Effects of Age and Cognitive Ability on Maturation of Resting-State Peak Alpha Frequency in Children with Autism

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Background

- Electroencephalographic (EEG) peak alpha frequency (PAF) represents a marker of neural maturation[1] that typically increases with age throughout childhood.[2]
- Abnormal maturation of PAF is observed in children with autism spectrum disorder (ASD), and these differences appear to depend upon age.[3]
- In contrast to TD peers, PAF in young children with ASD has been shown to be associated with cognitive ability rather than age.[4]

Objective: The current study aimed to clarify and extend previous findings by assessing the effects of age, cognitive ability, and diagnostic status on PAF in a sample of children and adolescents with and without ASD.

Methods

Participants	n (female)	Age in years (SD) range	NVIQ (SD) range
ASD	54 (15)	14.1 (2.4) 9.1 – 17.9	104.1 (15.7) 75 – 137
TD	48 (23)	12.9 (2.6) 9.0 – 18.0	104.9 (12.8) 83 – 136

Table 1. Participant demographics.

Behavioral Measures
- ASD diagnoses were confirmed with the *Autism Diagnostic Observation Schedule (ADOS-2)* and clinician endorsement of DSM-5 criteria for ASD.
- Cognitive ability was assessed with the *Differential Ability Scales-II (DAS-II)*; the special nonverbal composite (SNC) standard score was used as a proxy for nonverbal IQ (NVIQ).
- Autism-specific social impairment was measured with the *Social Responsiveness Scale (SRS-2).*

EEG Acquisition and Analysis
- Resting EEG data (with eyes closed) was recorded at 1000 Hz with a 128-channel Hydrocel Geodesic sensor net.
- At least 30 seconds of artifact free EEG data were available for each participant.
- Spectral power was extracted from and averaged across occipital electrodes (Figure 1).
- PAF was calculated as the alpha frequency (6 – 12 Hz) at which power was maximal.
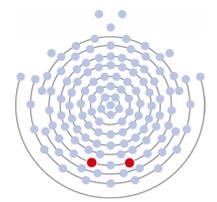
Figure 1. Electrodes included in analysis.

Statistical Analysis
- An independent samples t-test was used to evaluate between-group differences in PAF.
- Pearson correlations were used to examine bivariate relations between PAF, NVIQ, age, and ASD symptomatology.
- A multiple regression model was used to assess the incremental and joint effects of age, NVIQ, and diagnosis (TD vs. ASD) on PAF.

Results

- Mean PAF did not differ across TD (M = 9.69, SD = 0.77) and ASD (M = 9.79, SD = 0.75) groups (Figure 2).
- Age was positively associated with PAF in both TD and ASD groups (Figure 3).
- NVIQ was not associated with PAF in either the ASD (r(46) = .112, p > .05) or TD (r(38) = .130, p > .05) group.
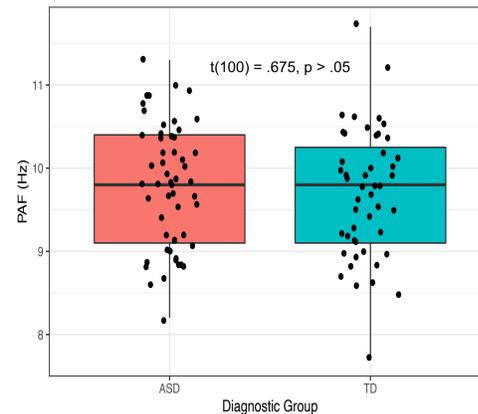
Figure 2. Distribution of PAF across ASD and TD groups.
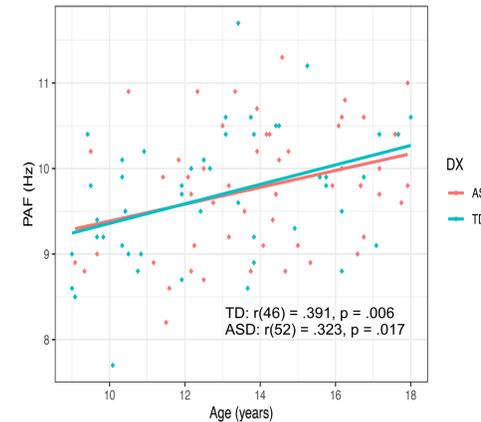
Figure 3. Positive relationship between age and PAF across ASD and TD groups.

- A multiple regression model with Age, NVIQ, and Diagnosis as predictors significantly predicted PAF (F(7, 80)= 2.78, p=.012, R^2=.196).

- **The significant three-way Age x NVIQ x Diagnosis interaction effect (p = 0.045)** indicates that the relationship between NVIQ and PAF:
  - Shifts from negative to positive as a function of age in TD children
  - Remains stable and slightly positive in ASD irrespective of age.

Predicted Values of Peak Alpha Frequency
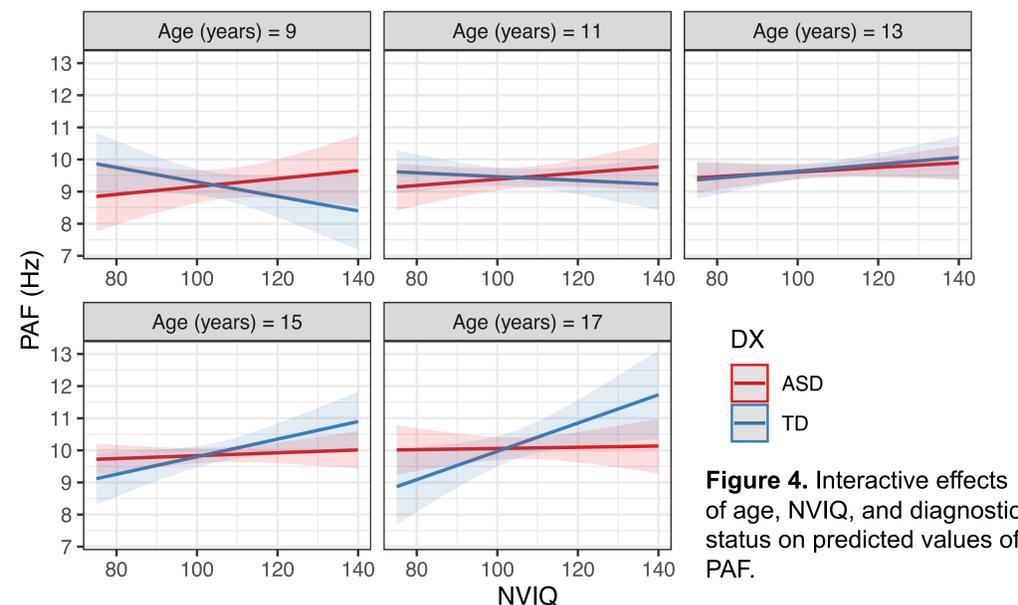
Figure 4. Interactive effects of age, NVIQ, and diagnostic status on predicted values of PAF.

Results

- PAF was positively associated with ADOS-2 Restricted and Repetitive Behaviors (RRB) scores in the ASD group (Figure 5).

- PAF was not related to any other measures of ASD symptomatology on the ADOS-2 or SRS-2.
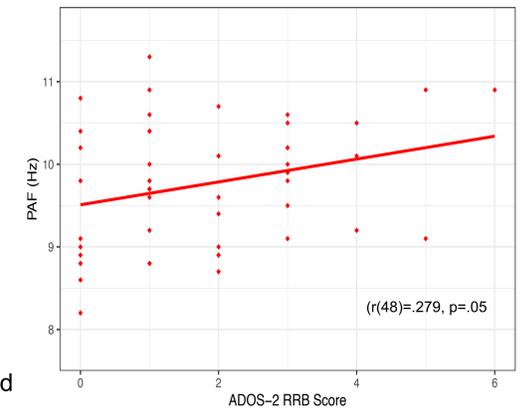
Figure 5. Positive relationship between ADOS RRB scores and PAF.

Conclusions

- Whereas previous studies utilizing younger ASD samples indicated the absence of association between age and PAF[4], current results indicated that age was positively associated with PAF in both ASD and TD groups.

- Notably, there was a significant 3-way **Age x NVIQ x Diagnosis** interaction when predicting PAF in a linear model.

  - The relationship between NVIQ and PAF shifted from negative to positive in the TD group during middle adolescence (13 years old).
  - By contrast, the ASD group maintained a stable relationship between NVIQ and PAF throughout adolescence, indicating a different trajectory of neural maturation.

- Findings underscore the importance of examining resting-state neural rhythms in relation to age and cognitive function to capture sensitive developmental periods of atypical neural maturation in ASD.

References

1. Miskovic, V., Ma, X., Chou, C.-A., Fan, M., Owens, M., Sayama, H. & Gibb, B.E. (2015) Developmental changes in spontaneous electrocortical activity and network organization from early to late childhood. *NeuroImage*, 118, 237–247.

2. Chiang, A. K. I., Rennie, C. J., Robinson, P. A., Van Albada, S. J., & Kerr, C. C. (2011). Age trends and sex differences of alpha rhythms including split alpha peaks. *Clinical Neurophysiology*, *122*(8), 1505-1517.

3. Edgar, J. C., Dipiero, M., McBride, E., Green, H. L., Berman, J., Ku, M., ... & Roberts, T. P. (2019). Abnormal maturation of the resting-state peak alpha frequency in children with autism spectrum disorder. *Human Brain Mapping*, 40(11), 3288-3298.

4. Dickinson, A., DiStefano, C., Senturk, D., & Jeste, S. S. (2018). Peak alpha frequency is a neural marker of cognitive function across the autism spectrum. *European Journal of Neuroscience*, *47*(6), 643-651.

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