The ACTIVATE Test of Embodied Cognition (ATEC)

Cognitive Remediation in Psychiatry

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*CHS: Computational Science for Improving Assessment of Executive Function in Children*

- Dr. Morris Bell at Yale
- Dr. Fillia Makedon and Dr. Vassilis Athitsos at University of Texas at Arlington
Disclosure

• Morris Bell, Ph.D. is on the scientific advisory board of Posit Science, but has no financial investment nor does he receive any consultation fees.

• Morris Bell, Ph.D. is on the scientific advisory board of C8 Sciences and is an investor in the company.

• These disclosures are unrelated to this presentation
• Embodied cognition has a great tradition in philosophy and psychology.
  • Edmund Husserl, Martin Heidegger, Maurice Merleau-Ponty, Raymond Gibbs. “The mind is an embodied system in the world rather than a neural network in the head.”

2010 Evan Thompson
But how do we measure these abilities?

- The history and traditions of Western science separated the mind and body (dualism)
- The brain was the organ of the mind and divided in localized functional areas
Embodied cognition is how we function.

• The brain was built for motion, and bodily action plays a key role in cognitive development.

• Neurocognitive assessments do not engage body movement and Functional Movement assessments do not engage higher cognitive function.

• Rhythmic movement is not assessed by either testing system, even though keeping rhythm demands both EF and body coordination.

• We are creating the first assessment system focused on executive function in motion: Activate Test of Embodied Cognition (ATEC).
Workshop Objectives:
The objective of this workshop is to identify gaps in research related to the science of interoception and its roles in nervous system disorders as well as to develop strategies and recommendations to facilitate the advancement of this area of research. The workshop will bring together expertise from diverse fields in basic neuroscience and clinical research to address two major connections – the connections between brain and body and the connections between basic research and human/clinical research.
ACTIVATE: A Revolution in Measuring Neurocognition.
Bilateral Coordination and Self-Regulation
Cross your Body game

• The most demanding game
• There are five levels to the game
• First, the child is asked to cross their body with each hand and touch the body part that is named, three times in rhythm to a song.
• Then, the child must do the opposite motion of what is named:
  - Ears ⇔ Knees
Scene 22.1
Opposites - Ears and Knees

The Activate Games
Activate Test of Embodied Cognition
Copyright 2018, Bell, Wexler, Makedon, & Athitos
Yale University & University of Texas-Arlington.
Video Producer, Phillip Simon
Then the game gets harder...

- Then, new opposite motions are added:
  - Hips ⇔ Shoulders

- Finally, all four motions are put together:
  - Ears ⇔ Knees
  - Hips ⇔ Shoulders
See how a normally developing 7 year-old performs the task
A 9-Year Old with Attention Problems has a lot more trouble.
ATEC Scoring Measures

Performance Categories

- Undeveloped: 0—12
- Very Early Development: 13—15
- Early Development: 16—18
- Early to Middle Development: 19—21
- Middle Development: 22—24
- Middle to Full Development: 25—27
- Full Development: 28—30
Test-Retest Reliability at 2 Weeks
N = 28

ATEC Total Time 1 Mean = 28.96 (4.48) N = 28
ATEC Total Time 2 Mean = 30.43 (4.46) N = 28

ICC = .945, df = 27, p < .000

Change from Time 1 to Time 2 = 1.47 = Cohen’s d’ = .33. Small but significant practice effect.
Relationship to age, grade and IQ

Children improve on ATEC with normal development.
• Age X ATEC Total r = .41, p = .024, N = 30
• Grade X ATEC Total r = .45, p = .012

Age correlates with EF Factor r = .37 (p < .02) and with Movement Factor r = .30 (P < .05).

ATEC scores are independent of IQ.
• PPVT X ATEC Total, Spearman r = .07, p = ns, n = 16
Factor Analysis of ATEC (N = 58)

- Because of high intercorrelations among ATEC subtests, PCA with Varimax rotation was used to produce a 2 factor solution, explaining 85% of Variance.

![Scree Plot](image_url)
Executive Function (EF) and Motor Movement (Move) Factors

Attention, Working Memory, Self-regulation, Response Inhibition are most heavily weighted on EF factor.

Balance and Motor Speed are most heavily weighted on Motor factor.

Rhythm and Coordination is weighted on both factors.

<table>
<thead>
<tr>
<th>Component Matrix</th>
<th>Component 1</th>
<th>Component 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>ATEC_S1_ResponseInhibition_Raw</td>
<td>.968</td>
<td>-.003</td>
</tr>
<tr>
<td>ATEC_S1_SelfRegulation_Raw</td>
<td>.965</td>
<td>-.100</td>
</tr>
<tr>
<td>ATEC_S1_Attention_Raw</td>
<td>.901</td>
<td>-.366</td>
</tr>
<tr>
<td>ATEC_S1_RhythmCoordination_Raw</td>
<td>.898</td>
<td>.103</td>
</tr>
<tr>
<td>ATEC_S1_WorkingMemory_Raw</td>
<td>.894</td>
<td>-.376</td>
</tr>
<tr>
<td>ATEC_S1_Balance_Raw</td>
<td>.539</td>
<td>.687</td>
</tr>
<tr>
<td>ATEC_S1_MotorSpeed_Raw</td>
<td>.507</td>
<td>.597</td>
</tr>
</tbody>
</table>

Extraction Method: Principal Component Analysis. a. 2 components extracted.

<table>
<thead>
<tr>
<th>Rotated Component Matrix</th>
<th>Component 1</th>
<th>Component 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>ATEC_S1_Attention_Raw</td>
<td>.968</td>
<td>.091</td>
</tr>
<tr>
<td>ATEC_S1_WorkingMemory_Raw</td>
<td>.967</td>
<td>.078</td>
</tr>
<tr>
<td>ATEC_S1_SelfRegulation_Raw</td>
<td>.902</td>
<td>.356</td>
</tr>
<tr>
<td>ATEC_S1_ResponseInhibition_Raw</td>
<td>.860</td>
<td>.443</td>
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<tr>
<td>ATEC_S1_RhythmCoordination_Raw</td>
<td>.750</td>
<td>.505</td>
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<tr>
<td>ATEC_S1_Balance_Raw</td>
<td>.162</td>
<td>.858</td>
</tr>
<tr>
<td>ATEC_S1_MotorSpeed_Raw</td>
<td>.175</td>
<td>.764</td>
</tr>
</tbody>
</table>

Relationships to Validity Criteria

• BRIEF – 2 Behavior Regulation Index
• CBCL Competency Scale
• Executive Function Neurocognitive Testing
• BART-C – Adaptive Risk Taking
# BRIEF-2 Index scores and CBCL Competency Scores by ATEC Factors

(Controlling for age)

## BRIEF-2

<table>
<thead>
<tr>
<th>BRIEF-2</th>
<th>BRI</th>
<th>ERI</th>
<th>CRI</th>
<th>GEC</th>
</tr>
</thead>
<tbody>
<tr>
<td>EF Factor</td>
<td>-.44*</td>
<td>-.38*</td>
<td>-.45*</td>
<td>-.47*</td>
</tr>
<tr>
<td>Move Factor</td>
<td>.03</td>
<td>.19</td>
<td>.11</td>
<td>.11</td>
</tr>
</tbody>
</table>

## CBCL

<table>
<thead>
<tr>
<th>CBCL</th>
<th>Activities</th>
<th>School</th>
<th>Social</th>
<th>Total Competency</th>
</tr>
</thead>
<tbody>
<tr>
<td>EF Factor</td>
<td>.21</td>
<td>.28</td>
<td>.43*</td>
<td>.47*</td>
</tr>
<tr>
<td>Move Factor</td>
<td>.36*</td>
<td>.24</td>
<td>.05</td>
<td>.22</td>
</tr>
</tbody>
</table>

* * p < .01
## Executive Function Neurocognitive Testing by ATEC Factors (Controlling for Age)

<table>
<thead>
<tr>
<th>Tests</th>
<th>Flanker (Attention Task)</th>
<th>Go/No Go (Response Inhibition)</th>
<th>Working Memory Test</th>
<th>BART Total Score (Adaptive Risk Taking)</th>
</tr>
</thead>
<tbody>
<tr>
<td>EF Factor</td>
<td>.38*</td>
<td>.50**</td>
<td>.42*</td>
<td>.17</td>
</tr>
<tr>
<td>Move Factor</td>
<td>.19</td>
<td>.01</td>
<td>.13</td>
<td>.31*</td>
</tr>
</tbody>
</table>

*p < .01; ** p < .001
ATEC explains more variance in childhood competency than other measures

Stepwise Linear Regression with Neurocognitive Tests and ATEC factors entered to predict CBCL Competency shows that ATEC EF factor explains most of the variance (Adjusted Rsq = .24) with WMT (Adjusted Rsq = .31) making a small (.07) but significant contribution to explained variance.

<table>
<thead>
<tr>
<th>Model</th>
<th>R</th>
<th>R Square</th>
<th>Adjusted R Square</th>
<th>Std. Error of the Estimate</th>
<th>R Square Change</th>
<th>F Change</th>
<th>df1</th>
<th>df2</th>
<th>Sig. F Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>.501\textsuperscript{a}</td>
<td>.251</td>
<td>.236</td>
<td>8.643</td>
<td>.251</td>
<td>16.724</td>
<td>1</td>
<td>50</td>
<td>.000</td>
</tr>
<tr>
<td>2</td>
<td>.580\textsuperscript{b}</td>
<td>.337</td>
<td>.310</td>
<td>8.214</td>
<td>.086</td>
<td>6.359</td>
<td>1</td>
<td>49</td>
<td>.015</td>
</tr>
</tbody>
</table>

\textsuperscript{a} Predictors: (Constant), REGR factor score EF1 for analysis 2

\textsuperscript{b} Predictors: (Constant), REGR factor score EF1 for analysis 2, NIH_WMT

\textsuperscript{c} Dependent Variable: CBCL_COMPETENCE
Motion Capture and Analysis Methods for Automated Scoring

**Cross your Body**

**Aim:** Detect *keypoints of interest*: ears, knees, shoulders, hips and hand movements

**Current results:** average accuracy of 87.3% (touch movement detection)

**Finger Tapping**

**Aim:** Hand Keypoint Detection for Rapid Sequential Movements

**Current Outcome:** The Hand Keypoints (HKD) Dataset and a comparison of state-of-the-art methods for finger tip detection and wrist detection – average accuracy: 80%
Motion Capture and Analysis Methods for Automated Scoring

Sailor Step
**Aim:** Detect and analyze lower-body movements – direction and rhythm
**Current Outcomes:** visualization and scoring interfaces and baseline approaches with accuracy between 73-88%

Ball Drop
**Aim:** Detect Ball Passes and Hand Movements
**Current Results:**
- Ball Pass – 89% accuracy
- No Ball Pass – 77% accuracy
- Hand raise – 69% accuracy
Next Steps for ATEC

• Discriminant validity will be determined comparing community samples with ADHD and ASD samples.
• Pre-post intervention studies to determine ATEC sensitivity to interventions and to study course of illness.
• Development of an adult version for use with mild to moderate TBI, Parkinson’s Disease and other movement disorders.
Cross-cultural validity in China
C8 Sciences ACTIVATE Physical Games
ACTIVATE Physical Games with Cognitive Demands
Thank you for your kind attention

Enjoy New York