the alpha, beta, and theta bands across participants separated into 4 groups based on EF scores and autism diagnosis. A median score of 54.5 on the GEC was used to subdivide ASD and TD groups into high and low EF groups

Question 2: Theta-Beta Ratio

A t-test was run to compare ASD and TD participants in their theta-beta ratios. A Pearson's correlation was run separately for ASD and TD participants to determine associations between EF scores and the theta-beta ratio. The theta-beta ratio was set as an independent variable and total GEC score as measured by the BRIEF was set as the dependent variable.

Table 6: Differences in the theta-beta ratio for ASD and TD participants

Group	N	Theta/Beta Ratio	SD	p value	Confidence Interval of Difference
ASD	109	1.564	0.747	0.631	-0.246 to 0.149
TD	108	1.613	0.729		

Table 7: Bivariate correlations between theta-beta ratio and GEC

Group	Theta-Beta ratio and GEC	
	r value	p value
ASD	-0.101	0.297
TD	-0.140	0.148

- There was not a significant difference in the theta-beta ratio between ASD and TD participants
- No significant differences were found after running an ANOVA tests comparing the theta-beta ratio across participants separated into 4 groups based on EF scores and autism diagnosis
- There was no significant correlation between the theta-beta ratio and the GEC score for ASD and TD participants

Results Continued

Question 3: EF Abilities and EEG Correlations

A series of Pearson's correlations were run for ASD and TD participants separately to determine associations between EF scores and RS-EEG activity levels. The whole-head alpha, beta, and theta activity levels were set as independent variables, and total GEC score, the Metacognition index, and the Behavioral Regulation Index as measured by the BRIEF were set as the dependent variables.

Table 8: Bivariate Correlation of Alpha, Beta, and Theta RS-EEG levels with GEC for ASD and TD participants

Group	Alpha and GEC		Beta and GEC		Theta and GEC	
	r value	p value	r value	p value	r value	p value
ASD	0.049	0.614	0.206	0.032	-0.101	0.297
TD	-0.201	0.037	-0.125	0.197	-0.140	0.148

- There was a significant positive correlation between beta band power and GEC scores for the ASD group
- There was a significant negative correlation between alpha power and GEC scores for the TD group
- No other significant correlations were found

Discussion

Summary

- The lack of significant differences in whole head RS-EEG in the alpha, beta, and theta bands between ASD and TD participants is consistent with some literature that finds no differences across these 3 bands for ASD and TD children (Chan, 2007) and inconsistent with other literature that found a significantly lower alpha power in ASD children in comparison to TD children (Neuhaus, 2021)
- The theta-beta ratio reflects cognitive processing and is typically higher in children with ADHD, although with high heterogeneity, when compared to TD children (Picken, 2020). However, no significant difference was found in this ratio between ASD and TD participants.
- The positive correlation of beta power and GEC for ASD participants and negative correlation of alpha power and GEC for TD participants warrants more research the use of EEG to distinguish between high EF and low EF ASD populations
- Further analysis revealed a significant positive correlation between frontal beta power and the behavioral regulation subindex measured by BRIEF

Limitations

- The large heterogeneity of ASD participants in this study as evidenced from the BRIEF scores may mean that significant differences between ASD and TD participants are unlikely without controlling for age, sex, IQ, or other factors
- The BRIEF, which is a parent-report measure of executive functioning, may not be as robust in measuring executive dysfunction for participants as a task-based activity
- This study only included ASD participants with IQ in the average to above average range meaning potential results are not generalizable to the entire ASD population

Future Directions

- Exploring correlations of executive functioning with EEG data and finding whether EF can serve as a moderator of relationships between ASD traits and EEG data might be a useful next step to learn more about the heterogeneity of ASD

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