A Connectionist Model of Impaired Reading and Reading Interventions

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Phonology and Reading Acquisition

• Phonological skills are a strong predictor of future reading ability
• Phonological impairments related to impairments in reading
• Phonological dyslexics exhibit:
  – Impaired ability to manipulate sounds of language
  – Impaired nonword reading
A Mysterious Result:

If poor phonology causes reading problems,

Interventions targeting spelling to sound skills typically lead to very small improvements – interventions targeting strictly phonological skills typically lead to very small improvements.

yet

Impaired phonology leads to poor reading.

why do attempts to fix phonology have such small effects?
Research Strategy

• Construct a computational model of reading
  – Including a phonological system

• Induce phonological impairments
  – Gain insights into why phonological impairments lead to reading impairments

• Apply different interventions
  – Understand principles behind successes and failures
Simulation Architecture

Phonological Attractor

Hidden Units

Orthography

Pretrain Phonology
Phonologically Impaired Simulation

Phonological Attractor

Hidden Units

Orthography

Damage Phonology
Normal and Impaired Simulation Results

Woodcock Word Attack

- Normal: 3.8
- Impaired: 3
Why Does Bad Phonology Impair Nonword Reading?

• Impaired model learns words *differently*
  – Forms more item specific representations
  – Less able to exploit similarities between words

• Why does this happen?
  – Impaired phonological attractor cannot repair partial activations
  – Orthography-\(\rightarrow\)phonology path must do more work
  – Forces *overlearning*
Demonstration of Non-Componential Representations

• Analyzed hidden unit representations for
  – Similar words: *eat, feat, meat, seat*
  – Exceptions: *great, sweat*
  – Nonword *geat*

• Performed multi dimensional scaling on representations over the course of training

• Items with similar representations are closer in 2d space
Normal and Impaired Simulations: Internal Representations

Normal Model

Phonologically Impaired Model
Summary of Impairment Simulations

• Poor phonology *causes* the reading problem:
  – Non-componenntional, item specific representations in the mapping from orthography to phonology
• Hence, repairing phonology won’t solve the problem once poor learning has set in
• Interventions need to directly target the orth-*>phon mappings
Experiment 1: Purely Phonological Intervention

- Take phonologically impaired simulation, and remove source of impairment
  - Allow it to learn more complex relationship among sounds
- Run several simulations, applying repair at different points in training
  - At onset of reading training, after 10K trials, 20K trials and 100K trials
Results of Purely Phonological Intervention

<table>
<thead>
<tr>
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<th>Woodcock Word Attack</th>
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<tbody>
<tr>
<td>Normal</td>
<td>3.8</td>
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<tr>
<td>Impaired</td>
<td>3</td>
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<td>Remed 0K</td>
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<td>Remed 10K</td>
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<td>Remed 20K</td>
<td>3.3</td>
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<td>Remed 100K</td>
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The McCandliss et al. (1999) Intervention

- Introduce “lessons” consisting of items that change by at most one letter at a time
  - \textit{cat - bat - bag - rag - rig}
- If child makes an error, \textit{split} the word into its component parts
  - \textit{c + at = cat}
- Continue until child gets every item in lesson correct. Then move onto next lesson
Experiment 2: Simulating McCandliss et al. (1999) Intervention

• Begin impaired simulation as before
• Every 1000 words, begin a lesson
  – Iterate over words in lesson
  – If sum squared error is > 1.0, split word
    • Train on component onset and rhyme
  – Proceed to next lesson only when all items have error < 1.0
Results of Intervention

![Bar Chart]

- Normal: 3.8
- Impaired: 3.0
- Remed 10K: 3.8
- Remed 20K: 3.8
- Remed 100K: 3.7
Altered Internal Representations from Intervention

Impaired Model

Impaired, Remediated Model
Conclusions

• Phonological impairments lead to poor reading in phonological dyslexics
  – Cause a failure to recognize the componential aspects of reading

• Interventions are more effective when they explicitly target this problem
And...

- Computational simulations are a valuable tool for understanding the bases of
  - Normal reading
  - Impaired reading
  - Reading interventions
- Don’t simply describe empirical findings, but provide causal explanations
Future Work

• Explore different training programs - structuring basals, feedback to children
• Interventions for other forms of developmental dyslexia
  – *Delay* dyslexia
• Specific Language Impairment (SLI)

*Watch This Space!*