

A Connectionist Model of Impaired Reading and Reading Interventions

Michael W. Harm, CMU

Bruce McCandliss, Sackler Institute

Mark S. Seidenberg, USC

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:

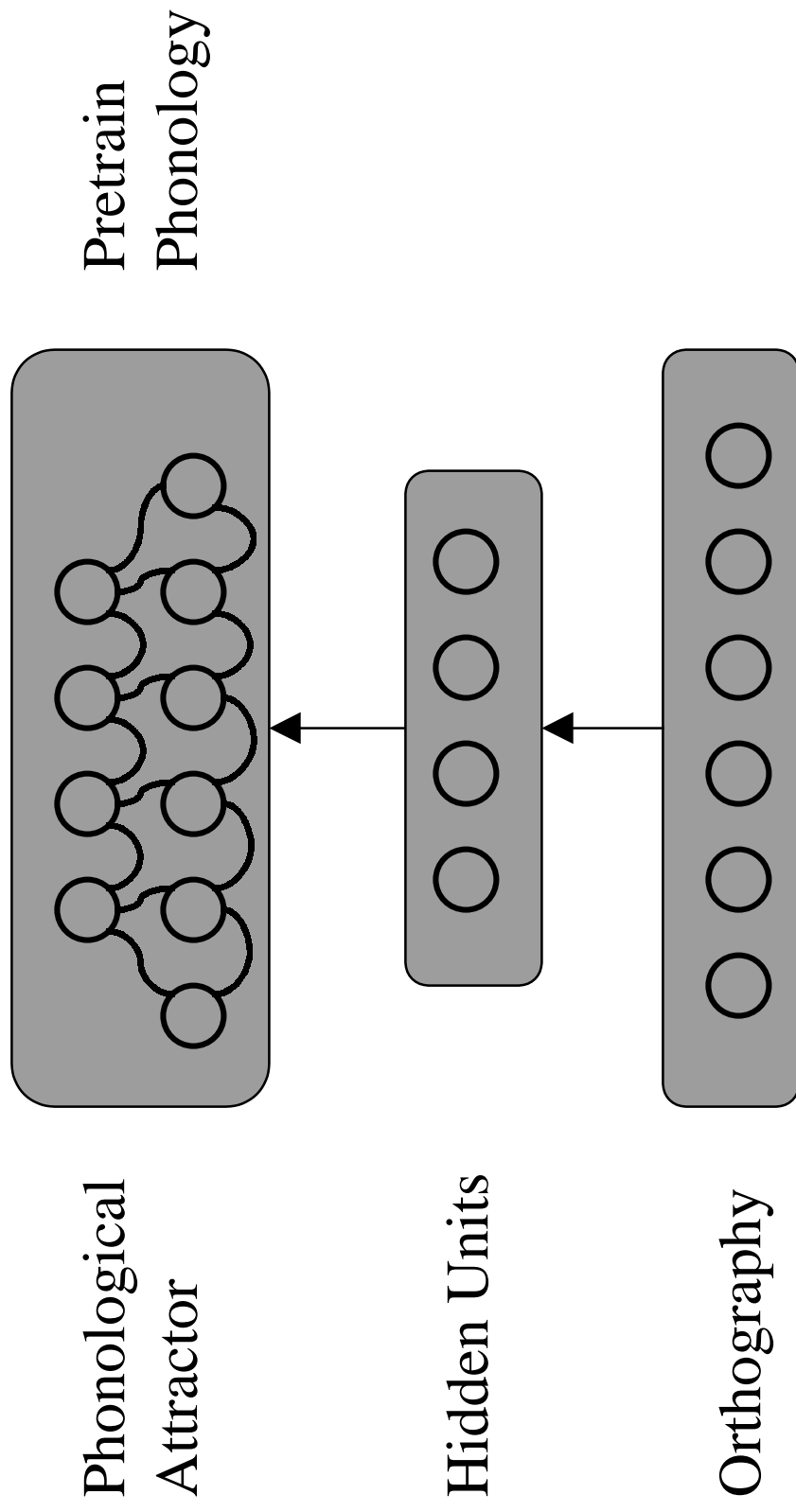
- Impaired phonology leads to poor reading, yet
 - Interventions targeting strictly phonological skills typically lead to very small improvements
 - Interventions targeting spelling to sound relationships have much greater success

If poor phonology causes reading problems, why do attempts to fix phonology have such small effects?

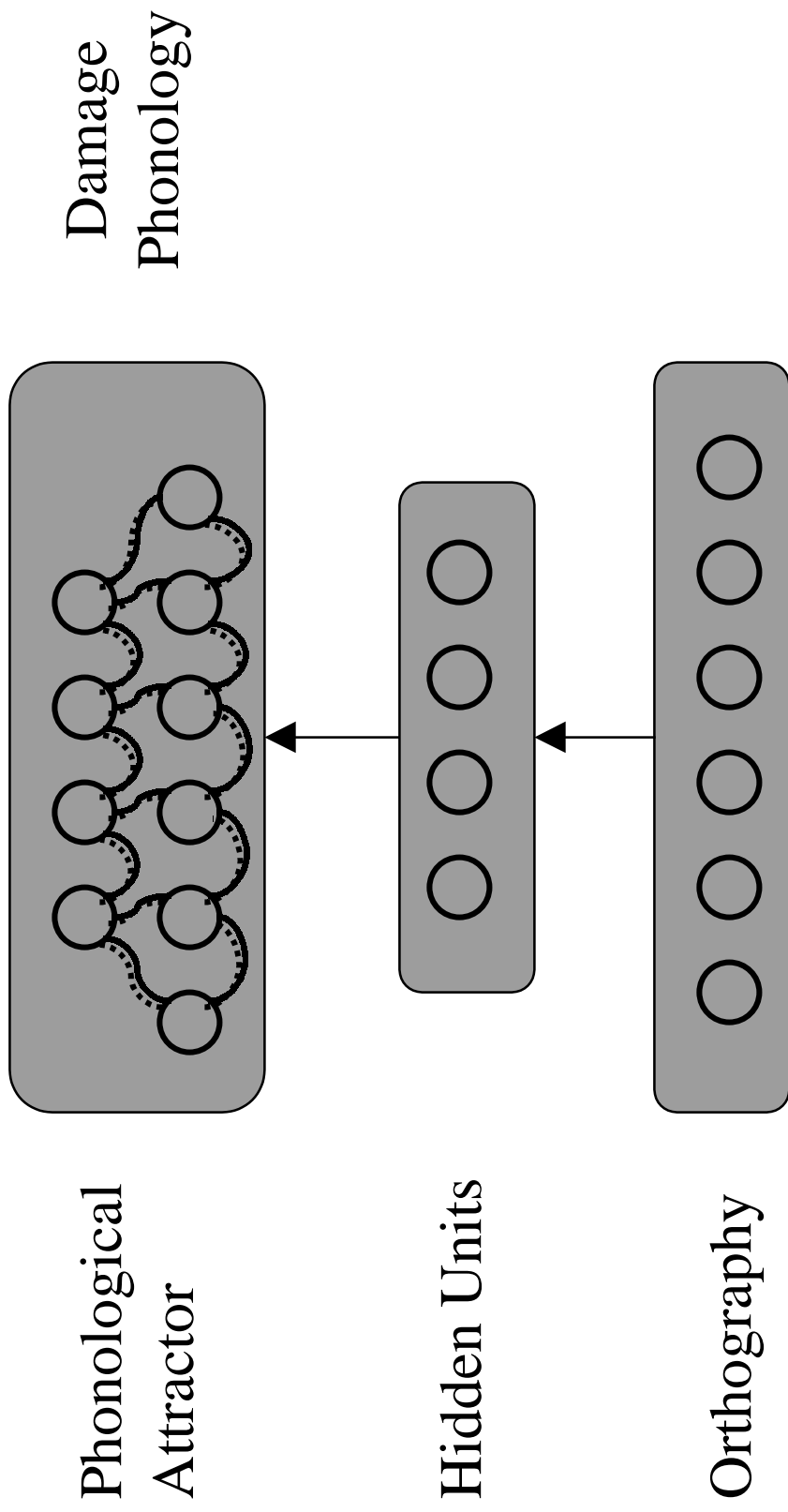
Research Strategy

- 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

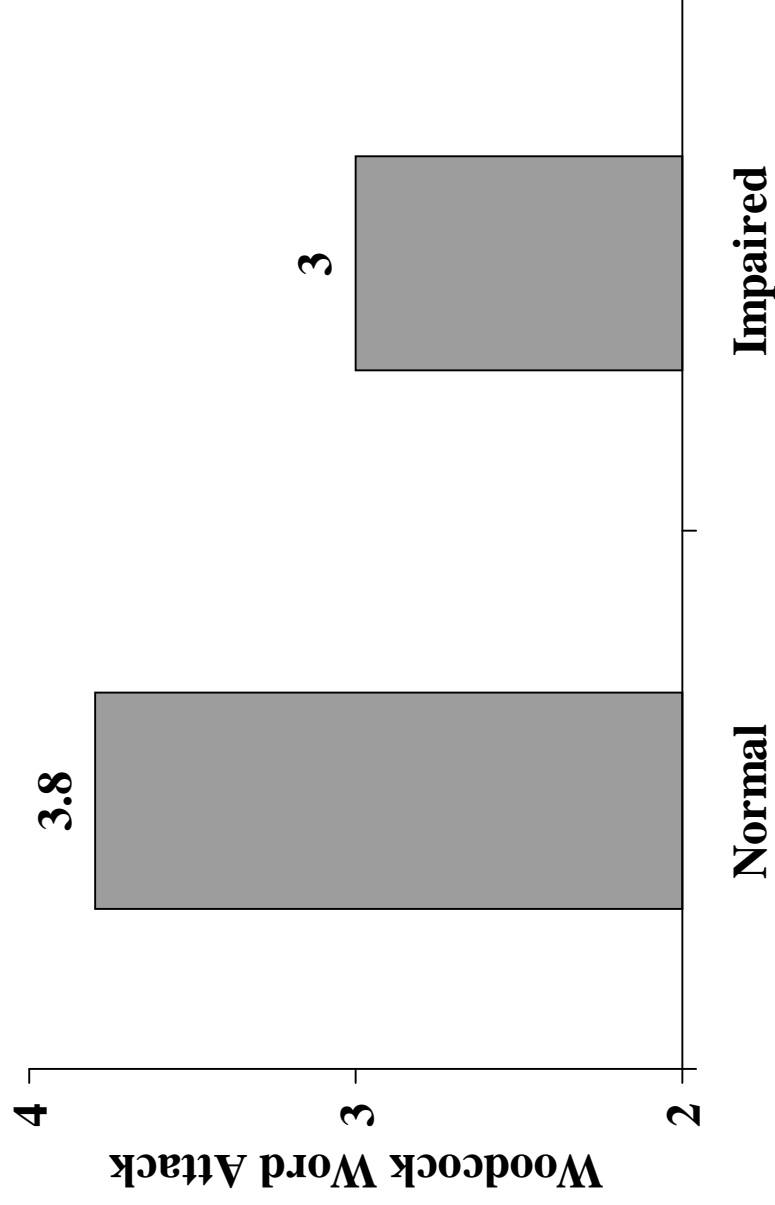
Simulation Architecture



Phonologically Impaired Simulation



Normal and Impaired Simulation Results



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->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

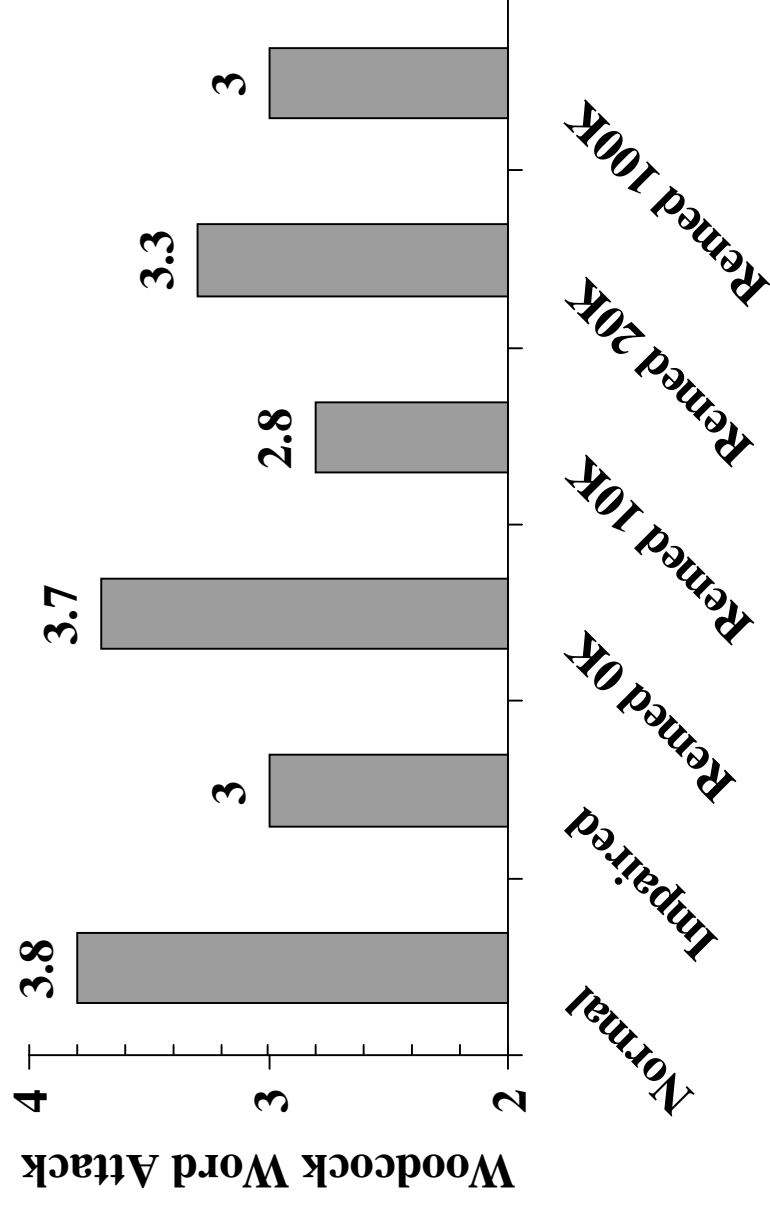
Summary of Impairment Simulations

- Poor phonology *causes* the reading problem:
 - Non-componential, 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



The McCandliss et al. (1999)

Intervention

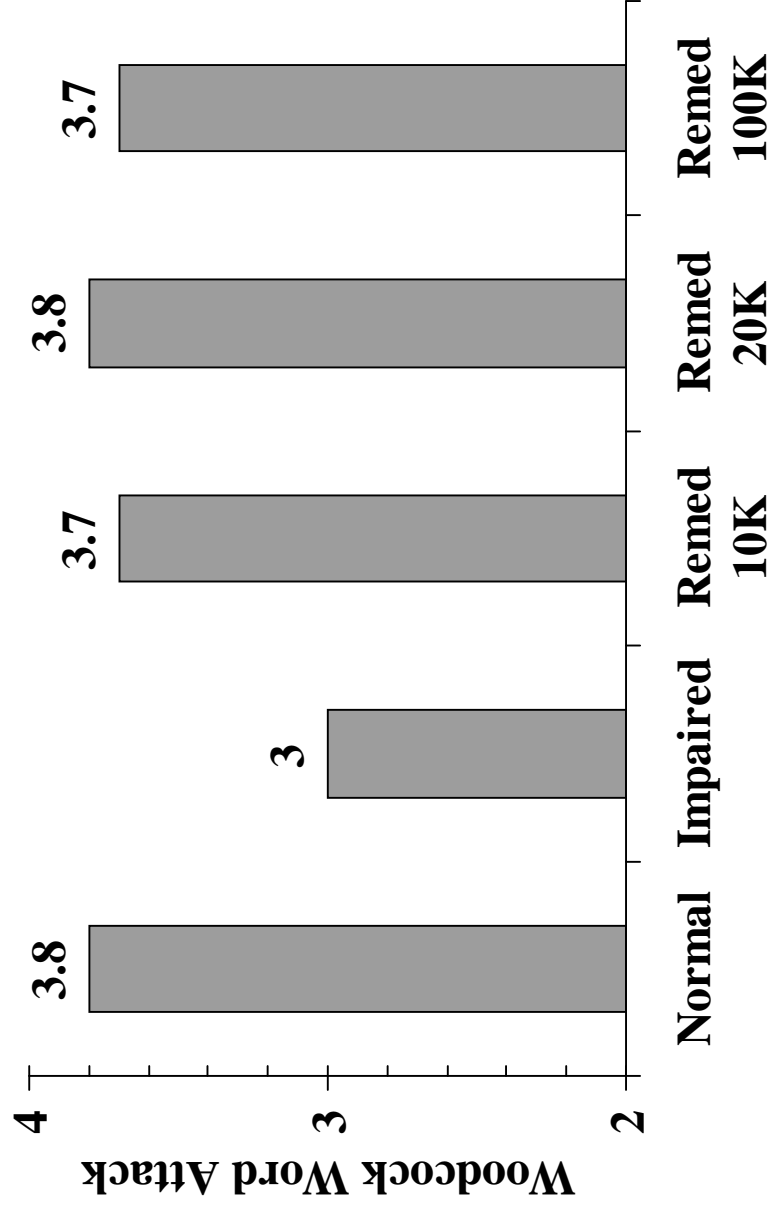
- Introduce “lessons” consisting of items that change by at most one letter at a time
 - *cat - bat - bag - rag - rig*
- If child makes an error, *split* the word into its component parts
 - *c + at = cat*
- Continue until child gets every item in lesson correct. Then move onto next lesson

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



Altered Internal Representation from Intervention

4000000

beat
feat
seafat

geat

heat

threat

great

4000000 Remediated

beat feat
geat heat

threat

great

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!