D-KEFS, NEPSY-II, and CMS: Performance in Pediatric Populations

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Overview of Cognitive Effects of Pediatric TBI

- There is considerable variability in the cognitive outcomes following pediatric TBI
  - Depends on severity of injury
  - Level of pre-morbid functioning
  - Location of brain injury
  - Closed versus open
  - Age at time of injury
- There is no single post-injury cognitive profile or outcome

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Overview of Cognitive Effects of Pediatric TBI

- Cognitive deficits experienced after TBI are not unique to TBI
  - Symptoms overlap with other disorders such as TBI
  - May be concurrent changes in mood
  - May be changes in social functioning
  - May have subtle language deficits difficult to detect with cognitive tests
  - Often have academic difficulties
- Outcomes often linked to family functioning

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Overview of Cognitive Effects of Pediatric TBI

- Injury
  - Primary injury damage at the site and contra-coup
  - Secondary-hypoxia, arterial hypotension, Intracranial pressure
  - Increase ICP is a big factor in short- and long-term outcomes
  - Hemorrhaging

Overview of Cognitive Effects of Pediatric TBI

- Epidemiological factors (Reid et al, 2001: Arch Ped Adol Med). TBI resulting in hosp or death in MN
  - Incidence 73/100,000
  - Death 9/100,000
  - 74% discharged to home self-care
  - Length of stay average 2 days
  - Higher SES = lower incidence
  - 35% severe
    - 46% of severe died or had disability

Overview of Cognitive Effects of Pediatric TBI

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  - May be changes in social functioning
  - May have subtle language deficits difficult to detect with cognitive tests
  - Often have academic difficulties
- Outcomes often linked to family functioning

Overview of Cognitive Effects of Pediatric TBI

- Common cognitive deficits after pediatric TBI include:
  - Executive Functioning
  - Attention/Concentration
  - Processing Speed
  - Working Memory
  - Memory
  - Social Cognition
- A variety of deficits associated with pediatric TBI but children will vary ion the degree the deficits occur

Overview of Cognitive Effects of Pediatric TBI

- Babikian and Asarnow (2009) Neuropsychology, 23(3), 283-296.
- Intellectual deficits Pediatric TBI (long-term > 24 months)
  - ES FSIQ Mild (< .3), Moderate (.5-.6), Severe (1.0-1.1)
  - ES VCI Mild (< .3), Moderate (.5-.6), Severe (.8-.9)
  - ES PRI Mild (< .3), Moderate (.5-.6), Severe (.7-.8)
- Processing speed deficits Pediatric TBI
  - ES Mild (< .4), Moderate (.6-.7), Severe (.8-.9)
- Working Memory deficits Pediatric TBI
  - ES Mild (< .2), Moderate (.3), Severe (.4-.5)

Overview of Cognitive Effects of Pediatric TBI

- Attention deficits Pediatric TBI (long-term)
  - ES Mild (< .3), Moderate (.3), Severe (.6-.7)
- Fluency deficits Pediatric TBI (long-term)
  - ES Mild (.5), Moderate (.5), Severe (1.0-1.2)
- Inhibition deficits Pediatric TBI (long-term)
  - ES Moderate and Severe (.4-.7)
- Problem Solving deficits Pediatric TBI (long-term)
  - ES Moderate and Severe (.4-.7)
- Visual Perceptual deficits Pediatric TBI (long-term)
  - ES Mild (< .2), Moderate (.2), Severe (.4)

Overview of Cognitive Effects of Pediatric TBI

- Verbal immediate memory deficits Pediatric TBI (long-term)
  - ES Mild (< .2), Moderate (.3), Severe (.5)
- Verbal delayed memory deficits Pediatric TBI (long-term)
  - ES Mild (< .2), Moderate (.3-.4), Severe (.7-.8)
- Visual immediate memory deficits Pediatric TBI (long-term)
  - ES Severe (.5)
- Visual delayed memory deficits Pediatric TBI
  - ES Severe (1.0)
- Population norms may not reveal severity of deficit compared to control samples (Massagli et al, 1996: Arch Phys Med Rehab).

Overview of Cognitive Effects of Pediatric TBI

- Children ages 3-6 years, severity of injury and family environment have a big influence on post-injury school readiness (Taylor, et al, 2008: JINS)
- Children ages 2-6. Adapative and behavioral outcomes associated with injury severity and pre-morbid abilities (Catroppa et al, 2008: J Ped Psych)
- African-American children have worse functional outcomes after pediatric TBI (Haider et al, 2007: J Trauma)
- Low-SES associated with worse functional outcomes after pediatric TBI (Keenan et al, 2006: Pediatrics)

Overview of Cognitive Effects of Pediatric TBI

- Social outcomes associated with executive functioning, pragmatic language skills and social problem-solving (Yeates et al, 2004: JINS).
- Behavior problems often emerge within 1st year post-injury associated with severe injury, low SES, pre-morbid behavior problems-concurrent issues low working memory skills, poor social skills, low school competence and poor family outcomes (Schwartz et al, 2003: J Ped Psych).
- Negative behavior affects sibling relationship and sibling behavior (Swift et al, 2003: J Dev Beh Ped).

Overview of Cognitive Effects of Pediatric TBI

- Parent psychological distress, perceived family burden, and coping skills affect outcomes (Yeates et al, 2002: J Ped Psych).
- Injury has long-term effects on academic and behavior outcomes but is moderated by family environment (Taylor et al, 2002: Neuropsychology).
- Parent acceptance of injury report lower stress than denial group, active coping increase stress use of humor decrease stress (Wade et la, 2001: J Clin Cons Psych).
- Web-based family interventions after pediatric TBI have been found effective in helping families and improving outcomes (Wade et al, 2008: J head Trauma Rehab).

Factors Related to Vocational Outcomes (adult but useful)

- Colantonio, Ratcliff, Chase et al. (2004)
  - Longitudinal study (7-24 years post injury an average of 14.2 ± 4.4 years)
  - N = 276
- On average EF (Trails) and Memory (Rivermead Story) significantly lower than norms
- Only 29.9% working full-time at time of interview compared to 64% pre-injury
- Self-Reported Health problems associated with more cognitive impairment

Factors Related to Vocational Outcomes

- Colantonio, Ratcliff, Chase et al. (2004)
- Biggest problem areas – shopping, managing money, and transportation – all correlate with EF.
- General problems with community integration although social integration rated as one of the better areas of functioning.

Factors Related to Vocational Outcomes

- Cattelani, Lombardi, & Mazzucchi (2002)
- Return to competitive employment after severe brain injury is related to intellectual functioning both on initial exam (inpatient) and post-acute exam (discharged).
  - Those who return to work had an average VIQ initial 95 up to 108 at discharge, PIQ initial 87 up to 103 at discharge.
  - Those not returning to work had an average VIQ initial 78 up to 88 at discharge PIQ initial 68 up to 83 at discharge.
- Neuropsychological test scores also better in the group returning to work.

Factors Related to Vocational Outcomes

- At 2-year follow-up:
  - Individuals with **TBI** reported higher levels of employment and earned income than reported at 1-year post-injury
  - Continued to exhibit declines relative to pre-injury baseline
  - Frequency and amount of major public agency payments continued to be increased relative to baseline. (Shigaki, Johnstone, & Schopp, 2009)
- Characteristics of TBI individuals seeking Voc Rehab services from Missouri Study (Johnstone, Reid-Arndta,Franklin,& Harper, 2006)
  - IQ scores typically low average not a lot of variability (84-86)
  - Memory Scores also low average (82-91)
  - Takes about 9 years to get referred
  - Counseling and On-Job Training predict outcomes more than np testing

Factors Related to Vocational Outcomes

- Concomitant Psychological and Learning Disabilities impact outcome (Johnstone, Martin, Bounds et al, 2006)
- Lack of awareness of deficits impacts daily living skills but not vocational outcomes (Hoofien, Gilboa, Vakil et al, 2004)
- Length of PTA, cognition, disability levels, GCS, functional status, length of acute stay and prior occupation discriminated those who returned to work (Fleming, Tooth, Hasseel et al, 1999).
- Most impaired had best work outcomes, most memory impaired got most services (Johnston, Schopp, Harper et al, 1999)

Factors Related to Vocational Outcomes

- Most neuropsychological impaired had worse outcomes, most memory impaired got most services (Satz, Zaucha, Forney et al, et al, 1998)
- A significant proportion of TBI patients, including those who are severely injured, are able to return to productive employment if sufficient and appropriate effort is invested (Shames,Treger, Ring,& Giaquinto, 2007).
- Cognitive rehabilitation strategies that address attention, memory and executive deficits can improve clients' abilities to manage workplace tasks and demands. Many clients continue to experience problems with social and emotional adjustment following a brain injury that impact return to work. (Mateer & Sira, 2006).

Factors Related to Vocational Outcomes

- Early referrals have more physical and cognitive limitations but obtain better social integration, emotional well-being and vocational functioning than individuals that entered the program after a longer period of recovery (Reid-Arndt, Schopp, Brenneke, et al 2007).
- Controlling for background variables and executive functioning, social communication (e.g. affect perception) uniquely predicted occupational outcomes and social integration. Executive functioning performance accounted for unique variance in both occupational functioning and social integration (Struchen,Clark, Sander et al, 2008).

Factors Related to Vocational Outcomes

- Working Memory and Executive functioning predict Independent Activities of Daily Living in patients with moderate to severe TBI (Bottari, Dassa, Rainville et al, 2009).

What is Considered a Low Score- Issues to Consider

- Mild MR WISC-IV Subtest Mean scores Range from 3.8 (Arithmetic) to 6.2 (Cancellation) with most means near 4.5. Most clinical groups are not as functionally impaired as children with MR. Therefore, it would be expected that mean scores for most clinical groups would fall in the range of 5 to 8 on average for mild to moderate disorders.
- An effect size above .8 is considered large on scaled scores this translates into clinical means of approximately 7.5 for large effects.
- Moderate Effect sizes are .4 to .8 or scaled scores of 7.6 to 8.8

Factors Related to Vocational Outcomes

- There are significant long-term negative effects on multiple aspects of the patients life including employment after TBI.
- Executive Functioning is related to obtaining competitive employment, occupational outcomes, and social integration. Biggest problem areas – shopping, managing money, and transportation – all correlate with EF.
- General Intellectual functioning post-injury relates to ability to return to work with less services – however in some cases not receiving enough services can interfere with a successful transition for those that are more cognitively intact.

Factors Related to Vocational Outcomes

- Concurrent learning disabilities, psychological functioning, and general neuropsychological deficits impact outcomes.
- Social perception abilities relate to interpersonal aspects of job functioning and social integration more generally.
- Addressing attention, memory and executive deficits can improve workplace outcomes. May also need to train on reading social cues and situations.

D-KEFS Overview

- Delis-Kaplan Executive Function System published in 2001 after nearly 10 years of development
- Authors: Dean Delis, Edith Kaplan, Joel Kramer
- 9 stand alone tests of executive functioning
- Normative sample covers ages 8-89

D-KEFS Overview

- Overarching design philosophy
  - Executive functioning is measured within a context
  - The context may be related to verbal or visual skills
  - To infer deficits in executive functioning you need to control for "context" (e.g. pre-cursor cognitive skills)
  - Need multiple scores to understand the nature of the executive functioning deficit

Key Concepts

- Executive Functions are higher order cognitive skills associated with the ability to engage in independent, goal-directed behavior.
- Impairments in executive functioning have been linked to dysfunction of or damage to the frontal lobes or specific frontal subcorticol networks.
- Deficits in executive functioning may result in obvious behavior disorder or subtle problems with behavioral regulation

Specific Skills Associated with Executive Functioning:

– mental flexibility
– set formation and maintenance
– behavioral initiation/productivity
– self-monitoring
– abstract reasoning/concept formation
– Inhibition of impulsive/pre-potent responses
– rule learning/application

Specific Skills Associated with Executive Functioning

- Problem Solving
- Creative Thinking
- Fluent Thinking
- Simultaneous Processing
- Planning and Organization
- Inhibit Old Patterns of Behavior

Behavior Associated with Deficits in Executive Functions

- Disinhibition-lacks behavioral control, impulsive
- Perseveration-repeats non-functional behavior, inability to change behavior despite corrective feedback, difficulties learning from experience
- Forgetfulness-off-task behaviors, mental errors, loses track of what they were doing

Behavior Associated with Deficits in Executive Functions

- Inefficiency-takes more steps to complete task than necessary
- Difficulty understanding consequences and cause-effect relationships
- Frequently violate rules despite apparent knowledge of the rules
- Apathetic-lacks motivation, does not set goals, engages in behavior only when prodded
- Anticipatory Behavior-failure to shift to new demands of situation

Behavior Associated with Deficits in Executive Functions

- Difficulties accessing knowledge
- Concrete thinking
- Emotional lability
- Poor frustration tolerance
- Disorganized
- Inconsistent performance on tasks within ability range
- Difficulties coping with change
- Poor judgment

Behavior Problems Defined by Situational Context

- Appropriateness of emotional response – (ex. provocation)
- Appropriateness of behavioral response
  - Intensity
  - Explicit rules
  - Implicit social norms
- External catalysts
- Perceived outcome
- Availability of alternative solutions
- Social standing and behavioral history
- Inconsistencies in responses (implication of control and choice)

Interpretation of Behaviors

- Intent
- Available Options
- No Obvious Cognitive Limitation
- Knowledge of Rules and 'Right from Wrong"
- Punitive Vs. Accommodative Response

Assessment of Executive Functions

- Assessment of executive functioning occurs within the context of another cognitive domain
  - Attention
  - Language
  - Visual-Spatial
  - Visuo-motor
  - Memory
- The test rules create the cognitive set
- Underlying processes and automaticity of skills affect sensitivity of the test
- Availability of normative data

Assessment of Executive Functions

- Assessment of underlying processes and use of age appropriate norms are magnified when assessing children.
  - Cannot assume children have acquired automaticity in basic skills
  - Brain development is continuous such that using normative data that is from a slightly older or younger group may not adequately reflect the functioning at the age level of interest.
  - Children display a high degree of within age variability on tests of executive functioning that decreases in adolescents

D-KEFS Overview

- Trail-Making Test
- Verbal Fluency
- Design Fluency
- Color-Word Interference
- Card Sorting
- Tower Test
- Word Context
- 20 Questions
- Proverbs

Trail-Making Test

- 5 conditions
  - Visual Scanning
  - Number Sequencing
  - Letter Sequencing
  - Number-Letter Switching
  - Motor Speed

Visual Scanning

- Examinee is required to scan the same visual field that will be used to measure the executive function
- Rules out or in that impairment in visual scanning are interfering with the examinees ability to express the executive functioning being expressed
- Total time score – how quickly can the examinee scan the visual field (Scaled Score)
- Omission Errors-is the examinee able to identify all the targets – inattentive
- Commission Errors-does the examinee misidentify items as targets that are not targets – impulsive or inattentive

Number Sequencing

- Evaluates the ability of the examinee to do the pre-cursor skill of rapidly identifying numbers in their proper order
- Rules out or in that poor automaticity of numeric sequencing is impeding the examinees ability to perform the higher-level switching task
- Time Score-how quickly can the examinee connect numbers in sequence – estimates the automaticity of this function (Scaled Score)
- Sequencing error-examinee connects numbers in incorrect order – number automaticity (if large number of these errors) issue or may be impulsive or inattentive
- Set-Loss error – examinee connects to a letter instead of numbers – inattentive, impulsive, or difficulty monitoring behavior or maintaining task rules during performance of the test
- Time Discontinue Error – examinee cannot complete task in the allotted time.

Letter Sequencing

- Evaluates the ability of the examinee to do the pre-cursor skill of rapidly identifying letters in their proper order
- Rules out or in that poor automaticity of letter sequencing is impeding the examinees ability to perform the higher-level switching task
- Time Score-how quickly can the examinee connect letters in sequence – estimates the automaticity of this function (Scaled Score)
- Sequencing error-examinee connects letters in incorrect order – letter automaticity (if large number of these errors) issue or may be impulsive or inattentive
- Set-Loss error – examinee connects to a number instead of letters – inattentive, impulsive, or difficulty monitoring behavior or maintaining task rules during performance of the test
- Time Discontinue Error – examinee cannot complete task in the allotted time.

Letter-Number Sequencing

- The primary measure of executive functioning on the Trail-Making Test – cognitive flexibility, mental tracking of information,
- In the absence of significant deficits in pre-cursor skills, poor performance on this task suggests difficulty correctly switching cognitive sets. This may be due to problems maintaining set, impulsivity, or cognitive rigidity.
- The switching on this task occurs at the stimulus level (i.e. the examinee evaluates the stimuli to select the proper response). The examinee changes their behavior in response to a cue or event in the environment.
- Time Score-how quickly can the examinee switch between numbers and letters in sequence – estimates the ease at which the examinee can engage in tasks requiring cognitive flexibility (Scaled Score)
- Sequencing error-examinee connects letters in incorrect order – need to review letter and sequencing to determine if it is an automaticity issue, if not then could be a break down in the automaticity of those functions in the presence of the demands of the switching condition.

Letter-Number Sequencing

- Set-Loss errors-examinee fails to switch correctly. This is another indicator of cognitive flexibility, high rates of errors suggest significant problems switching behavior accurately at the stimulus level (e.g. cued by environment). Impulsive responding or difficulty tracking ones behavior may result in some set-loss errors.
- Time Discontinue Errors – Examinee fails to complete the task in the allotted time. Indicates difficulty performing the task quickly signaling difficulties with cognitive flexibility
- Total Errors-provides an estimate of overall accuracy in performing the task, high error rates suggest difficulty monitoring behavior for accuracy when switching demands are present

Pediatric TBI Sample

- Moderate to Severe TBI (closed and open accepted)
- Loss of consciousness between 1 hour and 24 hours
- Testing performed at least 6 months post TBI
- No pre-morbid psychiatric diagnosis or intellectual disability
- Injury not due to medical illness (e.g. tumor, meningitis, etc….)

Pediatric TBI Sample

- N=31
- Demographics
  - Age: 8-16 (13.2 ± 2.5)
  - Sex: Male 67.7% Female 32.3%
  - Ethnicity: White 77.4 African-American 6.5% Hispanic-American 12.9%
  - Parent Education Level:
    High School Diploma 25.8%
    Some College 51.6%
    College Degree or Higher 22.6%

Matched Control Sample

- N=31
- Demographics
  - Age: 8-18 (13.3 ± 2.7)
  - Sex: Male 61.3% Female 38.7%
  - Ethnicity: White 87.1 African-American 12.9%
  - Parent Education Level:
    High School Diploma 35.5%
    Some College 45.2%
    College Degree or Higher 19.4%

TBI vs Matched Controls on IQ

Index	TBI	Controls
VCI	101.3 (13.3)	102.9 (11.6)
PRI	103.0 (12.7)	102.6 (11.8)
FSIQ	102.8 (13.5)	103.0 (11.2)

No significant multivariate or univariate differences

TBI vs Matched Controls on D-KEFS Trail-Making

Score	TBI	Controls
Visual Scanning	8.3 (3.9)	8.7 (3.4)
Number Sequencing*	8.4 (3.2)	10.1 (2.5)
Letter Sequencing**	6.7 (4.3)	10.3 (2.6)
Number-Letter Sequencing**	7.4 (3.8)	10.7 (2.1)
Number-Letter Errors *	9.6 (3.2)	11.0 (1.6)
Motor Speed	9.0 (3.0)	9.8 (2.7)

Wilk's Lambda $F_{(6,54)} = 3.36$ p < .01

TBI versus Matched Controls

- Is there a significant difference in switching controlling for number and letter sequencing effects?
- ANCOVA $F_{(1,58)}=4.24$ p< .05 (speed)
- Marginal Means: TBI 8.4 Controls 9.8
- ANCOVA $F_{(1,58)}=1.97$ p> .05 (errors)

TBI sample has deficits in speed associated with cognitive flexibility/switching but error rate not significant when controlling for pre-cursor skills

TBI Errors Descriptive

- VS Omissions – 1 = 19.4%, 2 = 6.5%
- VS Commission – 0 = 100%
- NS Sequence Error – 0 = 100%
- NS Set Loss Error- 1 = 3.2%
- NS Time Discontinue – 0 = 100%
- LS Sequence Error – 1 = 9.7%, 2=9.7%
- LS Set Loss Error- 1 = 3.2%
- LS Time Discontinue – 3 = 3.2%, 8=3.2%

TBI Errors Descriptive

- NLS Sequencing – 1 = 19.4%, 2 = 3.2%,
  3 = 6.5%, 4 = 6.5%
- NLS Set-Loss – 1 = 25.8%,2 = 3.2%,
  3 = 9.7%
- NLS Time Discontinue – 8=3.2% 12=3.2%
- Sequencing Errors - 19.4% had errors at or lower than 25% of normative sample
- Sequencing Errors - 22.6% had errors at or lower than 25% of normative sample

Verbal Fluency

- 3 conditions
  - Letter Fluency
  - Category Fluency
  - Category Switching Fluency
- Note-this is a language test in which deficits in executive functioning may be inferred if no significant language impairments are present

Letter Fluency

- Letter Fluency has 3 conditions F,A,S
- Measures cognitive flexibility at the ideational level (e.g. the stimulus does not change but the examinee has to think of many different ways to use the stimuli).
- Requires the examinee to use the stimuli in a novel way – usually do not search for information by first letter
- Measures behavioral productivity, initiation, maintaining set and effort, flexibility in thinking, and self-monitoring

Letter Fluency

- Letter Fluency Total Score – number of words correctly generated-estimate of behavioral productivity and cognitive flexibility (ideational).
- Interval scores measure initiation versus maintenance
- Repetition Errors (are summed across conditions) – monitoring of recall for redundant information – (percent – accounts for number of words produced)
- Set-Loss Errors – says words that do not start with correct letter (are summed across all tasks) – measures ability to maintain set and monitor behavior for accuracy– (percent – accounts for number of words produced) if dysgraphic – errors due to spelling difficulty not EF

Category Fluency

- Category Fluency Total Score – number of words correctly generated-estimate of behavioral productivity and cognitive flexibility (ideational).
- Is more of an automatized task than letter fluency as information is easily accessible by semantic category. Category Vs. Letter assesses the degree to which productivity is affected by automatic versus novel search strategies.
- Interval scores measure initiation versus maintenance
- Repetition Errors (are summed across conditions) – monitoring of recall for redundant information – (percent – accounts for number of words produced)
- Set-Loss Errors – says words that do not start with correct letter (are summed across all tasks) – measures ability to maintain set and monitor behavior for accuracy– (percent – accounts for number of words produced) – if history of language problems could be due to poorly developed semantic system or difficulties with semantic access

Category Switching Fluency

- Category Fluency Total Correct Score – number of words correctly generated-estimate of behavioral productivity and cognitive flexibility (ideational).
- Category Fluency Total Switching Accuracy – number of times the examinee correctly switched from one category to the other cognitive flexibility (stimulus and ideational). Adds a stimulus level switching component, the examinee must recognize that the word they just said came from a specific category and that they now must find a word from the other category (i.e. the stimulus cues the switch).
- Category Vs. Category Switching assesses the degree to which adding the stimulus level switching affects the examinees ability to access semantic information, requires more self-monitoring to maintain switching (e.g. remembering and tracking last word said)

Category Switching Fluency

- Category Switching Percent accuracy estimates the degree provides an estimate of accuracy controlling for the number of items generated.
- Interval scores measure initiation versus maintenance
- Repetition Errors (are summed across conditions) – monitoring of recall for redundant information – (percent – accounts for number of words produced)
- Set-Loss Errors – says words that do not start with correct letter (are summed across all tasks) – measures ability to maintain set and monitor behavior for accuracy– (percent – accounts for number of words produced) – if history of language problems could be due to poorly developed semantic system or difficulties with semantic access

TBI vs Matched Controls on D-KEFS Verbal Fluency

Score	TBI	Controls
Letter Fluency*	7.8 (3.5)	9.9 (3.1)
Category Fluency**	8.1 (3.1)	10.3 (2.4)
Category Switching**	8.1 (2.7)	9.9 (2.2)
Switching Accuracy	8.6 (2.6)	9.8 (3.0)
Set-Loss Errors	10.1 (2.6)	10.2 (2.7)
Percent Set-Loss Errors	9.6 (4.5)	10.6 (3.1)
Repetitions	8.8 (2.8)	9.8 (2.0)
Percent Repetitions	8.8 (4.0)	9.7 (2.6)

Wilk's Lambda F(8,53) = 1.79 p > .05

TBI vs Matched Controls on D-KEFS Verbal Fluency

Wilk's Lambda $F(4,57) = 2.80$ $p < .05$ when do not include error scores

ANCOVA – Letter Fluency controlling for Category Fluency $F(1,59)=1.38$ $p > .05$.

Design Fluency

- 3 conditions
  - Filled Dots
  - Empty Dots
  - Switching Fluency
- Note-this is a visual-perceptual test in which deficits in executive functioning may be inferred if no significant visual-perceptual impairments are present

Filled Dots

- Examinee has to generate as many novel designs as possible – measure of behavioral productivity, cognitive flexibility (ideational), initiation, and maintenance of effort, and ability to maintain set
- Total score – number of correct designs produced indicates productivity and flexibility.
- Set Loss Errors-examinee uses an empty dot in the design (summed across all conditions) – impulsivity, inattentiveness, and poor self-monitoring
- Repetition Errors-examinee repeats same design (summed across all conditions) – inattentiveness and poor self-monitoring

Empty Dots

- Examinee has to generate as many novel designs as possible – measure of behavioral productivity, cognitive flexibility (ideational), initiation, and maintenance of effort, and ability to maintain set, pulls for set loss errors as the examinee has to remember to not use filled dots
- Total score – number of correct designs produced indicates productivity and flexibility.
- Set Loss Errors-examinee uses a filled dot in the design (summed across all conditions) – impulsivity, inattentiveness, and poor self-monitoring
- Repetition Errors-examinee repeats same design (summed across all conditions) – inattentiveness and poor self-monitoring

Switching Dots

- Examinee has to generate as many novel designs as possible – but they must switch between empty and filled dots (stimulus level switching)-measure of behavioral productivity, cognitive flexibility (ideational and stimulus), initiation, and maintenance of effort, and ability to maintain set, pulls for set loss errors as the examinee has to remember to not use filled dots
- Total score – number of correct designs produced indicates productivity and flexibility.
- Set Loss Errors-examinee fails to switch between empty and filled in the design (summed across all conditions) – impulsivity, inattentiveness, and poor self-monitoring
- Repetition Errors-examinee repeats same design (summed across all conditions) – inattentiveness and poor self-monitoring

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Design Fluency

- Total of all 3 conditions
- Total for Switching
- Total Attempted
- Total Accuracy
- Total Set-Loss
- Total Repetitions
- Total Accuracy

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TBI vs Matched Controls on D-KEFS Design Fluency

Score	TBI	Controls
Filled Dots	9.4 (2.4)	10.3 (3.1)
Empty Dots**	8.9 (2.3)	10.8 (2.9)
Switching**	8.3 (2.6)	10.1 (2.6)
Total *	9.0 (2.4)	10.4 (3.0)
Set-Loss Errors	10.4 (3.0)	10.5 (3.3)
Repetitions	10.4 (2.0)	10.9 (2.4)
Attempted	10.2 (3.7)	10.6 (2.9)
Accuracy**	7.3 (3.7)	10.2 (2.6)

Wilk's Lambda F(8,51) = 11.73 p < .001

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TBI vs Matched Controls on D-KEFS Design Fluency

- Is there a significant difference in switching controlling for empty and filled dots effects?
- ANCOVA $F_{(1,56)}=5.71$ p< .05 (switching)
- Marginal Means: TBI 8.5 Controls 9.9
- ANCOVA $F_{(1,56)}=15.98$ p <.001 (total vs accuracy)
- Marginal Means: TBI 7.6 Controls 10.5

TBI sample has deficits in cognitive flexibility beyond productivity deficits and overall accuracy of production rather than specific error types.

Color-Word Interference

- 4 conditions
  - Color Naming
  - Word Reading
  - Interference
  - Interference/Switching
  - Note: This is a language and reading based test and impairments in EF can be inferred if there are no significant language or reading problems.

Color Naming

- Child rapidly identifies ink color – indicator of the automaticity of color naming and is a pre-cursor skill for the inhibition condition.
- Total Time – Speed of color naming indicates level of automaticity
- Total Errors – indicator of naming errors which would indicate problems with inattention or language based naming difficulties.

Word Reading

- Child rapidly reads color words-indicator of the automaticity of reading color words and is a pre-cursor skill for the inhibition condition-if reading is not automatic then stroop effect will not occur or will be lessened.
- Total Time – Speed of reading color words indicates level of automaticity
- Total Errors – indicator of reading errors which would indicate problems with inattention or reading based difficulties.

Inhibition

- Child rapidly reads color of ink of color words-indicator of the examinees ability to inhibit an automatic, pre-potent response.
- Total Time – ability to quickly say the ink color – may be an indicator of inhibitory control.
- Corrected Errors-examinee makes an impulsive response but is able to catch it and correct it.
- Uncorrected Errors-examinee makes an impulsive response but does not recognize the error or does not correct it.
- Total Errors – indicator of impulsive responding, Inhibition time should not be considered without evaluating error rate (e.g. very fast with high error rate still indicates an inhibitory problem).

Inhibition/Switching

- Child rapidly reads color of ink of color words, unless it appears in a box then they must read the color word (stimulus)-indicator of the examinees ability to inhibit an automatic, pre-potent response and stimulus based switching.
- Total Time – ability to quickly say the ink color – may be an indicator of inhibitory control.
- Corrected Errors-examinee makes an inaccurate response (either a switching or impulsive error) but is able to catch it and correct it.
- Uncorrected Errors-examinee makes an inaccurate response (either a switching or impulsive error) but does not recognize the error or does not correct it.
- Total Errors – indicator of inaccurate responding, Inhibition/Switching time should not be considered without evaluating error rate (e.g. very fast with high error rate still indicates an inhibitory or switching problem).

TBI vs Matched Controls on D-KEFS Color-Word Interference

Score	TBI	Controls
Color Naming[**]	7.8 (3.0)	10.3 (1.8)
Word Reading[**]	7.9 (3.2)	10.6 (2.5)
Inhibition Time	9.1 (2.7)	10.2 (2.0)
Inhibition Errors[*]	8.7 (4.0)	10.6 (2.0)
Inhibition/Switching Time[**]	7.3 (3.8)	10.0 (2.1)
Inhibition/Switching Errors[**]	7.5 (3.8)	10.4 (2.2)

Wilk's Lambda $F_{(6,54)} = 4.08$ $p < .01$

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TBI vs Matched Controls on D-KEFS Color-Word Interference

- Is there a significant difference in inhibition controlling for word reading and color naming?
- ANCOVA $F_{(1,58)}=.90$ $p> .05$ (inhibition)
- Marginal Means: TBI 9.8 Controls 9.4
- ANCOVA $F_{(1,58)}=.47$ $p >.05$ (errors)
- Marginal Means: TBI 9.4 Controls 9.6

TBI sample did not show deficits in inhibitory control beyond processing speed deficits.

PEARSON

TBI vs Matched Controls on D-KEFS Color-Word Interference

- Is there a significant difference in switching controlling for word reading, color naming, and inhibition?
- ANCOVA $F_{(1,57)}=.81$ $p> .05$ (switching)
- Marginal Means: TBI 8.2 Controls 8.9
- ANCOVA $F_{(1,57)}=1.72$ $p >.05$ (errors)
- Marginal Means: TBI 8.5 Controls 9.5

TBI sample did not show switching deficits beyond initial processing speed deficits.

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TBI Descriptive Results

- Color Naming Errors – 71% had at least 1 error, 38.7% had more than 1, 45% were at the 25% base rate or lower of the normative sample.
- Word Reading Errors – 45% had at least 1 error, 25.8% had more than 1, 38.7% were at the 25% base rate or lower of the normative sample.

Card Sort

- 2 Conditions
  - Free Sorting
  - Recognition Sort
- Note: this test requires both visual perceptual and language based skills. EF skills may be inferred if visual-perceptual and language skills are not significantly impaired.

Free Sort

- In the free sort condition, the examinee must sort cards into two piles and explain how the cards go together. This requires cognitive flexibility at the ideational level as well as expressive language abilities.
- Confirmed Correct Sorts-The total number of times the examinee sorted the 2 groups different and was able to explain how the cards went together.
- Confirmed/Unconfirmed Sorts – Total Number of correct sorts that were either correctly or incorrectly described.

Free Sort

- Free Sort Repeated Sorts-examinee makes same sort repeatedly, self-monitoring for redundant behavior.
- Free Sort Set-Loss Sort – examinee makes two piles have uneven number of cards-self-monitoring for following rules of the task.
- Free Sort Attempted Sorts – examinee productivity level and cognitive flexibility
- Free Sort Sort Accuracy-percent correct sorts taking into account the number attempted.
- Free Sort Time Per Sort-time it takes for the examinee to think of a different way to sort the cards-indicator of cognitive flexibility
- Free Sort Description – examinees ability to explain rationale for sorting behavior.

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Free Sort

- Free Sorting Repeated Descriptions-examinee makes same explanation for sorting repeatedly.

- Free Sort Incorrect Descriptions – examinees description does not match the common relationship of the cards.

- Free Sort Description Accuracy – correct descriptions controlling for number of sorts

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Recognition Sort

- Recognition Description Score-examinees ability to describe how the cards were sorted by the examiner.
- Recognition Description Incorrect Description – examinees description does not match the common relationship of the cards.
- Recognition Description Repetitions – Examinee repeats same description for multiple card sets
- Combined Free and Sort Recognition Descriptions – Overall ability to describe the relationship within a card set.
- Total No/Don't Know Responses-sum of the number of times the examinee states they cannot describe the relationship or simply do not respond.

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TBI vs Matched Controls on D-KEFS Color-Word Interference

Score	TBI	Controls
Confirmed Correct**	8.1 (2.9)	10.3 (3.0)
Unconfirmed/Confirmed **	8.8 (2.7)	10.8 (2.7)
Accuracy	8.6 (3.3)	9.7 (2.8)
Time Per Sort **	7.9 (2.6)	10.4 (2.6)

Wilk's Lambda F(10,51) = 7.70 p < .001

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TBI vs Matched Controls on D-KEFS Color-Word Interference

Score	TBI	Controls
Free Sort Description *	8.5 (2.8)	10.4 (2.9)
Free Sort Description Incorrect	10.0 (3.3)	9.5 (3.4)
Free Sort Description Accuracy	8.7 (3.4)	9.7 (3.2)
Sort Recognition Description **	7.0 (3.6)	10.4 (2.7)
Sort Recognition Incorrect *	7.5 (4.8)	9.7 (3.0)
Total No/Don't Know **	12.5 (1.7)	10.5 (2.9)

Wilk's Lambda F(6,54) = 4.08 p < .01

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TBI vs Matched Controls on D-KEFS Color-Word Interference

- Is there a significant difference Recognition Description controlling for Free Sort Description?
- ANCOVA F(1,59)=10.62 P < .01 (Total)
- Marginal Means: TBI 7.5 Controls 9.9
- ANCOVA F(1,58)=3.57 p <.10 (errors)
- Marginal Means: TBI 7.8 Controls 9.5

TBI group showed significant deficits on recognition controlling for Free Sort and trend for errors.

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TBI Card Sort Descriptive

- Card Sort Set-Loss Errors – 93.5% had 0
- Non-Target Even Sorts – 29% had 1 or more and were below 25% base rate
- Free Sort Repeated Description - 29% had 1 or more and were below 25% base rate
- Recognition Repeated Description- Repeated Sorts – 12.9% had 1 or more
- Non-Credit Descriptions – 41.9 % had more than 1 and 38.7% were below 25% of normative sample
- Overly Abstract Descriptions – 90.3% had 0

TBI vs Controls Most Significant Scores

- Trails Letter Sequencing, Number-Letter Sequencing
- Letter and Category Fluency
- Designs Switching and Accuracy
- Color-Word Word Reading
- Card Sort Confirmed Sorts, Time Per Sort Ratio, Sort Descriptions

TBI Versus Controls Logistic Regression

- Identifies subset of scores across measures that maximally discriminates between the two groups
- Backward removal based in likelihood ratio
- Using all variables classification rate is 91%
  - 96.8% controls correctly identified
  - 86.2% of TBI sample correctly identified

TBI Versus Controls Logistic Regression

- Final equation classification rate is 90%
  - 96.8% controls correctly identified
  - 82.8% of TBI sample correctly identified
- Variables in the equation:
  - Card Sorting Time Per Sort Ratio
  - Design Fluency Percent Correct
  - Card Sorting Recognition Description
  - Trail-Making Letter Sequencing
  - Color-Word Word Reading

Summary

- TBI groups have difficulty with speed based tasks in general.
- Executive functioning measures are still significant even after controlling for speed.
- Process scores are important for differentiating between clinicals and controls and a single achievement score will likely miss important cognitive constructs.
- While not all process scores differentiate between groups above and beyond total scores, they provide important information about how an individual examinee is approaching the test.

NEPSY-II Descriptive Study Pediatric TBI

- Moderate to Severe TBI (closed head injury only)
- Loss of consciousness between 1 hour and 24 hours
- Testing performed at least 6 months post TBI
- No pre-morbid psychiatric diagnosis or intellectual disability
- Injury not due to medical illness (e.g. tumor, meningitis, etc.…)

NEPSY-II Descriptive Study
Pediatric TBI

- N=10
- Demographics
  - Age: 8-16
  - Sex: Male 70% Female 30%
  - Ethnicity: White 70% African-American 20% Hispanic-American 10%
  - Parent Education Level:
    High School Diploma 50%
    Some College 20%
    College Degree or Higher 30%

Attention/Working Memory/Executive Functioning

- Auditory Attention and Response Set
  - Auditory Attention Total Correct
  - Auditory Attention Combined
  - Auditory Response Set Total Correct
  - Auditory Response Set Combined
  - Contrast Auditory Attention vs Reponse Set
- Word Repetition and Recall
  - Repetition
  - Recall
  - Contrast Repetition Versus Recall

Auditory Attention & Response Set

- Measures selective attention, maintenance of attention, and shift of set
- Simplified administration from NEPSY-II
  - no foam squares
  - Simplified and improved accuracy of scoring
- Child listens to same audio and points to appropriate colored circle when he/she hears a target word.

Word Interference

- The child listens to two word series and then recalls the first group and the second group.
- This subtest assesses immediate word span, working memory for novel, random language, and interference to auditory short-term memory

Attention/Working Memory/Executive Functioning

- Inhibition-
  - Naming
  - Inhibition
  - Switching
  - Total Errors
  - Contrast Naming Versus Inhibition
  - Contrast Inhibition Versus Switching
- Animal Sorting
  - Total
  - Combined score (correct and errors)
- Clocks

Inhibition

- A timed subtest assessing the ability to inhibit automatic responses in favor of novel responses. Two items - shapes, arrows
  - **Naming** - Names the shapes (*circle, square*) quickly
  - **Inhibition** - When sees circle, child says *square*. When sees square, child says *circle*.
  - **Switching** - When shape is black, say the shape's name. But if shape is white, say the alternate shape's name

Animal Sorting

- Measures the ability to formulate basic concepts into action (sort into categories), and to shift set from one concept to another
- Child sorts 8 cards into two self-initiated categories of 4 each.
  - There are 12 possible categories; 6 min. cumulative sorting time
  - No reading is necessary

TBI versus Matched Controls
Auditory Attention/Response Set

Score	TBI	Control
Auditory Attention Correct	5.6 (4.7)	8.6 (3.4)
Auditory Attention Combined	7.7 (4.8)	9.7 (3.2)
Auditory Response Correct	6.8 (4.4)	9.6 (3.8)
Auditory Response Combined	8.4 (3.5)	9.6 (3.4)
Attention VS Response	8.8 (2.2)	9.3 (3.1)

Clocks

- **Assesses planning and organization, as well as visuoperceptual and visuospatial skills, and the concept of time in relation to analog clocks.**
  - **Drawing to Command -** Child draws the face of the clock and sets hands to *three o'clock*. Draws another and sets hands for *ten after eleven*.
  - **Digital to Analogue -** Draws hands on face of clock to show same time as an analog clock (2 items)
  - **Clock reading without numbers**
  - **Clock reading with numbers**
  - **Copy items - Copying clock faces**

TBI versus Matched Controls Word Recall and Recognition and Clocks

Score	TBI	Control
Word Repetition	9.7 (2.9)	11.2 (2.3)
Word Recall	8.1 (4.4)	10.9 (2.4)
Repetition Vs Recall	8.1 (4.4)	10.2 (2.6)
Clocks Total Score	8.8 (1.9)	8.4 (1.3)

TBI versus Matched Controls Inhibition

Score	TBI	Controls
Naming Time	7.3 (2.7)	11.5 (3.2)
Naming Combined	6.6 (2.7)	10.0 (3.4)
Inhibition Time	8.1 (2.4)	10.7 (3.0)
Inhibition Combined	9.1 (2.3)	10.7 (2.2)
Switching Time	8.6 (4.2)	9.4 (2.8)
Switching Combined	8.0 (3.8)	9.4 (2.0)
Total Errors	7.8 (2.6)	9.8 (2.0)
Naming Versus Inhibition	10.3 (2.6)	10.8 (2.0)
Inhibition Versus Switching	8.0 (4.4)	9.2 (2.1)

TBI versus Matched Controls Animal Sorting

Score	TBI	Controls
Animal Sort Total Correct	9.1 (2.3)	10.4 (2.5)
Animal Sort Combined Score	9.1 (2.7)	10.4 (2.4)

Summary

- Remarkable similarity of results obtained on D-KEFS and NEPSY-II EF measures including marginal means similar to contrast scores.
- Processing speed deficits make it difficult to identify EF deficits but cognitive control difficulties evident in error rates.
- Basic attention difficulties also make it difficult to identify deficits higher order attention regulation although contrast score would indicate some difficulties.
- Working Memory – no problems with span but susceptible to recall interference

Children's Memory Scale

- Author: Morris Cohen
- Published 1997
- Assesses
  - Working Memory
  - Immediate and delayed memory\
  - Visual and verbal memory
  - Recognition memory
- Ages: 5-16

Children's Memory Scale

- Verbal Memory
  - Stories-2 stories presented vary by age group (5-8,9-12,13-16)
    - Immediate story recall, delayed recall, delayed recognition
  - Pairs-like verbal paired associates on WMS, hear a word and a word that goes with it. Must remember the target word when cue provided number of pairs varies by age. Multiple learning trials
    - Immediate, delayed, and recognition trials

Children's Memory Scale

- Visual Memory
  - FACES- See a series of faces that they are asked to learn and then must pick them out of a second group of face
    - Immediate and delayed recognition
  - DOTS-see a 4 x 4 grid (or 3 X 3 for younger). See 8 blue dots (or 6 for younger) must remember and place dots where saw on page. 3 learning trials, 1 interference trial, immediate recall and delayed recall trials.
- Pediatric TBI sample, 16 children with a history of moderate to severe TBI.

Children's Memory Scale

Index	TBI Mean (SD)	Control Mean (SD)	p	ES
Verbal Immediate	83.4 (14.9)	108.8 (14.2)	p < .001	-1.79
Verbal Delayed	84.0 (17.4)	107.2 (14.3)	p < .001	-1.62
Visual Immediate	95.2 (17.1)	106.6 (12.3)	p < .05	-.93
Visual Delayed	88.6 (14.0)	103.2 (16.8)	p < .05	-.87
Attention/ Concentration	97.1 (19.6)	104.9 (15.5)	p > .05	-.50
Learning	87.1 (17.0)	110.1 (10.9)	p < .001	-2.11
Delayed Recognition	87.9 (15.9)	104.6 (11.7)	p < .01	-1.44

Children's Memory Scale

- Consistent with meta-analysis, verbal memory deficits larger than visual memory deficits.
- ES substantially larger than reported in meta-analysis
- Observe higher end of average performance in control due to matching on parent education level-population based norms not yield results consistent with > 1 standard deviations below the means
- Delayed recognition memory only slightly better than free recall suggesting encoding deficits but slight problems with retrieval.
- Immediate versus delayed only different on visual and not verbal.

Children's Memory Scale

- Presenting information multiple times may improve individual memory performance but does not change performance compared to controls/norms.
- Visual memory tests have a high degree of guessing (50%) and primary rely on recognition memory paradigm.
- Visual memory difficult to measure.
- On WMS-IV, delayed visual memory was best predictor of post-injury adaptive functioning so it's an important construct to evaluate in TBI.

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