A Multiple Deficit Model of Dyslexia

Learning Objectives

- Understand the multiple deficit model of developmental disorders
- Describe (some) profiles of cognitive deficits associated with reading disability
- Discuss practical implications of a multiple deficit model for intervention

Consensus Definition of Dyslexia

1. “Dyslexia is characterized by difficulties with accurate and/or fluent word recognition and by poor spelling and decoding abilities.
2. These difficulties typically result from a deficit in the phonological component of language that is often unexpected in relation to other cognitive abilities and the provision of effective classroom instruction.
3. Secondary consequences may include problems in reading comprehension and reduced reading experience that can impede growth of vocabulary and background knowledge.”

Phonological Processes and Reading

- Alphabetic Principal depends on ‘awareness of internal phonological structure of words’ (Liberman et al., 1989)
- Phonological awareness correlates with reading ability (Calfee et al., 1973)
- Early phonological awareness predicts later reading skill (Wagner & Torgesen, 1987)
- Children with reading disability present with compromised phonological skills (Vellutino & Scanlon, 1987)
- Poor readers respond to intervention combining phonological awareness and alphabetic instruction (Hatcher et al., 1994)

Problems with Single Deficit Model

- Some children with phonological awareness deficits do not develop reading deficits (e.g., Snowling et al., 2003)
- Some children without phonological awareness deficits present with a reading deficit (e.g., Manis et al., 1997)
- Comorbidity
  - Reading disability prevalence of 7% (Petersen & Pennington, 2012)
  - ADHD prevalence of 5% (Boada, Willcutt, & Pennington, 2012)
  - Co-occurrence rate 25-40% (Willcutt & Pennington, 2000)

Multiple Deficit Model

Adapted from Pennington (2006). Cognition, 101, 385-413. Figure 2.
Multiple Deficits of ADHD and RD

- Phonological Awareness
- Inhibition
- Verbal Working Memory
- Naming Speed
- Processing Speed

Adapted from McGrath et al. (2011). Journal of Child Psychology and Psychiatry, 52, 547-557. Figure 3.

Multiple Deficits of Reading Disability

- Phonological Awareness
- Component Skill
- Single Word Reading

Multiple Deficits of Reading Disability

- Component Skill
- Single Word Reading

Cut-off Deficit Definition

- Deficit ≤ 80 SS
Theoretical Models of Reading Deficit

<table>
<thead>
<tr>
<th>Deficit Category</th>
<th>Single</th>
<th>Multiple</th>
</tr>
</thead>
<tbody>
<tr>
<td>Is PA Deficit Necessary?</td>
<td>Yes</td>
<td>L. Single phonological deficit III. Phonological core, multiple deficit</td>
</tr>
</tbody>
</table>

Note: PA refers to phonological awareness

Pennington et al. (2012). Journal of Abnormal Psychology, 121, 212-224. Table 1

Luke Waites Center Diagnostic Clinic

- Average 1200 psycho-educational evaluations each year
- Eligibility Criteria
  - Academic concerns include reading, math, and writing
  - Ages 5 through 14 years
  - English as primary language
- Demographics
  - 45% Female
  - 30% Ethnic minority
  - 70% public school

Sample Selection

Total patients with WISC-IV, CTOPP, WIAT Reading N = 2653

School and diagnosis inclusion criteria

- Exclude n = 1032
- Include n = 1621

Typical Reader
- Word Reading > 90SS n = 901

Reading Deficit
- Word Reading ≤ 80SS n = 215
Cognitive Predictors

- Phonological Awareness (PA)\(^1\): segmentation, manipulation, and blending
- Rapid Automatic Naming (RAN)\(^1\): serial naming colors, letters, and numbers
- Working Memory (WM)\(^2\): digit recall forward and backward, letter-number sequencing
- Verbal Comprehension (VCI)\(^2\): vocabulary, analogy, and pragmatics

\(^1\) Comprehensive Test of Phonological Processing (Wagner et al., 1999).
\(^2\) Wechsler Intelligence Scale for Children IV (Wechsler, 2004).

Cutoff-Defined Deficit Profiles

### Distribution of Reading Deficit Sample

- **Percent of Patients**
- **Deficit Type**: None, PA, RAN, WM, VCI, PA-Core, Multiple

**Notes:**
- "Mild" deficit > 80 SS and < 90 SS.
- Differences in reading ability by deficit type are not significant, \(F(6, 208) = 1.5, p = .17\).

### Distribution of Typical Reading Sample

- **Percent of Patients**
- **Deficit Type**: None, PA, RAN, WM, VCI, PA-Core, Multiple

**Notes:**
- RD and Non-RD deficit distributions are significantly different, \(\chi^2(6, N=1116) = 294.9, p < .0001\).
### Distribution of Deficit Types

<table>
<thead>
<tr>
<th>Is PA Deficit Necessary?</th>
<th>Single</th>
<th>Multiple</th>
<th>Totals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>9%</td>
<td>23%</td>
<td>32%</td>
</tr>
<tr>
<td>No</td>
<td>25%</td>
<td>14%</td>
<td>39%</td>
</tr>
<tr>
<td>Totals</td>
<td>34%</td>
<td>36%</td>
<td></td>
</tr>
</tbody>
</table>

**Note:** Reading deficit sample. PA refers to phonological awareness.

### Path Analysis

\[ R^2 = .37 \]

**Note:** Analysis includes total sample (n=1621). Coefficients in bold if \( p < .05 \).

### Individual Prediction of Reading Deficit

Individual Prediction of Reading Deficit

Single Deficit Models
Model 1: Word Reading = Phonological Awareness (PA)
Model 2: Word Reading = Rapid Automatic Naming (RAN)
Model 3: Word Reading = Working Memory (WM)
Model 4: Word Reading = Verbal Comprehension (VCI)

Phonological Core Multiple Deficit
Model 5: Word Reading = PA + RAN
Model 6: Word Reading = PA + WM
Model 7: Word Reading = PA + VIQ
Model 8: Word Reading = PA + RAN + WM
Model 9: Word Reading = PA + RAN + VIQ
Model 10: Word Reading = PA + WM + VIQ
Model 11: Word Reading = PA + RAN + WM + VIQ
Other Multiple Deficit Models

Model 12: Word Reading = RAN + WM
Model 13: Word Reading = RAN + VIQ
Model 14: Word Reading = WM + VIQ
Model 15: Word Reading = RAN + WM + VIQ

Regression-Defined Profiles

Distribution of RD Patients by Deficit Type

Distribution of Regression-Defined Deficits

<table>
<thead>
<tr>
<th>Deficit Category</th>
<th>Single</th>
<th>Multiple</th>
<th>Totals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>11%</td>
<td>37%</td>
<td>48%</td>
</tr>
<tr>
<td>No</td>
<td>24%</td>
<td>29%</td>
<td>53%</td>
</tr>
<tr>
<td>Totals</td>
<td>35%</td>
<td>66%</td>
<td></td>
</tr>
</tbody>
</table>

Note: PA refers to phonological awareness
**RAN as Phonological Processing**

<table>
<thead>
<tr>
<th>Deficit Category</th>
<th>Single</th>
<th>Multiple</th>
<th>Totals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Is PA Deficit Necessary?</td>
<td>13%</td>
<td>52%</td>
<td>75%</td>
</tr>
<tr>
<td>No</td>
<td>15%</td>
<td>14%</td>
<td>29%</td>
</tr>
<tr>
<td>Totals</td>
<td>34%</td>
<td>66%</td>
<td>100%</td>
</tr>
</tbody>
</table>

*Note: PA refers to phonological awareness + Rapid Automatic Naming*

See Wagner, Torgesen, & Rashotte (1994) for model details.

**Agreement of Deficit Definitions**

<table>
<thead>
<tr>
<th>Cut-off Defined Deficit</th>
<th>PA</th>
<th>RAN</th>
<th>WM</th>
<th>VCI</th>
<th>PA-Core</th>
<th>Multiple</th>
<th>Totals</th>
</tr>
</thead>
<tbody>
<tr>
<td>PA</td>
<td>13</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>23</td>
</tr>
<tr>
<td>RAN</td>
<td>9</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>9</td>
</tr>
<tr>
<td>WM</td>
<td>2</td>
<td>0</td>
<td>7</td>
<td>0</td>
<td>2</td>
<td>1</td>
<td>12</td>
</tr>
<tr>
<td>VCI</td>
<td>16</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>1</td>
<td>0</td>
<td>20</td>
</tr>
<tr>
<td>PA-Core</td>
<td>12</td>
<td>11</td>
<td>7</td>
<td>5</td>
<td>0</td>
<td>4</td>
<td>20</td>
</tr>
<tr>
<td>Multiple</td>
<td>9</td>
<td>0</td>
<td>13</td>
<td>9</td>
<td>0</td>
<td>5</td>
<td>26</td>
</tr>
<tr>
<td>Totals</td>
<td>61</td>
<td>19</td>
<td>31</td>
<td>50</td>
<td>3</td>
<td>21</td>
<td>11</td>
</tr>
</tbody>
</table>

**Effect of Number of Deficits**

- Reading Ability by Deficit Number
- Total Sample
- Reading Deficit Sample
- Standard Score
- Number of Deficits
### Individual Prediction Summary

- Phonological awareness deficit is sufficient, but not necessary for word reading deficits
- Moderate agreement (61%) between cut-off and regression deficit definition methods ($\kappa = .40, p < .0001$)
- Both definition methods support a multiple deficit model of reading disability, primarily a phonological-core deficit model
- *In the total sample*, the data suggest an additive effect of increasing number of deficits on reading ability

### Cognitive Profiles and Intervention

“Assessment of cognitive and neuropsychological processes should be used not only for identification, but for intervention purposes as well, and these assessment-intervention relationships need further empirical investigation.” (Hale et al., 2010)

### Patterns of Strengths and Weaknesses

- **Aptitude-Achievement Consistency** (or Cross-Battery Assessment; Flanagan, Ortiz, & Alfonso, 2007)
- **Concordance/Discordance Method** (Hale & Fiorello, 2004)
- **Discrepancy/Consistency Method** (Naglieri, 1999)
Cognitive Profiles and Reading Intervention

- Pre-intervention phonological awareness and rapid naming are most consistent predictors of response (e.g., Torgesen et al., 1999, c.f. Torgesen et al., 2001)
- Verbal intelligence is an inconsistent predictor of treatment response (e.g., Al Otaiba & Fuchs, 2002)
- Verbal working memory is associated with reading disability, but less so for treatment response (Swanson et al., 2009; but c.f. Savage et al., 2007)

Luke Waites Center Dyslexia Lab

- Clinically-referred sample (n=92) without access to adequate reading remediation services
- Instruction from an Orton Gillingham-based, multisensory, structured language curriculum (Avrit et al., 2006)
- Small group intervention model
- Comprehensive reading curriculum teaches phonological awareness, phonics, fluency, vocabulary, comprehension
- Intervention delivered for two academic years (5 hours per week for total of 230 hours contact time)

Cognitive Predictors

<table>
<thead>
<tr>
<th>Measure</th>
<th>Average</th>
<th>SD</th>
<th>Minimum</th>
<th>Maximum</th>
<th>W</th>
</tr>
</thead>
<tbody>
<tr>
<td>PA</td>
<td>88.2</td>
<td>10.2</td>
<td>64</td>
<td>112</td>
<td>.98</td>
</tr>
<tr>
<td>RAN</td>
<td>84.2</td>
<td>12.7</td>
<td>52</td>
<td>109</td>
<td>.97</td>
</tr>
<tr>
<td>WMF</td>
<td>91.5</td>
<td>10.6</td>
<td>56</td>
<td>120</td>
<td>.97</td>
</tr>
<tr>
<td>VCI</td>
<td>100.5</td>
<td>10.2</td>
<td>81</td>
<td>129</td>
<td>.98</td>
</tr>
</tbody>
</table>

Note: N = 92. SD = standard deviation. W = Shapiro-Wilk test of distribution normality. \( n = 61 \)
### Treatment Outcomes

![Graph showing treatment outcomes](image)

**Note:** Reading measures from Wechsler Individual Achievement Test. Baseline to posttest: Word Reading, $t(91) = 10.1, p < .0001$, and Comprehension, $t(87) = 9.4, p < .0001$.

### Prediction of Baseline Status

<table>
<thead>
<tr>
<th>Cognitive Predictor</th>
<th>Word Reading</th>
<th>Comprehension</th>
</tr>
</thead>
<tbody>
<tr>
<td>PA</td>
<td>.26</td>
<td>.26</td>
</tr>
<tr>
<td>RAN</td>
<td>.53</td>
<td>.32</td>
</tr>
<tr>
<td>WM1</td>
<td>-.09</td>
<td>.11</td>
</tr>
<tr>
<td>VCI</td>
<td>.28</td>
<td>.36</td>
</tr>
</tbody>
</table>

**Note:** $\beta = \text{standardized regression coefficient}; R^2 = \text{squared correlation}. * p < .05$, $n = 61$.

### Prediction of Post-Treatment Status

<table>
<thead>
<tr>
<th>Cognitive Predictor</th>
<th>Word Reading</th>
<th>Comprehension</th>
</tr>
</thead>
<tbody>
<tr>
<td>PA</td>
<td>.04</td>
<td>.13</td>
</tr>
<tr>
<td>RAN</td>
<td>.11</td>
<td>.09</td>
</tr>
<tr>
<td>WM1</td>
<td>.07</td>
<td>.17</td>
</tr>
<tr>
<td>VCI</td>
<td>.06</td>
<td>.36</td>
</tr>
</tbody>
</table>

**Note:** Regression models include baseline status. $\beta = \text{standardized regression coefficient}; sr^2 = \text{squared semi-partial correlation}; * p < .05$, $n = 61$. 
Moderating Deficits with Treatment

<table>
<thead>
<tr>
<th>Deficit</th>
<th>Intervention</th>
<th>Accommodation</th>
</tr>
</thead>
<tbody>
<tr>
<td>PA</td>
<td>Specific instruction in phonological awareness</td>
<td>Scaffolding</td>
</tr>
<tr>
<td>RAN</td>
<td>Repeated accurate practice</td>
<td>Additional response time</td>
</tr>
<tr>
<td>WM</td>
<td>Reduced text processing requirements</td>
<td>Additional opportunity to engage summarizing, etc.</td>
</tr>
<tr>
<td>VCI</td>
<td>Specific instruction in vocabulary, figurative language, strategies</td>
<td>Additional opportunities reading authentic text, Scaffolding</td>
</tr>
</tbody>
</table>

Deficits that Matter for Intervention

<table>
<thead>
<tr>
<th>Deficit</th>
<th>Intervention</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phonological Awareness</td>
<td>• articulatory awareness, phoneme-grapheme correspondence</td>
</tr>
<tr>
<td>Decoding</td>
<td>• phonological awareness, grapheme-phoneme correspondence</td>
</tr>
<tr>
<td>Word Recognition</td>
<td>• orthographic patterns, morpho-phonemic structure, Fry's Instant Word lists, Print exposure</td>
</tr>
<tr>
<td>Fluency</td>
<td>• repeated readings, print exposure</td>
</tr>
<tr>
<td>Comprehension</td>
<td>• vocabulary and background knowledge, figurative language, strategies, print exposure</td>
</tr>
</tbody>
</table>

Treatment Summary

- Good curricula will meet some component deficits with direct instruction (e.g., phonological awareness)
- Good therapists will accommodate some individual differences within therapeutic environment (e.g., working memory)
- Deficits that matter most for reading intervention content decisions involve the child’s specific reading problem(s) (e.g., Miciak et al., 2013)
**General Conclusions**

- Phonological awareness deficit is sufficient for a reading deficit, but not necessary
- Phonological-core multiple deficit model reflects most common profile of children with reading deficit (Stanovich, 1988; Morris et al., 1998; Pennington et al., 2012)
- Quality intervention may moderate effects of individual variation in component skills, but this effect needs to be formally evaluated
- Profile analysis for intervention may be promising, but has “...yet to meaningfully inform the design of targeted reading-related interventions ...” (Elliott & Grigorenko, 2014)

**Consensus Definition of Dyslexia**

1. “Dyslexia is characterized by difficulties with accurate and/or fluent word recognition and by poor spelling and decoding abilities.
2. These difficulties typically result from a deficit in the phonological component of language that is often unexpected in relation to other cognitive abilities and the provision of effective classroom instruction.
3. Secondary consequences may include problems in reading comprehension and reduced reading experience that can impede growth of vocabulary and background knowledge.”

**Important Limitations**

- Identification questions limited to word level outcomes
- Analyses used a small set of predictors and excluded some important components of reading (e.g., orthographic processing)
- The sample was clinically-referred and distributions of deficits may not accurately reflect general population
- Component deficits may be a consequence of the reading deficit rather than cause (e.g., Wagner et al., 1994)
Thank You
Jerry.Ring@TSRH.ORG
References


Multiple Deficit Model

Adapted from Pennington (2006). *Cognition, 101*, 385-413. Figure 2.

**Level of Analysis**
- Etiologic Risk and Protective Factors
  - G1
  - E1
  - G2
  - E2
  - G3

**Non-Independence at each Level**
- GxE Interaction & G-E Correlation

**Neural Systems**
- N1
- N2
- N3

**Pleiotropy**

**Cognitive Processes**
- C1
- C2
- C3

**Interactive Development**

**Complex Behavioral Disorders**
- D1
- D2
- D3

**Comorbidity**

**KEY**
- G = genetic risk protective factor, E = environmental risk or protective factor,
- N = neural system, C = cognitive process, D = disorder