Neural connectivity during semantic processing of pictures and spoken words in autism spectrum disorders

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Introduction

Autism is a pervasive developmental disorder that manifests in a wide variety of cognitive deficits. Complex language is especially impaired in autism spectrum disorders (ASD), particularly higher-level functions like semantic integration and pragmatics (Tager-Flusberg et al. 2005).

In ERP studies of language processing, the N400 indexes semantic integration, showing a reduced negative amplitude for congruent semantic contexts compared to incongruent contexts (Kutas & Federmeier, 2010). Individuals with ASD show reduced or absent N400 effects compared to controls (e.g. McCleery et al., 2010), suggesting impaired semantic integration.

There is also evidence for a general pattern of underconnectivity, both during the resting state and during language processing, in ASD compared to controls (Just et al., 2004). Specifically, underconnectivity between left fronto-parietal networks may contribute to the observed deficits in higher-level language in ASD (Jones et al, 2010).

However, all previous studies investigating connectivity during language processing in ASD have used fMRI. EEG coherence analysis is better suited to capture the dynamic changes in neural connectivity during semantic processing. Only one study has performed spectral analyses of EEG data during a language processing task in ASD (Braeutigam et al., 2008), but was limited to investigations of spectral power and only in the gamma band. Spectral analyses at lower frequencies are warranted, however, as the N400 effect has been associated with increased theta power, as well as with gamma-band effects (Maguire & Abel, 2013).

The current study uses EEG spectral analysis (power and coherence) and ERP analysis to examine patterns of neural activity and connectivity during semantic processing in high-functioning individuals with autism (HFAs) and normal controls (NCs).

Hypotheses:

- ASD will show a reduced or absent N400 compared to NCs
- The N400 will be associated with increased theta power, which may be reduced or absent in HFAs in accordance with N400 differences
- HFAs will show reduced EEG coherence compared to NCs between left fronto-parietal electrode pairs during, or just before, the N400 window

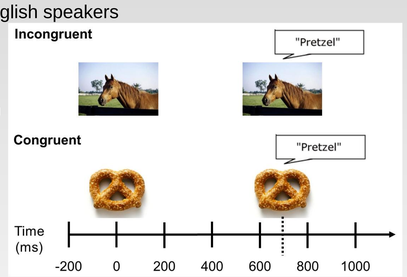
Methods

Participants

- 11 HFAs; mean age 29 years (SD = 14); 10 males, 1 female; 7 Caucasian; 2 African American; 1 Asian; 1 Hispanic
- 11 NCs matched on age and sex; mean age 28 years (SD = 12); 10 males, 1 female; 7 Caucasian; 3 African American
- All right-handed native English speakers

***Procedure*:**

- Picture-word incongruency paradigm: 80 high-frequency spoken words paired with 80 pictures.
- Each picture presented twice, once with a congruent and once with an incongruent spoken word



EEG Data Acquisition and Preprocessing

- EEG recorded at 250 Hz using an Electrical Geodesics Inc. GES 300 EEG System with 256-channel Hydrocel Geodesic Sensor Nets and NetStation version 4.3
- Epochs time-locked to picture stimulus
- Motion and eye movement artifacts corrected using ICA decomposition

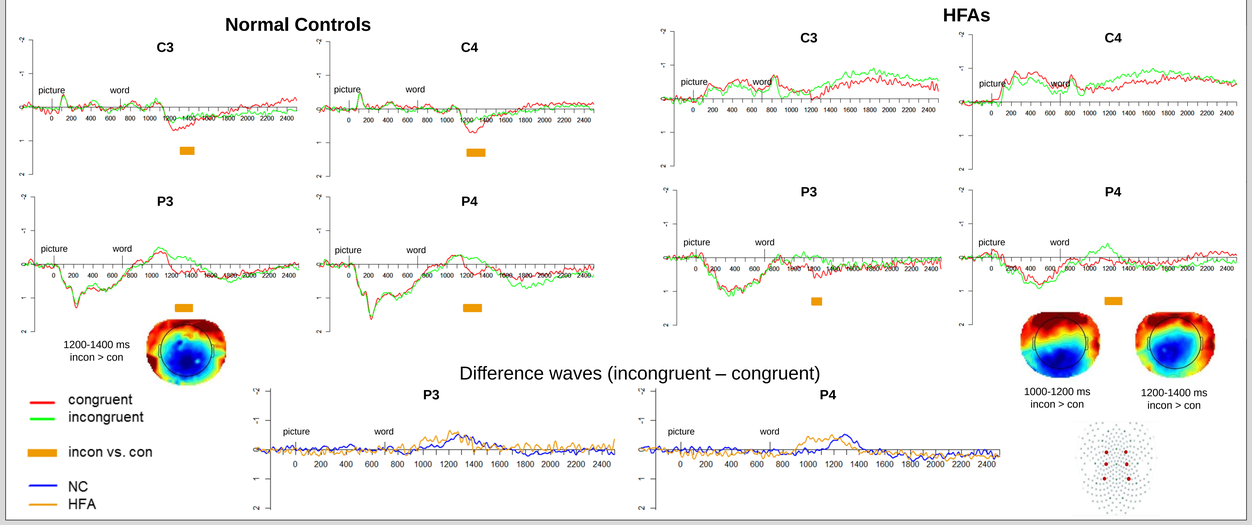
***Time-frequency analysis*:**

- Morlet wavelet of 2 cycles with expanding factor of 0.5 and Hanning taper
- Frequencies 2-50 Hz (delta to gamma)

Results

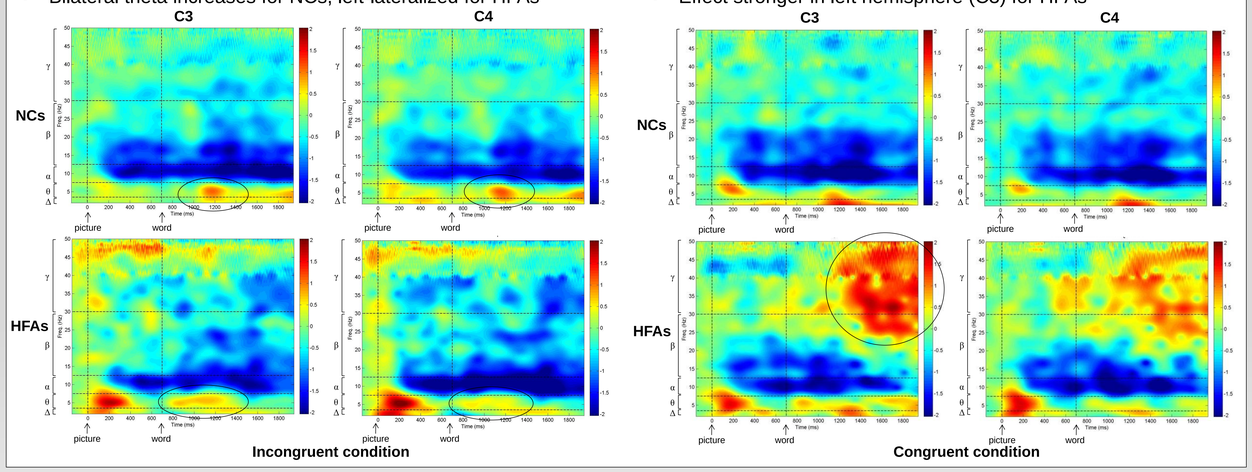
ERPs

- Centro-parietal N400 effect for both groups; slightly earlier onset and more sustained effect for HFAs than for NCs



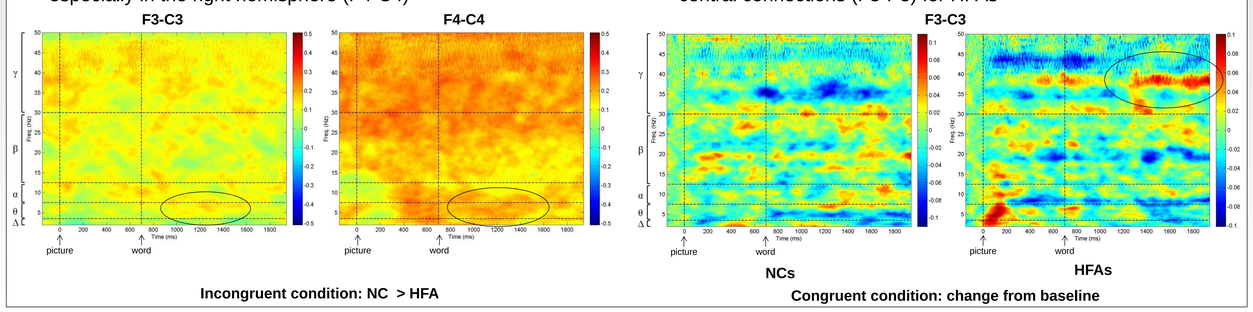
Power

- In the **incongruent condition**, both groups show increased theta power just before N400 onset
- Bilateral theta increases for NCs, left-lateralized for HFAs
- In the **congruent condition**, increased gamma activity starting 700 ms after sound presentation for HFAs but not NCs.
- Effect stronger in left hemisphere (C3) for HFAs



Coherence

- Theta power in incongruent conditions is associated with greater coherence in theta-band for NCs in fronto-central connections, especially in the right hemisphere (F4-C4)
- Gamma power in congruent conditions is associated with greater gamma-band coherence in left-hemisphere fronto-central connections (F3-P3) for HFAs



Discussion

ERPs:

Both NCs and HFAs showed an N400 effect, although it was earlier and more sustained for HFAs. This does not support previous literature, which had found no N400 for HFAs in a picture-spoken word semantic integration task (e.g. McCleery et al., 2010).

Spectral analyses:

In **incongruent conditions**, both groups showed increased power in the theta band starting just before N400 onset. Theta power increases were larger for NCs. NCs also showed a bilateral theta power increase for NCs, whereas this effect was left-lateralized for HFAs.

Theta power changes were associated with reduced fronto-central theta coherence for HFAs vs. NCs for left (F3-C3) and especially right (F4-C4) hemispheres.

These results suggest reduced theta power and reduced fronto-central connectivity for HFAs compared to NCs, especially in the right hemisphere, during the N400 window.

In **congruent conditions**, HFAs showed an increase in gamma-band power starting approximately 600 ms after word presentation; this effect was absent in NCs. This supports previous findings that HFAs show stronger gamma-band increases than NCs (Braeutigam et al., 2008).

Gamma power changes have been associated with the predictability of language, showing larger power increases in response to highly-predictable, congruous semantic contexts (Maguire & Abel, 2013; Wang et al. 2012). The larger gamma activity in HFAs could suggest that they were actively predicting the picture name in preparation for the spoken word. This could explain why HFAs also showed an N400 effect: because they were given explicit instruction to attend to the semantic relationship between picture-word pairs, HFAs may have developed a compensatory strategy that allowed them to perform similarly to NCs (Koolen et al., 2014).

This change in gamma power was associated with increased gamma-band coherence in left fronto-central (F3-C3) connections for HFAs. This suggests that language networks in the left hemisphere may be intact in ASD, but may be recruited in ways that differ from NCs.

The results presented here are preliminary; we are still in the process of collecting data. Currently there are no statistically significant group differences in the spectral analyses due to the strict corrections needed for multiple comparisons and due to the lack of power from so few subjects; however, we expect that this will change with additional data.

Conclusions

Overall, these results suggest differences in event-locked power and coherence during semantic processing in HFAs compared to NCs.

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