An Analysis of Reading Skill Development using E-Z Reader

Objectives
The topic of this PhD is to understand the cognitive processes that occur during reading. This was accomplished by collecting eye-movement data from children with both normal reading ability and reading comprehension difficulties (e.g., dyslexia), and then using a computational model (E-Z Reader; Reichle, 2011) to simulate the eye movements and cognitive processes of those children.

Computational cognitive modeling
Computational cognitive modeling is used to understand cognition (e.g., motivation, emotion, perception, etc.) by developing detailed, process-based descriptions of the representations and processing mechanisms that support human performance in various tasks (Sun, 2008). In the context of this research, computational modeling was used to understand the development of normal and impaired reading skill.

What eye – movement data tell us about the reading processes?
Variability of eye-fixation measures is thought to reflect the on-line processing of the text that is read (Calvo, 2001; Chaffin, Morris & Seely, 2001; Rayner, 1998; Rayner, Kambe & Duffy, 2000; Reynolds, 2000).

Eye fixation data can reflect the:
• time course of language processing
• overall difficulty of text processing
• immediate perceptual/lexical processing
• reading strategy being employed (e.g., skimming vs. careful reading for comprehension)
• allocation of attention

Children’s eye movements during reading
Compared to (skilled) adult readers, children with normal reading abilities (Byrne & Joseph, 2011),
• read more slowly (i.e., fewer words per minute)
• make more fixations
• make longer fixations
• make shorter saccades
• make more regressive saccades
• have a smaller perceptual span (i.e., region of effective vision)

Dyslexic children also exhibit:
• longer duration fixations
• shorter saccades
• more fixations
• smaller perceptual span

Children with reading comprehension difficulties exhibit:
• more regressions
• more fixations
• longer saccades
• increased saccade latency

Data acquisition
Participants
• 106 children (10-13 years; M = 11 years), native speakers ,
• 4 bilinguals
• 15 adults (23–29 years)

Materials
• 212 words long text
• 12 3-alternative multiple-choice comprehension questions
• Eye-link 1000 eye – tracker

Participants pre-screening with standardized tests to evaluate:
(1) orthographic processing
(2) phonological processing
(3) reading comprehension
(4) general intelligence

Pre-attentive visual processing (V): eye - brain transmission time duration (in ms) = 50

Lexical processing:
(1) Familiarity check (L1): duration (in ms) for a given word:
\[ t_1 = \alpha_1 \ln(frequency) - \beta_1 \]
Familiarity check duration is also modulated by visual acuity:
\[ t_1 = \alpha_1 \ln(frequency) - \beta_1 \times \text{subject's visual acuity} \]
(2) Lexical access (L2): duration (in ms) for a given word, \( t_L \):
\[ t_L = \alpha_L \times t_1 + \beta_L \]
(3) Post-lexical integration (I): mean integration time duration (in ms) = \( \Gamma(I) \)

Saccadic Programming:
Compared to (skilled) adult readers, children with normal reading abilities (Blythe & Joseph, 2011):
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Results

<table>
<thead>
<tr>
<th>Variables</th>
<th>Model Parameter Values</th>
<th>Observed</th>
<th>Psychometric Test Scores</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \alpha_0 )</td>
<td>( \alpha_1 )</td>
<td>( \alpha_2 )</td>
<td>( \Delta )</td>
</tr>
<tr>
<td>FID</td>
<td>1.10</td>
<td>0.60</td>
<td>0.84</td>
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<tr>
<td>GD</td>
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<td>Orthography</td>
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<td>Phonology</td>
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<td>-0.56</td>
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<td>Comprehension</td>
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<td>-0.01</td>
<td>0.06</td>
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<tr>
<td>IQ</td>
<td>0.25</td>
<td>0.15</td>
<td>0.25</td>
</tr>
</tbody>
</table>

**Table 1:** Relationships between best-fitting model parameters for individual children participants (\( N = 75 \)), their reading-skill test scores, mean first-fixation duration (FID), gaze durations (GD), test-comprehension scores, and general intelligence.

Conclusion
• We observed the pattern of word-frequency effects on eye-fixation measures (Rayner, 2009) and difference between the eye-fixation measures of children and adults (Byrne & Joseph, 2011).
• Simulation 1 replicated the results reported by Reichle et al. (2013) that overall differences between the patterns of eye movements observed in beginning versus skilled readers can be explained by differences in the proficiency of lexical processing.
• With Simulation 2, we found that the best-fitting values of the parameter that controls the rate of lexical processing (i.e., \( \alpha_0 \)) were more robustly related to orthographic- than phonological-processing skill. This finding suggests that “decisions” about when to move the eyes off of a word during reading are influenced more by orthographic than phonological processing, and thus by implication suggests that the first stage of lexical processing in E-Z Reader (i.e., the familiarity check) is based on orthographic processing.