What processing deficits are associated with decoding-based reading disability?

Individuals with decoding-based reading disability (dyslexia) often exhibit deficits in lower-level speech sound processing:

- Phonological processing (Shaywitz, 1996)
- Tasks requiring production of speech sounds (Schats-Kooij & Bosker, 2000; Volman et al., 2004)
- Low-level auditory processing more generally (Giraud & Ramus, 2013; Lehongre et al., 2011)

Although reading disability can leave higher-level oral language processes relatively spared, it is sometimes associated with higher-level language difficulties (Adolfs & Hagoort, 2010).

Children with dyslexia exhibit deficits in vocabulary, syntactic knowledge (Giraud & Ramus, 2013; Lehongre et al., 2011), and low-level auditory processing more generally (Brennan & Hale, 2019). (e.g., Shulz et al., 2008)

The current study

Goal: Investigate higher-level language processing in a reading-disabled population using a naturalistic task

- Population: Students with language-based learning difficulties
- Task: Listening to audiobooks while measuring EEG
- Effect of interest: Semantic integration (N400 effect of word frequency; e.g., Kutas & Hillyard, 1984)

Children with reading difficulties show smaller N400s with printed sentence processing (e.g., Skiba et al., 2008), but it is not known whether such effects extend to auditory language tasks.

Methods

Participants:

- 50 students at schools that treat language-based learning difficulties (AIM Academy, n=27; The Windward School, n=21)
- Student diagnoses include dyslexia, ADHD, anxiety, Asperger’s
- Assessment battery was administered to measure phonological processing, word reading, and nonword reading:

<table>
<thead>
<tr>
<th>Measure</th>
<th>Range</th>
<th>M</th>
<th>SD</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>7.5-13.5</td>
<td>10.8</td>
<td>1.9</td>
<td></td>
</tr>
<tr>
<td>TOWRE-Sight Word Efficiency</td>
<td>0.4-6.7</td>
<td>2.2</td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td>TOWRE-Oral Decoding Efficiency</td>
<td>0.0-11.0</td>
<td>4.8</td>
<td>3.15</td>
<td>10.13</td>
</tr>
</tbody>
</table>

Population: Students with language-based learning difficulties (Adolfs & Hagoort, 2010)

...but not always (Adolfs et al., 2000; Fiser et al., 2008)

Materials/Task:

- Audiobook stimuli: 3 excerpts from Alice in Wonderland and 3 excerpts from Stuart Little
- Each participant heard 1 excerpt per story (~11 min total)
- Normal speaking rate (M=2.9 words/sec)
- Attention checked via 4 comprehension questions (2AFC)

Pre-processing:

- Bandpass filtered 0.1-1.30 Hz; re-referenced to average
- EEG epoched from [-300 1000] ms; baseline-corrected; time-locked to auditory onset of content words
- # artifact-free epochs: Range=[520,1062], M=890, SD=130

Figure adapted from Brennan & Hale (2019), Fig. 2.

Analyses

- Effect of log word frequency (WF) on VW computed via regression-based ERPs (Smith & Kutas, 2013; Brennan & Hale, 2019)
  - For each participant, VW regressed on WF across epochs at every latency/channel
  - Covariates: WF of words a-1 and +1
  - Yields β coefficients representing WF effect across time/space
  - Time window and electrode montage based on prior N400 findings using naturalistic speech (e.g., Brennan & Hale, 2019)
  - WF: 0-200 ms
  - WF: 7 centroparietal channels
- Significant test: Correlation
- IV: Mean β across latencies/channels
- IVs: Letters-Word-ID score

Better readers show larger N400 effects during naturalistic listening

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Results

- More positive relationship between WF and μ (p is < .001)
- More negative μ to lower-frequency words

Conclusions

1. Better readers show larger effects of word frequency on N400 amplitude during naturalistic listening
   - Reliably significant only for the most skilled readers in our sample—those with average or above-average reading scores
   - Similar to word frequency effects observed in adults

2. Our results provide further evidence that reading disability may be associated with higher-level language difficulties, even in non-visual modalities.

Acknowledgements

This research was supported by funding from AIM Academy and The Windward School. We thank Grace Ashton, Arisa Carson-Green, Joe Sydnor, Jan Russell, Annie Stutzmian, and AIM/Windward faculty and staff for assistance with logistics and data collection. Special thanks to the many AIM and Windward students and families who participated and/or assisted with coding.

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