Current Concepts of Concussion Evaluation and Management
Alex M Taylor, PsyD
DISCLOSURES

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• The planners and presenters have declared that no conflicts of interest exist.
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Boston College Connell School of Nursing Continuing Education Program is accredited as a provider of continuing nursing education by the American Nurses Association Massachusetts, an accredited approver by the American Nurses Credentialing Center’s Commission on Accreditation.
SESSION OBJECTIVES

• Explain the need to identify and protect athletes with sports related concussion and establish return to play criteria.
• Identify indications for referral to a specialist, and considerations for treatment of patients with prolonged recovery.
Neurocognitive Assessment of SRC (ImPACT)

Alex M. Taylor, PsyD
Neuropsychologist
Rationale

1. Concussion results in cognitive impairment
2. Impairment signifies increased vulnerability to repeat injury
3. Measurement of cognitive function allows for more reliable detection of cognitive impairment (sometimes in the absence of self-reported symptoms)
# Assessment paradigms

## Paper and pencil (traditional)
- Excellent norms for peds
- Limited access
- Cost
- Time / labor intensive

## Computerized
- Capacity to test large #s quickly (baseline)
- Access
- Alternate forms
- Reaction Time
- Automatized scoring
- Language
- Questionable norms for peds
- Reliability / validity

## Hybrid
- Professional / college model
- Paper/pencil & computerized
- Include behavioral measures
What N-cognitive assessment does and doesn’t do

<table>
<thead>
<tr>
<th>Does</th>
<th>Does not do</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measure cognitive function</td>
<td>Replace clinical judgment</td>
</tr>
<tr>
<td>Identify the ‘not so forthcoming’ athlete</td>
<td>Provide prognosis for future problems</td>
</tr>
<tr>
<td>Help detect incomplete recovery</td>
<td>Act as the sole determining factor for return to play</td>
</tr>
<tr>
<td>Assist return to play decision making</td>
<td>Prevent repeat concussion</td>
</tr>
</tbody>
</table>
Neurocognitive findings

• Areas that are particularly vulnerable
  – Attention / concentration
  – Working memory (online memory)
  – New learning & memory: storage / retrieval
  – Processing speed
  – Reaction time

• Typical recovery 10-14 days
Normative model

No baseline

Performance compared to normative sample

**Percentile Ranges**

- Superior/Very Superior: 90 – 99th %ile
- High Average: 75 – 89th %ile
- Average: 26 – 74th %ile
- Low Average: 16 – 25th %ile
- Poor (Borderline Impaired): 6 – 15th %ile
- Impaired: < 5th %ile

*ImPACT™*

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Valid | Reliable | Safe
Baseline model

Baseline → Post-injury → Post-injury → Post-injury

Neurocognitive Functioning

Pre-injury | Day 1 | Day 3 | Day 14 | 3 months
ImPACT (Immediate postconcussion assessment and cognitive testing)

- Demographic/concussion history

- Postconcussion Symptom Scale
  - 22 Item Likert Scale (e.g. headache, dizziness, nausea, etc.)

- Neurocognitive Tasks
  - 6 subtests measuring memory, working memory, visual attention/discrimination, inhibition, processing speed, reaction time
  - Provides Index Scores in areas of: Verbal Memory, Visual Memory, Processing Speed & Reaction Time

- Detailed Clinical Report
  - Outlines demographic information, symptoms, neurocognitive data
  - Automatically computer scored
Module 1

Design Memory

Attention and verbal recognition memory
On the next screen, words will be presented one at a time in the center of the screen. Try to remember each of the words as you will be asked to remember them later.

Click the button below when you are ready to begin.
Ice
Woman
Was Plate one of the words displayed?

[buttons: Yes, No]
Was Ice one of the words displayed?

Yes  No
Was **Can** one of the words displayed?

Yes  No
Module 2
Design Memory
Attention and visual recognition memory
Next, you will be asked to remember designs. You will see designs in the middle of the screen. Remember each design EXACTLY as it is presented. Later, you will be tested to see if you recognize this design.

Click the button below to see an example..
Next you will see a number of designs on your screen. You will be asked to pick the designs that are exactly as you saw them before.

Click on the YES button if the design is EXACTLY THE SAME as the design that you just saw. Click the NO button if the design is different in any way.

Click the button below when you are ready to begin.
Was this one of the designs displayed?
Was this one of the designs displayed?
Module 3

Xs and Os

Visual working memory and processing speed
In this window, do the following for each shape displayed:

Press the left button on the mouse when you see: •

Press the right button on the mouse when you see: □

PLEASE RESPOND AS FAST AS YOU CAN!

Press this button when you are ready to begin: Start
In this window, do the following for each shape displayed:

Press the left button on the mouse when you see:  

Press the right button on the mouse when you see:  

PLEASE RESPOND AS FAST AS YOU CAN!
Click on the symbols that were highlighted on the initial screen.
Module 4

Symbol Match

Processing speed and learning / memory
Click on the number that corresponds to the following symbol:

∞
Symbol Search

Click on the number that corresponds to the following symbol:

△
Module 5

Color Match

Impulse control / response inhibition and reaction time
This is a test of SPEED or REACTION TIME.

On the next screen, you will see the words RED, GREEN and BLUE presented one at a time. Click the word inside the box when it shown in the same color in which it is written. Do not click the word when it is shown in a different color.

For example:

Click as fast as you can when you see:  
RED  or  GREEN  or  BLUE

Do not click when you see:

RED  or  GREEN  or  BLUE

Click this button when you are ready to begin:

Continue >>
Module 6

Three Letters

Visual motor speed / working memory
This next test is a SPEED test.

On the next screen, you will see 25 numbers. You will be asked to count BACKWARDS from 25 to 1 clicking on the numbers as fast as you can in REVERSE order.

Remember, start with 25 and count down to 1 as fast as you can.

If you make a mistake, use the GO BACK button to clear the buttons that you have clicked one at a time.

Click the button below when you are ready to begin.

Continue >>
Three Letters

Click each of these buttons in BACKWARD ORDER.

Start with 25 and count down to 1 AS FAST AS YOU CAN.

If you make a mistake, use the "Go back" button to clear the buttons you have already clicked, one at a time.
Type the letters from the prior screen in the same order that they were displayed:
Delayed Verbal / Visual Memory

Memory storage
Was Plate one of the words displayed?

Yes  No
Was **Ice** one of the words displayed?  

Yes  

No
Was this one of the designs displayed?
Was this one of the designs displayed?
### ImPACT™ Clinical Report

**Kaela Murphy**

<table>
<thead>
<tr>
<th>Organization:</th>
<th>Brain Injury Center</th>
<th>Age:</th>
<th>17</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date of Birth:</td>
<td>08/14/1993</td>
<td>Height:</td>
<td>70 inches</td>
</tr>
<tr>
<td>Gender:</td>
<td>Female</td>
<td>Weight:</td>
<td>143 lbs</td>
</tr>
<tr>
<td>Handedness:</td>
<td>Right</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Native country/region:</td>
<td>United States</td>
<td>Second language:</td>
<td></td>
</tr>
<tr>
<td>Native language:</td>
<td>English</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Years of education completed excluding kindergarten:</td>
<td>12</td>
<td>Repeated one or more years of school:</td>
<td>No</td>
</tr>
<tr>
<td>Received speech therapy:</td>
<td>No</td>
<td>Diagnosed learning disability:</td>
<td>No</td>
</tr>
<tr>
<td>Attended special education classes:</td>
<td>No</td>
<td>Problems with ADD/Hyperactivity:</td>
<td>No</td>
</tr>
<tr>
<td>Current sport:</td>
<td>Volleyball</td>
<td>Current level of participation:</td>
<td>Collegiate</td>
</tr>
<tr>
<td>Primary position/event/class:</td>
<td>utility</td>
<td>Years of experience at this level:</td>
<td>0</td>
</tr>
<tr>
<td>Number of times diagnosed with a concussion (excluding current injury):</td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Concussions that resulted in loss of consciousness:</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Concussions that resulted in confusion:</td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Concussions that resulted in difficulty remembering events that occurred immediately after injury:</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Concussions that resulted in difficulty remembering events that occurred:</td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total games missed as a result of all concussions combined:</td>
<td>20+</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Treatment for headaches by physician:</td>
<td>No</td>
<td>History of meningitis:</td>
<td>No</td>
</tr>
<tr>
<td>Treatment for migraine headaches by physician:</td>
<td>No</td>
<td>Treatment for substance/alcohol abuse:</td>
<td>No</td>
</tr>
<tr>
<td>Treatment for epilepsy/seizures:</td>
<td>No</td>
<td>Treatment for psychiatric condition (depression, anxiety):</td>
<td>No</td>
</tr>
<tr>
<td>History of brain surgery:</td>
<td>No</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diagnosed with ADD/ADHD:</td>
<td>No</td>
<td>Diagnosed with Autism:</td>
<td>No</td>
</tr>
<tr>
<td>Diagnosed with Dyslexia:</td>
<td>No</td>
<td>Strenuous exercise in the last 3 hours:</td>
<td>No</td>
</tr>
</tbody>
</table>

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[HARVARD MEDICAL SCHOOL TEACHING HOSPITAL]

[Boston Children's Hospital]
**ImPACT™ Clinical Report**

**Kaela Murphy**

<table>
<thead>
<tr>
<th>Exam Type</th>
<th>Post-Injury 1</th>
<th>Post-Injury 2</th>
<th>Baseline</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date Tested</td>
<td>03/08/2011</td>
<td>05/19/2011</td>
<td>08/02/2011</td>
</tr>
<tr>
<td>Last Concussion</td>
<td>02/14/2011</td>
<td>02/14/2011</td>
<td>02/14/2011</td>
</tr>
<tr>
<td>Exam Language</td>
<td>English</td>
<td>English</td>
<td>English</td>
</tr>
<tr>
<td>Test Version</td>
<td>2.0</td>
<td>2.1</td>
<td>2.1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Composite Scores</th>
<th>Percentile scores if available are listed in small type.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Memory composite (verbal)</td>
<td>79  25%  85  44%  91  66%</td>
</tr>
<tr>
<td>Memory composite (visual)</td>
<td>56  14%  59  18%  70  40%</td>
</tr>
<tr>
<td>Visual motor speed composite</td>
<td>26.55  &lt;1%  34.08  21%  36.78  35%</td>
</tr>
<tr>
<td>Reaction time composite</td>
<td>0.71  5%  0.65  12%  0.52  75%</td>
</tr>
<tr>
<td>Impulse control composite</td>
<td>8  2  8  8</td>
</tr>
<tr>
<td>Total Symptom Score</td>
<td>46  37  14</td>
</tr>
</tbody>
</table>

**Cognitive Efficiency Index:**

The Cognitive efficiency Index measures the interaction between accuracy (percentage correct) and speed (reaction time) in seconds on the Symbol Match test. This score was not developed to make return to play decisions but can be helpful in determining the extent to which the athlete tried to work very fast on symbol match (decreasing accuracy) or attempted to improve their accuracy by taking a more deliberate and slow approach (jeopardizing speed). The range of scores is from approximately zero to approximately .70 with a mean of .34. A higher score indicates that the athlete did well in both the speed and memory domains on the symbol match test. A low score (below .20) means that they performed poorly on both the speed and accuracy component. If this score is a negative number, the test taker performed very poorly on the reaction time component.

| Hours slept last night | 5  0.5  7 |
| Medication            | *  # |

* Topiramate, amitriptyline, oxycodon-acetaminophen, proair

# ProAirTriSpintec

The information provided by this report should be viewed as only one source of information regarding an individual’s level of [neurocognitive] functioning. Even though impact is based on demonstrated scientific principles and research, external factors such as improper test administration or improper test taking environment may result in inaccurate test results. These factors and others must be considered in making return-to-play decision. The information provided by this report is of a general nature and does not represent medical advice, a diagnosis, or prescription for treatment. Additionally, diagnostic or return to play decisions should not be solely based on the data generated by this report, but on an in-person evaluation made by a professional trained in concussion management in accordance with usual and standard medical practice. An individual suspected of suffering traumatic brain injury or concussion should immediately seek the advice of qualified and trained personnel for interpretation of test results and should be monitored carefully for the emergence of symptoms. Impact is not responsible for any decisions based on information contained in the report. A test-taker’s qualified and trained personnel has the sole
<p>| | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Word Memory</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hits (Immediate)</td>
<td>11</td>
<td>10</td>
<td>12</td>
</tr>
<tr>
<td>Correct distractors (immed.)</td>
<td>12</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>Learning percent correct</td>
<td>96%</td>
<td>92%</td>
<td>100%</td>
</tr>
<tr>
<td>Hits (delay)</td>
<td>12</td>
<td>10</td>
<td>11</td>
</tr>
<tr>
<td>Correct distractors (delay)</td>
<td>11</td>
<td>10</td>
<td>11</td>
</tr>
<tr>
<td>Delayed memory pct. correct</td>
<td>96%</td>
<td>83%</td>
<td>92%</td>
</tr>
<tr>
<td>Total percent correct</td>
<td>96%</td>
<td>87.5%</td>
<td>96%</td>
</tr>
<tr>
<td><strong>Design Memory</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hits (Immediate)</td>
<td>12</td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>Correct distractors (immed.)</td>
<td>8</td>
<td>5</td>
<td>7</td>
</tr>
<tr>
<td>Learning percent correct</td>
<td>83%</td>
<td>50%</td>
<td>83%</td>
</tr>
<tr>
<td>Hits (delay)</td>
<td>10</td>
<td>11</td>
<td>10</td>
</tr>
<tr>
<td>Correct distractors (delay)</td>
<td>8</td>
<td>6</td>
<td>6</td>
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<tr>
<td>Delayed memory pct. correct</td>
<td>75%</td>
<td>71%</td>
<td>87%</td>
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<tr>
<td>Total percent correct</td>
<td>79%</td>
<td>60.5%</td>
<td>65%</td>
</tr>
<tr>
<td><strong>X’s and O’s</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total correct (memory)</td>
<td>4</td>
<td>7</td>
<td>9</td>
</tr>
<tr>
<td>Total correct (interference)</td>
<td>102</td>
<td>119</td>
<td>119</td>
</tr>
<tr>
<td>Avg. correct RT (interference)</td>
<td>0.6</td>
<td>0.48</td>
<td>0.43</td>
</tr>
<tr>
<td>Total incorrect (interference)</td>
<td>7</td>
<td>2</td>
<td>8</td>
</tr>
<tr>
<td>Avg. incorrect RT (interfer.)</td>
<td>0.44</td>
<td>0.44</td>
<td>0.34</td>
</tr>
<tr>
<td><strong>Symbol Match</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total correct (visible)</td>
<td>27</td>
<td>27</td>
<td>27</td>
</tr>
<tr>
<td>Avg. correct RT (visible)</td>
<td>1.78</td>
<td>1.46</td>
<td>1.26</td>
</tr>
<tr>
<td>Total correct (hidden)</td>
<td>6</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>Avg. correct RT (hidden)</td>
<td>2.07</td>
<td>1.48</td>
<td>1.15</td>
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<tr>
<td><strong>Color Match</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total correct</td>
<td>9</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>Avg. correct RT</td>
<td>0.92</td>
<td>0.97</td>
<td>0.72</td>
</tr>
<tr>
<td>Total commissions</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Avg. commissions RT</td>
<td>0.5</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Three Letters</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total sequence correct</td>
<td>3</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Total letters correct</td>
<td>11</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>Pct. of total letters correct</td>
<td>73.33%</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>Avg. time to first click</td>
<td>1.79</td>
<td>1.54</td>
<td>2.4</td>
</tr>
<tr>
<td>Avg. counted</td>
<td>9.2</td>
<td>12.8</td>
<td>15</td>
</tr>
</tbody>
</table>
# ImPACT™ Clinical Report

<table>
<thead>
<tr>
<th>Symptom</th>
<th>Score</th>
<th>Score</th>
<th>Score</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Headache</td>
<td>5</td>
<td>6</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>Nausea</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Vomiting</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Balance Problems</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Dizziness</td>
<td>3</td>
<td>5</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Fatigue</td>
<td>4</td>
<td>3</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Trouble falling asleep</td>
<td>4</td>
<td>N/A</td>
<td>3</td>
<td>N/A</td>
</tr>
<tr>
<td>Sleeping more than usual</td>
<td>0</td>
<td>N/A</td>
<td>0</td>
<td>N/A</td>
</tr>
<tr>
<td>Sleeping less than usual</td>
<td>3</td>
<td>N/A</td>
<td>3</td>
<td>N/A</td>
</tr>
<tr>
<td>Drowsiness</td>
<td>4</td>
<td>3</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Sensitivity to light</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Sensitivity to noise</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Irritability</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Sadness</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Nervousness</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Feeling more emotional</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Numbness or tingling</td>
<td>2</td>
<td>2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Feeling slowed down</td>
<td>3</td>
<td>4</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Feeling mentally foggy</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Difficulty concentrating</td>
<td>4</td>
<td>5</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Difficulty remembering</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Visual problems</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

**Total Symptom Score**: 46 45 37 35 14

*First column displays symptoms immediately before test*

*The ImPACT Symptom Increase Score*
### ImPACT™ Clinical Report

**Sample Student**

<table>
<thead>
<tr>
<th>Exam Type</th>
<th>Baseline</th>
<th>Post-Injury 1</th>
<th>Post-Injury 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date Tested</td>
<td>07/14/2009</td>
<td>08/25/2010</td>
<td>08/31/2010</td>
</tr>
<tr>
<td>Last Concussion</td>
<td>08/23/2010</td>
<td>08/23/2010</td>
<td></td>
</tr>
<tr>
<td>Exam Language</td>
<td>English</td>
<td>English</td>
<td>English</td>
</tr>
<tr>
<td>Test Version</td>
<td>2.0</td>
<td>2.0</td>
<td>2.0</td>
</tr>
</tbody>
</table>

### Composite Scores

<table>
<thead>
<tr>
<th>Composite Score</th>
<th>Baseline</th>
<th>Post-Injury 1</th>
<th>Post-Injury 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Memory composite (verbal)</td>
<td>90</td>
<td>72</td>
<td>94</td>
</tr>
<tr>
<td>Memory composite (verbal)</td>
<td>80%</td>
<td>17%</td>
<td>88%</td>
</tr>
<tr>
<td>Memory composite (visual)</td>
<td>79</td>
<td>55</td>
<td>71</td>
</tr>
<tr>
<td>Memory composite (visual)</td>
<td>69%</td>
<td>8%</td>
<td>39%</td>
</tr>
<tr>
<td>Visual motor speed composite</td>
<td>29.08</td>
<td>19.65</td>
<td>33.17</td>
</tr>
<tr>
<td>Visual motor speed composite</td>
<td>33%</td>
<td>&lt;1%</td>
<td>34%</td>
</tr>
<tr>
<td>Reaction time composite</td>
<td>0.55</td>
<td>0.79</td>
<td>0.59</td>
</tr>
<tr>
<td>Reaction time composite</td>
<td>93%</td>
<td>4%</td>
<td>56%</td>
</tr>
<tr>
<td>Impulse control composite</td>
<td>8</td>
<td>13</td>
<td>13</td>
</tr>
<tr>
<td>Total Symptom Score</td>
<td>0</td>
<td>31</td>
<td>0</td>
</tr>
</tbody>
</table>

Scores in **bold RED** type exceed the Reliable Change Index (RCI) when compared to the baseline score. However, scores that do not exceed to RCI index may still be clinically significant. Percentile scores if available are listed in small type.
How is Verbal Memory Calculated?

This composite score represents the average performance on:

- Word Memory (module 1) Total Percent Correct
- Symbol Match (module 4) (Total Correct Hidden)/9*100
- Three Letters (module 6) Percent Total Letters Correct

<table>
<thead>
<tr>
<th>Word Memory</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Hits (Immediate)</td>
<td>12</td>
<td>8</td>
<td>12</td>
</tr>
<tr>
<td>Correct distractors (immed.)</td>
<td>12</td>
<td>12</td>
<td>11</td>
</tr>
<tr>
<td>Learning percent correct</td>
<td>100%</td>
<td>93%</td>
<td>96%</td>
</tr>
<tr>
<td>Hits (delay)</td>
<td>12</td>
<td>8</td>
<td>10</td>
</tr>
<tr>
<td>Correct distractors (delay)</td>
<td>12</td>
<td>8</td>
<td>11</td>
</tr>
<tr>
<td>Delayed memory pct. correct</td>
<td>100%</td>
<td>57%</td>
<td>69%</td>
</tr>
<tr>
<td>Total percent correct</td>
<td>100%</td>
<td>75%</td>
<td>92%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Symbol Match</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Total correct (visible)</td>
<td>27</td>
<td>27</td>
<td>27</td>
</tr>
<tr>
<td>Avg. correct RT (visible)</td>
<td>1.56</td>
<td>1.73</td>
<td>1.24</td>
</tr>
<tr>
<td>Total correct (hidden)</td>
<td>7</td>
<td>5</td>
<td>8</td>
</tr>
<tr>
<td>Avg. correct RT (hidden)</td>
<td>1.39</td>
<td>2.18</td>
<td>1.2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Three Letters</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Total sequence correct</td>
<td>4</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Total letters correct</td>
<td>14</td>
<td>13</td>
<td>15</td>
</tr>
<tr>
<td>Pct. of total letters correct</td>
<td>83.33%</td>
<td>86.67%</td>
<td>100%</td>
</tr>
<tr>
<td>Avg. time to first click</td>
<td>2.09</td>
<td>3.85</td>
<td>1.74</td>
</tr>
<tr>
<td>Avg. counted</td>
<td>11.2</td>
<td>5.8</td>
<td>13.2</td>
</tr>
<tr>
<td>Avg. counted correctly</td>
<td>10.8</td>
<td>6.6</td>
<td>13.2</td>
</tr>
</tbody>
</table>
How is Visual Memory Calculated?

This score in its current form is comprised of the average of:

- Design Memory (module 2) Total Percent Correct
- X’s and O’s (module 3) (Total Correct Memory)/12*100

<table>
<thead>
<tr>
<th>Design Memory</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Hits (Immediate)</td>
<td>11</td>
<td>10</td>
<td>11</td>
</tr>
<tr>
<td>Correct distractors (immed.)</td>
<td>11</td>
<td>9</td>
<td>8</td>
</tr>
<tr>
<td>Learning percent correct</td>
<td>92%</td>
<td>79%</td>
<td>79%</td>
</tr>
<tr>
<td>Hits (delay)</td>
<td>10</td>
<td>11</td>
<td>12</td>
</tr>
<tr>
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<td>12</td>
<td>7</td>
<td>9</td>
</tr>
<tr>
<td>Delayed memory pct. correct</td>
<td>92%</td>
<td>75%</td>
<td>88%</td>
</tr>
<tr>
<td>Total percent correct</td>
<td>92%</td>
<td>77%</td>
<td>83.5%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>X’s and O’s</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Total correct (memory)</td>
<td>8</td>
<td>4</td>
<td>7</td>
</tr>
<tr>
<td>Total correct (interference)</td>
<td>103</td>
<td>78</td>
<td>107</td>
</tr>
<tr>
<td>Avg. correct RT (interference)</td>
<td>0.58</td>
<td>0.88</td>
<td>0.51</td>
</tr>
<tr>
<td>Total incorrect (interference)</td>
<td>7</td>
<td>7</td>
<td>13</td>
</tr>
<tr>
<td>Avg. incorrect RT (interference)</td>
<td>Å·</td>
<td>0.87</td>
<td>0.41</td>
</tr>
</tbody>
</table>
How is Visual Motor Speed Calculated?

This score is comprised of the average of following scores:

- Total Number Correct/4 during Interference of X’s and O’s (module 3).
- Average Counted Correctly*3 from Countdown Phase of Three Letters (module 6).

### X’s and O’s

<table>
<thead>
<tr>
<th></th>
<th>8</th>
<th>4</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total correct (memory)</td>
<td>8</td>
<td>4</td>
<td>7</td>
</tr>
<tr>
<td>Total correct (interference)</td>
<td>103</td>
<td>78</td>
<td>107</td>
</tr>
<tr>
<td>Avg. correct RT (interference)</td>
<td>0.38</td>
<td>0.88</td>
<td>0.51</td>
</tr>
<tr>
<td>Total incorrect (interference)</td>
<td>7</td>
<td>7</td>
<td>13</td>
</tr>
<tr>
<td>Avg. incorrect RT (interference)</td>
<td>0.87</td>
<td>0.87</td>
<td>0.41</td>
</tr>
</tbody>
</table>

### Three Letters

<table>
<thead>
<tr>
<th></th>
<th>4</th>
<th>3</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total sequence correct</td>
<td>4</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Total letters correct</td>
<td>14</td>
<td>13</td>
<td>15</td>
</tr>
<tr>
<td>Pct. of total letters correct</td>
<td>93.33%</td>
<td>86.67%</td>
<td>100%</td>
</tr>
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<td>Avg. time to first click</td>
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<td>3.85</td>
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<tr>
<td>Avg. counted</td>
<td>11.2</td>
<td>6.8</td>
<td>13.2</td>
</tr>
<tr>
<td>Avg. counted correctly</td>
<td>10.8</td>
<td>6.6</td>
<td>13.2</td>
</tr>
</tbody>
</table>
How is Reaction Time Calculated?

This score is comprised of the average of the following scores:
- Average Correct RT of Interference Stage of X’s and O’s (module 3).
- Symbol Match (module 4) Average Correct RT Visible/3.
- Color Match (module 5) Average Correct RT.

<table>
<thead>
<tr>
<th>X’s and O’s</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Total correct (memory)</td>
<td>8</td>
<td>4</td>
<td>7</td>
</tr>
<tr>
<td>Avg. correct RT (memory)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total correct (interference)</td>
<td>103</td>
<td>78</td>
<td>107</td>
</tr>
<tr>
<td>Avg. correct RT (interference)</td>
<td>0.58</td>
<td>0.88</td>
<td>0.51</td>
</tr>
<tr>
<td>Total incorrect (interference)</td>
<td>7</td>
<td>7</td>
<td>10</td>
</tr>
<tr>
<td>Avg. incorrect RT (interference)</td>
<td>0.87</td>
<td>0.41</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Symbol Match</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Total correct (visible)</td>
<td>27</td>
<td>27</td>
<td>27</td>
</tr>
<tr>
<td>Avg. correct RT (visible)</td>
<td>1.56</td>
<td>1.73</td>
<td>1.24</td>
</tr>
<tr>
<td>Total correct (hidden)</td>
<td>7</td>
<td>5</td>
<td>8</td>
</tr>
<tr>
<td>Avg. correct RT (hidden)</td>
<td>1.39</td>
<td>2.18</td>
<td>1.2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Color Match</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Total correct</td>
<td>1</td>
<td>9</td>
<td>8</td>
</tr>
<tr>
<td>Avg. correct RT</td>
<td>0</td>
<td>0.93</td>
<td>0.84</td>
</tr>
<tr>
<td>Total commissions</td>
<td>1</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td>Avg. commissions RT</td>
<td>1.34</td>
<td>0.86</td>
<td>0</td>
</tr>
</tbody>
</table>
How is Impulse Control Calculated?

This score is obtained by adding:

- Total Incorrect on the Interference Phase of X’s and O’s (module 3).
- Color Match Total Commissions (module 5).

### X’s and O’s

<table>
<thead>
<tr>
<th></th>
<th>8</th>
<th>4</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total correct (memory)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total correct (interference)</td>
<td>103</td>
<td>78</td>
<td>107</td>
</tr>
<tr>
<td>Avg. correct RT (interference)</td>
<td>0.58</td>
<td>0.88</td>
<td>0.51</td>
</tr>
<tr>
<td>Total incorrect (interference)</td>
<td>7</td>
<td>7</td>
<td>13</td>
</tr>
<tr>
<td>Avg. incorrect RT (interference)</td>
<td></td>
<td>0.87</td>
<td>0.41</td>
</tr>
</tbody>
</table>

### Color Match

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>9</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total correct</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Avg. correct RT</td>
<td>0</td>
<td>0.03</td>
<td>0.84</td>
</tr>
<tr>
<td>Total commissions</td>
<td>1</td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Avg. commissions RT</td>
<td>1.34</td>
<td>0.86</td>
<td>0</td>
</tr>
</tbody>
</table>
Interpretation Guidelines: Sources of Test Invalidity

Suspect Test Invalidity if Any of the Following Occur:

- Word Memory Learning is below 69
- Design Memory Learning is below 50
- X’s and O’s Total Incorrect Interference is > 30
- Symbol Match Average Correct RT is > 1.75
- Color Match Total Correct is < 7
- Three Letters Total Correct < 9
- Three Letters Average Counted Correctly < 10
- If 0 is Obtained on Three Letters Average Counted Correctly, profile is invalid due to athlete counting forwards versus backwards
Test considerations

• Consider
  – Setting (e.g., group, office)
  – Distractions
  – Time of day
• Arousal / fatigue
• Level of engagement / motivation
• “Sandbagging”
• Anxiety/depression
Common Error – X’s and O’s

- Mixing up P & Q will result in switched scores between Total Correct & Total Incorrect Interference (INCORRECT will be very high)
- Contributes to decrease in Visual Motor Speed Composite
- Example
In this window, do the following for each shape displayed:

Press the left button on the mouse when you see:

Press the right button on the mouse when you see:

PLEASE RESPOND AS FAST AS YOU CAN!
### Correction

**Average of:**

- Xs and Os Total incorrect interference/4
- 3 Letters Average counted correctly

<table>
<thead>
<tr>
<th>Composite Scores</th>
<th>Percentile scores if available are listed in small type.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Memory composite (verbal)</td>
<td>93 80%</td>
</tr>
<tr>
<td>Memory composite (visual)</td>
<td>65 18%</td>
</tr>
<tr>
<td>Visual motor speed composite</td>
<td>1.5 &lt;1%</td>
</tr>
<tr>
<td>Reaction time composite</td>
<td>0.6 40%</td>
</tr>
<tr>
<td>Impulse control composite</td>
<td>98</td>
</tr>
<tr>
<td>Total Symptom Score</td>
<td>0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Word Memory</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Hits (Immediate)</td>
<td>12</td>
</tr>
<tr>
<td>Correct distractors (immed.)</td>
<td>12</td>
</tr>
<tr>
<td>Learning percent correct</td>
<td>100%</td>
</tr>
<tr>
<td>Hits (delay)</td>
<td>12</td>
</tr>
<tr>
<td>Correct distractors (delay)</td>
<td>12</td>
</tr>
<tr>
<td>Delayed memory pct. correct</td>
<td>100%</td>
</tr>
<tr>
<td>Total percent correct</td>
<td>100%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Design Memory</th>
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</thead>
<tbody>
<tr>
<td>Hits (Immediate)</td>
<td>11</td>
</tr>
<tr>
<td>Correct distractors (immed.)</td>
<td>11</td>
</tr>
<tr>
<td>Learning percent correct</td>
<td>92%</td>
</tr>
<tr>
<td>Hits (delay)</td>
<td>7</td>
</tr>
<tr>
<td>Correct distractors (delay)</td>
<td>9</td>
</tr>
<tr>
<td>Delayed memory pct. correct</td>
<td>67%</td>
</tr>
<tr>
<td>Total percent correct</td>
<td>79.5%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>X’s and O’s</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Total correct (memory)</td>
<td>6</td>
</tr>
<tr>
<td>Total correct (interference)</td>
<td>12</td>
</tr>
<tr>
<td>Avg. correct RT (interference)</td>
<td>0.54</td>
</tr>
<tr>
<td>Total incorrect (interference)</td>
<td>98</td>
</tr>
<tr>
<td>Avg. incorrect RT (interfer.)</td>
<td>0.57</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Symbol Match</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Total correct (visible)</td>
<td>27</td>
</tr>
<tr>
<td>Avg. correct RT (visible)</td>
<td>1.97</td>
</tr>
<tr>
<td>Total correct (hidden)</td>
<td>7</td>
</tr>
<tr>
<td>Avg. correct RT (hidden)</td>
<td>2.99</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Color Match</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Total correct</td>
<td>0</td>
</tr>
<tr>
<td>Avg. correct RT</td>
<td>0</td>
</tr>
<tr>
<td>Total commissions</td>
<td>0</td>
</tr>
<tr>
<td>Avg. commissions RT</td>
<td>0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Three Letters</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Total sequence correct</td>
<td>5</td>
</tr>
<tr>
<td>Total letters correct</td>
<td>15</td>
</tr>
<tr>
<td>Pct. of total letters correct</td>
<td>100%</td>
</tr>
<tr>
<td>Avg. time to first click</td>
<td>1.5</td>
</tr>
<tr>
<td>Avg. counted</td>
<td>15.8</td>
</tr>
<tr>
<td>Avg. counted correctly</td>
<td>0</td>
</tr>
</tbody>
</table>
Common Error – Three Letters

- Counting forward from 1-25 (instead of backward) will result in abnormally low Average Counted Correctly (numbers should be pretty close, and average is 13-18). Contributes to decreased Visual Motor Speed Composite

- Example
# Three Letters

Click each of these buttons in **BACKWARD ORDER**.

Start with 25 and count down to 1 **AS FAST AS YOU CAN**.

If you make a mistake, use the "Go back" button to clear the buttons you have already clicked, one at a time.

<table>
<thead>
<tr>
<th>24</th>
<th>6</th>
<th>20</th>
<th>22</th>
<th>19</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>13</td>
<td>14</td>
<td>21</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>11</td>
<td>18</td>
<td>12</td>
<td>23</td>
</tr>
<tr>
<td>8</td>
<td>4</td>
<td>5</td>
<td>1</td>
<td>7</td>
</tr>
<tr>
<td>16</td>
<td>17</td>
<td>25</td>
<td>9</td>
<td>15</td>
</tr>
</tbody>
</table>

<< Go back
**Correction**
Average of:
Xs and Os Total correct interference/4
3 Letters Average counted

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<td>Total Symptom Score</td>
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</table>

<table>
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<td>Total percent correct</td>
<td>100%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Design Memory</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Hits (Immediate)</td>
<td>11</td>
</tr>
<tr>
<td>Correct distractors (immed.)</td>
<td>11</td>
</tr>
<tr>
<td>Learning percent correct</td>
<td>92%</td>
</tr>
<tr>
<td>Hits (delay)</td>
<td>7</td>
</tr>
<tr>
<td>Correct distractors (delay)</td>
<td>9</td>
</tr>
<tr>
<td>Delayed memory pct. correct</td>
<td>67%</td>
</tr>
<tr>
<td>Total percent correct</td>
<td>79.5%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>X's and O's</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Total correct (memory)</td>
<td>6</td>
</tr>
<tr>
<td>Total correct (interference)</td>
<td>12</td>
</tr>
<tr>
<td>Avg. correct RT (interference)</td>
<td>0.54</td>
</tr>
<tr>
<td>Total incorrect (interference)</td>
<td>98</td>
</tr>
<tr>
<td>Avg. incorrect RT (interference)</td>
<td>0.57</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Symbol Match</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Total correct (visible)</td>
<td>27</td>
</tr>
<tr>
<td>Avg. correct RT (visible)</td>
<td>1.97</td>
</tr>
<tr>
<td>Total correct (hidden)</td>
<td>7</td>
</tr>
<tr>
<td>Avg. correct RT (hidden)</td>
<td>2.99</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Color Match</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Total correct</td>
<td>0</td>
</tr>
<tr>
<td>Avg. correct RT</td>
<td>0</td>
</tr>
<tr>
<td>Total commissions</td>
<td>0</td>
</tr>
<tr>
<td>Avg. commissions RT</td>
<td>0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Three Letters</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Total sequence correct</td>
<td>5</td>
</tr>
<tr>
<td>Total letters correct</td>
<td>15</td>
</tr>
<tr>
<td>Pct. of total letters correct</td>
<td>100%</td>
</tr>
<tr>
<td>Avg. counted</td>
<td>15.8</td>
</tr>
<tr>
<td>Avg. time to first click</td>
<td>1.5</td>
</tr>
<tr>
<td>Avg. counted correctly</td>
<td>0</td>
</tr>
</tbody>
</table>
Color Match Error

- Reaction Time Composite will look TOO GOOD
- 0.00 seconds for Average Correct Reaction Time in Color Match will result in abnormally low RT composite (less than 0.40 seconds)
- Throw out 0.00 and average the other two scores for a corrected Reaction Time Composite score
Blue
### Composite Scores

<table>
<thead>
<tr>
<th></th>
<th>Xs and O's</th>
<th>Symbol Match</th>
</tr>
</thead>
<tbody>
<tr>
<td>Memory composite (verbal)</td>
<td>90  80%</td>
<td></td>
</tr>
<tr>
<td>Memory composite (visual)</td>
<td>79  69%</td>
<td></td>
</tr>
<tr>
<td>Visual motor speed composite</td>
<td>29.08  33%</td>
<td></td>
</tr>
<tr>
<td>Reaction time composite</td>
<td>0.55  93%</td>
<td></td>
</tr>
<tr>
<td>Impulse control composite</td>
<td>8  93%</td>
<td></td>
</tr>
<tr>
<td>Total Symptom Score</td>
<td>0  93%</td>
<td></td>
</tr>
</tbody>
</table>

Scores in **bold RED** type exceed the Reliable Change Index (RCI) scores that do not exceed to RCI index may still be clinically significant type.

**Correction**

Average of:
- Xs and Os average correct RT
- Symbol Match average correct RT/3
Additional interpretive considerations

- Learning Disability
- Attention Deficit Hyperactivity Disorder
- Emotional factors
- Hx concussion
- Age

<table>
<thead>
<tr>
<th></th>
<th>LD 12 to 14</th>
<th>LD 15 to 18</th>
<th>NORMS 12 to 14</th>
<th>NORMS 15 to 18</th>
<th>ADD 12 to 14</th>
<th>ADD 15 to 18</th>
<th>NORMS 12 to 14</th>
<th>NORMS 15 to 18</th>
</tr>
</thead>
<tbody>
<tr>
<td>Verbal</td>
<td>81.1 (10.2)</td>
<td>81.6 (10.0)</td>
<td>82.2 (9.5)</td>
<td>83.5 (9.9)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Visual</td>
<td>68.9 (13.9)</td>
<td>67.7 (14.0)</td>
<td>68.4 (13.8)</td>
<td>69.5 (13.4)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VisMot</td>
<td>30.7 (6.8)</td>
<td>32.5 (7.1)</td>
<td>33.5 (7.4)</td>
<td>36.3 (7.4)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RT</td>
<td>.65 (.10)</td>
<td>.62 (.09)</td>
<td>.62 (.09)</td>
<td>.60 (.09)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sympt.</td>
<td>4.3 (5.0)</td>
<td>4.1 (4.7)</td>
<td>4.2 (4.6)</td>
<td>4.6 (4.9)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>120</td>
<td>421</td>
<td>319</td>
<td>724</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Subtests: guidelines for interpretation

**Word Memory**
- High 80s WNL (total % correct)

**Design Memory**
- Mid-70s WNL (total % correct)

**X/O’s**
- 8-12 WNL

**Symbol Match**
- Total correct visible >25
- Avg correct RT visible <1.5
- Total correct hidden: 6-9

**3 Letters**
- Total correct: ~13-15
Table 3. Quick Reference Reliable Change Estimates: 80% Confidence Interval.

<table>
<thead>
<tr>
<th>Composite</th>
<th>Declined</th>
<th>Improved</th>
</tr>
</thead>
<tbody>
<tr>
<td>Verbal Memory</td>
<td>9 points</td>
<td>9 points</td>
</tr>
<tr>
<td>Visual Memory</td>
<td>14 points</td>
<td>14 points</td>
</tr>
<tr>
<td>Reaction Time</td>
<td>0.06 s</td>
<td>0.06 s</td>
</tr>
<tr>
<td>Processing Speed</td>
<td>3 points</td>
<td>7 points</td>
</tr>
<tr>
<td>Postconcussion Scale</td>
<td>10 points</td>
<td>10 points</td>
</tr>
</tbody>
</table>

Iverson et al., 2003
Resources

• www.impacttest.com

Suggested Reading

Thank you

Alex Taylor
Boston Children’s Hospital
617-355-2490