Identifying Subtypes of Mathematics Disabilities

Sally Kemp, Ph.D.
Gloria Maccow, Ph.D.

Objectives

- Describe the cognitive processes involved in the acquisition of mathematics skills.
- Describe assessment batteries to identify subtypes of mathematics disability.
- Describe interventions based on subtype of mathematics disability.

Learning Mathematics . . .

. . . requires continual integration and coordination of conceptual and procedural knowledge.

(Rittle-Johnson, Siegler, Alibali, 2001)

\[
349 + 23 = \boxed{3 \ 4 \ 9} + \boxed{2 \ 3} \]

\[\boxed{3\ 4\ 9} + \boxed{2\ 3} \]
Mathematics: Two Major Areas of Difficulty

1. Lacks mastery of basic number facts
   - Partial mastery of some facts
   - Fact retrieval is not automatic
   - Difficulty using facts for calculation

2. Has difficulty solving word problems
   - Ineffective, inefficient, or missing strategy.
   - Difficulty understanding the language of the problem.
   - Difficulty identifying the salient information.
   - Difficulty “setting up” the problem (reasoning).
   - Difficulty implementing the appropriate algorithms (performing the calculations).

And one minor—visual-spatial difficulties
Math-Related Cognitive Processes

Cognitive Processes

- Coding in working memory
- Visual symbols of numbers (numerals)
- Writing numeric symbols
- Making automatic associations of verbal names with visual numerals
- Visual-spatial and temporal-sequential aspects of computational operations
- Accessing math facts in long-term memory (LTM)
- Executive monitoring of math operations
- Reasoning with numbers to solve math problems
- Holding in memory quantitative, visual-spatial, and verbal information while working on the problem

Coding Alphanumeric Stimuli in Working Memory (Berninger, 2007)
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Working Memory Theory
(Baddeley, 2003)

Executive Functions–Switching Set
(Berninger, 2007)

Executive Functions–Inhibition
(Berninger, 2007)
Executive Functions—Monitoring
(Berninger, 2007)

Cognitive Mechanism | Math Deficit
--- | ---
Language Systems | Information representation, as in articulating number words.
Working Memory | Information manipulation as during the act of counting.
Visual-Spatial Processing | Representations of conceptual knowledge, such as number magnitudes and information in a spatial form (as in a chart).
Attentional and Inhibitory Processes (Executive Controls) | Using procedures during problem-solving.

(See, e.g., Geary's work)

Mathematics Learning Disabilities:
Core Deficit of "Number Sense?"
Identifying Subtypes of Mathematics Disabilities
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Subtypes of Math LD (Geary, 2004)

<table>
<thead>
<tr>
<th>Procedural</th>
<th>Semantic Memory</th>
<th>Visuospatial</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adequate quantitative and quantity-symbol knowledge.</td>
<td>Weak math fact retrieval.</td>
<td>Weak spatial representation of number.</td>
</tr>
<tr>
<td>Weak arithmetic strategies and algorithm use with many calculation errors.</td>
<td>Weak number-symbol association.</td>
<td>Difficulties with column alignment, place values.</td>
</tr>
<tr>
<td>Limitations in verbal working memory and conceptual knowledge.</td>
<td>Difficulty encoding and retrieving phonological and/or semantic information from long-term memory.</td>
<td>Relative strengths in rote memory and verbal tasks.</td>
</tr>
</tbody>
</table>

Causes and Effect

Math LD: Evaluation and Assessment
Areas to Assess

- Domains of Development
- Current levels of Academic Functioning for Math Assessment
- Neuropsychological Processes for Comprehensive Assessment of Math

Using the NEPSY-II Diagnostic Referral Battery for Mathematics To Identify Neuropsychological Factors Underlying Mathematics Disorders (MD)

The Eight Diagnostic Referral Batteries* of NEPSY-II

<table>
<thead>
<tr>
<th>Learning Differences:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reading: 12 subtests</td>
</tr>
<tr>
<td>Mathematics: 11 subtests</td>
</tr>
<tr>
<td>Attention/Concentration: 14 subtests</td>
</tr>
<tr>
<td>Behavior Management: 13 subtests</td>
</tr>
</tbody>
</table>

*The examiner may add or delete subtests. The number of tests varies by age.

<table>
<thead>
<tr>
<th>Lang. Delays/Disorder</th>
</tr>
</thead>
<tbody>
<tr>
<td>14 subtests</td>
</tr>
<tr>
<td>Perceptual Motor Delays/Disorder</td>
</tr>
<tr>
<td>13 subtests</td>
</tr>
<tr>
<td>Social/Interpersonal</td>
</tr>
<tr>
<td>18 subtests</td>
</tr>
<tr>
<td>School Readiness</td>
</tr>
<tr>
<td>10 subtests</td>
</tr>
</tbody>
</table>

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Selection of Subtests for the Diagnostic Referral Batteries

Subtests for each referral battery were selected from 34 subtests according to:

1) Age for which test was designed
2) The largest effect sizes for significant differences in performance between a validity group (e.g. mathematics) and matched controls.
3) Identification with particular diagnostic clusters in the current literature.

Reviewing Effect Sizes and Interpretation

- A p value of .04 is a significant difference (alpha=.05) between mean scores for two groups. If there are a number of significant results, which are likely to make the most difference in comparing the groups.
- Values ranging from .20 -.49 = small effects
- Values from .50 -.79 = moderate effect size
- Values of >.80 = large effect sizes (Cohen, 1988)

Effect sizes show evidence of reliability & validity

The Interpretation of a Significant Difference in Terms of Effect Size

- When a p value of .04 is paired with an effect size of .03, the effect is probably too small to be meaningful in assessing group differences.
- Conversely, if a p value of .04 shows an effect size of .90, the significant difference in this case would suggest a large effect.
- Therefore, the latter subtest is a good candidate for measuring the difference between a particular validity group & matched controls.
### Mean Performance By Domain of MD Group & Matched Control Group with Large Effect Sizes

#### Attention/Executive Functioning Domain

<table>
<thead>
<tr>
<th>Score</th>
<th>MD Grp.</th>
<th>Controls</th>
<th>N</th>
<th>Differ.</th>
<th>T value</th>
<th>P value</th>
<th>Effect Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>RS Total Correct</td>
<td>8.3</td>
<td>11.1</td>
<td>16</td>
<td>2.75</td>
<td>3.13</td>
<td>&lt;.01</td>
<td>.86</td>
</tr>
<tr>
<td>RS Comb. Score</td>
<td>7.8</td>
<td>10.7</td>
<td>16</td>
<td>2.88</td>
<td>3.46</td>
<td>&lt;.01</td>
<td>.99</td>
</tr>
<tr>
<td>AA vs RS Contrast</td>
<td>8.3</td>
<td>10.9</td>
<td>15</td>
<td>2.60</td>
<td>2.98</td>
<td>&lt;.01</td>
<td>.94</td>
</tr>
<tr>
<td>IN Inhib Comb.</td>
<td>7.2</td>
<td>10.3</td>
<td>18</td>
<td>3.11</td>
<td>3.29</td>
<td>&lt;.01</td>
<td>1.14</td>
</tr>
<tr>
<td>IN Total Errors</td>
<td>7.0</td>
<td>9.8</td>
<td>17</td>
<td>2.82</td>
<td>3.07</td>
<td>&lt;.01</td>
<td>.99</td>
</tr>
<tr>
<td>IN Nam vs. Inhib Contrast</td>
<td>7.8</td>
<td>10.5</td>
<td>18</td>
<td>2.67</td>
<td>3.20</td>
<td>&lt;.01</td>
<td>1.12</td>
</tr>
</tbody>
</table>

**Legend:**
- **AA** = Auditory Attention Test
- **RS** = Response Set Test
- **IN** = Inhibition Subtest
- **Nam** = IN Naming section

**Note:** Effect Size is calculated as "Effect Size = (Score - Control Score) / SD of Controls".

#### Memory and Learning Domain

<table>
<thead>
<tr>
<th>Score</th>
<th>MD Grp.</th>
<th>Controls</th>
<th>N</th>
<th>Differ.</th>
<th>t value</th>
<th>p value</th>
<th>Effect Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>MD Content</td>
<td>6.6</td>
<td>10.2</td>
<td>18</td>
<td>3.56</td>
<td>3.23</td>
<td>&lt;.01</td>
<td>1.05</td>
</tr>
<tr>
<td>MD Spatial</td>
<td>7.0</td>
<td>10.0</td>
<td>18</td>
<td>3.00</td>
<td>2.59</td>
<td>.02</td>
<td>.96</td>
</tr>
<tr>
<td>MD Total</td>
<td>6.1</td>
<td>10.3</td>
<td>18</td>
<td>4.22</td>
<td>3.80</td>
<td>&lt;.01</td>
<td>1.27</td>
</tr>
<tr>
<td>MDD Content</td>
<td>6.5</td>
<td>10.3</td>
<td>18</td>
<td>3.50</td>
<td>2.79</td>
<td>&lt;.01</td>
<td>1.04</td>
</tr>
<tr>
<td>MDD Spatial</td>
<td>7.3</td>
<td>9.9</td>
<td>18</td>
<td>2.56</td>
<td>2.30</td>
<td>&lt;.03</td>
<td>.88</td>
</tr>
<tr>
<td>MDD Tot</td>
<td>6.7</td>
<td>9.9</td>
<td>18</td>
<td>3.28</td>
<td>3.38</td>
<td>&lt;.01</td>
<td>1.18</td>
</tr>
<tr>
<td>MFD Tot</td>
<td>8.4</td>
<td>10.3</td>
<td>19</td>
<td>1.95</td>
<td>2.61</td>
<td>.02</td>
<td>.88</td>
</tr>
</tbody>
</table>

**Legend:**
- **MD** = Mem for Designs
- **MDD** = Mem for Designs Delayed
- **Content** = Design
- **MFD** = Mem for Faces Delayed
- **Spatial** = Location

#### Visuospatial Processing Domain

<table>
<thead>
<tr>
<th>Score</th>
<th>MD Grp.</th>
<th>Controls</th>
<th>N</th>
<th>Differ.</th>
<th>T value</th>
<th>p value</th>
<th>Effect Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Block Construction</td>
<td>8.1</td>
<td>10.1</td>
<td>20</td>
<td>2.00</td>
<td>2.30</td>
<td>.03</td>
<td>.88</td>
</tr>
<tr>
<td>Geometric Puzzles Total</td>
<td>7.2</td>
<td>10.4</td>
<td>20</td>
<td>3.20</td>
<td>3.16</td>
<td>&lt;.01</td>
<td>1.23</td>
</tr>
<tr>
<td>Picture Puzzles Total</td>
<td>6.8</td>
<td>10.3</td>
<td>20</td>
<td>3.20</td>
<td>3.00</td>
<td>&lt;.01</td>
<td>1.00</td>
</tr>
</tbody>
</table>

**Legend:**
- **Block** = Construction
- **Geometric** = Puzzles
- **Picture** = Puzzles
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LANGUAGE & SENSORIMOTOR FUNCTION–
Causes of Math Problems?

- NEPSY-II results suggest that language and sensorimotor function *per se* are not root causes of math disorders.
- However, the child may have an underlying language or sensorimotor deficit contributing to poor math performance.
- There were no significant differences in the language or sensorimotor domain results for the MD group in relation to Controls.

LANGUAGE & SENSORIMOTOR FUNCTION–
Causes of Math Disorder?

Language Areas assessed included:
1. Comprehension of (oral) Instructions
2. Phonological Processing
3. Speeded Naming

Sensorimotor Areas assessed included:
1. Dominant and Nondominant Finger-Tapping - Repetitions & Sequential;
2. Visuomotor Precision Time & Accuracy (Pencil Line through Winding Tracks)

No Significant Differences or Large Effects in either area.

Diagnostic Referral Battery for Learning Differences–Mathematics

<table>
<thead>
<tr>
<th>Attention/Executive Function</th>
<th>Age</th>
<th>Subtest</th>
<th>Processes Assessed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>5-16</td>
<td>Auditory Attention and Response Set *</td>
<td>Auditory attention, maintenance/inhibition, and shift of auditory set.</td>
</tr>
<tr>
<td>5-16</td>
<td></td>
<td>Inhibition *</td>
<td>Visual attention, maintenance, inhibition, and shift of visual set.</td>
</tr>
<tr>
<td>3-6</td>
<td></td>
<td>Statue</td>
<td>Motor/auditory inhibition.</td>
</tr>
</tbody>
</table>

*Significant difference and large effect size.
### Diagnostic Referral Battery for Learning Differences–Mathematics

#### Language Domain

<table>
<thead>
<tr>
<th>Age</th>
<th>Subtest</th>
<th>Processes Assessed</th>
</tr>
</thead>
<tbody>
<tr>
<td>3-16</td>
<td>Comprehension of Instructions*</td>
<td>Understanding of Oral Language</td>
</tr>
<tr>
<td>3-16</td>
<td>Speeded Naming*</td>
<td>Rapid Naming – rapid semantic access and production of names (language labels).</td>
</tr>
</tbody>
</table>

*No significant difference in performance between MD & controls. These tests are included to check that language deficits are not affecting math.

#### Memory and Learning

<table>
<thead>
<tr>
<th>Age</th>
<th>Subtest</th>
<th>Processes Assessed</th>
</tr>
</thead>
<tbody>
<tr>
<td>3-16</td>
<td>Memory for Designs* and Memory for Designs Delayed</td>
<td>Visuospatial immediate and long-term memory for visual designs and location.</td>
</tr>
<tr>
<td>5-16</td>
<td>Memory for Faces and Memory for Faces Delayed*</td>
<td>Encoding of facial features; a specific form of visuospatial memory.</td>
</tr>
<tr>
<td>7-16</td>
<td>Word List Interference (No significant difference)</td>
<td>Verbal working memory; repetition and recall after interference.</td>
</tr>
</tbody>
</table>

*Significant difference and large effect sizes.

#### Sensorimotor

<table>
<thead>
<tr>
<th>Age</th>
<th>Subtest</th>
<th>Processes Assessed</th>
</tr>
</thead>
<tbody>
<tr>
<td>3-12</td>
<td>Visuomotor Precision*</td>
<td>Graphomotor speed and accuracy.</td>
</tr>
</tbody>
</table>

*No Significant difference between math validity group and control. Included in referral battery for math because a child with problems in this area may appear to have math difficulty.

#### Social Perception**

**Include only if social deficits are present.
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Diagnostic Referral Battery for Learning Differences—Mathematics

<table>
<thead>
<tr>
<th>Age</th>
<th>Subtest</th>
<th>Processes Assessed</th>
</tr>
</thead>
<tbody>
<tr>
<td>3-6</td>
<td>Block Construction*</td>
<td>Visuospatial/visuomotor ability to reproduce 3-D constructions from models or 2-D drawings.</td>
</tr>
<tr>
<td>3-16</td>
<td>Design Copying</td>
<td>Visuomotor/visuo perceptual skills in copying 2-D designs.</td>
</tr>
<tr>
<td>3-16</td>
<td>Geometric Puzzles*</td>
<td>Visuospatial analysis, mental rotation, attention to detail.</td>
</tr>
<tr>
<td>7-16</td>
<td>Picture Puzzles*</td>
<td>Visual discrimination, spatial location, part/whole relations. Both puzzles non-motor.</td>
</tr>
</tbody>
</table>

*Significant difference and large effect size.

Identifying Math Disorders from the Diagnostic Referral Battery

The MD Group displayed significant **PRIMARY VISUOSPATIAL DEFICITS** on two nonmotor tasks, therefore, problems are likely to occur in:

1) Basic visuospatial concepts of math: shapes of numerals, spatial representation of numbers, counting, place value, column alignment.

2) Further, visuospatial and temporal aspects of computational operations are apt to be difficult, such as columnar trading, spatial relationships.

Identifying Math Disorders from the Diagnostic Referral Battery

The MD Group displayed significant problems in **VISUOSPATIAL MEMORY AND LEARNING, IMMEDIATE & DELAYED** due to a primary visuospatial weakness; therefore, problems are likely to occur in:

1) Conceptual knowledge of place value/part-whole relationships.

2) Poor recall & mental calculations. Needs to write calculations due to inability to visualize the configuration and location of numbers. Manipulative materials to cue memory and visuospatial factors.

3) Poor coding of stimuli in orthographic memory.
Identifying Math Disorders from the Diagnostic Referral Battery

The MD Group displayed significant problems in **EXECUTIVE FUNCTIONING** therefore, problems are likely to occur in:

1) Working memory due to poor ability to inhibit auditory or visual stimuli.
2) Focusing attention on relevant stimuli & suppressing irrelevant stimuli. Self-monitoring, updating, and revising will be difficult.
3) Planning steps for problem-solution. Holding in memory quantitative, visuospatial information.
4) Switching attention, mental set, strategies.

Interventions

**INTERVENTIONS for VISUOSPATIAL MATH DISORDER**

- Should be evaluated for ADHD due to presence of executive dysfunction.
- Manipulatives, 3-D number lines, balance bar, work on graph paper to keep columns uniform, Cuisenaire rods, sequenced computer programs.
- Fewer math topics should be covered, but more in depth before moving on.
**INTERVENTIONS for VISUOSPATIAL MATH DISORDER**

- Explicit instruction: Clear models for solving a problem type with extensive practice; talk aloud and get extensive feedback.
- Work with tangrams, block constructions, follow directions to construct a Lego toy.
- When learning different names for shapes, provide plastic models of each so the child can “feel” and internalize the shape.

- Help the child learn a tactile shape then he/she can recreate it from memory on paper.
- Play with a sibling or parent assembling puzzles. Show child visual cues on the piece that will help him/her to find where it goes.
- Play checkers so he/she becomes aware of monitoring his/her moves.
- Work with child for short periods with a break.

**Interventions for Semantic Memory Subtype**

To help the student commit math facts to automatic recall, allow him/her to practice the facts with different combinations of input (looking or listening) and output (writing or saying).

<table>
<thead>
<tr>
<th>Input</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>Look</td>
<td>Write</td>
</tr>
<tr>
<td>Look</td>
<td>Say</td>
</tr>
<tr>
<td>Listen</td>
<td>Write</td>
</tr>
<tr>
<td>Listen</td>
<td>Say</td>
</tr>
</tbody>
</table>
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Students who know the cluster facts already have learned the majority of the basic addition facts.

<table>
<thead>
<tr>
<th>+</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
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<tbody>
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<td>14</td>
<td>15</td>
<td>16</td>
<td>17</td>
<td>18</td>
</tr>
</tbody>
</table>

For older students, start with the larger numbers.

Using Color Coding

Magic 9s

| 0 x 9 = 00 | 0 + 9 = 9 |
| 1 x 9 = 09 | 0 + 9 = 9 |
| 2 x 9 = 18 | 1 + 8 = 9 |
| 3 x 9 = 27 | 2 + 7 = 9 |
| 4 x 9 = 36 | 3 + 6 = 9 |
| 5 x 9 = 45 | 4 + 5 = 9 |
| 6 x 9 = 54 | 5 + 4 = 9 |
| 7 x 9 = 63 | 6 + 3 = 9 |
| 8 x 9 = 72 | 7 + 2 = 9 |
| 9 x 9 = 81 | 8 + 1 = 9 |
| 10 x 9 = 90 | 9 + 0 = 9 |

Examples of visual fact retrieval strategies

Use visual cues

To teach doubles

To visualize ten sums, 10 + 1, or 10 - 1

4 + 6 = 10

3 + 7 = 10

4 + 7 = 11
Examples of Verbal Fact Retrieval Strategies

- Putting facts to rhyme or music (by cluster).
- Using skip counting to retrieve multiplication fact (by 10's, by 5's, by 2's, by 3's ...).
- Pair verbal with visual by using fingers, number line, beads on string, etc. Student talks aloud as he reviews facts.
- Practice computational process using known facts.

Interventions for Procedural Deficits

The following strategies can improve attention to task:

- Preview assignments.
- Read aloud written math problems.
- Self-monitor.
- Prompt sign checking.

These and other strategies are from http://www.allkindsofminds.org/basics-of-mathematics#mathematics-basics

Interventions for Procedural Deficits

Provide explicit instruction in the procedures/algorithms to solve specific problems. For example, for the subtraction algorithm, teach the student to complete renaming before subtracting. Ask child to verbalize while completing each step.

\[
\begin{array}{c}
8 & 4 & 7 & 2 \\
-6 & 6 & 7 & 3 \\
\hline
1 & 7 & 9 & 9 \\
\end{array}
\]

\[
\begin{array}{c}
8 & 4 & 7 & 2 \\
7 & 1 & 3 & 6 & 2 \\
-6 & 6 & 7 & 3 \\
\hline
1 & 7 & 9 & 9 \\
\end{array}
\]
Algorithms: Sometimes you need a recipe

Addition of multi-digit numbers with regrouping

Step 1. Start with the numbers on the far right, in the units place, and add them together.
Step 2. etc.

Interventions for Number Sense

To enable students to develop an understanding of number, provide direct instruction in
- counting,
- combining,
- sorting,
- comparing sets of objects,
- comparing whole numbers,
- rounding of numbers, and
- exploring place-value, fraction, and decimal concepts.


Counting

Hundreds Board

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- One more
- One less
- Count by 5s
- Count by 10s
### Place Value Chart

<table>
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<th>Place Value Chart – Whole Numbers</th>
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<tbody>
<tr>
<td>Thousands</td>
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</tbody>
</table>

### Greater than, Less than, or Equal to

Model A  
Model B

\[
\frac{3}{6} < \frac{4}{6} \\
> \text{ or } < \text{ or } =
\]

### References


Identifying Subtypes of Mathematics Disabilities
Sally Kemp, Ph.D. and Gloria Maccow, Ph.D.

References


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