Automatic Detection of Behaviors of Autistic Children

Dr. Fahd Albinali¹, Dr. Matthew Goodwin¹,², Dr. Stephen Intille¹
¹Massachusetts Institute of Technology
²The Groden Center
Autism Spectrum Disorders

**Facts***
- 1 in 150 Children
- 1558% growth since 1992
- Number of cases in 2007: 297,739

**Possible Causes**
- Genes
- Environment
- Genes x Environment

*From the web site for the Center of Disease Control (CDC) http://www.cdc.gov/ncbudd/autism
The Cost of Autism*

Direct Medical
- e.g. clinic services, behavioral therapies, medical supplies
  - $305,956

Direct Non-Medical
- e.g. special education, home and vehicle modification
  - $978,761

Indirect
- e.g. switching to a lower pay job, leaving work force
  - $1,875,667

Total Cost = $3.2 millions / individual over lifetime
Population Cost = $35 billions

Estimated Global Prevalence of Autism 2007*

*From the web site for the Center of Disease Control (CDC) [http://www.cdc.gov/ncbudd/autism](http://www.cdc.gov/ncbudd/autism)

Measurement Techniques of Autism

- Paper and Pencil Rating
- Direct Observation
- Video-based Methods

IDEA

Explore the possibility of using accelerometers to measure and detect stereotypical motor movements
Goal: Real-time Recognition of Stereotypical Movements

- To use accelerometers to provide a measure of behavior that may be more objective, detailed, and precise than rating scales and direct observation, and more time efficient than video-based methods

- To examine the potential of automated pattern-recognition in detecting stereotypes

- To determine the viability of real-time coding and to compare it to offline video-based coding
Experimental Setup

Participants

- 6 diagnosed with ASD
- Between the ages of 12-17 yr
- Clinically significant score on the Stereotyped Behavior subscale RBS-R
- Tolerated the accelerometers
- Exhibited at least 10 hand flapping or body rocking incidents per hour
Experimental Setup

Measurement System

- 3 X 3-axis +/-2g 60 Hz accelerometers located on wrists and torso
- 2 Settings (lab and classroom)
- Video recorded
- Offline and real-time annotation
Experimental Setup

Pattern Recognition Algorithm

- C4.5 for stereotype detection

Feature Extraction
- Body Posture (difference between means)
- Motion Variability (variances and ranges)
- Similarity across sensors (correlations)
- Motion spectral content and Energy (FFT coefficients, frequencies and energy)
Characterizing Participants’ Stereotypical Movements

<table>
<thead>
<tr>
<th>PID</th>
<th>Total Duration (min:sec)</th>
<th>% Engaged</th>
<th>Mean Duration (sec)</th>
<th>Num Stereo</th>
<th>Consistency</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>47:42</td>
<td>28%</td>
<td>0:07</td>
<td>3</td>
<td>Mild</td>
</tr>
<tr>
<td>7</td>
<td>18:18</td>
<td>17.5%</td>
<td>0:04</td>
<td>2</td>
<td>Very</td>
</tr>
<tr>
<td>8</td>
<td>10:00</td>
<td>8.5%</td>
<td>0:04</td>
<td>3</td>
<td>Very</td>
</tr>
<tr>
<td>9</td>
<td>36:53</td>
<td>45%</td>
<td>0:13</td>
<td>2</td>
<td>Very</td>
</tr>
<tr>
<td>10</td>
<td>32:14</td>
<td>48%</td>
<td>0:07</td>
<td>3</td>
<td>Mild</td>
</tr>
<tr>
<td>11</td>
<td>67:28</td>
<td>71%</td>
<td>0:13</td>
<td>2</td>
<td>Very</td>
</tr>
</tbody>
</table>
### Performance of C4.5 using participant dependent data

<table>
<thead>
<tr>
<th>PID</th>
<th>Classroom</th>
<th></th>
<th></th>
<th></th>
<th>Lab</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Offline</td>
<td>Real-time</td>
<td>Agreement</td>
<td>K</td>
<td>Offline</td>
<td>Real-time</td>
<td>Agreement</td>
<td>K</td>
</tr>
<tr>
<td>6</td>
<td>86.5%</td>
<td>75.8%</td>
<td>84.5%</td>
<td>0.42</td>
<td>79.0%</td>
<td>77.5%</td>
<td>77.7%</td>
<td>0.55</td>
</tr>
<tr>
<td>7</td>
<td>86.8%</td>
<td>80.4%</td>
<td>89.2%</td>
<td>0.32</td>
<td>96.5%</td>
<td>96.4%</td>
<td>92.8%</td>
<td>0.37</td>
</tr>
<tr>
<td>8</td>
<td>95.0%</td>
<td>91.1%</td>
<td>91.9%</td>
<td>0.54</td>
<td>95.8%</td>
<td>95.1%</td>
<td>91.7%</td>
<td>0.33</td>
</tr>
<tr>
<td>9</td>
<td>83.7%</td>
<td>82.2%</td>
<td>92.1%</td>
<td>0.76</td>
<td>86.0%</td>
<td>91.8%</td>
<td>93.6%</td>
<td>0.69</td>
</tr>
<tr>
<td>10</td>
<td>81.9%</td>
<td>85.9%</td>
<td>91.4%</td>
<td>0.71</td>
<td>77.5%</td>
<td>82.0%</td>
<td>87.5%</td>
<td>0.59</td>
</tr>
<tr>
<td>11</td>
<td>84.0%</td>
<td>82.6%</td>
<td>92.3%</td>
<td>0.68</td>
<td>83.2%</td>
<td>93.5%</td>
<td>95.3%</td>
<td>0.81</td>
</tr>
<tr>
<td>Mean</td>
<td>86.3%</td>
<td>83.0%</td>
<td>90.2%</td>
<td>0.57</td>
<td>86.3%</td>
<td>89.4%</td>
<td>89.8%</td>
<td>0.56</td>
</tr>
</tbody>
</table>
Performance of C4.5 using participant independent data

<table>
<thead>
<tr>
<th>PID</th>
<th>Accuracy</th>
<th>TP</th>
<th>FP</th>
<th>Precision</th>
<th>Recall</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>74.3%</td>
<td>0.52</td>
<td>0.13</td>
<td>0.48</td>
<td>0.52</td>
</tr>
<tr>
<td>7</td>
<td>77.1%</td>
<td>0.53</td>
<td>0.23</td>
<td>0.61</td>
<td>0.53</td>
</tr>
<tr>
<td>8</td>
<td>72.9%</td>
<td>0.48</td>
<td>0.15</td>
<td>0.58</td>
<td>0.48</td>
</tr>
<tr>
<td>9</td>
<td>82.3%</td>
<td>0.60</td>
<td>0.19</td>
<td>0.62</td>
<td>0.60</td>
</tr>
<tr>
<td>10</td>
<td>73.0%</td>
<td>0.45</td>
<td>0.14</td>
<td>0.45</td>
<td>0.45</td>
</tr>
<tr>
<td>11</td>
<td>83.1%</td>
<td>0.67</td>
<td>0.19</td>
<td>0.61</td>
<td>0.67</td>
</tr>
<tr>
<td>Mean</td>
<td>77.1%</td>
<td>0.54</td>
<td>0.17</td>
<td>0.56</td>
<td>0.54</td>
</tr>
</tbody>
</table>
Conclusion

Key Results

• Reliable recording and detection of stereotypy using participant-dependent data.
• Real-time annotation is possible for children with long stereotypes (>10 seconds)

Significance and Potential Impact

• Technology can assist in treatment decisions
• Facilitate efficacy studies of behavioral and pharmacologic interventions
• Reduction in the societal cost of Autism through interventional and caregiver relief technologies
Autistic Children Reaching Age 22 in the US*

385,000 entering adulthood by 2023

• EXTRAS
**DSM-IV Criteria**

- Impairments in social relatedness
- Impairments in communication and play
- Restricted activities and interests
The Cost of Autism Revisited

Direct Medical
e.g. clinic services, behavioral therapies, medical supplies
$305,956

Direct Non-Medical
e.g. special education, home and vehicle modification
$978,761

Indirect
e.g. switching to a lower pay job, leaving work force
$1,875,667

Total Cost = $3.2 millions /individual over lifetime
Direct Nonmedical Cost

Lifetime Cost Breakdown

- Child Care $74,963
- Adult Care $662,192
- Respite Care $17,858
- Home Improvements $2,388
- Special Education $150,483
- Supported Work $19,349
- Other $51,528
Cost of Adult Care for Individuals with Autism

$27 billions by 2023
Potential Impact on the Cost of Autism in 2023

Without Technology
- Expected Staffing: 958,000 full-time
- Assumptions
  - Ratio Caregiver: Autistic Individual 1:2.5
  - Minimum wage $6.55
- Cost: $11 billions

Working Technology
- Assume ratio Caregiver: Autistic Individual 1:3
  - Cost reduced to $9.2 billions
- Assume staffing goes from full-time to 7 hrs:
  - Cost reduced to $9.6 billions
- Combined Cost: $8 billions

Conclusion
- Accelerometery measures stereotypical behavior and can determine type
- Technology can potentially reduce the cost of Autism
- Building homes and schools suited for Autistic adults and caregivers
- The economics of Autism will have a significant impact on public policy