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Motor Differences Identify Children with Autism Engaged in iPad Gameplay

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Abstract

Autism is a developmental disorder evident from infancy.1 Yet, its clinical identification is often not possible until after the third year of life. New evidence indicates disruption to motor timing and integration may underpin the disorder, providing a potential new marker for its early identification.2,3 We employed smart tablet computers with touch-sensitive screens and embedded inertial movement sensors to record the movement kinematics and gesture forces made by 37 children 3-6 years old with autism and 45 age- and gender-matched children developing typically. Machine learning analysis of the children’s motor patterns identified autism with 93% accuracy. Analysis revealed these patterns consisted of greater forces at contact and with a different distribution of forces within a gesture, and gesture kinematics were faster and larger, with more distal use of space. These data support the notion disruption to movement is a core feature of autism,4 and demonstrate autism can be assessed by smart device gameplay.

Method

Participants. ASD Group: 37 children 3-6 years old clinically diagnosed with Childhood Autism (ICD-10 2010), 12 female. TD Group: 45 children age- and gender-matched with no concern for developmental pathology. Inclusion criteria normal or corrected-to-normal vision, no other sensory or motor deficits.

Serious Games. Two games (www.duckdecoom.com) running on iPad mini tablets (Apple Inc.) set within a bespoke app to organise the display of the games sequentially for a 2 minute training phase followed by a single 5 minute test phase. The app included code for collecting inertial sensor and touch screen data.

Data Acquisition. (A) Touch Screen and (B) Inertial Movement Unit sensors (tri-axial accelerometers; tri-axial gyroscope; magnetometer). Simple metrics or computations of these data were extracted to obtain two hundred forty-seven features.

Motor Kinematic Differences

Ten features with the greatest Kolmogorov-Smirnov (KS) distance give an approximation of those most significant to the machine-learning differentiation (Figure 4).

Results

Machine Learning Identification of Autism

Three machine learning algorithms differentiated individuals within the autism group from the control group with accuracy up to 93% (Table 1). Data from Creativity produced greater predictive accuracy. The most effective algorithm was the Regularized Greedy Forest5 with age and gender data excluded (RGF; Figure 3, Table 2).

Conclusions

- Children with autism can be identified by iPad gameplay.
- Identification based on simple computations of an autism-specific motor signature.
- Gesture force patterns appear significant contributors.
- Motor differences appear to be a core component of autism.
- Machine learning identification of autism by motor analysis of serious tablet gameplay provides a promising new bio-behavioural marker for early detection.

Future Work. (1) To replicate these findings. (2) To commercialise this assessment for clinical, educational, and parent use (playcareapp.com).

References


(A) Sharing. Gameplay consisted of dividing a piece of food and distributing it evenly among four cartoon children present on the screen. When the food was distributed evenly, all children exclaimed, “Yippee!” and proceeded to munch the food in a delightful manner for 3 seconds. Then the trial repeated.

(B) Creativity. This was a colouring game with no specific rules of engagement. An object outline appeared for tracing, then a colouring wheel appeared and the child could select a colour for colouring. The toy or animal outline always remained undisturbed.

Figure 1. iPad mini screen shots of (A) Sharing and (B) Creativity.

Figure 2. Data were collected on gesture (A) kinematics from the touch screen and (B) impact and pressure from the inertial sensors during (C) children’s gameplay at the table.

Figure 3. Receiver operating characteristic curves (ROC) of the RGF models. Creativity is the best performer. The plot was obtained by aggregating all predictions from 10 replications of 10-fold cross-validation (716 observations).

Table 1. Area Under Curve mean (and SD) obtained from three machine learning algorithms.

<table>
<thead>
<tr>
<th>Algorithm</th>
<th>Creativity</th>
<th>Sharing Food</th>
<th>Sharing Hand</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>RBF SVM</td>
<td>0.93</td>
<td>0.92</td>
<td>0.92</td>
<td>0.92</td>
</tr>
<tr>
<td>RBF SVM</td>
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<td>0.92</td>
<td>0.92</td>
<td>0.92</td>
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<tr>
<td>Random Forest</td>
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<td>0.92</td>
<td>0.92</td>
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</tbody>
</table>

Table 2. Sensitivity and specificity of RGF with thresholds selected at 0.50 and 0.55.

<table>
<thead>
<tr>
<th>Algorithm</th>
<th>Sensitivity</th>
<th>Specificity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sharing Food</td>
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<td>0.89</td>
</tr>
<tr>
<td>Sharing Hand</td>
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<td>0.86</td>
</tr>
<tr>
<td>Creativity</td>
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<td>0.85</td>
</tr>
<tr>
<td>Total</td>
<td>0.90</td>
<td>0.90</td>
</tr>
</tbody>
</table>

Figure 4. Boxplot of ten features ranked by greatest KS distance between Autism and Control groups.