Neurocognitive Factors Associated with Neural Specialization for Letters in ASD

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Background

Neural Specialization in ASD
• Problems with neural specialization for social information are hypothesized to negatively impact social functioning in ASD
• Recent evidence suggests that children with ASD display normative patterns of specialization for non-social information such as alphabet letters (McPartland et al., 2011)
• Event-related potentials (ERPs) demonstrate similar time course and morphology for specialized face and letter perception at occipitotemporal sites (N170)

Visual Word Form Area (VWFA)
• Left fusiform gyrus demonstrates neural specialization for perception of visual stimuli
  ○ VWFA is a neural generator of the N170
  ○ Words and letter strings activate left fusiform gyrus to a greater degree than similar non-letter stimuli, such as symbols (Maurer, Brandeis, & McCandliss, 2005)
  ○ Stronger left N170 is associated with higher levels of visual expertise for letters and words (McCandliss, Cohen, & Dehaene, 2003)
• Greater activity in the left fusiform gyrus is associated with rapid reading ability

Reading Proficiency in ASD
• An estimated 5-10% of children with ASD display hyperlexia (Newman et al., 2007), characterized by advanced reading skills and a high level of interest in reading words
• Children with hyperlexia can read words precociously, but this advanced skill does not necessarily extend to comprehension of words
• Scant research on neural correlates of letter and word processing in ASD
• Understanding the brain bases of letter perception and their behavioral correlates holds potential to clarify areas of strength in ASD and to inform strategies to target compensatory function

The current investigation aimed to:
1. Explore neural and behavioral correlates of letter perception in children with ASD
2. Examine variability in neural responses to letters as a function of
   a. Performance on standardized assessments of word decoding
   b. Verbal cognitive abilities
   c. Functional use of verbal and written language in daily life and communication

Method

Participants
• 36 children with ASD as determined by ADOS and DSM-IV-TR diagnosis
• 18 children with typical development matched for sex, handedness, age, and IQ

Table 1. Participant Demographics

	TD (N=18)	ASD (N=36)
Number Male (%)	15 (83.3)	32 (88.9)
Number Right-Handed (%)	16 (88.9)	31 (86.1)
Number White (%)	15 (83.3)	34 (94.4)
Mean Age (SD)	12.6 (2.4)	11.2 (3.4)
Mean Full Scale IQ (SD)	112.9 (13.4)	105.2 (15.0)

ERP Data Acquisition
• ERPs recorded continuously at 250 Hz
• 256 electrode Geodesic sensor net
• Data averaged across eight electrodes over left (95, 96, 97, 106, 107, 108, 116, 117) and right (151, 152, 153, 160, 161, 162, 170, 171) lateral posterior scalp
• Extracted N170 peak amplitude

ERP Data Extraction
• Artifact detection and replacement of bad channels
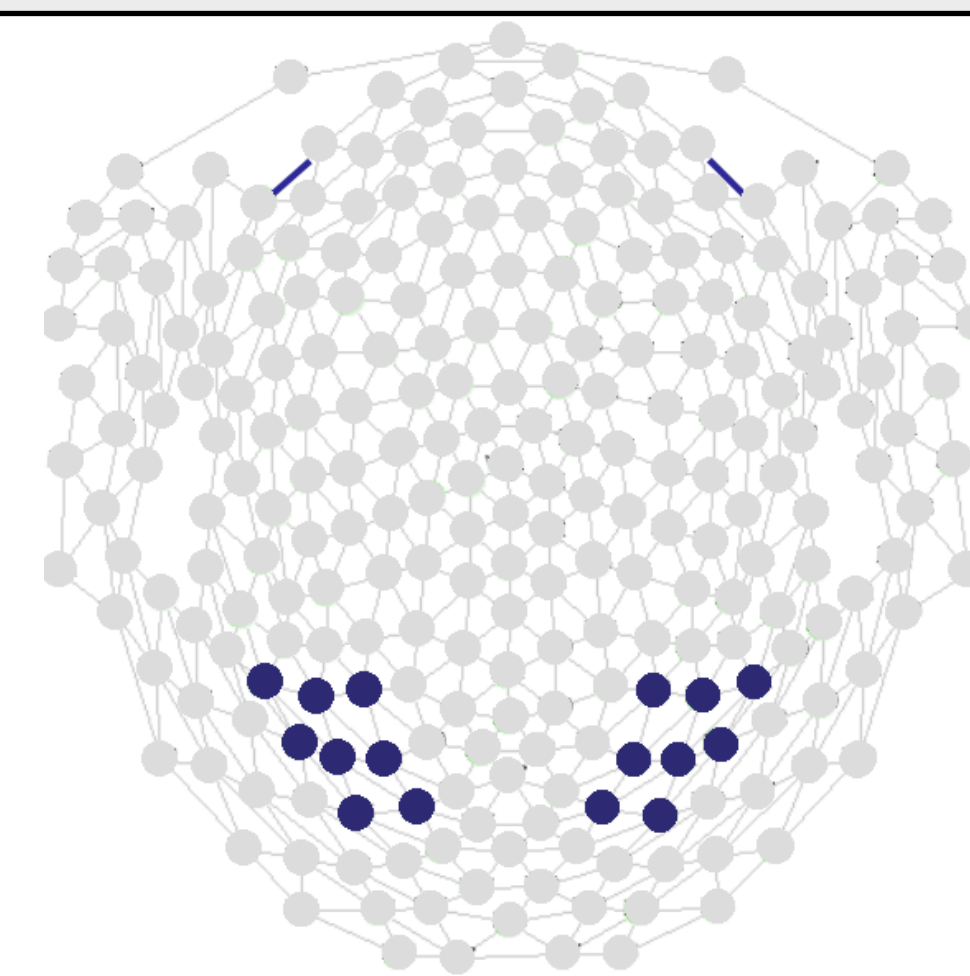• Segmentation window set at 100ms pre-stimulus onset to 500ms post-stimulus onset

Figure 1. Electrodes included in ERP extraction highlighted in blue

Method

Behavioral Measures
• Woodcock-Johnson Tests of Achievement-III
  ○ Letter-Word Identification: Single word reading
  ○ Word Attack: Novel word decoding
• Vineland Adaptive Behavior Scales, Communication subscale
  ○ Expressive, receptive, and written communication skills
• Benton Facial Recognition Test
• Verbal component of IQ

Figure 2. Examples of letter (blue) and pseudoletter (orange) stimuli

Study Design
• Two blocks of stimuli presented in a counterbalanced and pseudo random order, with 92 stimuli from each category
  ○ Block 1: faces, houses, and inverted houses (not included in current analysis)
  ○ Block 2: Roman letters and pseudoletters
• Trial: Crosshair(250-750 ms)→Stimulus(500 ms)→Blank Screen(500ms)

Statistical Analyses
• Repeated measures ANOVA for N170 amplitude in the left hemisphere with condition as within-subjects factor (letter vs. pseudoletter)
• Bivariate correlations between Vineland Communication and difference scores for left N170 amplitude in letter and pseudoletter conditions
  ○ To explore correlation, contrasted results for individuals with ASD and higher/lower Vineland Communication scores (median split)
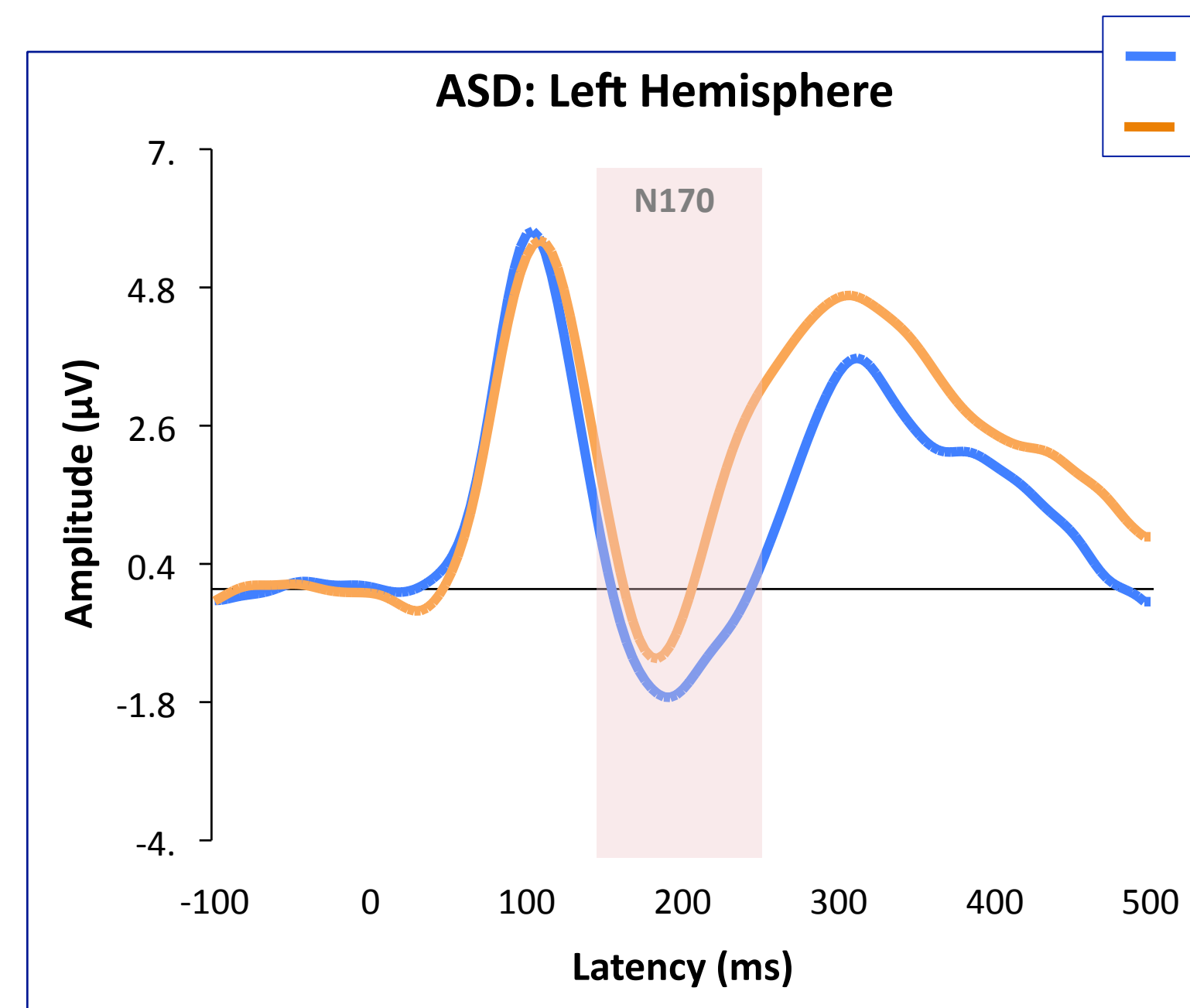
Results

Figure 3. Grand averaged waveforms for children with ASD demonstrate increased amplitude for letters in the left hemisphere
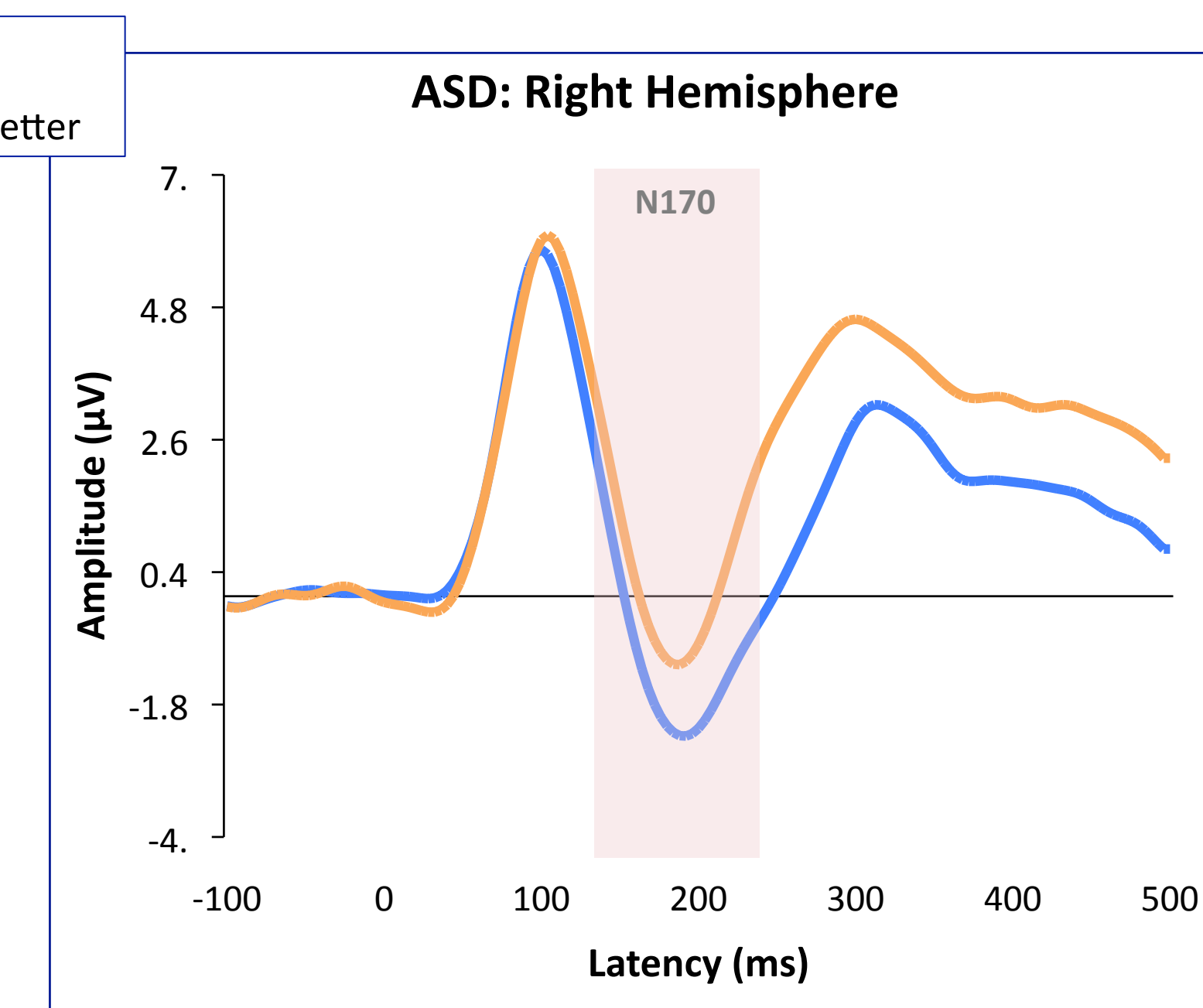

Figure 4. Grand averaged waveforms for children with ASD demonstrate increased amplitude for letters in the right hemisphere
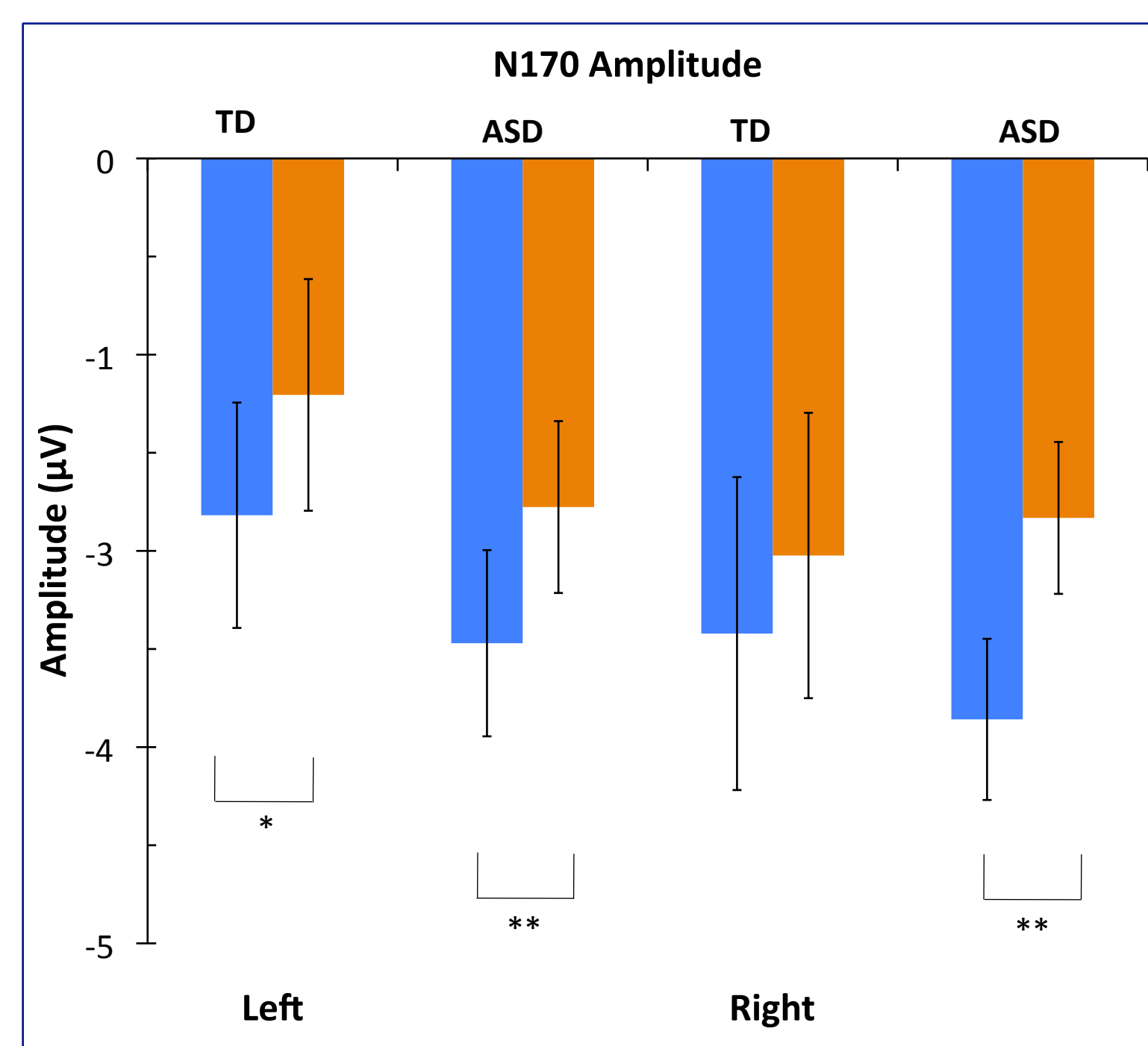

Figure 5. N170 amplitude indicates differentiation between letters and pseudoletters for the ASD group across both hemispheres, and for the TD group only in the left hemisphere
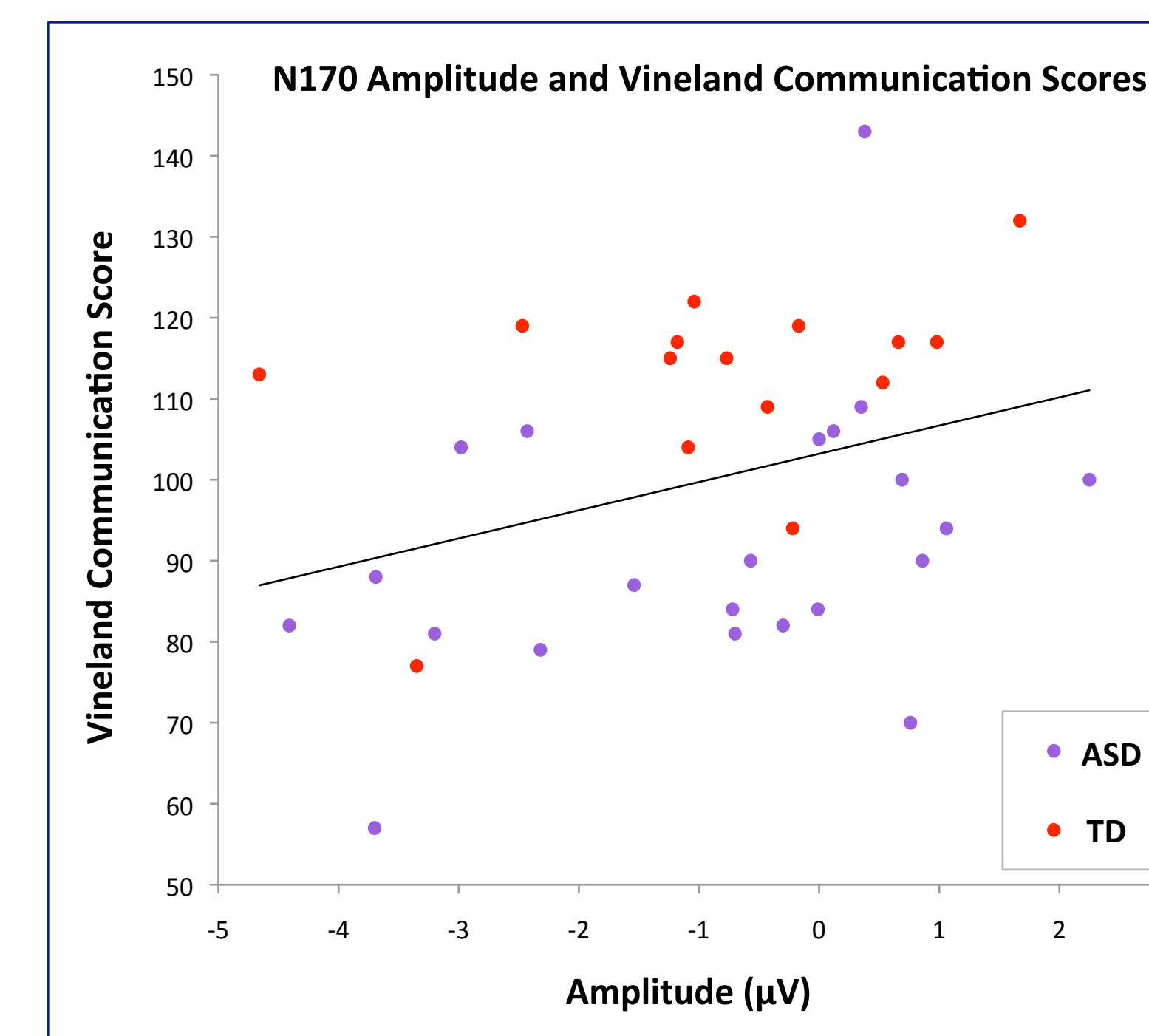

Figure 6. Correlations show that greater ERP difference scores for left N170 amplitude between letter and pseudoletter conditions predict higher Vineland Communication scores

Results

ERP Results
• Across both groups, children exhibited greater N170 amplitude in response to letters than pseudoletters, $F(1, 52) = 14.67$, $p \leq .01$
  ○ ASD group: letters elicited greater N170 amplitude than pseudoletters in both the left hemisphere, $t(1, 35) = 2.90$, $p \leq .01$, and right hemisphere, $t(1, 35) = 3.34$, $p \leq .01$
  ○ TD group: letters elicited greater N170 amplitude than pseudoletters in the left hemisphere, $t(1, 17) = 2.12$, $p \leq .05$

ERP-Behavioral Correlations
• Communication scores of the Vineland Adaptive Behavior Scales correlated with greater differences between N170 amplitude in letter and pseudoletter conditions across diagnostic categories in the left hemisphere ($r = 0.330$, $p \leq .05$)
  ○ Higher adaptive communication skills are associated with greater specialization for letters (increased N170 amplitude for letters relative to pseudoletters)

Within-ASD Difference in Adaptive Communication
• Individuals with lower Vineland Communication scores exhibited a main effect for condition, $F(1, 9) = 8.74$, $p \leq .05$, such that letters elicited a more negative N170 amplitude
• Individuals with higher scores on the Vineland Communication subtest did not exhibit a main effect for condition, $F(1, 10) = .484$, $\leq .05$, such that N170 amplitude did not differ between letter and pseudoletter conditions
• These findings indicate increased specialization for letters among individuals with ASD and lower communication skills relative to those with stronger communication

Conclusions

• Children with ASD demonstrate intact specialization for letters relative to pseudoletters. However, the ASD group's differentiation for letters and pseudoletters in both hemispheres suggests recruitment of right hemisphere regions typically involved in face perception

• Across groups, neural specialization for letters in relation to pseudoletters predicts greater communication skills in the areas of expressive, receptive, and written communication skills

• Within the ASD group, greater specialization for letters was most pronounced in individuals with lower adaptive communication skills

• The paradoxical relationship between specialization and adaptive communication in ASD suggests that, for some children, enhanced specialization may reflect circumscribed interest rather than functional ability (e.g., hyperlexia)

• Further research is required to determine whether specialization among children with ASD and lower adaptive communication abilities reflects a functional strength or neural specialization driven by non-functional interest in letters

Future Directions

• Explore neural correlates of reading fluency and comprehension in children with ASD with hyperlexic traits and specialized interests relating to words and letters

• Investigate neural specialization for words and pseudowords in addition to letters and psuedoletters, given that the visual properties are more similar to faces and entail holistic processing

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