Understanding Impairments and Interventions in Dyslexia: A Connectionist Investigation of Learning to Read

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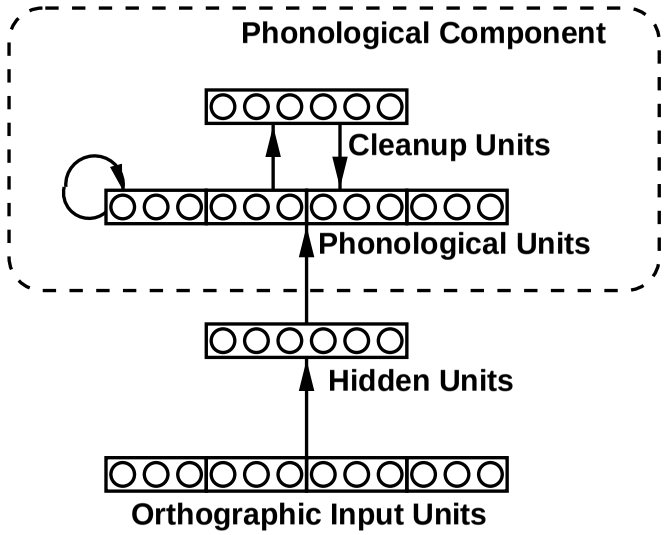
Developmental Phonological Dyslexia

- Primary impairment in nonword reading (Castles & Coltheart, 1993).
- Word reading compromised in more severe cases (Manis et al., 1996; Stanovich et al., 1997).
- Caused by phonological impairments (Bradley & Bryant, 1983; Tunmer & Nesdale, 1985)

Simulating Developmental Phonological Dyslexia: Harm and Seidenberg (1999)



- Constructed spelling to sound model.
- Impaired phonological attractor to varying degrees.
- Found impairments in word and nonword reading that match emprical studies.

Why Impairing Phonology Impairs Nonword Reading

- Spelling to sound system must compensate for noise in output (phonological) layer.
- Forces over-attention to details of the input, which causes…
- Overly item specific representations to be formed in spelling to sound,
- Causing poor generalization.

Componentiality in Harm and Seidenberg (1999) Reading Model

- Compared normal and phonologically impaired models.
- Measured hidden unit contribution to phonology for a set of rhyming items (EAT, MEAT, SEAT, TREAT and nonword GEAT)
- Normal model read words and nonword correctly.
- Phonologically impaired model read words correctly, failed to read nonword.

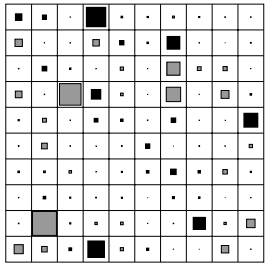
Why?

- This is because the normal model exhibited strong overlap in hidden unit representations of these items. Learned componential internal structure.
- Impaired model treated each word differently in learning. Treated items more wholistically.
- Hence could not generalize to novel item.

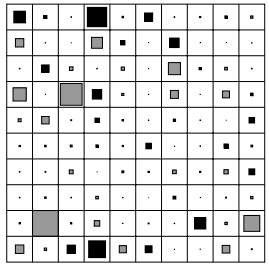
Normal and Impaired Models: Internal Representations

Normal Model

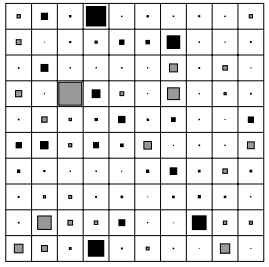
EAT



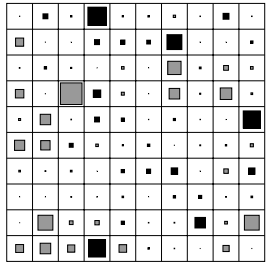
MEAT



TREAT

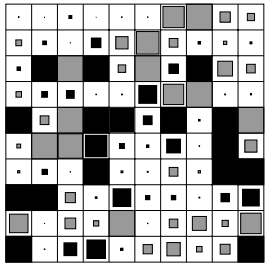


GEAT

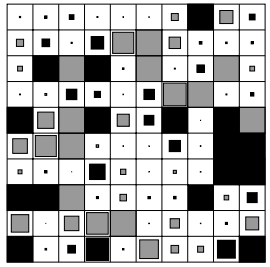


Impaired Model

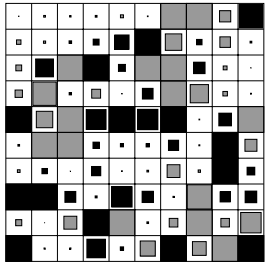
EAT



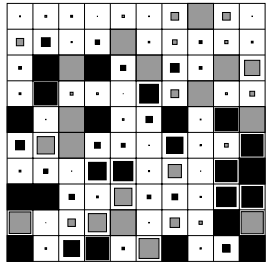
MEAT



TREAT



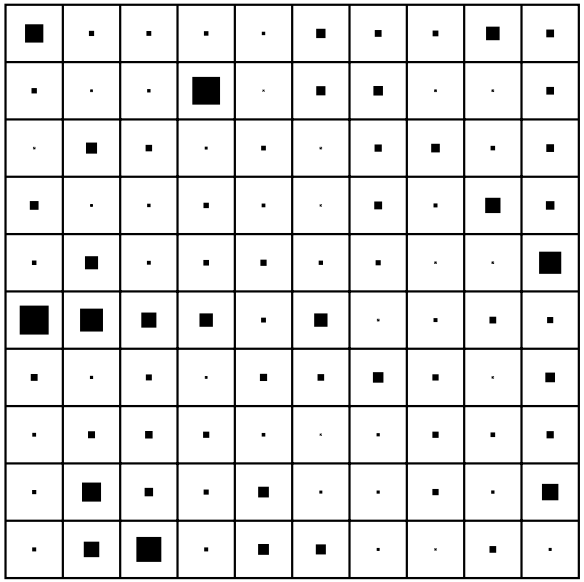
GEAT



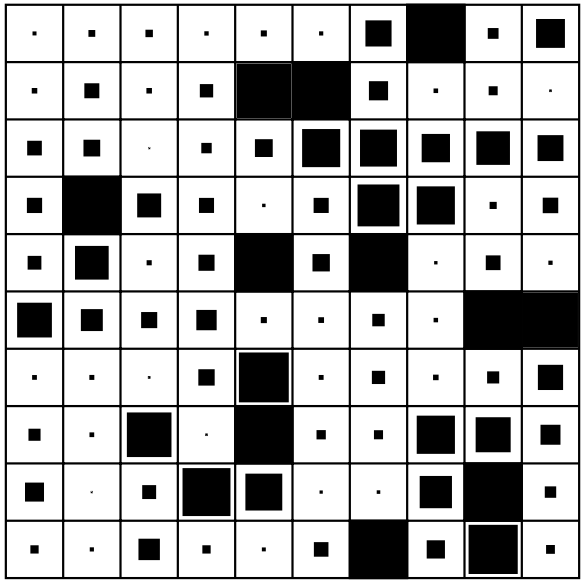
Normal and Impaired Models: Internal Representations (cont.)

Generalization: Plot difference between representation of nonword GEAT and average of words EAT, MEAT, TREAT.

Normal Model



Impaired Model



Impaired model has far less overlap between nonword and word representations than normal model.

The Next Step: Remediations

- The HS99 simulation models effect of impaired phonology on reading.
- Provides a vehicle to explore various remediation schemes…
- …and provide computational explanations of what does and does not work.

Simulating What Doesn't Tend to Work: Remediating Phonology

- Empirical efforts to remediate phonology in isolation tend to produce little or no improvement.
- We took the HS99 model, trained under conditions of impaired phonology for 100,000 iterations.
- Then, removed the source of the phonological impairment. Trained for a further 9 million iterations.
- Result: virtually no improvement. Poor representations had already crystalized, even though word accuracy was low.

What Does Tend to Work: Emphasizing Componential Aspects of Orth→Phon (McCandliss et al., 1999)

- Construct "Lessons" of word sequences differing by one letter (e.g., CAT HAT RAT RUT ROT TOT)
- When child makes an error, split the sound and spelling of the word into its component parts (CAT -> /k/ and /æt/)
- Don't move on until all items in lesson correct

Results of McCandliss et al. (1999) Intervention

- Average 0.9 grade levels improvement in Woodcock word attack (nonword reading test) over improvement seen in control group.
- 11 of 12 children surpassed learning criteria of 0.33 grade levels over the span of 4 months.

Simulation of McCandliss et al. (1999) Intervention

- Took phonologically impaired HS99 simulation. Also, “normal” model as control.
- “Intervened” training using same materials and paradigm of McCandliss et al. (1999).
- Compared to control condition, impaired model improved by 0.666 grade levels (Woodcock word attack) over improvement seen in control simuation.
- No disruption in exception word reading seen.

Implications of this Work

- Impaired phonology causes the real problem:
- The Real Problem is non-componential learning.
- Hence, remediating phonology once learning is underway should have little effect.
- Effective remediations need to target orth$\rightarrow$phon translations. Must emphasize componential aspects of reading.

Future Directions

- Explore the impact of other remediation paradigms.
- Explore remediations for other kinds of developmental dyslexics (e.g., “delay” dyslexics).
- Try manipulations of training materials during normal training.
- Make predictions as to exactly which kinds of intervention materials will have maximal effect.

Conclusions

- Computational modeling can inform and explain reading impairments seen in children.
- Models can provide computational explanations as to what remediations do and do not work and why.
- Remediation programs should be informed by mechanistic accounts of the reading impairments in children.

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