The Time-Locked Neurodynamics of Semantic Processing in Autism Spectrum Disorder: An EEG Study

Azilee Curl, B.S. & Emily L. Coderre, PhD.
Department of Communication Sciences and Disorders, University of Vermont, Burlington, VT

The University of Vermont

THE UNIVERSITY OF VERMONT COLLEGE OF NURSING AND HEALTH SCIENCES

BACKGROUND

- Individuals with Autism Spectrum Disorder (ASD) often have difficulties with various aspects of language processing, including *semantic processing:* the ability to receive a stimulus and apply meaning based on previously stored knowledge [1]
- The *N400 Effect*, an established ERP component elicited upon recognition of a disruption in semantics, occurs from approximately 300-500 ms [2] and is generally reduced or absent in response to linguistic stimuli in ASD [3], suggesting impairments in semantic processing
- This difficulty with semantic processing could arise from an impairment in the language system (**Fig. 1a**). However, findings of intact word decoding and hyperlexia [4] in ASD rule out this scenario.
- Alternatively, the semantic processing system could be impaired in ASD (**Fig. 1b**). However, findings of intact semantic processing of non-linguistic stimuli like pictures and environmental sounds [3,5] rule out this scenario.

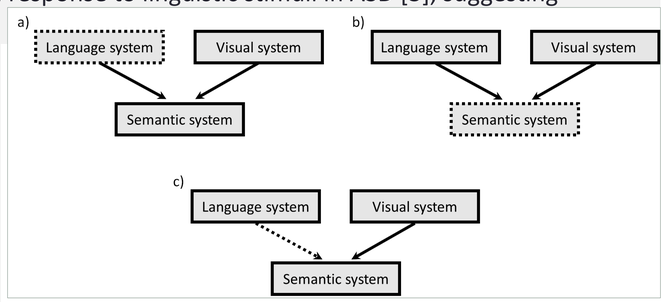

Fig. 1: Theoretical model of lexico-semantic impairments in ASD

- A final possibility is that the connections between the language and semantic systems are impaired (**Fig. 1c**). This has been proposed by previous neuroimaging work finding atypical structural connectivity in ASD brains, notably in left fronto-parietal areas (linked to semantic/language processing) and their connections [6]
- However, the temporal aspects of this underconnectivity remain unclear.
  - If impaired communication occurs in pre-semantic time windows, underconnectivity should be apparent before N400 onset.
  - If impaired communication occurs at post-lexical integration steps, underconnectivity should be apparent after N400 offset.
- *EEG coherence* time-locks changes in coherence (the synchronicity of oscillations) to specific events or changes in stimuli, recording changes in the timecourse of neural activation and connectivity [7]
- Identifying the temporal focus of underconnectivity during lexico-semantic processing could provide important insights into which particular aspect of neural communication is going awry.

METHODS

The data used here is the same as that reported in our prior study examining the N400 ERP component in this paradigm [5]. The participants and experimental methods described here can also be found in that publication.

Participants
- 20 adults with ASD (M = 28 years); 20 typically-developing (TD) participants (M = 25 years).
- Groups matched on age (p=0.34). Groups differed on receptive vocabulary (p=0.07) and verbal/non-verbal IQ (p<0.05); these were included as covariates in analyses.

Stimuli and Procedure
- Participants viewed pairs of pictures or pairs of words that were semantically related or unrelated (100 pairs per trial type).
- Participants monitored for "catch trials" (16% of stimuli) in which a smiley face (picture blocks) or consonant string (word blocks) were presented, and were instructed to hit a button when they saw the catch stimulus. Catch stimuli were not included in analyses.

EEG Data Acquisition, Preprocessing, and Analysis
- EEG data recorded at 500 Hz using a 128-channel Geodesics Sensor net and NetStation 5.3.
- Data bandpass filtered from 0.1-50 Hz and segmented into epochs time-locked to the onset of the first stimulus.
- Time-frequency analysis of theta band (3.5-7 Hz); Morlet wavelet of 2 cycles with expanding factor of 0.5 and Hanning taper.
- Coherence calculated for 12 intrahemispheric electrode pairs based on 9 electrodes taken from the 10-20 distribution system [8]; at 393 frequencies from 2-50 Hz (approximately every 0.1 Hz) and at 300 time points from -242 ms to 2440 ms around first stimulus
- Theta frequency band defined as 3.5-7.5 Hz

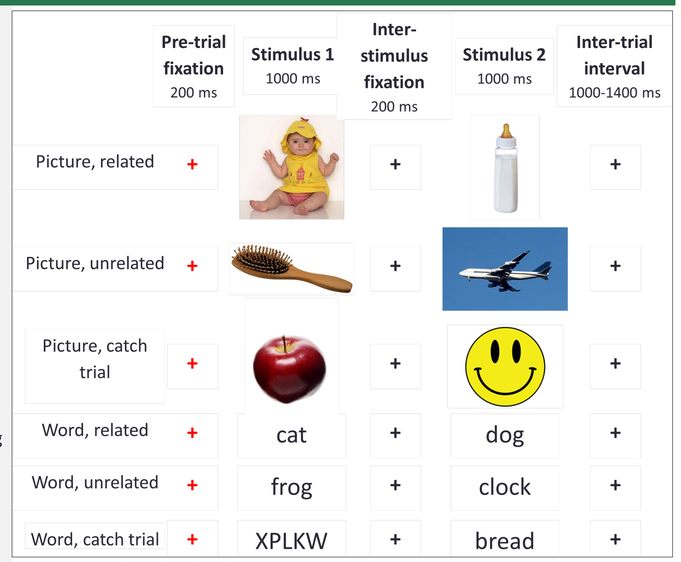

Fig. 2: Examples of stimuli from the experimental paradigm

RESULTS

- Early after the first and second stimuli (100-300 ms), the TD group showed large peaks in theta coherence at fronto-parietal connections (F3-P3 and F4-P4).
- After both word stimuli, the ASD group showed trends of reduced theta coherence at the left fronto-parietal pair (F3-P3; all p's<0.07) but not the right fronto-parietal pair (F4-P4; all p's>0.86); no group differences for pictures.

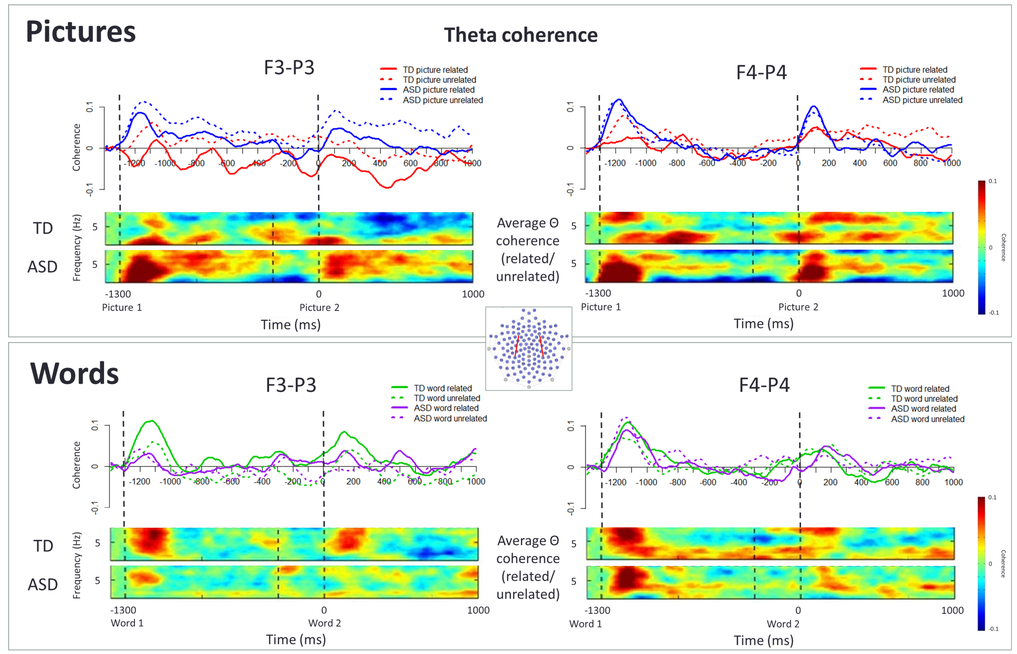

Fig. 3: Theta coherence at left fronto-parietal (F3-P3) and right fronto-parietal (F4-P4) electrode pairs. Top: line graphs of averaged theta coherence over the entire frequency band in each group and condition. Bottom: full frequency distribution in the theta band.

CONCLUSIONS

- The observation of group differences in early (100-300ms) peaks in theta coherence at left fronto-parietal connections, in the language domain only, supports our prediction that neural connectivity during lexico-semantic processing is selectively impaired.
  - This underconnectivity was absent in the analogous right-hemisphere pair, replicating prior findings that underconnectivity in ASD is more prominent in left fronto-parietal areas [6].
- Our data identify a clear temporal locus of underconnectivity: 100-300 ms after stimulus presentation, clearly before the onset of the N400 ERP component.
- In accordance with a recent model [9], early increases in theta coherence could represent semantic information flowing from temporal to frontal areas (rising phase of the N400).
- Future directions include an extension to fMRI, where we plan to replicate the paradigm to confirm that underconnectivity is centered around the left-hemisphere connections.

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