Predictive sentence comprehension during story-listening in Autism Spectrum Disorder

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Introduction

• Individuals with Autism Spectrum Disorder (ASD) show a range of language production deficits (1)
• But, language comprehension in ASD remains under-studied in part because co-morbid social deficits affect behavioral compliance (2)
• This challenge can be overcome by engaging participants in a naturalistic task while passively collecting neural signals (3)
• We use naturalistic story-listening and passive neural recording with MEG to study predictive sentence comprehension in ASD

To test predictive processing with naturalistic language, MEG data collected while 8–12 year old participants listen to an audiobook are correlated with word-by-word states from a computational model of incremental sentence prediction (8).

Results are consistent with predictive parsing that is equivalent between high-functioning individuals with ASD and TD peers.

Participants and MEG data collection

<table>
<thead>
<tr>
<th></th>
<th>Typically Developing</th>
<th>Autism Spectrum Disorder</th>
</tr>
</thead>
<tbody>
<tr>
<td>N (mlvl)</td>
<td>13 (12/1)</td>
<td>14 (13/1)</td>
</tr>
<tr>
<td>Age (y)</td>
<td>9.8</td>
<td>9.6</td>
</tr>
<tr>
<td>Communication (Vineland)</td>
<td>105</td>
<td>78</td>
</tr>
<tr>
<td>IQ (Wechsler Full)</td>
<td>114</td>
<td>104</td>
</tr>
</tbody>
</table>

Participants 16 high-functioning children with a clinical diagnosis of ASD participated in the study along with 16 age- and gender-matched typically developing (TD) controls (All IQ ≥ 70). Data from 2 ASD and 3 TD participants was excluded due to recording errors or excessive noise.

Procedure Participants listened passively to chapter 1 of Alice in Wonderland (12.6 m, 2129 words) while neuromagnetic signals were recorded from a 148-channel magnetometer in a magnetically shielded room.

Data processing: Data between 0.5–40 Hz were divided into 1 s epochs around each content word in the story. Ocular and cardiac signals were removed with ICA, and other artifacts were visually identified and excluded. About 500–700 epochs were retained per participant after exclusions.

Computational modeling & statistics

Predictive sentence comprehension modeled using the surprisal of a word’s part-of-speech (POS) for two different contexts, following (9):

\[ \text{surprisal}(w) = -\log(P(w|\text{Context})) \]

Where:

\[ \text{Ngram surprisal} \]

\[ \text{CFG surprisal} \]

Models were trained on entire story text (\(\text{Ngram} = 2.22, \text{Mora} = 1.18 \text{ bits of information from context.} \)

Word-by-word surprisal values were entered into a linear regression per-subject together with control predictors (word frequency, epoch order, and sound power) against MEG sensor signals. Null models were created by permuting the rows of the design matrix. Regression coefficients converted to planar gradient to facilitate group analysis.

Group-level statistical significance was tested using a non-parametric permutation test to identify contiguous <time,channel>-clusters showing a reliable effects while controlling for multiple-comparisons (10).

MEG results

Word Frequency

<table>
<thead>
<tr>
<th>TD</th>
<th>ASD</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.05</td>
<td>0.15</td>
</tr>
<tr>
<td>0.55</td>
<td>0.65</td>
</tr>
</tbody>
</table>

No main effects or interactions for Word Frequency.

Ngram surprisal successfully models MEG correlates of linguistic prediction in school-aged children.

Conclusions

• Ngram surprisal successfully models MEG correlates of linguistic prediction in school-aged children
• Sequence-based predictions for school-aged children consistent with prior eye-tracking evidence (11)
• Extends prior work by showing similar sentence-level predictive processing across high-functioning children with ASD and TD peers in a naturalistic context