Cross-validation of measures used for the assessment of sports-related concussion, and applications of concussion testing to at-risk athletes.

Philip Schatz, PhD
Saint Joseph’s University, Philadelphia PA

Overview

• Historical Aspects
• Previous Findings
• Current Research
• Cross-validation of computer-based measures
• At risk club sport athletes
• Future Directions
• http://schatz.sju.edu/nan/

Historical Aspects:
UVA Football Study - Barth, et al., 1989

Trail Making B: Pre-Season and Post-Injury Performances

Historical Aspects:
UVA Football Study - Barth, et al., 1989

PASAT-4: Pre-Season and Post-Injury Performances

Historical Aspects:
Echemendia PSU: Hockey: COWAT

Historical Aspects:

• Egocentric view:
  – The Virginia Football Study
  – Echemendia’s PSU Program
  – Saint Joseph’s University
    • Division I, No Football, 400+ varsity athletes
  – Where can I find a place?
  – Computers circa 1998
What We Knew/Know

• Effects of Cerebral Concussions last approximately 7-10 days
  – Primarily attention and concentration
  Barth, et al., 1989. in H. Levin's Mild Head Injury; Oxford Press

• Effects of cerebral concussions last up to 30 days and beyond (Echemendia, et al., 1999)
  – Extends to other cognitive processes

• LOC is not a predictor of concussion, and incidence of LOC does not effect cognitive performance

• Individuals with history of Concussion and/or Learning Disability show lowered baseline performance on testing.
  (Collins, et al., JAMA, 1999)

What We Knew/Know

• Previous concussions decrease cognitive and academic performance, even in non-concussed individuals.
  (Mueller & Schum 2001, ACNI, 17(1), 91-100)

• Individuals with history of Concussion and/or Learning Disability show lowered baseline performance on testing.
  (Collins, et al., JAMA, 1999)

Current Research: How do I develop a Concussion Program at SJU?

(Hopefully) based on Professional and Collegiate Concussion Management Programs

• NFL - Majority
• NHL - Mandatory
• Baseline, Serial Post-concussion Evals.
• Wide Network of Neuropsychologists
• Colleges test teams pre-season

SJU Concussion Pilot Study: Trails B

SJU Concussion Pilot: Digit-Symbol
SJU Concussion Pilot Study: d2

There already was a trend towards computer-based assessment

- CRI (HeadMinder.com) .............. 1999
  - Web based
- CogSport (CogState.com) ............ 1999
  - Windows/Mac
- ImPACT (ImPACTtest.com) .......... 2000
  - Windows based

Why should we opt for computer-based assessment?

- Sensitive to RT, Processing Speed
- Randomized Trials: Improved reliability
- Ability to test entire team at once (benefit?)
- Better/Objective date for Athletic Trainers, Team Physicians
  - Assistance with Return to play decisions
  (Schatz & Zillmer, 2003, Applied Neuropsych; Schatz & Browndyke, 2003, JHTR)

Why should we not opt for computer-based assessment?

- Perhaps timing is not millisecond-accurate
- Limited validation with np “standards”
- Little qualitative or “verbal” data
- Can be used by Athletic Trainers, Team Physicians in absence of Neuropsych
  - May determine Return to play decisions
  (Schatz & Zillmer, 2003, Applied Neuropsych)

And a whole lot of tests and schedules for measuring post-concussion status

Power In Numbers:
Philadelphia Sports Concussion Program

- Mandatory for Participation in Athletics
- Drexel, Temple, SJU… Delaware, Rutgers
- Baseline, 24-48 hr, 3, 5, 7, 10, weekly if Sx
- ImPACT @ 4 schools, CRI @ Temple
- Dissertations (McKeever, Covassin, Schneider), Master’s Theses
  - Validate multiple measures
  (ImPACT, CRI, CogSport, Trails, Digit Symbol, d2)
  - Gender, Sport, History, Club Sports, Cheerleaders, School Norms
Study 1: Cross-Validation of Computer-Based Measures - Rationale

- Limited “shared validation” of existing computer-based measures with standards
- SDMT correlates with:
  - ImPACT PROCESSING SPEED (r=.70) and Reaction Time (r=-.60)
- Trails correlates with:
  - CRI RESPONSE SPEED (A: r=.73; B: r=.74)
  - CRI PROCESSING SPEED (B: r=.37)
  - CogSport Complex RT (B: r=.34)
  - CogSport Simple RT (B: r=.44)

Study 1: Cross-Validation of Computer-Based Measures - Methodology

- 30 Normal Volunteers
- Computer-based: ImPACT, CRI, CogSport, d2, Trails A&B, Digit Symbol
- Paper-based: Trails A&B, Digit Symbol
- Administration: MWF, Individually
  - Grouping A: ImPACT, d2 Test of Attention (computerized)
  - Grouping B: CRI, Trails A and B and Digit Symbol (pencil and paper).
  - Grouping C: CogSport, Trails A and B and Digit Symbol (computerized).
  - ABC, ACB, BAC, BCA, CBA.

Study 1: Cross-Validation Example: ImPACT CRT

- After the X’s and O’s are displayed, you will be asked to do a REACTION TIME or SPEED TEST. Below are the directions for the SPEED TEST. Remember, this is a sample.
- Do the following for each shape that you see:
  - Press the LEFT mouse button as quickly as you can when you see:
  - Press the RIGHT mouse button as quickly as you can when you see:
  - PLEASE RESPOND AS FAST AS YOU CAN
  - Click the continue button to start the sample.

Study 1: Cross-Validation Example: CogSport CRT

- Cued Reaction Time:
  - Press the spacebar as quickly as possible only when a white circle immediately follows the presentation of a black square.

Study 1: Cross-Validation of Computer-Based Measures - SRT Results
Study 1: Cross-Validation of Computer-Based Measures - CRT Results

<table>
<thead>
<tr>
<th></th>
<th>Digit Symbol</th>
<th>ImPACT</th>
<th>HeadMinder</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trails B</td>
<td>-.381*</td>
<td>-.506**</td>
<td>.601***</td>
</tr>
<tr>
<td>Digit Symbol</td>
<td>-</td>
<td>.542**</td>
<td>-.610***</td>
</tr>
<tr>
<td>ImPACT</td>
<td>-</td>
<td>-</td>
<td>-.373*</td>
</tr>
</tbody>
</table>

Study 1: Cross-Validation of Computer-Based Measures - Processing Speed Results

<table>
<thead>
<tr>
<th></th>
<th>Digit Symbol</th>
<th>ImPACT</th>
<th>HeadMinder</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trails B</td>
<td>-.381*</td>
<td>-.506**</td>
<td>.601***</td>
</tr>
<tr>
<td>Digit Symbol</td>
<td>-</td>
<td>.542**</td>
<td>-.610***</td>
</tr>
<tr>
<td>ImPACT</td>
<td>-</td>
<td>-</td>
<td>-.373*</td>
</tr>
</tbody>
</table>

Study 1: Cross-Validation of Computer-Based Measures - Memory Results

<table>
<thead>
<tr>
<th></th>
<th>ImPACT Verbal</th>
<th>CogSport Verbal</th>
<th>CogSport Learning</th>
</tr>
</thead>
<tbody>
<tr>
<td>ImPACT Verbal</td>
<td>.340</td>
<td>-.160</td>
<td>-.302</td>
</tr>
<tr>
<td>ImPACT Visual</td>
<td>-</td>
<td>-.012</td>
<td>-.058</td>
</tr>
<tr>
<td>CogSport Verbal</td>
<td>-</td>
<td>-</td>
<td>.723*</td>
</tr>
</tbody>
</table>

Study 1: Cross-Validation of Computer-Based Measures - Implications

- These tests share some common variance on constructs such as processing speed and reaction time, but not within the domain of memory.
- The Processing Speed Indices/measures (ImPACT, HeadMinder, Trails B and Digit Symbol) correlated the most consistently.
- Baseline evaluations using one measure can not be used as a basis for post-concussion assessment using another measure.

Study 1: Cross-Validation of Computer-Based Measures - Limitations

- Small sample size.
- Reliance on univariate correlations.
- Subjects assessed independently.
- Non-concussed subjects.
- Not comparing tests’ sensitivity to effects of concussion.

Study 2: Assessment of Club Sport Athletes - Rationale

(Schultz, Cooney, McKee, Palumbo, in review)

- Little data on club sport participants
- Limited if any support from University/ATC
- Are club sport athletes sustaining more concussions?
- Are club sport athletes suffering from a lack of proper concussion management?
Study 2: Assessment of Club Sport Athletes - Methodology

- 232 Athletes: 116 Club Sport

<table>
<thead>
<tr>
<th>Club Sport</th>
<th>Men's</th>
<th>Woman's</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ice Hockey</td>
<td>31 (13.4%)</td>
<td>10 (4.3%)</td>
</tr>
<tr>
<td>Rugby</td>
<td>35 (15.1%)</td>
<td>40 (17.2%)</td>
</tr>
<tr>
<td>Total</td>
<td>66 (28.5%)</td>
<td>50 (21.5%)</td>
</tr>
</tbody>
</table>

- 232 Athletes: 116 Varsity

<table>
<thead>
<tr>
<th>Varsity Sports</th>
<th>Men's</th>
<th>Woman's</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cross Country/Track</td>
<td>6 (2.6%)</td>
<td>5 (2.2%)</td>
</tr>
<tr>
<td>Baseball/Softball</td>
<td>7 (3.0%)</td>
<td>10 (4.3%)</td>
</tr>
<tr>
<td>Basketball</td>
<td>8 (3.4%)</td>
<td>12 (5.2%)</td>
</tr>
<tr>
<td>Football</td>
<td>12 (5.2%)</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>Gymnastics</td>
<td>5 (2.2%)</td>
<td>9 (3.9%)</td>
</tr>
<tr>
<td>Lacrosse</td>
<td>6 (2.6%)</td>
<td>6 (2.6%)</td>
</tr>
<tr>
<td>Soccer</td>
<td>11 (4.7%)</td>
<td>10 (4.3%)</td>
</tr>
<tr>
<td>Wrestling</td>
<td>9 (3.9%)</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>Total</td>
<td>66 (27.6%)</td>
<td>52 (22.4%)</td>
</tr>
</tbody>
</table>

All evaluations were baseline, pre-season, non-concussed athletes
- From 5 NE Division I NCAA Schools
- Group Administration of ImPACT
- Club sport athletes completed voluntarily
- Varsity athletes completed as part of mandatory pre-season evaluations.

Study 2: Assessment of Club Sport Athletes - Results

- Club sport athletes showed no greater likelihood of having experienced previous concussions. \[\chi^2 (1) = 1.98; p = .16\]

<table>
<thead>
<tr>
<th>Number of Previous Concussions</th>
<th>None</th>
<th>One</th>
<th>Two+</th>
</tr>
</thead>
<tbody>
<tr>
<td>Varsity Athletes</td>
<td>84 (72%)</td>
<td>18 (16%)</td>
<td>14 (12%)</td>
</tr>
<tr>
<td>Club Sport Athletes</td>
<td>74 (64%)</td>
<td>20 (17%)</td>
<td>22 (19%)</td>
</tr>
</tbody>
</table>

- Club sport athletes showed no greater likelihood of having a Learning Disability. \[\chi^2 (1) = 0.81; p = .78\]

<table>
<thead>
<tr>
<th>Learning Disability</th>
<th>None</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Varsity Athletes</td>
<td>84 (65%)</td>
<td>84 (65%)</td>
</tr>
<tr>
<td>Club Sport Athletes</td>
<td>74 (64%)</td>
<td>74 (64%)</td>
</tr>
</tbody>
</table>
### Study 2: Assessment of Club Sport Athletes - Results

- Multivariate Effect of Sport Level on Baseline Cognitive Performance (Hotelling’s Trace) \[F(5,211) = 2.49; p=.033\]
- Explained by Univariate effects on:
  - Verbal Memory \[F(1,215)=4.03; p=.046\]
  - Visual Memory \[F(1,215)=4.48; p=.036\]
  - Processing Speed \[F(1,215)=6.68; p=.01\]
  - Reaction Time \[F(1,215)=7.91; p=.005\]

### Study 2: Assessment of Club Sport Athletes - Implications

- Club Sport athletes matched for history of concussion and learning disability showed significantly decreased performance on baseline evaluations.
  - Return to play too soon after experiencing a concussion
  - Lack of awareness of concussion
  - Interaction with alcohol use?
- Points to the need for concussion management programs in club sport athletes.

### What we know/need to know:

- Mild, enduring effects of cerebral concussion can be identified in otherwise healthy youth athletes with only a history of concussion.
- These enduring effects of previous cerebral concussions appear to involve attentional processes, and warrant further investigation.

### What we think we know:

Contributing to these findings:
- Participation in multiple sports over a period of years (1980’s “soccer moms”?).
- More vulnerable and susceptible youth brains, “improperly managed” brains.

### What we need to know more about:

Diagnosing and managing concussions with computer-based measures:
- Ongoing, external validation of existing measures
- Ongoing validation of these measures in prospective clinical samples.