Autism, Attention, and Alpha Oscillations: An Electrophysiological Study of Attentional Capture

Supplemental Information

Supplemental Methods and Materials

Participants

Of the final sample of 19 children with ASD and 21 TD children included in the present study, 15 ASD and 20 TD children participated in our previous report (1).

RSVP

Digits subtended approximately 1º by 1.3º visual angle and peripheral streams were located at 5.1º to the left and right of the central stream. Target present and absent trials were separated by 2.4 to 6.24 seconds (i.e., 5 to 13 null trials of 480ms duration each). Only responses occurring between 200 and 2400ms after the onset of a target were included. Participants completed 16 blocks, each 3 minutes long and containing 10 trials per condition and 325 null trials for a total of 160 trials per condition and 5200 null trials across the 16 blocks.

Baseline Number Task

To ensure that any group differences in accuracy were not due to general impairments in numerical processing, participants also completed a baseline number task after the experimental paradigm. The task consisted of one block of 60 trials. For each trial, a single grey number (0–9) was displayed in the center of the screen and remained onscreen until the participant responded. Similar to the primary experimental task, participants responded via a dominant-hand, two-choice, button-box response as to whether the number was between 0 and 4 or 5 and 9 (left button ≤ 4; right button ≥ 5) and were instructed to respond as quickly as possible without making errors.

Eye-tracking

Eye movements were recorded at a sampling rate of 500Hz using a SR Research Eyelink 1000 remote eye-tracking system. A rectangular region of interest (ROI) was drawn around the center number location and two contiguous and identical rectangular ROIs were drawn around both the left and right peripheral distractor locations (see Figure 1). The width of each ROI was fixed and was determined by selecting the midpoint between the target and distractor. Two dependent measures were calculated from eye-tracking data: 1) percentage of fixations in center ROI, and 2) percentage of distractor-driven saccades. Percentage of fixations to center ROI for all trials was determined by dividing trials with a center fixation by the total number of trials presented. To identify distractor-related eye movements, saccades originating in the central ROI and directed to the peripheral ROIs were identified. Only saccades directed towards ROIs in which the target- and non-target-colored distractors appeared were included. Additionally, saccades with a latency of less than 80ms from the onset of the colored distractors were considered anticipatory and removed. For each trial type, the percentage of distractor-directed saccades was calculated based on the number trials with acceptable saccades divided by the total number of trials for that condition.

Resting State EEG

Epochs were rejected if they exceeded a threshold of ±150 μV or a sample-to-sample threshold of 50 μV. Artifact-free resting state EEG were analyzed using the EEGLAB function spectopo, which applies a hamming window and computes power spectral density with the frequency resolution of 0.5 Hz.

Supplemental Results

Baseline Number Task

Error rates and median RT for correct trials were entered into a 2 (group: ASD, TD) x 2 (number: ≤ 4, ≥ 5) mixed-model repeated-measures ANOVA. Four individuals did not complete the baseline task (ASD = 2; TD = 2). For error rate, there was no significant main effect of group (ASD = 6.7%, TD =

3.7%), $F(1, 34) = 1.93$, $p = .17$, $\eta_p^2 = .05$, nor a significant number ´ group interaction, $F(1, 34) = 0.27$, $p = .61$, $\eta_p^2 = .00$. Likewise for RT, there was no main effect of group (ASD = 664ms; TD = 584ms), $F(1, 34) = 2.54$, $p = .12$, $\eta_p^2 = .07$, nor a significant number ´ group interaction, $F(1, 34) = 0.09$, $p = .77$, $\eta_p^2 = .00$, suggesting that there were no group differences in numerical processing.

Eye-Tracking

Four participants (ASD = 3; TD = 1) did not have usable eye-tracking data due to calibration issues. Percentage of fixation within the center ROI was high for both groups (ASD = 97%; TD = 98%), and there was no significant difference between the groups, $t(34) = -0.57$, $p = .57$, indicating that ASD and TD groups were attending equally to the central stream. Analysis of eye-tracking data also permits examination of attentional capture in the absence of an overt manual response in target absent trials. For target absent trials, the percentage of trials with distractor-driven saccades was entered into a 2 (group: ASD, TD) x 2 (distractor type: TC, NTC) mixed-model repeated measures ANOVA. There was no difference in percentage of distractor-driven saccades between groups (ASD = 2.0%; TD = 1.0%), $F(1, 34) = 1.83$, $p = .19$, $\eta_p^2 = .05$, nor were there significant interactions between group and distractor type, $F(1, 34) = 1.40$, $p = .25$, $\eta_p^2 = .04$. However, there was a significant main effect of distractor type, $F(1,34) = 5.12$, $p = .03$, $\eta_p^2 = .13$, with a greater percentage of distractor-driven saccades to target-colored (2.0%) compared to non-target-colored (1.0%), indicating that target-colored distractors were more likely to result in an overt shift of attention to the distractor location. Smaller amplitude saccades that do not terminate in the left or right ROI may nevertheless also reflect capture by peripheral distractors. A separate analysis was conducted on leftward and rightward saccades that originated in the center ROI but may not have been of sufficient amplitude to reach peripheral ROI. Similarly, there was a main effect of distractor type, $F(1, 34) = 12.56$, $p = .001$, $\eta_p^2 = .27$, and no interaction between group and distractor type, $F(1, 34) = 1.36$, $p = .25$, $\eta_p^2 = .04$, as both groups made more saccades to TC (M = 7%) compared to NTC (M = 4%) distractors. In contrast, there was a marginally significant main effect of group (ASD = 7%, TD = 4%), $F(1, 34) = 3.64$, $p = .065$, $\eta_p^2 = .1$.

Supplementary Table S1. Outline of Target Absent and Present Conditions for Each Distractor Type

	Peripheral distractor color		
	Gray (N)	Red (TC)	Green (NTC)
Target absent	Null trials (92%)	Absent target-colored (A-TC; 1.6%)	Absent non-target-colored (A-NTC; 1.6%)
Target present	Present neutral (P-N; 1.6%)	Present target-colored (P-TC; 1.6%)	Present non-target-colored (P-NTC; 1.6%)

Percentage of total trials listed in parentheses

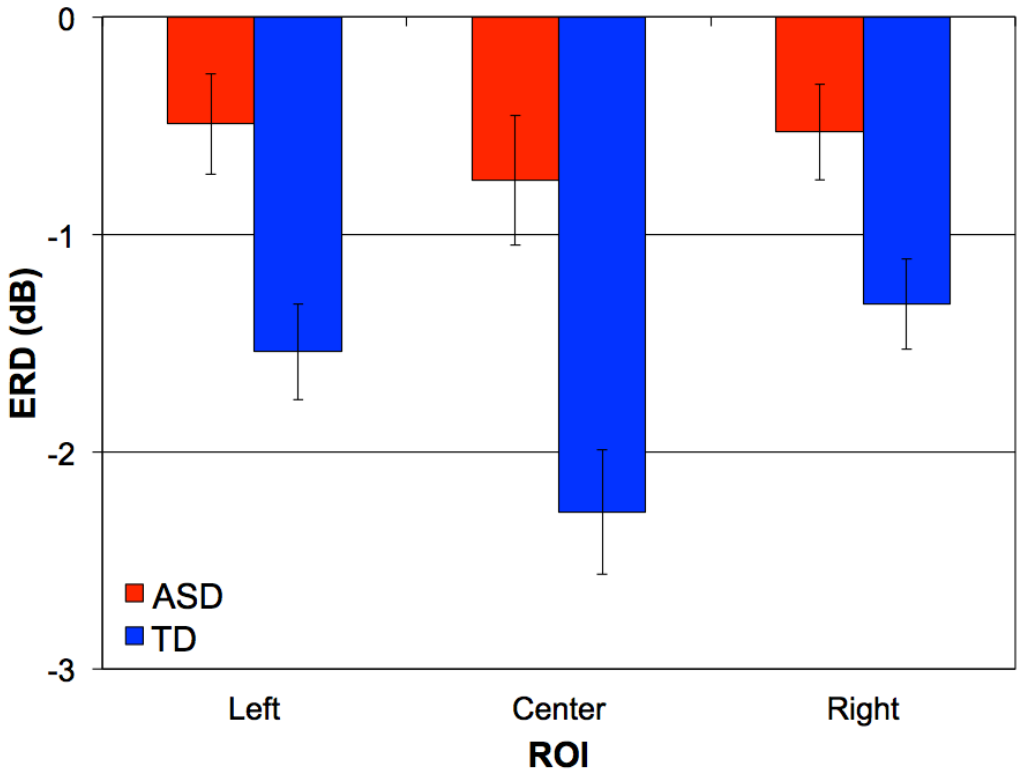
Supplementary Table S2. Proportion of Usable Trials

	ASD (n = 19)	TD (n = 21)	*t*-value	*p*
Target present neutral (P-N)	.87 (.16)	.92 (.08)	-1.09	0.28
Target absent target-colored (A-TC)	.89 (.14)	.92 (.08)	-0.81	0.43
Target absent non-target-colored (A-NTC)	.89 (.13)	.92 (.08)	-0.89	0.38
Resting state	.59 (.17)	.60 (.23)	-0.27	0.79

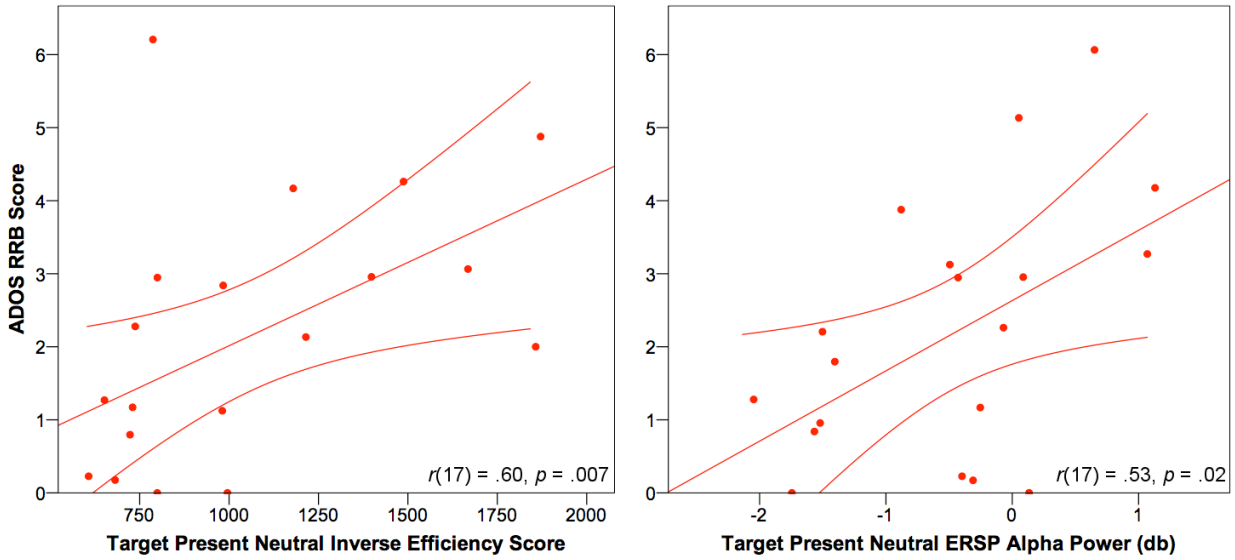
Supplementary Table S3. Correlations between ADOS scores and P-N behavioral and alpha ERD measures

	ADOS scores		
	Communication	Social	Repetitive behavior
Inverse Efficiency Score	.05	.26	.60**
Alpha ERD			
Left ROI	.25	.10	.53*
Center ROI	.29	.18	.33
Right ROI	.15	-.00	.47*

* $p < .05$, ** $p < .01$



Supplementary Figure S1. Average alpha (8 – 12 Hz) event-related desynchronization (ERD) from 400 to 700ms at posterior ROIs (error bars represent ± 1 SEM).



Supplementary Figure S2. Scatterplot of ADOS Restricted and Repetitive Behavior (RRB) score and target present neutral (P-N) inverse efficiency (IE) score (left) and target present neutral event-related spectral perturbations (ERSP) alpha power for the left region of interest (right) for the ASD group.

Supplemental Reference

1. Keehn B, Nair A, Lincoln AJ, Townsend J, Muller RA. Under-reactive but easily distracted: An fMRI investigation of attentional capture in autism spectrum disorder. Dev Cogn Neurosci. 2016;17:46-56. doi: 10.1016/j.dcn.2015.12.002. PubMed PMID: 26708773; PMCID: PMC4728050.