Predictive Executive Functioning Models Using Interactive Tangible-Graphical Interface Devices

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Agenda

• Executive Functioning, ADHD
• Current diagnostic modalities
• Study
• Tangible User Interfaces
• Groundskeeper Game
• Machine Learning
• Results and Comparison
• The future
Background of Problem

• 5.4 million children ages 4-17 meet criteria for ADHD
• 50% of these have been diagnosed and treated
• Limited early identification
• Long term risks if untreated:
  • Children/adolescents
    • Social/educational problems, drug experimentation, oppositional behavior
  • Adults
    • Vocational/relationship/legal problems
    • Mood disorders, excessive alcohol/drug use
    • Limited self care resulting in acute/chronic medical illnesses
Background of Problem

• Pathophysiology of ADHD identified as executive functioning deficits

• Four frontostriatal regions affected
  • Frontal structures: lateral prefrontal cortex and dorsal anterior cingulate cortex
  • Striatal regions: caudate and putamen

• Inattention due to deficits in working memory manifest as distractibility and poor academic performance
  • Low neurotransmitters: norepinephrine and dopamine

• Working memory may be improved by intensive, adaptive computerized training

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Current Approaches

What are the current methods?

• Methods of diagnosis are subjective/ utilize rating scales
  • High inter-rater differences
  • Requires coordination between people

• Trained clinicians
  • Availability/access to professionals is very limited

• Computer tests for screening tools: Continuous Performance Test and the TOVA
  • Limited access
  • Resource intensive
  • Expensive
  • Limited engagement
Testing a New Approach – Study Design I

- 52 children and adolescents
- 26 with ADHD (17 with combined type) and 26 without

Those with ADHD

- Data de-identified
- Participants recruited from multiple clinics
- Age and gender matched
Testing a New Approach – Study Design II

• Participants underwent diagnostic assessment by psychiatrist

• Comorbidities allowed: mood disorders, anxiety disorders, autistic spectrum disorder

• All received traditional rating scales for attention deficits, anxiety, depression and underwent a standard computer based screening tool

• Completed a 30 minute diagnostic session playing Groundskeeper on Sifteo Cubes gaming platform
Tangible User Interfaces

• Sifteo Cubes - motion-sensitive wireless blocks containing accelerometers, multiple sensors, and graphical full-color LCD displays
• Interact with each other on all four sides and can be pressed, flipped, and moved spatially
• Bridges the gap between physical and digital worlds
• Growing body of research indicating interfaces encourage collaboration, excitement and engagement
• Allows for sub-second data capture
Groundskeeper

• Game play like “Whack-a-mole”
• Records spectrum of player behavior at a sub-second interval
• Records behavior in response to audio, visual, and spatial distracters
• Variables collected, broadly on movement and reaction time
Analysis

• Machine Learning Method
• Game data collection
Analysis

• Game designed to capture every type of ‘base’ behavior possible

• Almost 30 variables at 10 Hz. For 17 levels of 90 seconds each
  • 15,300 samples per game
• Feature variable creation
• Game data transformed into hypothesized data set for predictive analysis
  • Aggregations and statistical functions
• Based on neural correlates – what we know about brain to behavior mapping
• Resulted in ~75 variables in feature space
• 4 models, dependent variable (1|0) = ADHD, Autism, Depression, Anxiety
• Feature variable evaluation
Analysis

• Weka used for modeling / checking feature space variables

• Attribute evaluation / Principal Component Analysis (PCA) used to generate the most useful features

• Expert involvement crucial
  • Discover ADHD should two independent models based on type: Inattentive and Combined Type
  • Dropped Autism Model, N = 7
• Example, Combined Model Evaluation with PCA

=== Weka Run information ===

Evaluator: weka.attributeSelection.PrincipalComponents -R 0.95 -A 5
Search:weka.attributeSelection.Ranker -T -1.7976931348623157E308 -N -1
Relation: source_data-weka.filters.unsupervised.attribute.Remove-R77-78,80-83
Instances: 52
Attributes: 77
  mCRR
  mIRR
  mEOM
  mCOM
  .......

Evaluation mode: evaluate on all training data
• Machine Learning Method
Analysis

- Constructed 4 predictive models
  - 2 models for ADHD, 1 for Anxiety, and 1 for Depression
- Input to each model is output of PCA
- Tried several different algorithms/classes (DT, Rule-based, Functions)
- Selected Random Forest
  - Ensemble Classifier
• Inattention model, Random Forest
### Results for ADHD Model

<table>
<thead>
<tr>
<th>Algorithm</th>
<th>Combined F-Measure</th>
<th>Inattention F-Measure</th>
</tr>
</thead>
<tbody>
<tr>
<td>J48</td>
<td>63%</td>
<td>52%</td>
</tr>
<tr>
<td>JRip</td>
<td>54%</td>
<td>54%</td>
</tr>
<tr>
<td>RandomForest</td>
<td>69%</td>
<td>69%</td>
</tr>
<tr>
<td>AdaBoost</td>
<td>66%</td>
<td>54%</td>
</tr>
<tr>
<td>RandomForest w/PCA</td>
<td>75%</td>
<td>78%</td>
</tr>
</tbody>
</table>

- Non-normal distribution
- F-measures for Depression and Anxiety (76%, 71%)
## Results for ADHD Model

<table>
<thead>
<tr>
<th>Inattention</th>
<th>Predicted - No</th>
<th>Predicted - Yes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual – No</td>
<td>21</td>
<td>5</td>
</tr>
<tr>
<td>Actual - Yes</td>
<td>6</td>
<td>20</td>
</tr>
</tbody>
</table>

FP = 5, TP = 20, FN = 6, TN = 21

<table>
<thead>
<tr>
<th>Combined</th>
<th>Predicted - No</th>
<th>Predicted - Yes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual – No</td>
<td>29</td>
<td>6</td>
</tr>
<tr>
<td>Actual - Yes</td>
<td>7</td>
<td>10</td>
</tr>
</tbody>
</table>

FP = 6, TP = 10, FN = 7, TN = 29
Comparison for ADHD Model

• Comparison of model to current methods
Comparison for ADHD Model

- Method comparison of diagnostic model to current approaches
What’s Next?

• Accurate and early diagnosis is first step
• Next is personalized treatment through games, tailored to a patient’s cognitive profile
• CogCubed has already developed two games for this purpose - being used to collect data in schools and clinics
• Ongoing research initiatives!
  • New data / more data
  • New models / better models
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