“Seeing the forest for the trees”: Simultaneous interpretation of multiple test scores to reduce misdiagnosis

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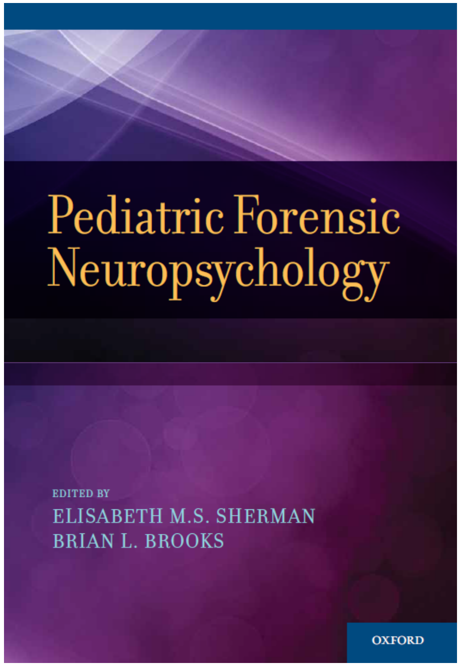
Disclosure

- Royalties from Oxford University Press for the edited book, *Pediatric Forensic Neuropsychology*
  - the Brooks & Iverson chapter provides a basis for this talk



- Funding from Psychological Assessment Resources, Inc., test publisher

Objectives

1. Understand the difference between univariate and multivariate clinical interpretation.
2. Learn the key principles of multivariate base rates.
3. Appreciate how using multivariate base rates can reduce chances of misinterpreting isolated low scores.

- Neuropsychology is well positioned to provide valuable information to the forensic process about whether a child's cognitive abilities have been negatively affected by a disease or injury, the extent of the change in cognitive functioning, and the impact of cognitive problems on day-to-day functioning.

- No other specialty has developed, normed, and validated measures of cognitive abilities in the same manner as neuropsychology.
- The diligence of our field leads to lengthy assessments covering multiple cognitive domains and generating numerous scores

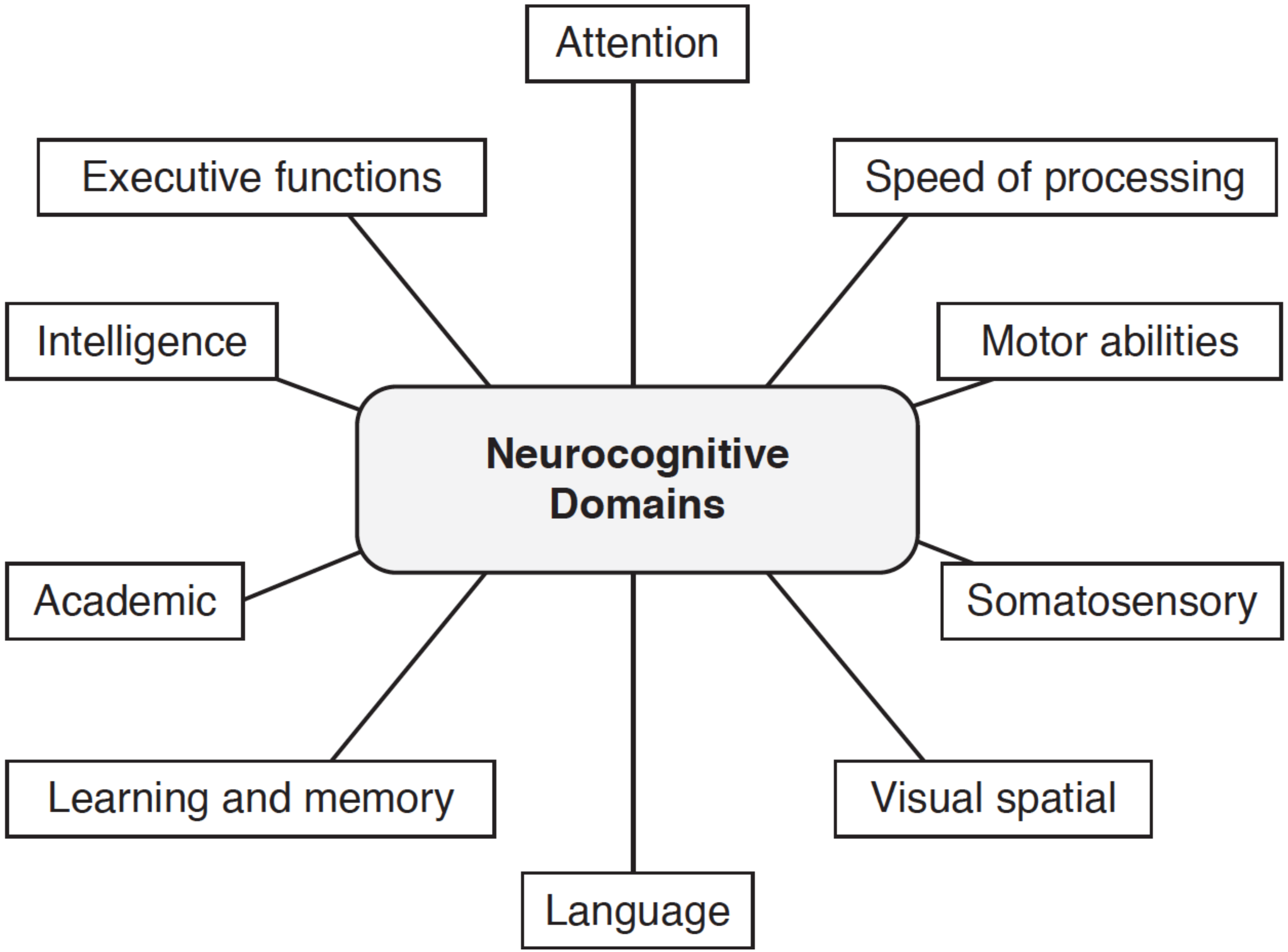


Figure 4.1; Brooks & Iverson, 2012

- Clinical neuropsychological assessments are estimated between 4.4-6.5 hours (Sweet et al., 2002)

- The average forensic neuropsychological assessment is estimated at 9.5 hours (Sweet et al., 2002)

- These assessments result in a large amount of data being gathered and analyzed

“Seeing the forest for the trees”

To discern an overall pattern from a mass of detail; to see the big picture, or the broader, more general situation

http://en.wiktionary.org/wiki/

Intellectual Abilities					
Estimated Intellectual Abilities (WPPSI-III[CDN] FSIQ)			X		
Verbal Intellectual Abilities (WPPSI-III[CDN] VCI)			X		
Nonverbal Intellectual Abilities (WPPSI-III[CDN] PRI)			X		
Verbal Knowledge and Expressive Language					
Vocabulary and Fund of Knowledge (WPPSI-III[CDN] Vocabulary)			X		
Verbal Knowledge (WPPSI-III[CDN] Information)			X		
Word Retrieval (NEPSY-II Word Generation Semantic Score)			X		
Information Processing Speed					
Visual-Motor Processing Speed (WPPSI-III[CDN] PSI)			X		
Visual-Motor Scanning Speed (WPPSI-III[CDN] Symbol Search)			X		
Visual-Motor Scanning Speed (WPPSI-III[CDN] Coding)			X		
Response Speed During Sustained Attention (TOVA Response Time)				X	
Verbal-Motor Speed (NEPSY-II IN-Naming Completion Time)			X		
Motor Abilities					
Right Hand, Motor Dexterity (Purdue Pegboard)			X		
Left Hand, Motor Dexterity (Purdue Pegboard)			X		
Attention and Concentration					
Sustained Visual Attention (TOVA Omission Errors)			X		
Executive Functioning[4]					
Verbal Reasoning (WPPSI-III[CDN] Word Reasoning)			X		
Nonverbal Reasoning and Concept Formation (WPPSI-III[CDN] Pic Concepts)			X		
Nonverbal Abstract Reasoning (WPPSI-III[CDN] Matrix Reasoning)			X		
Impulse Control – Visual (TOVA Commission Errors)			X		
-First Half Performance ("low arousal")			*X*		
-Second Half Performance ("high arousal")		*X*			
Impulse Control – Verbal (NEPSY-II IN Inhibition Completion Time)			X		
Impulse Control – Verbal (NEPSY-II IN Errors)			X		
Design Generation (MNI Design Fluency)			X		
Learning and Memory for Verbal Information					
Verbal Immediate Memory (CMS Verbal Immediate Index)			X		
Verbal Delayed Memory (CMS Verbal Delayed Index)				X	
Verbal Meaningful Immediate Memory (CMS Stories Immediate)			X		
Verbal Meaningful Delayed Memory (CMS Stories Delayed)			X		
Verbal Meaningful Recognition Memory (CMS Stories Recognition)			X		
Verbal Learning of Unrelated Information (CMS Word Pairs Total Score)			X		
Verbal Delayed Memory for Unrelated Info (CMS Word Pairs Long Delay)					X
Verbal Recognition Memory for Unrelated Info (CMS Word Pairs Recognition)				X	
Word List Learning (CVLT-C Trials 1-5)			X		
Rate of Learning (CVLT- C Slope Trials 1-5)			X		
Long Delay Free Recall of Word List (CVLT- C LDFR)			X		
Delayed Recognition of Word List (CVLT- C Recognition)			X		
Learning and Memory for Visual Information					
Visual Immediate Memory (CMS Visual Immediate Index)				X	
Visual Delayed Memory (CMS Visual Delayed Index)				X	
Visual Immediate Memory for Faces (CMS Faces Immediate)					X
Visual Delayed Memory for Faces (CMS Faces Delayed)				X	
Visual Learning of Locations (CMS Dot Locations Total)			X		
Visual Delayed Memory for Locations (CMS Dot Locations Delayed)				X	
Spatial Abilities					
Visuo-Spatial Construction (WPPSI-III[CDN] Block Design)			X		

Intellectual Abilities					
General Intellectual Abilities (WAIS-IV^{CDN} GAI[1])			X		
Verbal Intellectual Abilities (WAIS-IV^{CDN} VCI)[2]			X		
Nonverbal Intellectual Abilities (WAIS-IV^{CDN} PRI)				X	
Verbal Knowledge and Expressive Language					
Vocabulary and Fund of Knowledge (WAIS-IV^{CDN} Vocabulary)			X		
Expressive Vocabulary (WJ-III Picture Vocabulary)			X		
Following Directions (WJ-III Understanding Directions)			X		
Word Generation, First Letter Cue (DKEFS Verbal Fluency-Letter)					X
Word Generation, Category Cue (DKEFS Verbal Fluency Category)			X		
Word Decoding (WRAT-IV Word Reading)			X		
Information Processing Speed					
Visual-Motor Processing Speed (WAIS-IV^{CDN} PSI)		X			
Visual-Motor Scanning Speed (WAIS-IV^{CDN} Symbol Search)		X			
Visual-Motor Scanning Speed (WAIS-IV^{CDN} Coding)			X		
Visual-Motor Reaction Time (CAT Reaction Time)					X
Motor Abilities					
Motor Speed (Right Hand; CNS VS Finger Tapping)		X			
Motor Speed (Left Hand; CNS VS Finger Tapping)			X		
Right Hand, Motor Dexterity (Purdue Pegboard)			X		
Left Hand, Motor Dexterity (Purdue Pegboard)			X		
Attention and Concentration					
Sustained Visual Attention (CAT Hits)			X		
Executive Functioning[3]					
Verbal Reasoning and Concept Formation (WAIS-IV^{CDN} Similarities)		X			
Nonverbal Reasoning (WAIS-IV^{CDN} Matrix Reasoning)			X		
Verbal Set Switching (DEKFS Verbal Fluency-Switching Accuracy)			X		
Cognitive Flexibility (CNS VS Cognitive Flexibility Index)			X		
Impulse Control – Verbal (CNS VS Stroop Commission Errors)			X		
Learning and Memory for Verbal Information					
Word List Learning (CVLT-II Trials 1-5)			X		
Rate of Learning (CVLT- II Slope Trials 1-5)			X		
Long Delay Free Recall of Word List (CVLT- II LDFR)			X		
Delayed Recognition of Word List (CVLT- II Recognition)		X			
Verbal Recognition (CNS VS Verbal Memory)	X				
Learning and Memory for Visual Information					
Visual Immediate Memory (CVMT Hits)					X
Visual Delayed Memory (CVMT Delayed Recognition)			X		
Visual Memory (CNS VS Visual Memory)			X		
Spatial Abilities					
Visuo-Spatial Construction (WAIS-IV^{CDN} Block Design)					X
Visuo-Spatial Integration (VMI)			X		

Verbal Knowledge and Expressive Language					
Following Multi-Step Instructions (NEPSY-II Comprehension of Instructions)			X		
Word Generation, Semantic Category Cue (NEPSY-II WG-Semantic)			X		
Word Generation, First Letter Cue (NEPSY-II WG- Letter)	X				
Phonological Decoding of Words (WJ-III Word Attack)	X[5]				
Attention and Concentration					
Sustained Visual Attention (TOVA Omission Errors)		X			
Information Processing Speed					
Visual-Motor Speed (CNS VS Processing Speed Composite)			X		
Response Speed During Sustained Attention (TOVA Response Time)			X		
Verbal-Motor Speed (NEPSY-II IN-Naming Combined Score)	X				
Motor Abilities					
Motor Speed in Right Hand (Right Hand; CNS VS Finger Tapping)			X		
Right Hand Motor Dexterity (Purdue Pegboard)		X			
Motor Speed in Left Hand (Left Hand; CNS VS Finger Tapping)			X		
Left Hand Motor Dexterity (Purdue Pegboard)			X		
Executive Functioning[6]					
Impulse Control – Verbal (NEPSY-II IN Errors)	X				
Impulse Control – Verbal (NEPSY-II IN Inhibition Combined Score)		X			
Visual Impulse Control (TOVA Commission Errors)	X				
Verbal Set Switching and Inhibition (NEPSY-II IN-Switching Combined Score)		X			
Fluid Design Production (MNI Design Fluency)			X		
Learning and Memory for Verbal Information					
Word List Learning (CVLT-C Trials 1-5)			X		
Rate of Learning (CVLT- C Slope Trials 1-5)			X		
Long Delay Free Recall of Word List (CVLT- C LDFR)			X		
Delayed Recognition of Word List (CVLT- C Recognition)			X		
Learning and Memory for Visual Information					
Delayed Visual Recognition (CVMT Delayed Recognition)			X		
Visual Recognition (CNS VS Visual Memory Composite)		X			
Spatial Abilities					
Visuo-Spatial Skills (NEPSY-II Geometric Puzzles)			X		

Univariate vs. multivariate

- Univariate analyses: consideration of single test scores in isolation
- Bell curve generally applies

Univariate vs. multivariate

- Assuming a normal distribution, what percent of the population obtains a score at or below the 5th percentile?

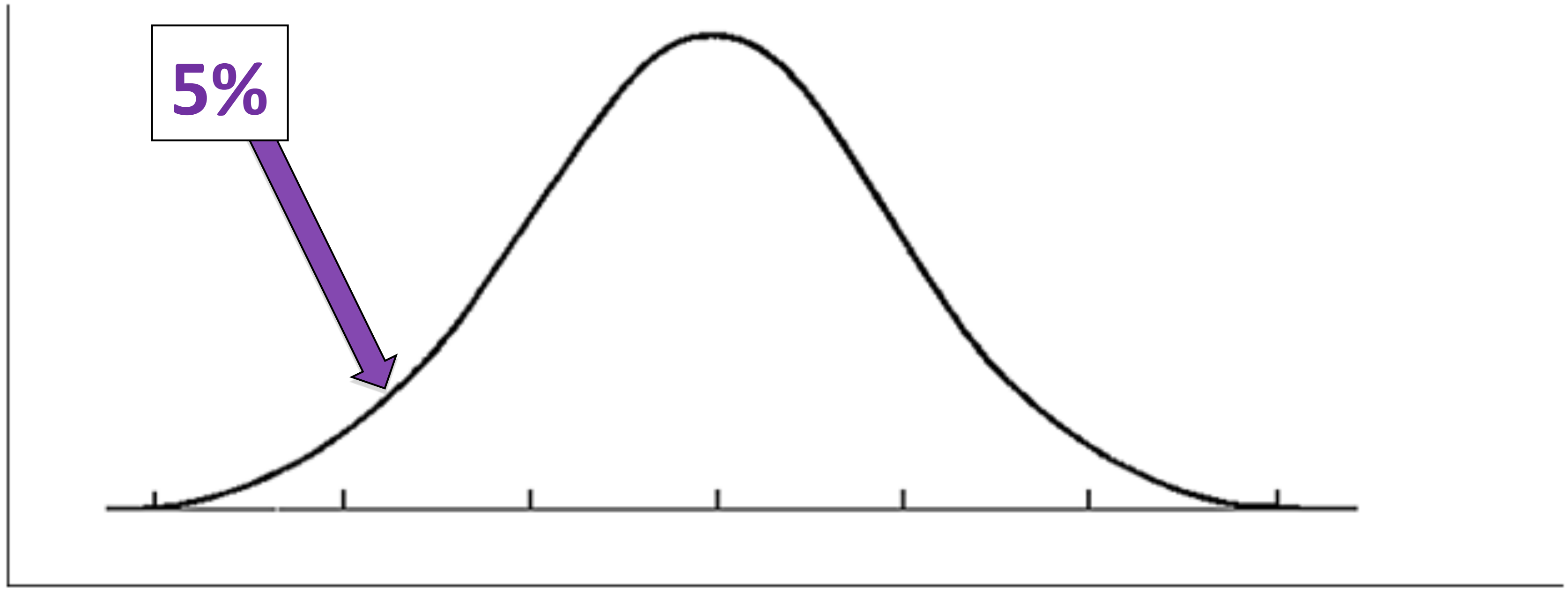


Image from http://marketingchristianbooks.wordpress.com/2012/11/15/the-bell-curve-and-books/

Univariate vs. multivariate

- What about….?
  - If two scores are interpreted?
  - If five scores are interpreted?
  - If 50 scores are interpreted?
  - If the person has low IQ?
  - If the person has high IQ?

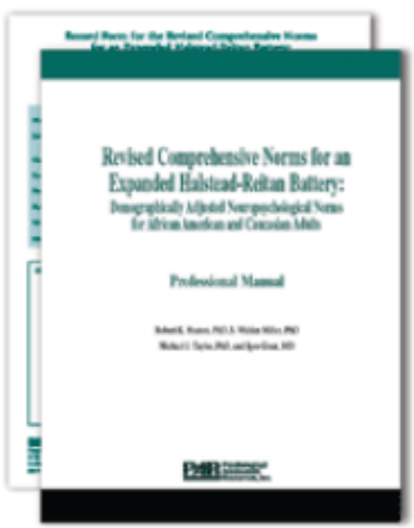
Is it still 5% having a score ≤5th percentile?

Univariate vs. multivariate

- Multivariate analyses: consideration of multiple test scores simultaneously
- Reliance on the bell curve <u>will lead us astray</u>…

Multivariate base rates

- What is the history of multivariate base rates?
  - Earliest work using the Halstead-Reitan NB
    - Reitan & Wolfson, 1985, 1993; Heaton et al., 1991
  - Majority has been done with adult tests



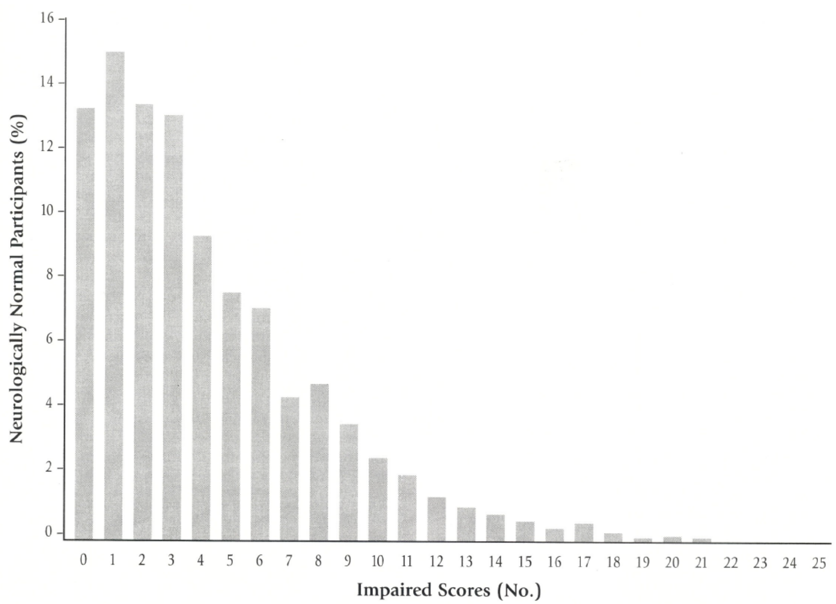


Figure 9. Frequency of "impaired" test scores (*T* scores ≤39) for 1,189 neurologically normal participants on 25 measures of the test battery.

Five principles to understand when interpreting multiple scores

Principles to understand when interpreting multiple scores

1. Test-score variability (scatter) is common
2. Having some low scores is common
3. The number of low scores is related to the cutoff score used
4. The number of low scores is related to the number of tests administered
5. The number of low scores varies by examinee characteristics

Principle 1

Variability (or scatter) is common

Variability (or scatter) is common

Percent with 1, 2, 3, or 4SD spread between highest and lowest subtest scores on WPPSI-III or WISC-IV

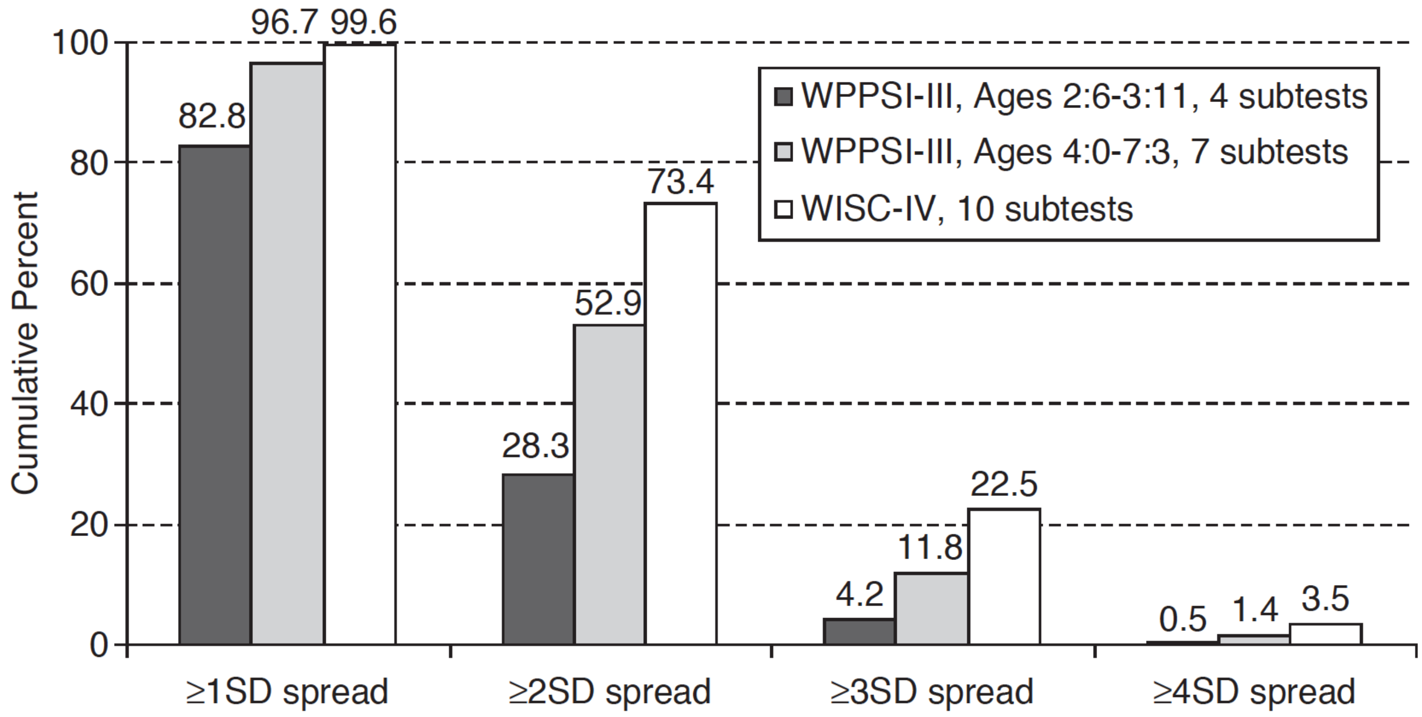


Figure 4.2; Brooks & Iverson, 2012

Principle 2

Low scores are common

Low scores are common across various batteries

Percent with 1 or more scores at or below 5th percentile on different pediatric batteries

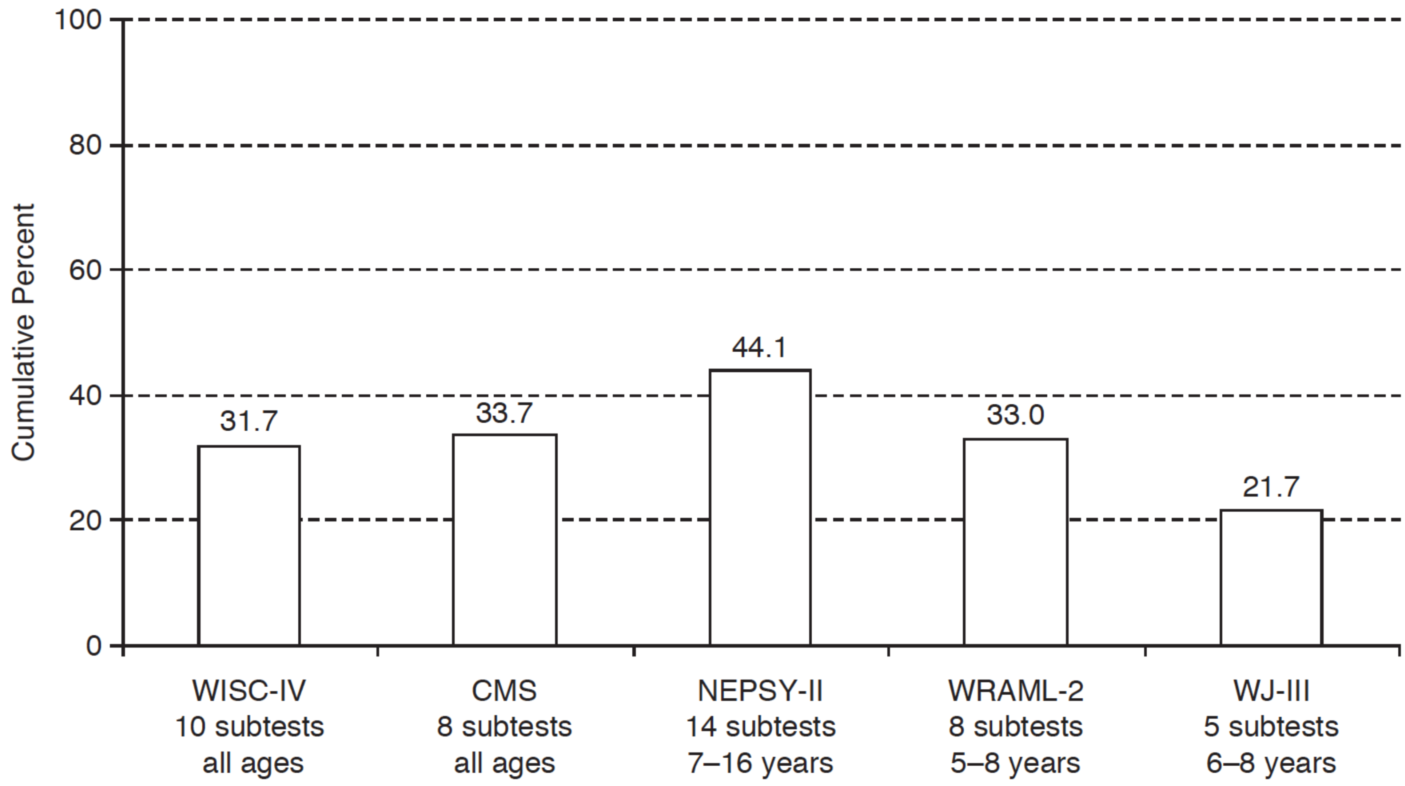


Figure 4.3; Brooks & Iverson, 2012

Principle 3

Number of low scores depends on cutoff

Number of low scores depends on the cutoff score

Percent with 1 or more low scores across different cutoff scores on three pediatric memory batteries

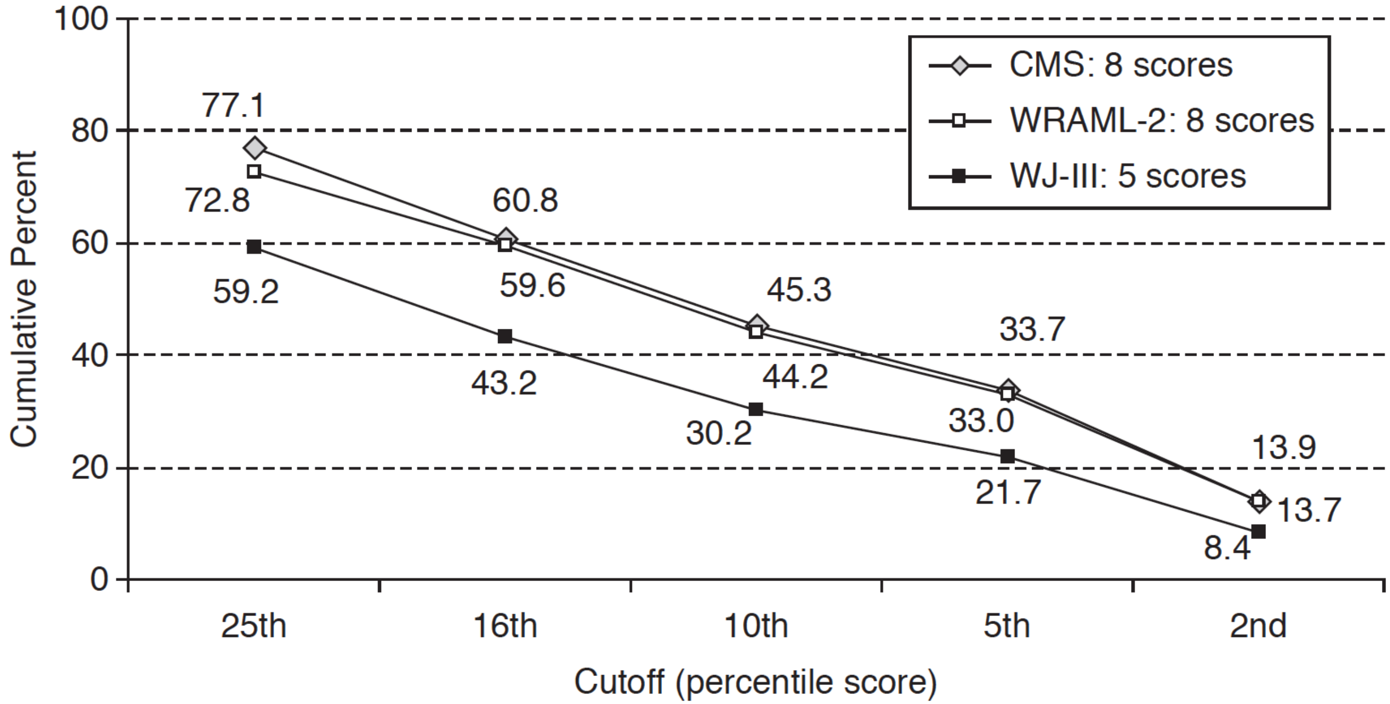


Figure 4.4; Brooks & Iverson, 2012

Principle 4

Number of low scores depends on the number of tests

Number of low scores depends on the number of tests

Percent with 1 or more scores at or below 5th percentile

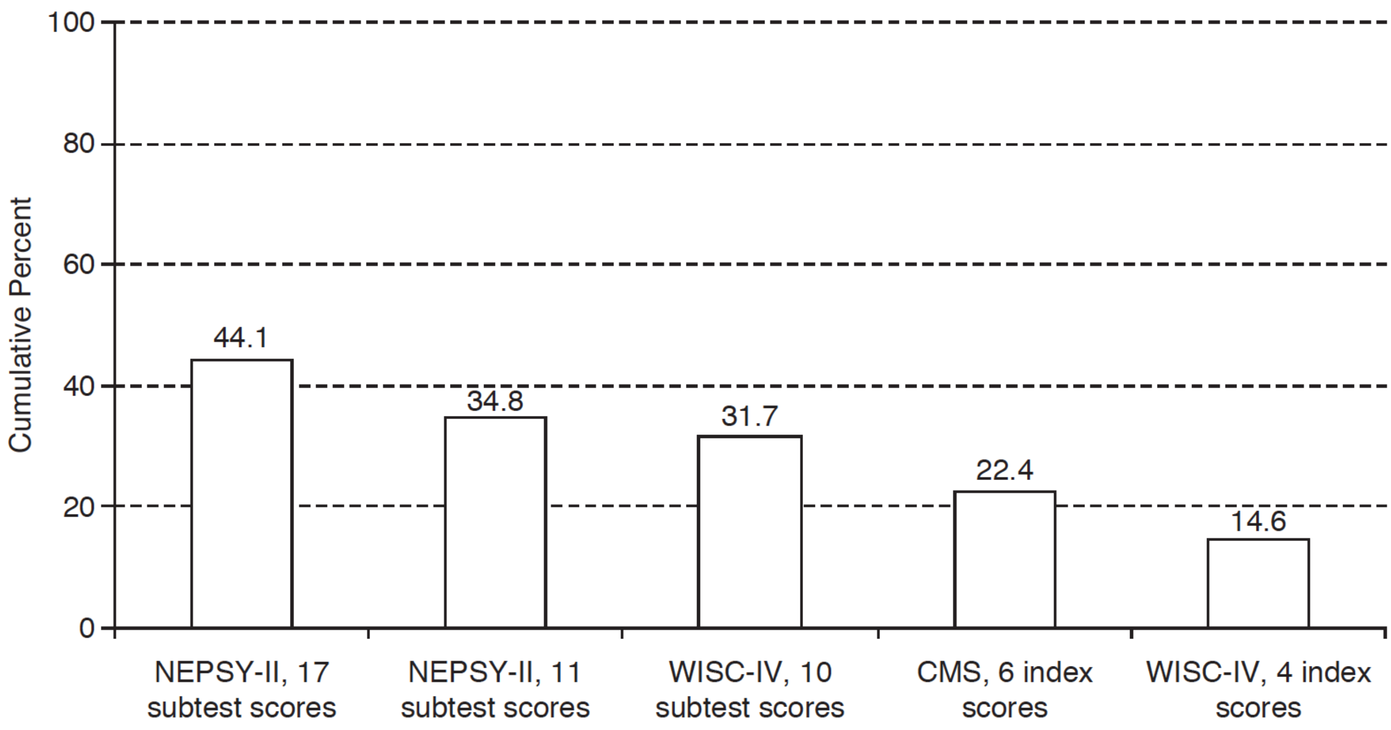


Figure 4.5; Brooks & Iverson, 2012

Principle 5

Number of low scores varies by examinee characteristics

Number of low scores varies by intellectual level

Percent with 1 or more WISC-IV subtest scores at or below 5th percentile by FSIQ categories

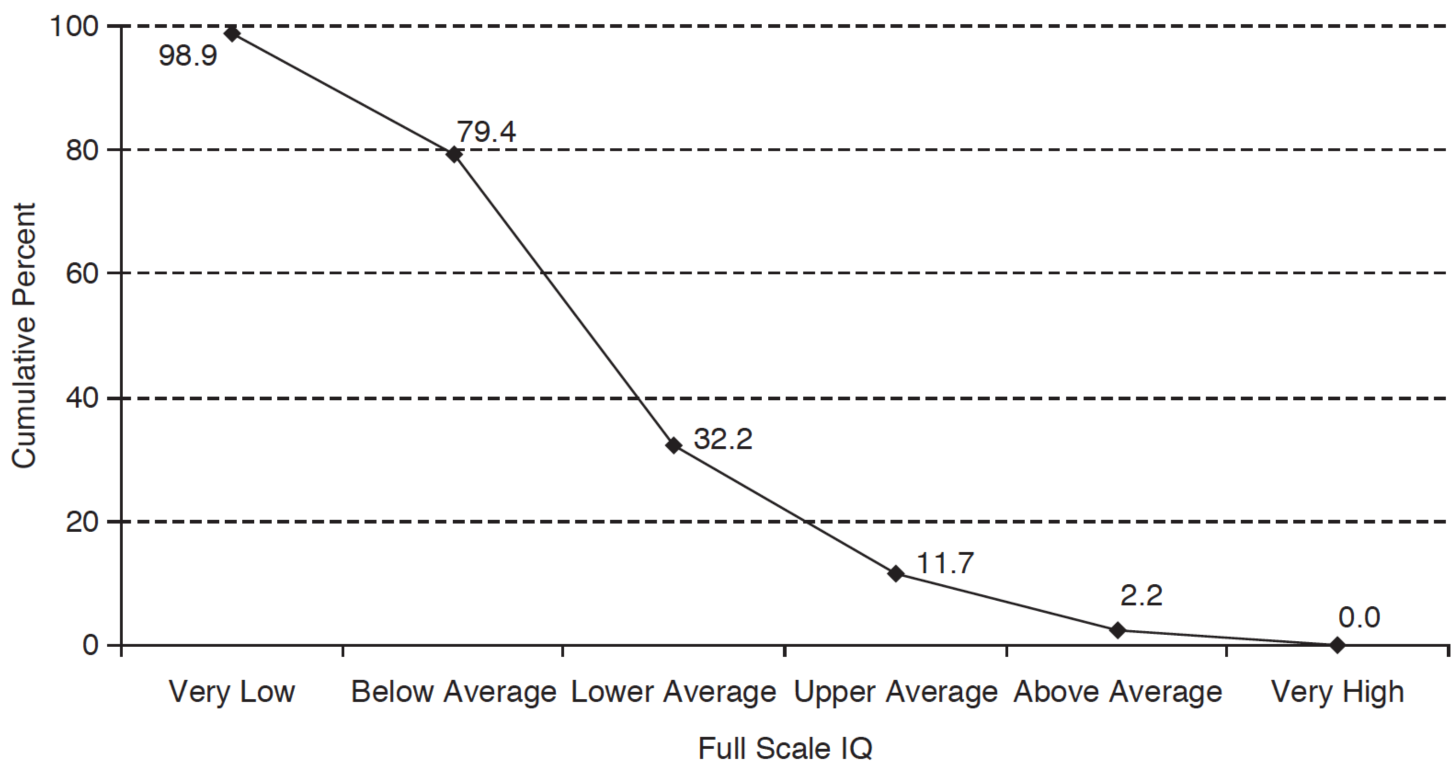


Figure 4.6; Brooks & Iverson, 2012

Number of low scores varies by intellectual level

Percent with 1 or more Children's Memory Scale index scores at or below 5th percentile by WISC-IV FSIQ

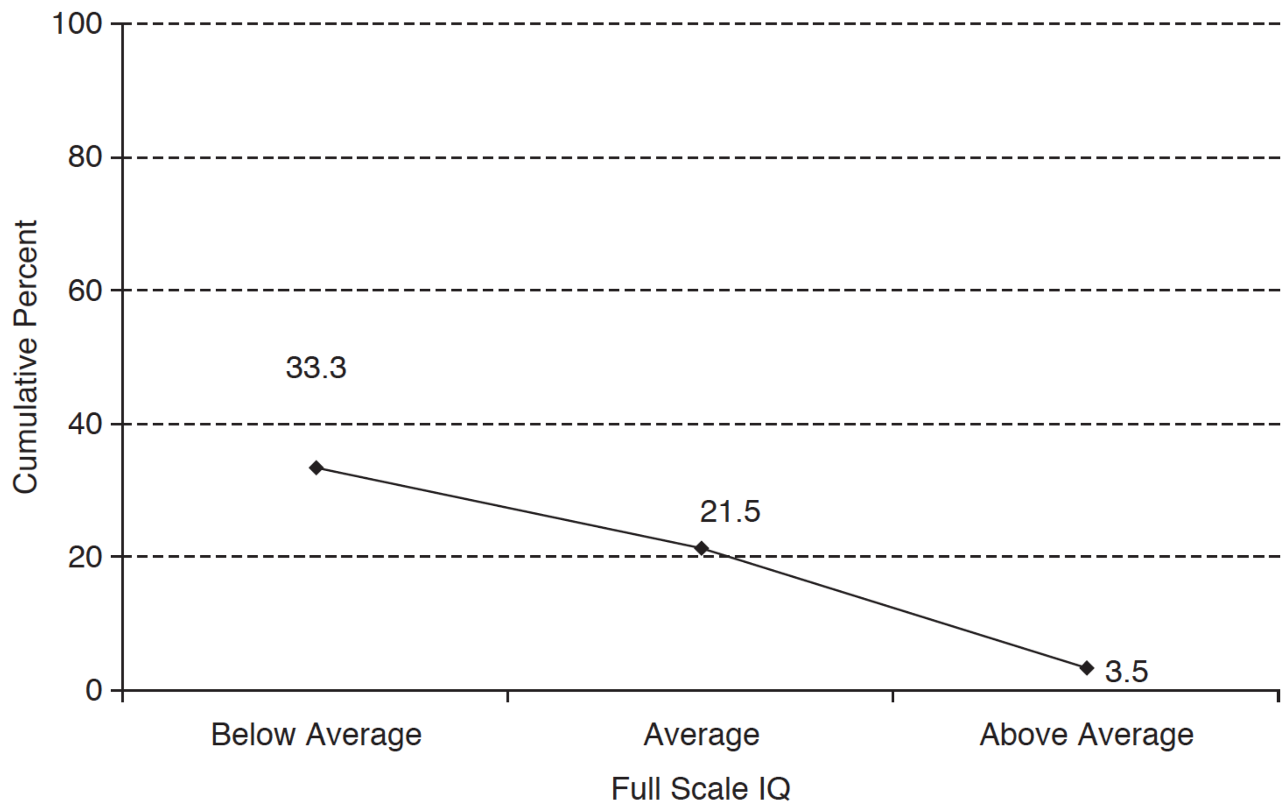


Figure 4.7; Brooks & Iverson, 2012

Number of low scores varies by parental education

Percent with 1 or more scores at or below 5th percentile by parent education

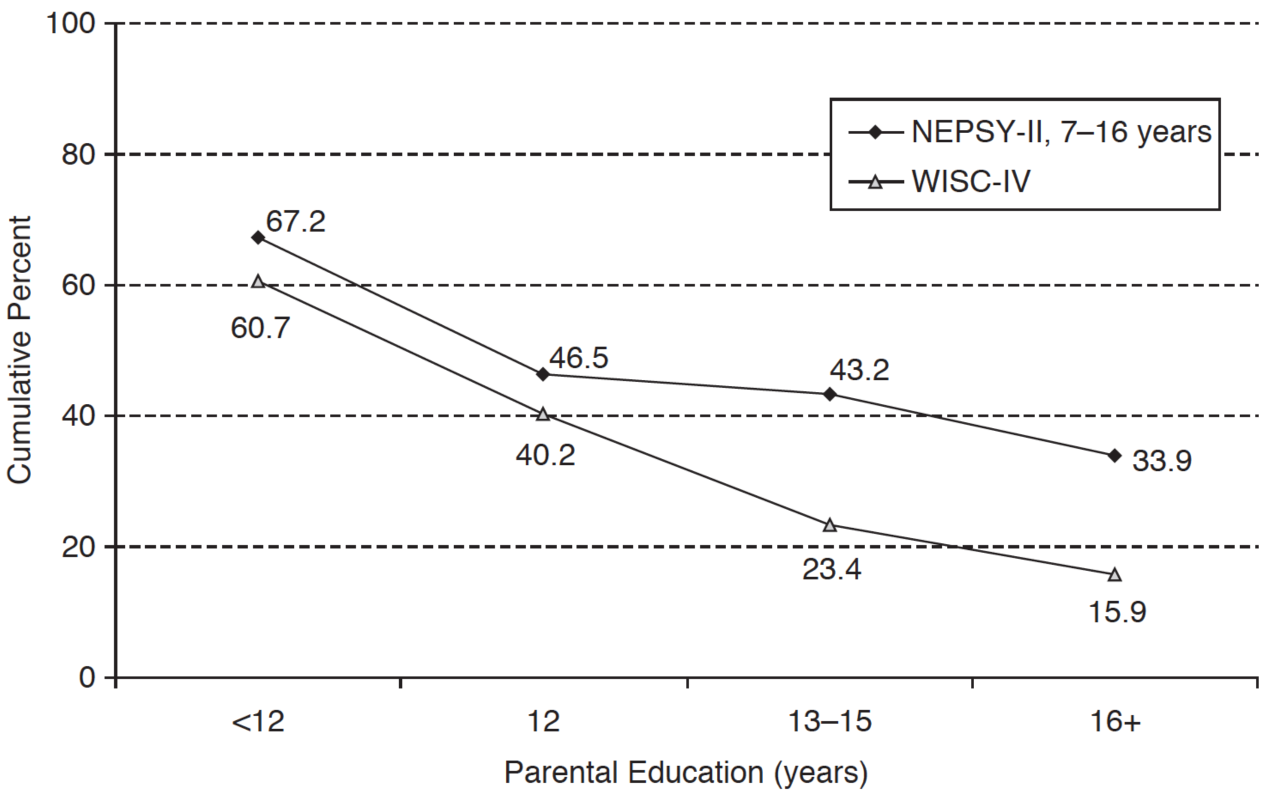


Figure 4.8; Brooks & Iverson, 2012

What is a clinician to do?

Using multivariate analyses in pediatric forensic evaluations

Using multivariate analyses in pediatric forensic evaluations

- Knowing the prevalence of low scores can help to minimize the chance of misinterpretation of isolated low scores
  - Misdiagnosis and Missed diagnosis
- Multivariate analyses help determine if a certain number of low scores is uncommon

Using multivariate analyses in pediatric forensic evaluations

- Published tables with multivariate analyses are available for some pediatric neuropsychological tests
  - WISC-IV (Brooks, 2010; Brooks, 2011; Crawford et al., 2007)
  - Children's Memory Scale (Brooks et al., 2009)
  - NEPSY-II (Brooks et al., 2010)

Using multivariate analyses in pediatric forensic evaluations

Brooks, 2010

Table 1

Base Rates of Low WISC-IV Subtest Scores by Impairment Cutoff, Level of Intelligence, and Parental Education

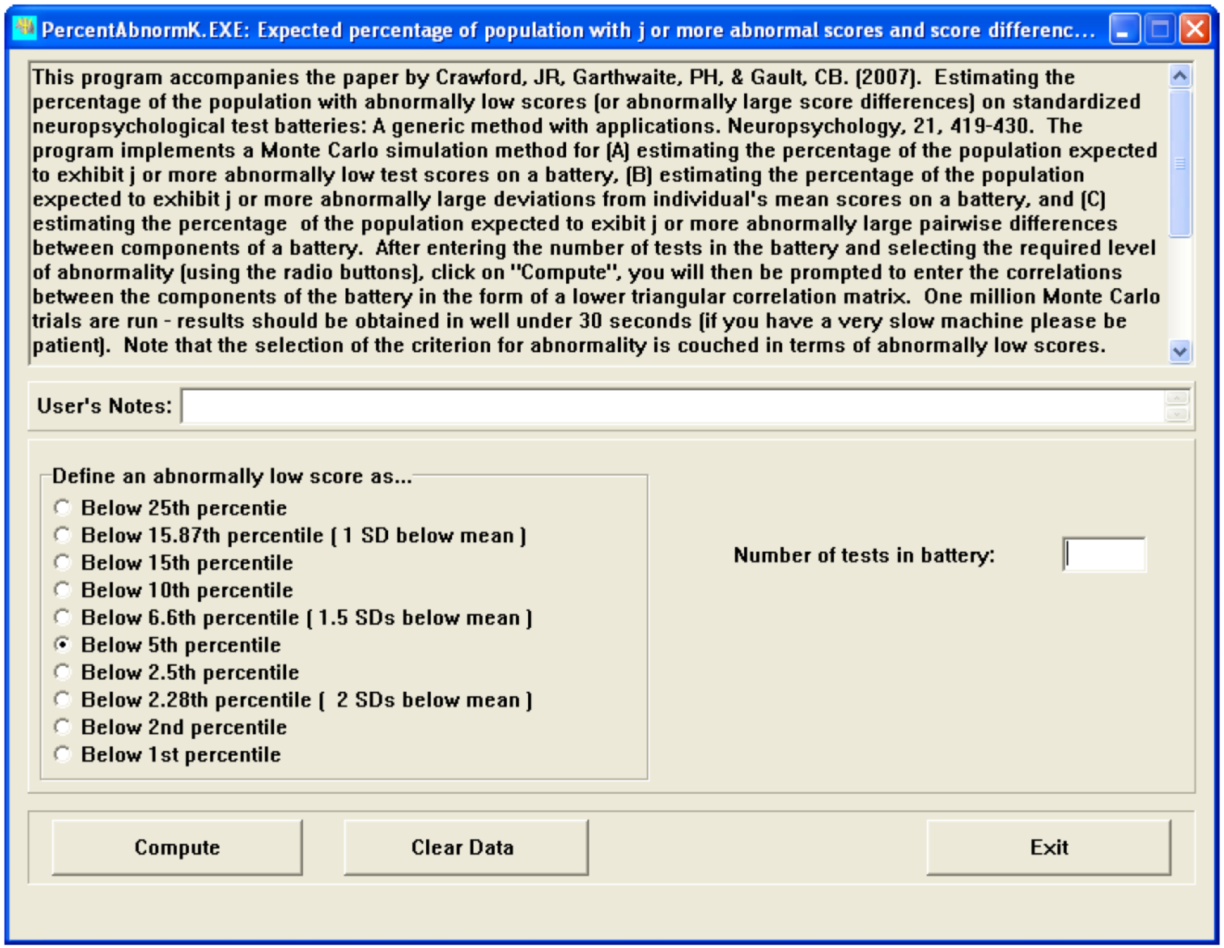
		Level of intelligence (FSIQ)						Parental education (years)				
Number of low WISC-IV scores	Total sample	Very low (<80)	Below average (80–89)	Lower average (90–99)	Upper average (100–109)	Above average (110–119)	Very high (120+)	≤8	9–11	12	13–15	16+
≤5th percentile												
10 or more	0.5	5.9	—	—	—	—	—	—	0.5	0.8	0.3	0.5
9 or more	0.9	10.2	—	—	—	—	—	0.9	1.9	1.0	0.4	0.9
8 or more	1.3	15.1	—	—	—	—	—	1.9	3.8	1.3	0.7	0.9
7 or more	1.8	21.0	—	—	—	—	—	2.8	6.1	1.6	1.1	0.9
6 or more	2.2	26.3	—	—	—	—	—	3.7	8.0	2.1	1.4	0.9
5 or more	3.0	34.9	—	—	—	—	—	5.6	10.3	3.2	1.5	1.1
4 or more	4.7	53.8	0.9	—	—	—	—	9.3	13.6	5.7	2.8	1.6
3 or more	8.0	76.3	10.0	—	—	—	—	20.4	21.6	10.3	4.2	2.7
2 or more	14.2	93.5	34.4	3.5	0.2	0.3	—	33.3	35.2	17.9	8.6	5.5
1 or more	31.7	98.9	79.4	32.2	11.7	2.2	—	58.3	62.0	40.2	23.4	15.9
No low scores	68.3	1.1	20.6	67.8	88.3	97.8	100	41.7	38.0	59.8	76.6	84.1

Using multivariate analyses in pediatric forensic evaluations

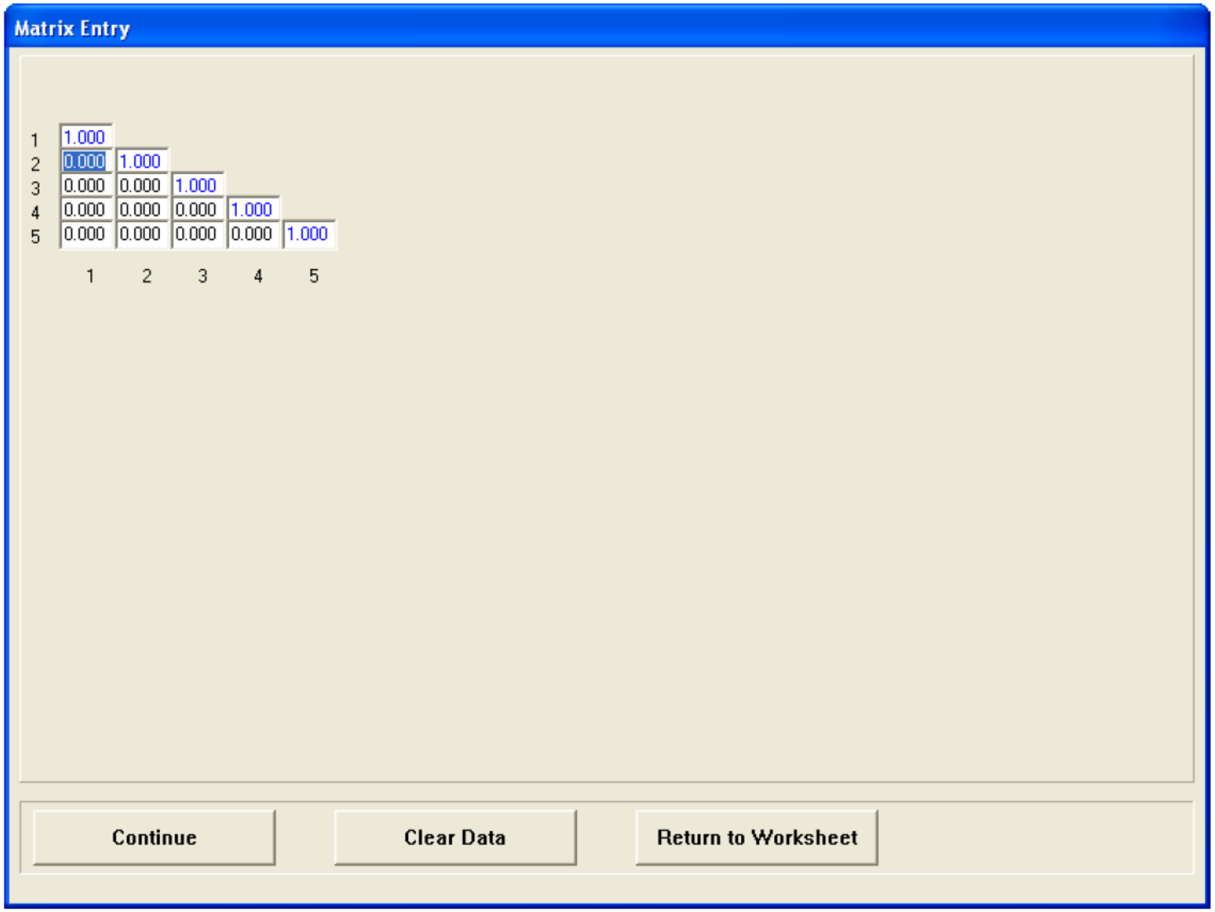
- Can compute multivariate base rates for any group of scores using a Monte Carlo program *if intercorrelations are known*

- Program publically available by Dr. John Crawford at http://www.abdn.ac.uk/~psy086/dept/PercentAbnormKtests.htm

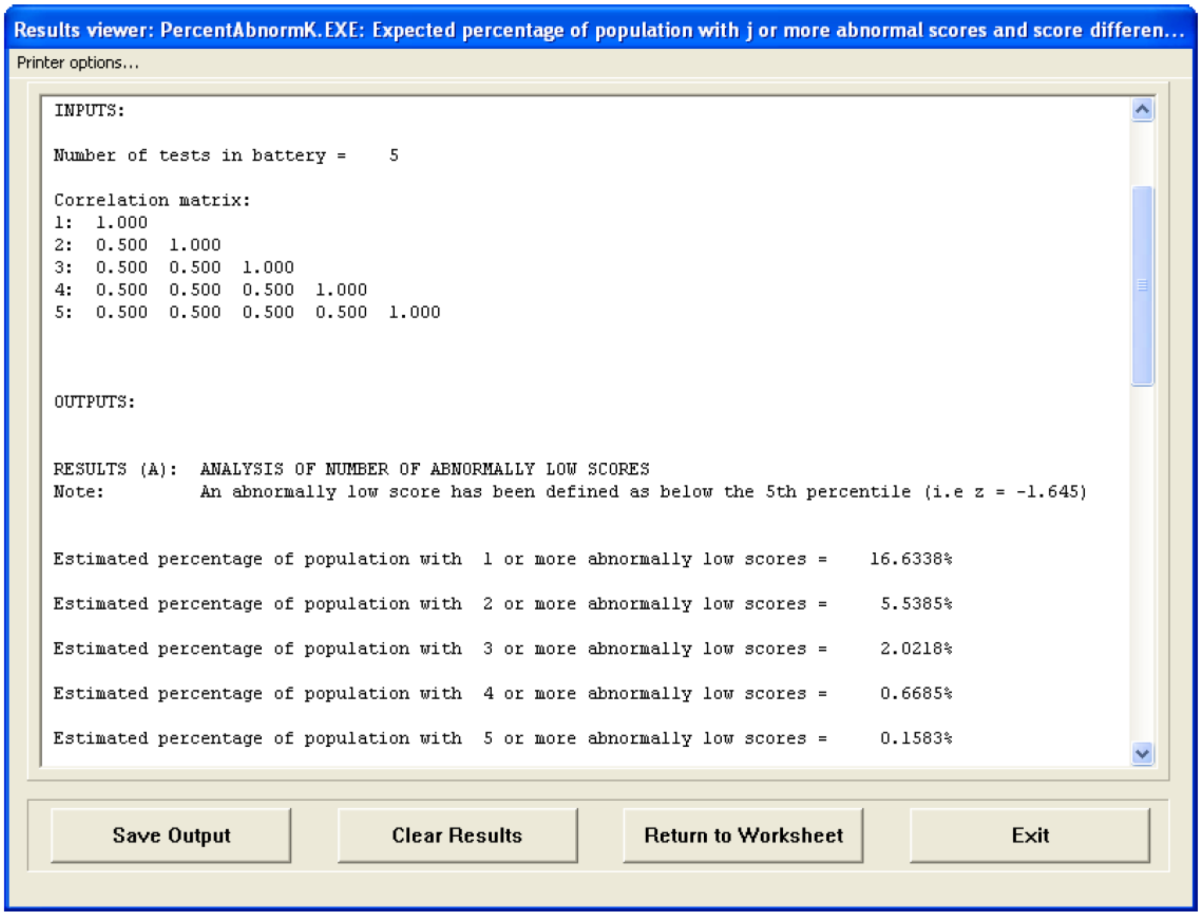
Using multivariate analyses in pediatric forensic evaluations



Using multivariate analyses in pediatric forensic evaluations



Using multivariate analyses in pediatric forensic evaluations



Using multivariate analyses in pediatric forensic evaluations

- Case Example #1:
  - 14-year-old previously healthy boy who sustained a concussion two years before assessment (slip and fall)
  - Although family report vague, appears to be functioning similar to before the injury; similar academic performance
  - Intellectual abilities estimated to be within the average range
  - Administered the CMS as part of assessment

Using multivariate analyses in pediatric forensic evaluations

TABLE 4.2. Performance on the Children's Memory Scale (CMS) Indexes in a 14-Year-Old Boy Who Sustained a Concussion

	Standardized Performance and Descriptions		
CMS Index Scores	**Index Score**	**Percentile Rank**	**Classification**
Learning	103	58	Average
Visual Immediate	103	58	Average
Visual Delayed	84	14	Low Average
Verbal Immediate	115	84	High Average
Verbal Delayed	106	66	Average
Delayed Recognition	103	58	Average

Using multivariate analyses in pediatric forensic evaluations

- Case #1 summary using multivariate:
  - Obtained 1 index score at 14th percentile on CMS
  - According to Brooks et al. (2009), having 1+ index scores ≤16th percentile is found in 37% of healthy children and adolescents
  - Considering only those with average intelligence, 1+ index scores ≤16th percentile is found in 36% of healthy children and adolescents
  - Number of low index scores on the CMS would be considered 'common'

Using multivariate analyses in pediatric forensic evaluations

- Case Example #2:
  - 11-year-old previously healthy girl who sustained a severe TBI in a high-speed MVC
  - Lowest GCS 4/15, PTA and fluctuating orientation for 10 days, brain MR scan with diffuse and focal findings, numerous extra-cranial injuries
  - Assessment 1.5 years after injury
  - Patient was administered 17 subtests from the NEPSY-II as part of her assessment

TABLE 4.3. Performance on Selected NEPSY-II Subtests in an 11-Year-Old Girl Who Sustained a Severe Traumatic Brain Injury

NEPSY-II Domains and Subtests	**Standardized Performance and Descriptions**		
	Scaled Score	**Percentile**	**Classification**
Attention and Executive Functioning			
Animal Sorting Total Correct Sorts	6	9	Borderline
Auditory Attention Total Correct	6	9	Borderline
Response Set Total Correct	5	5	Borderline
Inhibition: Naming Total Completion Time	6	9	Borderline
Inhibition: Inhibition Total Completion Time	4	2	Extremely Low
Inhibition: Switching Total Completion Time	2	<1	Extremely Low
Language			
Comprehension of Instructions Total	11	63	Average
Phonological Processing Total	9	37	Average
Speeded Naming Total Completion Time	7	16	Low Average
Memory and Learning			
Memory for Designs Total	9	37	Average
Memory for Designs Delayed Total	8	25	Average
Narrative Memory Free & Cued Recall Total	6	9	Borderline
Narrative Memory Free Recall Total	5	5	Borderline
Word List Interference Repetition Total	8	25	Average
Word List Interference Recall Total	7	16	Low Average
Visuospatial Processing			
Block Construction Total Score	10	50	Average
Geometric Puzzles Total Score	12	75	Average

Using multivariate analyses in pediatric forensic evaluations

- Case #2 summary using multivariate:
  - Several low scores found on the NEPSY-II
    - 12 scores ≤25th percentile
    - 8 scores ≤10th percentile
    - 4 scores ≤5th percentile
    - 2 scores ≤2nd percentile
  - Brooks et al. (2010), this many low scores found in 0.9-5.2% of healthy children and adolescents (range depends on cutoff selected)
  - Number of low scores on NEPSY-II is 'uncommon'

Conclusions

- Interpretation of *multiple* test scores is different than interpretation of an isolated *single* test score
- Clinicians need to appreciate the five principles of multivariate test interpretation
- Multivariate interpretation increases empirically-based conclusions on neuropsychological data

Caveats

- Multivariate analyses *supplement, but do not replace,* clinical judgment
- Presence of more low scores than expected is not diagnostic
- Having a low score may not be ‘uncommon’, but could still impact functioning and merit accommodation
- Only possible with co-normed tests
- Cannot substitute tests and use existing tables

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- Primary reference:

Brooks, B.L. and Iverson, G.L. (2012). Improving accuracy when identifying cognitive impairment in pediatric neuropsychological assessments. In E.M.S. Sherman and B.L. Brooks (Eds.), *Pediatric Forensic Neuropsychology* (pp. 66-88). New York: Oxford University Press.