Intelligence
What Is Intelligence?

- Intelligence is difficult to define.
- Intelligence can be legitimately described at three levels of analysis:
  - As consisting of one thing
  - As consisting of a few things
  - As consisting of many things
Intelligence as a Single Trait

• **Is intelligence a single entity that influences all aspects of cognitive functioning?**
  – Maybe each of us possess a certain amount of \( g \), or general intelligence, that influences our ability on all intellectual tasks.
  – **Support:** Overall scores on intelligence tests correlate positively with school grades and achievement test performance and with speed of information processing.
Intelligence as a Few Basic Abilities

- Are there two types of intelligence (Cattell)?
  - **Crystallized intelligence:**
    - Factual knowledge about the world, word meanings, arithmetic, etc.
  - **Fluid intelligence:**
    - The ability to think on the spot by drawing inferences and understanding relations between concepts not previously encountered.
    - Measured on IQ tests by object assembly, analogies, and identification tasks.
Intelligence as a Few Basic Abilities

- **Thurstone’s seven primary mental abilities:**
  - Word fluency, verbal meaning, reasoning, spatial visualization, numbering, rote memory, and perceptual speed.
- **Support for Thurstone’s view:**
  - Performance on various tests of a single ability tend to be more similar than performance on tests that are dissimilar.
- **Difference from Cattell’s view**
  - The seven-primary-ability view is more precise and complex than Cattell’s crystallized/fluid distinction.
Intelligence as Multiple Processes

- Others see intelligence as comprising many information processing tasks, such as:
  - Attending
  - Perceiving
  - Encoding
  - Associating
  - Planning
  - Reasoning
  - Problem solving
  - Generating strategies
  - Language production and comprehension.
Resolving the Competing Perspectives

• John Carroll proposed the “three-stratum theory of intelligence,” a hierarchical integration consisting of
  • g
  • eight generalized abilities
  • many specific processes
Carroll’s Three-Stratum Model of Intelligence

- Fluid intelligence
  - Sequential reasoning
  - Induction
  - Quantitative reasoning

- Crystallized intelligence
  - Printed language
  - Language comprehension
  - Vocabulary knowledge

- General memory and learning
  - Memory span
  - Associative memory

- Broad visual perception
  - Visualization
  - Spatial relations
  - Closure speed

- Broad auditory perception
  - Speech sound discrimination
  - General sound discrimination

- Broad retrieval ability
  - Creativity
  - Ideational fluency
  - Naming facility

- Broad cognitive speediness
  - Rate of test taking
  - Numerical facility
  - Perceptual speed

- Processing speed
  - Simple reaction time
  - Choice reaction time
  - Semantic processing speed
Measuring Intelligence: Intelligence Tests

- Intelligence means different things at different ages.
  - E.g., you cannot measure an infant’s language ability.
- Wechsler Intelligence Test for Children (WISC) is the most widely used instrument for children 6 years and older.
- The WISC is divided into two main sections:
  - **Verbal**: general knowledge and language skills (crystallized intelligence)
  - **Performance**: spatial and perceptual abilities (fluid intelligence)
Intelligence Quotient (IQ)

- Intelligence tests like the WISC and the Stanford-Binet provide overall quantitative measures of a child’s intelligence relative to that of other children of same age, producing the Intelligence Quotient, or IQ.
Intelligence Quotient (IQ)

- IQ computation is based on a normal distribution of scores, a pattern of data in which scores fall symmetrically around a mean value, with most scores falling close to the mean and fewer scores at the high and low ends.
  - The “mean” is the average of all scores normed.
  - The mean has been arbitrarily set at 100.
  - The normal distribution signifies that most scores are at the mean.
  - IQ scores also reflect a “standard deviation,” a measure of variability of scores within a distribution. By definition, 68% of scores must be 1 SD below the mean and 1 SD above the mean.
  - On most IQ tests, the SD is 15 points.
A Normal Distribution in IQ Scores
Stability of IQ Scores

- **Scores are stable from the age of 5 onward.**
  - Children’s IQs at 5 have high correlation with their IQs at age 15.
  - Scores, however, do show an average change, up or down a few points.
  - Changes in IQ scores over time may be influenced by characteristics of children and their parents other than intelligence, such as interest in learning and academic success.
What Do IQ Scores Predict?

- IQ is a strong predictor of academic, economic, and occupational success.
  - People with lower IQs are more likely to
    - permanently drop out of high school
    - be unemployed
    - earn an income that fails to surpass the poverty line
    - have children without being married
    - smoke during pregnancy
    - have low birth weight babies
    - be on welfare
    - be involved in crime
    - divorce
Academic Achievement & Income

- Correlation between IQ and academic achievement scores is about .85
- $25,000 in 1974 is equal to $93,300 in 2003
IQ adds to schooling

1992 weekly wages

IQ Quintile High school  IQ Quintile 2-Year college  IQ Quintile 4-Year college
Quality of IQ as Predictor

• Generally, three properties seem key in determining the importance of a dimension of individual differences.
  • Association with a broad range of qualities measured at the same time
  • Stability over time
  • Predictiveness of later outcomes in other areas
Intelligence and Individual Differences

7-year-olds
- General knowledge
  - Grades
  - Achievement test scores

15-year-olds
- Achievement test scores
  - Grades
  - Earnings

Adults
- Years of education
  - Income
  - IQ score

IQ score
  - IQ score
Development of Intelligence

- **Development of intelligence may be a product of**
  - Qualities of the child (inherited features)
  - Qualities of the environment (shared and non-shared environment)
    - home
    - school
    - economic-based environments (e.g., high-poverty neighborhoods with lots of public housing and high crime)
Genetic similarity and IQ

- **About 50% of the variation in IQs is attributable to genetic variation.**
  - Genetic contribution relative to the environmental contribution is greater in older children than in younger children.
  - IQs of adopted children increasingly correlate with their biological parents’ as the children get older.
### TABLE 3.1
Summary of Family Studies of Intelligence

<table>
<thead>
<tr>
<th>Relationship</th>
<th>Average $R$</th>
<th>Number of Pairs</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Reared-together biological relatives</td>
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</tr>
<tr>
<td>MZ twins</td>
<td>0.86</td>
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<td>DZ twins</td>
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<td>Siblings</td>
<td>0.47</td>
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<td>Half-siblings</td>
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<td>Cousins</td>
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<td></td>
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<td>MZ twins</td>
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<td></td>
<td>Reared-together nonbiological relatives</td>
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<td>Siblings</td>
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</tr>
<tr>
<td>Parent–offspring</td>
<td>0.24</td>
<td>720</td>
</tr>
</tbody>
</table>

Note: MZ = monozygotic; DZ = dizygotic.
SES and influence of genetic similarity

- Turkheimer et al. (2003) calculated heritability for twins who differed in SES
- Sample median family income: $22,000 (in 1997 dollars); 1997 US median: $53,000
Sex and IQ

• Boys and girls have almost the same IQ scores.
• There are small differences in average performance between boys and girls in specific areas:
  • Girls are more fluent in writing, perceptual speed, and verbal fluency
  • Boys as a group are stronger in visual–spatial processing, science, and math problem solving.
• Pattern of sex differences in academic achievement is similar in many countries
HOME and IQ

- How much does the home environment matter to IQ scores?
- **Home Observation for Measurement of the Environment** (HOME) is a scale used to measure factors in the home environment that might affect children’s intellectual and environmental well-being.
TABLE 6.1

Items and Subscales on the HOME (Infant Version)

I. Emotional and Verbal Responsivity of Mother
   1. Mother spontaneously vocalizes to child at least twice during visit (excluding scolding).
   2. Mother responds to child’s vocalizations with a verbal response.
   3. Mother tells child the name of some object during visit or says name of person or object in a “teaching” style.
   4. Mother’s speech is distinct, clear, and audible.
   5. Mother initiates verbal interchanges with observer—ask questions, makes spontaneous comments.
   6. Mother expresses ideas freely and easily and uses statements of appropriate length for conversation (e.g., gives more than brief answers).
   7. Mother permits child occasionally to engage in “messy” types of play.
   8. Mother spontaneously praises child’s qualities or behavior twice during visit.
   9. When speaking of or to child, mother’s voice conveys positive feelings.
   10. Mother caresses or kisses child, mother’s voice conveys positive feelings.
   11. Mother shows some positive emotional responses to praise of child offered by visitor.

II. Avoidance of Restriction and Punishment
   12. Mother does not shout at child during visit.
   13. Mother does not express overt annoyance with or hostility toward child.
   14. Mother neither slaps nor spanks child during visit.
   15. Mother reports no more than one instance of physical punishment occurred during the past week.
   16. Mother does not scold or derogate child during visit.
   17. Mother does not interfere with child’s actions or restrict child’s movements more than three times during visit.
   18. At least ten books are present and visible.
   19. Family has a pet.

III. Organization of Physical and Temporal Environment
   20. When mother is away, care is provided by one of three regular substitutes.
   21. Someone takes child into grocery store at least once a week.
   22. Child gets out of house at least four times a week.
   23. Child is taken regularly to doctor’s office or clinic.
   24. Child has a special place in which to keep his or her toys and “treasures.”
   25. Child’s play environment appears safe and free of hazards.

IV. Provision of Appropriate Play Materials
   26. Child has some muscle-activity toys or equipment.
   27. Child has push or pull toy.
   28. Child has stroller or walker, kiddie car, scooter, or tricycle.
   29. Mother provides toys or interesting activities for child during interview.
   30. Provides learning equipment appropriate to age—cuddly toy or role-playing toys.
   31. Provides learning equipment appropriate to age—mobile, table and chairs, high chair, play pen.
   32. Provides eye-hand coordination toys—items to go in and out of receptacle, fit-together toys, beads.
   33. Provides eye-hand coordination toys that permit combinations—stacking or nesting toys, blocks or building toys.
   34. Provides toys that incorporate literature or music.

V. Maternal Involvement with Child
   35. Mother tends to keep child within visual range and to look at him or her often.
   36. Mother “talks” to child while doing her work.
   37. Mother consciously encourages developmental advances.
   38. Mother invests “maturing” toys with value via her attention.
   39. Mother structures child’s play periods.
   40. Mother provides toys that challenge child to develop new skills.

VI. Opportunities for Variety of Daily Stimulation
   41. Father provides some caretaking every day.
   42. Mother reads stories at least three times weekly.
   43. Child eats at least one meal per day with mother and father.
   44. Family visits or receives visits from relatives.
   45. Child has three or more books of his or her own.
HOME and IQ

- Scores on HOME correlate with Child’s IQ
- Why?

**Some effect of HOME:**
- Parents’ IQ
- HOME score
- Child’s IQ

**No effect of HOME:**
- Parents’ IQ
- HOME score
- Child’s IQ
HOME and IQ

- Scores on HOME correlate with child IQ because
  - Home environment is affected by parents’ genes
  - Almost all studies using HOME have focused on biological parents
- With non-biological parents, scores on HOME have very low correlations with child IQ

No effect of HOME:
- Child’s IQ
- Parents’ IQ
- HOME score
Schooling and IQ

- **School attendance makes children smarter.**
  - Average IQ scores rise during the school year and drop during the summer.
  - Jumps between grade levels indicate schooling affects IQ in addition to age.
Relations of Age and Grade to IQ Scores

- **Verbal oddities**
  - Grade 4
  - Grade 5
  - Grade 6

- **Word arithmetic problems**
  - Grade 4
  - Grade 5
  - Grade 6
Poverty and IQ

- **Poverty affects intelligence in several ways:**
  - Inadequate diet can disrupt brain development.
  - Reduced access to health service, poor parenting, and insufficient stimulation and emotional support can impair intellectual growth.
  - In all countries studied, children from wealthier homes scored higher on IQ than did children from poor homes.
  - In countries where there is the greatest economic diversity, the diversity in IQ is the greatest.
Poverty and IQ

- The effect of poverty on IQ may be conceptualized in terms of ‘risk factors’
  - Mother did not complete high school
  - No father or stepfather in home
  - Large number of stressful life events
  - Maternal anxiety
Poverty and IQ

![Graph showing the relationship between number of risks and IQ for 4-Year-Olds and 13-Year-Olds. The graph indicates a decreasing trend in IQ as the number of risks increases.](image-url)
Programs for Helping Poor Children

- **Programs that may work:**
  - **Home-based programs:** Focus on improving the parenting skills of mothers.
  - **Center-based programs:** Nursery schools with emphasis in teaching reading and arithmetic skills, reinforcement of learning, and providing stimulating environment.
Effectiveness of Programs

- Gains in IQ scores from participation in early intervention programs are short-lived
- There are other long-term effects:
  - Fewer children needed special education classes
  - Fewer children were held back in school
  - More program participants graduated from high school.
Academic Achievement
Academic achievement

- Research in cognitive development has led to understanding of basic cognitive processes involved in academic achievement.
  - These basic processes provide a natural target for intervention and assessment of progress.
Reading

- Chall (1979): Description of the typical chronological progression
  - Another stage theory...
Acquisition of Reading Skills

- **Five stages of reading development**
  - **Stage 0, birth through first grade:**
    - Acquiring skills for reading, including the letters of alphabet and phonemic awareness (identification of sounds within spoken word).
  - **Stage 1, first and second grades:**
    - Acquisition of phonological recoding skills, the ability to translate letters into sounds and to blend the sounds into words ("sounding out").
  - **Stage 2, second and third grades:**
    - Gaining fluency in reading simple material.
Acquisition of Reading Skills

- **Five stages of reading development (continued)**
  - **Stage 3, fourth through eighth grades:**
    - Developing the ability to acquire new information from print—"reading to learn, rather than learning to read" (as in earlier grades).
  - **Stage 4, eighth through twelfth grades:**
    - Obtaining information from reading and acquiring the ability to appreciate multiple perspectives and viewpoints.
Information-Processing Analysis

- Rapid, effortless identification of words is central to reading and the enjoyment of reading.
- Words can be identified by
  - Phonological recoding: Converting the visual form of a word into a verbal, speechlike form
  - Visually based (Orthographic) retrieval: Proceeding directly from the visual form of a word to its meaning.
Basic Processes as “Strategies”

- Children choose between these two word identification approaches through a “strategy-choice process,” in which they choose the fastest approach that is likely to be correct.
  - On hard words, they go with the surer strategy.
  - On easier words, they go on the fastest approach.
Strategy Choices in Reading

$r = .86$
Dyslexics are much less likely to use phonological-recoding than non-dyslexics -- even when it is necessary to do so

Siegel, 1993
Functional disruption in the organization of the brain for reading in dyslexia

SALLY E. SHAYWITZ*, BENNETT A. SHAYWITZ*,‡, KENNETH R. PUGH*,§, ROBERT K. FULBRIGHT¶, R. TODD CONSTABLE¶, W. EINAR MENCL*,§, DONALD P. SHANKWEILER§, ALVIN M. LIBERMAN§, PAWEL SKUDLARSKI¶, JACK M. FLETCHER¶, LEONARD KATZ§, KAREN E. MARCHIONE*, CHERYL LACADIE¶, CHRISTOPHER GATENBY¶, and JOHN C. GORE¶‡**

FIG. 1. Number of activated pixels for brain regions where activation patterns across tasks differ significantly between NI and DYS readers. Activations (mean ± SEM) are shown on ordinate and tasks are on abscissa. We performed an overall ANOVA and followed up those interactions that were significant (minimizing type I error). Data are also shown for regions with marginal P values (minimizing type II error). Significance levels of the task by group effect (Huynh–Feldt corrected P values): STG, F(3, 171) = 4.3 and P = 0.009; BA 17, F(3, 171) = 4.0 and P = 0.012; IFG, F(3, 171) = 3.8 and P = 0.012; angular gyrus, F(3, 171) = 2.7 and P = 0.054; BA 46/47/11, F(3, 171) = 2.4 and P = 0.071; ILES, F(3, 171) = 2.2 and P = 0.094. The six anatomic regions (with center or ROI given in x, y, and z coordinates of Talairach) are (i) posterior STG, BA 22 (53, −43, 11); (ii) angular gyrus, BA 39, angular gyrus of the inferior parietal lobe (47, −45, 33); (iii) ILES, BA 18, 19, inferior occipital gyrus, inferior aspect of lateral occipital gyrus (36, −80, −5); (iv) BA 17, striate cortex (8, −89, 3); (v) IFG, BA 44 posterior aspect (pars operculum) of IFG and BA 45 middle aspect (pars triangularis) of IFG (47, 18, 18); (vi) BA 47, 11, 46, anterior inferior aspect of IFG, lateral and medial orbital gyri, and superior aspect of IFG and inferior aspect of middle frontal gyrus (33, 36, 0). Coordinates are shown for right hemisphere where x is positive (x is negative for left hemisphere).
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Fig. 3. Relative increase in activation during phonologic compared with orthographic coding in different brain regions in NI and DYS readers. As shown in the key, the shadings represent the relative magnitude of the increase in activation (mean pixel counts) for a given ROI calculated as: (NWR - C/C) = R. In posterior regions [e.g., posterior BA 22 (STG) and BA 39 (angular gyrus)], the relative change in activation is large (>2, shown in black) in NI readers but very small in DYS readers (<0.5, shown as lightest gray). A contrasting pattern is shown in anterior regions, for example, in BA 44 and 45 (IFG), where NI readers demonstrate an increase in activation (0.5–1) and DYS readers demonstrate an even greater increase (>2). There are regions where NI and DYS readers show similar increases in activation, for example, BA 6 and anterior STG (BA 41, BA 42, anterior BA 22). Brain regions shown in white were not part of the 17 ROIs examined; numbers represent BAs.
Treating the Core Deficits of Developmental Dyslexia: Evidence of Transfer of Learning After Phonologically- and Strategy-Based Reading Training Programs

Maureen W. Lovett, Susan L. Borden, Teresa DeLuca, Léa Lacerenza, Nancy J. Benson, and Demaris Brackstone

Table 1
Pre- and Posttest Means and Standard Deviations for the Training and Transfer Measures in the Different Treatment Programs

<table>
<thead>
<tr>
<th>Dependent measure</th>
<th>WIST</th>
<th></th>
<th>PHAB/DI</th>
<th></th>
<th>CSS</th>
<th></th>
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<tbody>
<tr>
<td></td>
<td>Pretest</td>
<td>Posttest</td>
<td>Pretest</td>
<td>Posttest</td>
<td>Pretest</td>
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<tr>
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<td>SD</td>
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<td>Training</td>
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<tr>
<td>Key words (no. correct/120; range: pre = 4–116, post = 15–120)</td>
<td>65.0</td>
<td>37.5</td>
<td>103.3</td>
<td>22.8</td>
<td>61.8</td>
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<td>Letter sound (no. correct/37; range: pre = 8–35, post = 14–37)</td>
<td>23.4</td>
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<td>2.6</td>
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<td>6.5</td>
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<td>Sound combinations (no. correct/30; range: pre = 0–19, post = 1–29)</td>
<td>6.1</td>
<td>5.2</td>
<td>15.1</td>
<td>3.2</td>
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<td>Transfer to real words</td>
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<td>Test-of-transfer words (no. correct/37; range: pre = 0–303, post = 2–342)</td>
<td>111.9</td>
<td>92.2</td>
<td>196.8</td>
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<td>Challenge words (no. correct/15; range: pre = 0–65, post = 0–81)</td>
<td>10.5</td>
<td>12.4</td>
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<td>22.6</td>
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<td>Regular word inventory (no. correct/298; range: pre = 3–256, post = 8–259)</td>
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<td>59.0</td>
<td>120.5</td>
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<td>72.4</td>
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<td>Exception word inventory (no. correct/298; range: pre = 2–213, post = 4–211)</td>
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<td>56.9</td>
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<td>Transfer to nonwords</td>
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<td>GFW nonword reading (no. correct/70; range: pre = 0–34, post = 0–48)</td>
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<td>WRMT-R nonword reading (no. correct/45; range: pre = 0–23, post = 0–28)</td>
<td>6.9</td>
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<td>11.0</td>
<td>7.1</td>
<td>5.8</td>
<td>4.9</td>
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<td>Word attack strategies</td>
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<tr>
<td>Select strategies (max. score = 40; range: pre = 0–40, post = 0–40)</td>
<td>11.9</td>
<td>11.5</td>
<td>26.8</td>
<td>12.0</td>
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<td>15.3</td>
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<tr>
<td>Apply strategies (max. score = 60; range: pre = 0–49, post = 0–56)</td>
<td>13.9</td>
<td>13.3</td>
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<td>16.1</td>
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<tr>
<td>Monitor success (max. score = 20; range: pre = 0–7, post = 0–18)</td>
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<td>0.6</td>
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<td>Word identification success (max. score = 40; range: pre = 0–27, post = 0–34)</td>
<td>3.8</td>
<td>5.3</td>
<td>16.1</td>
<td>9.7</td>
<td>5.6</td>
<td>6.9</td>
</tr>
</tbody>
</table>

Note. WIST = Word Identification Strategy Training; PHAB/DI = Phonological Analysis and Blending/Direct Instruction program; CSS = Classroom Survival Skills; GFW = Goldman-Fristoe-Woodcock tests; WRMT-R = Woodcock Reading Mastery Tests—Revised. Slash symbol indicates the number correct out of stated quantity.
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Table 2
Pre- and Posttest Means and Standard Deviations for the Standardized Test Measures in the Different Treatment Programs

<table>
<thead>
<tr>
<th>Dependent measure (standard scores)*</th>
<th>WIST</th>
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<td></td>
<td>M</td>
<td>SD</td>
<td>M</td>
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<tr>
<td>Word identification</td>
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<tr>
<td>WRAT–R Reading (range: pre = 47–83, post = 48–95)</td>
<td>61.9</td>
<td>10.5</td>
<td>66.6</td>
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<tr>
<td>WRMT–R Word Identification (range: pre = 35–88, post = 44–93)</td>
<td>60.5</td>
<td>11.1</td>
<td>64.4</td>
</tr>
<tr>
<td>Spelling</td>
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<td></td>
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<td>WRAT–R Spelling (range: pre = 47–87, post = 49–106)</td>
<td>66.5</td>
<td>9.5</td>
<td>68.1</td>
</tr>
<tr>
<td>PIAT–R Spelling (range: pre = 55–94, post = 55–100)</td>
<td>66.3</td>
<td>11.0</td>
<td>71.2</td>
</tr>
<tr>
<td>GFW Spelling (range: pre = 26–54, post = 8–54)</td>
<td>34.4</td>
<td>7.2</td>
<td>36.0</td>
</tr>
<tr>
<td>Phonological processing skills</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GFW Sound Analysis (range: pre = 26–63, post = 26–63)</td>
<td>37.3</td>
<td>8.9</td>
<td>42.2</td>
</tr>
<tr>
<td>GFW Sound Blending (range: pre = 27–54, post = 12–62)</td>
<td>41.3</td>
<td>5.9</td>
<td>45.2</td>
</tr>
<tr>
<td>GFW Sound–Symbol Association (range: pre = 32–64, post = 34–71)</td>
<td>48.5</td>
<td>6.9</td>
<td>52.9</td>
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<td>Additional measures</td>
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<td></td>
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<tr>
<td>WRMT–R Passage Comprehension (range: pre = 34–91, post = 40–97)</td>
<td>62.8</td>
<td>13.5</td>
<td>66.8</td>
</tr>
<tr>
<td>WRAT–R Arithmetic (range: pre = 51–112, post = 55–103)</td>
<td>75.8</td>
<td>13.2</td>
<td>75.8</td>
</tr>
<tr>
<td>Piers–Harris Self-concept (percentile range: pre = 3–99, post = 2–99)</td>
<td>45.3</td>
<td>35.6</td>
<td>68.1</td>
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</tbody>
</table>


* Mean standard scores and their standard deviations are reported. Standard scores are deviation quotients and represent an interval scale. For the WRAT–R, WRMT–R, and PIAT–R subtests, the average standard score for normative samples is 100 with a standard deviation of 15. Subjects whose standard scores are less than 70 are more than two standard deviations below age-level expectations. For the GFW subtests, the mean standard score is 50 with a standard deviation of 10.
Development of Left Occipitotemporal Systems for Skilled Reading in Children After a Phonologically-Based Intervention

Bennett A. Shaywitz, Sally E. Shaywitz, Benita A. Blachman, Kenneth R. Pugh, Robert K. Fulbright, Pawel Skudlarski, W. Einar Menczl, R. Todd Constable, John M. Holahan, Karen E. Marchione, Jack M. Fletcher, G. Reid Lyon, and John C. Gore

**Figure 1.** Composite contrast maps demonstrating the interaction of study group and intervention on brain activation patterns. Red-yellow indicates the differences in brain activation between year 1 and year 2 that were more active (p = .05) in the first group compared with the second; blue-purple indicates the differences in brain activation between year 1 and year 2 that were more active (p = .05) in the second group compared with the first. For example, the left column (community control group [CC] vs. experimental intervention group [EI]) indicates how the brain activation differences in year 1 and 2 in the CC group compared with the brain activation differences in year 1 and year 2 in the EI group. The slice locations are 12 and −4 in Talairach space. The legend for brain activation (Talairach x, y, z, coordinates in parentheses) is as follows: 1, inferior frontal gyrus (41, 23, 12); 2, caudate nucleus (−7, 10, −4); and 3, posterior aspect of the middle temporal gyrus (58, −38, −4). CI, community intervention group.

**Figure 2.** Composite maps indicating the difference in activation between year 3 and year 1 in the EI study group (n = 25). Red-yellow indicates brain regions that were more active (p = .05) in the third year; blue-purple indicates brain regions that were more active (p = .05) in the first year. The slice locations are 12 and −4 in Talairach space. Brain regions (Talairach x, y, z, coordinates in parentheses) more active in the third year compared with the first were as follows: 1, bilateral inferior frontal gyri (±41, 23, 12); 2, the left superior temporal sulcus (51, −42, 12); 3, the occipital temporal region involving the posterior aspects of the middle and inferior temporal gyri and the anterior aspect of the middle occipital gyrus (42, −49, −4); 4, the inferior occipital gyrus (34, −71, −4); and 5, the lingual gyrus (13, −88, −4). The brain regions more active in the first year compared with the third year were 6, the right middle temporal gyrus (−35, −69, 12); and 7, the caudate nucleus (−7, 10, −4).
Mathematics

- Achievement in mathematics can be studied similarly by addressing core conceptual deficits and poor strategy choices
Figure 2.2
Central conceptual structure hypothesized to underlie six-year-old’s early understanding of mathematics (dotted lines indicate “optional”—i.e., non-universal—notational knowledge)
### Basic Mathematical Concepts

#### Table 2.2
Kindergartner’s performance on number knowledge task: Percent correct on selected items

| Level  | Items                              | High SES  
|--------|------------------------------------|------------|
|        |                                    | *(n=60)*   | Mid SES  
|        |                                    | *(n=13)**  | Low SES  
|        |                                    | *(n=261)** |
| 0      | How many candies altogether         | 100        | 100       | 92        |
| (4 yrs.)| Which pile has more chips          | 100        | 100       | 93        |
|        | Count triangles                    | 85         | 92        | 79        |
| 1      | How many chocolates altogether      | 72         | 69        | 14        |
| (6 yrs.)| What number comes two numbers 7    | 64         | 69        | 28        |
|        | Which is bigger/smaller (4 items)  | 96         | 77        | 18        |
| 2      | Which is bigger/smaller (2 items)  | 48         | 15        | 1         |
| (8 yrs.)| Which is closer to 21: 25 or 18    | 53         | 31        | 2         |
|        | How much is 54 + 12                | 15         | 0         | 0         |

* 2 schools (public and private) in CA
** 1 school (private, Catholic) in CA
*** 6 schools (public) in CA and MA
Training Basic Concepts

Table 2.3
Percentage of children passing number knowledge test before and after training

<table>
<thead>
<tr>
<th>Study</th>
<th>Pretest</th>
<th>Posttest</th>
</tr>
</thead>
<tbody>
<tr>
<td>Study 1 (n = 20)</td>
<td>15</td>
<td>80</td>
</tr>
<tr>
<td>Study 2 (n = 23)</td>
<td>0</td>
<td>87</td>
</tr>
<tr>
<td>Study 3 (n = 7)</td>
<td>0</td>
<td>71</td>
</tr>
<tr>
<td>Study 4 (n = 38)</td>
<td>7</td>
<td>53</td>
</tr>
<tr>
<td>Study 5 (n = 10)</td>
<td>10</td>
<td>70</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Study</th>
<th>Pretest</th>
<th>Posttest</th>
</tr>
</thead>
<tbody>
<tr>
<td>Study 1:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Math control (n = 20)</td>
<td>15</td>
<td>37</td>
</tr>
<tr>
<td>Language control (n = 20)</td>
<td>15</td>
<td>35</td>
</tr>
<tr>
<td>Study 2 (n = 24)</td>
<td>0</td>
<td>25</td>
</tr>
<tr>
<td>Study 4 (n = 38)</td>
<td>7</td>
<td>14</td>
</tr>
</tbody>
</table>

* Groups drawn from twelve classrooms in six schools located in Canada, California, and Massachusetts.
Strategy-Choice in Mathematics

- Children use different arithmetic strategies, just as they use different word-identification strategies.
- Children use strategies of counting, retrieval, decomposition (dividing a problem into easier problems) to solve math problems.
A. Addition

Addends $\leq 5$
Sum $\leq 10$

$r = .91$
B. Subtraction

$r = .83$
C. Multiplication

$r = .83$
Individual Differences in Learning Arithmetic

- There are three different types of arithmetic learners, based on individual rate of learning and cognitive style:
  - **Good students**: Answer quickly and accurately retrieve answers.
  - **Not-so-good students**: Answer more slowly and less accurately.
  - **Perfectionists**: Answer quickly and accurately, but only use retrieval when they are sure of the answer. If they are not 100% sure, they use strategies to check their answers.
Cultural Context of Arithmetic Performance

- Some national educational systems are better than others in teaching math.
  - Teachers in countries with higher math achievement (Japan, Hong Kong, Hungary, the Netherlands)
  - spend more time on math overall than do American teachers,
  - spend more time on math concepts than on memorization of procedures.
Exam
Review Questions.

1. In Piaget’s theory, what are the sources of continuity and discontinuity in cognitive development? Provide an example of each. For example, what would be an example of equilibration?

2. How does the object concept develop? According to Piaget, what does this development indicate about infants’ thinking? What evidence indicates that Piaget’s interpretation of the A-not-B error is mistaken?

3. How did Piaget interpret failure on the conservation tasks? What did he think failure indicated about children’s thinking? What did he think success indicated about children’s thinking?

4. Why did Piaget give children the pendulum problem?

5. In what ways do the sociocultural, information-processing, and core-knowledge approaches address weaknesses in Piaget’s theory?

6. According to the information processing approach, children improve their ability to solve problems as a result of improved planning and analogical reasoning. Why do children fail to plan in situations where it would be adaptive? What obstacles do children face in analogical reasoning?

7. What evidence indicates that children’s basic cognitive processes improve with age?

8. What evidence supports the core-knowledge approach to infant cognition?

9. How do the Piagetian, information-processing, and core-knowledge theories offer unique contributions to the improvement of educating children? Provide an example of each.

10. What evidence indicates that humans possess a language acquisition device?

11. What evidence suggests that children have certain assumptions about language before they learn the meanings of words?
12. What evidence suggests that children use grammatical structure before they actually speak in fully grammatical sentences? Why is analogical reasoning unlikely to be helpful in acquiring grammar?

13. What environmental support is there for the acquisition of language? Does the evidence suggest that all, some, or none of this support is necessary for the acquisition of grammar? Justify your answer with experimental findings.

14. How do humans use symbolic reference in ways that other species do not?

15. What does gesture tell us about language?

16. What is cue validity, and how does this concept help to explain perceptual categorization, the order in which children acquire concepts, different levels of object hierarchies, and why some members of a category are more prototypical than others?

17. How did Krascum & Andrew’s (1998) study about the learning of the categories wugs and gillies indicate the importance of knowing causal relations? What evidence indicates that children go beyond perceptual similarities in their concepts?