Tablet-based gameplay identifies movement patterns related to autism spectrum disorder

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Introduction

It has been recently proposed that one of the early markers of autism spectrum disorder (ASD) are abnormalities in the development of intentional movements, which can be observed from early childhood. New evidence suggests that disruption of motor timing and integration may underpin the disorder, providing a new potential marker for its identification [1].

In this study, we used widely available tablet devices (iPads) to identify differences in kinematics between children diagnosed with ASD and their typically developing (TD) peers. We also compared movement patterns of children diagnosed with neurodevelopmental disorders other than autism (OND) with movement patterns exhibited by ASD and TD children.

We utilised tablet devices' inertial sensors (accelerometer, gyroscope, and touchscreen to record the movements children make while playing two educational games on a tablet.

Method

Ninety-six children (aged 3-6) diagnosed with ASD, 37 diagnosed with OND, and 387 TD children took part in the study.

The children were asked to play two educational games on a tablet (Figure 1). During the gameplay, the children were seated, and the tablet was placed on the table. Each game consisted of two parts: 2-minute long training and 5-minute long test session. During the gameplay, we collected data from tablet's sensors and screen.

After the experimental session, 262 variables obtained by simple calculation of the raw sensor data (e.g. acceleration of the movements) were extracted and analysed using machine learning algorithms. To increase generalisation properties of the models, we reduced dimensionality to 49 most significant variables.

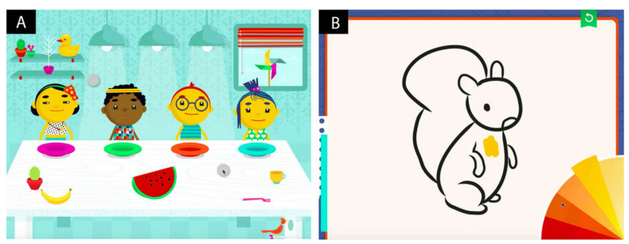

Figure 1. The games used in the study. (**A**) 'Sharing Food' where the main gameplay involved touching a fruit (the one in the centre of the screen). After this interaction, the fruit was sliced into four equal pieces. Then, the child was asked to distribute the slices among the four children. (**B**) 'Sharing Creativity' where the children were free to choose a shape, then trace it. Then, they could colour the shape in freely, selecting a colour from the colour wheel.

Results

To compare movement patterns of children with ASD, OND, and TD children, we used machine learning algorithms. Each algorithm differentiated individuals within the ASD group from the other groups using 49 variables derived from the touch screen and inertial sensors.

Dataset was split into three parts: the training set, validation set, and test set. Eighty-two samples were used as a test set, 420 samples were used for the training set and 105 for the validation set. Additionally, stratified k-fold cross-validation was used to ensure the stability of the results and to decrease variance. To visualise differences between the groups, we used a t-SNE, which is a non-linear technique used for reducing the dimensionality of the data [2].

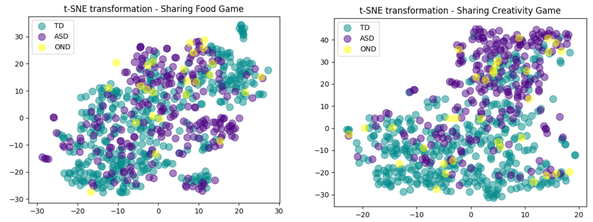

Figure 2. The visualisation shows that although not linearly separable, data from Sharing Creativity game can be classified relatively easily. The difference is particularly noticeable when we compare the ASD group with the TD group. In case of the Sharing Food Game, the classification is more problematic, as the groups seem to come from similar distributions. The OND children are clustered in two groups: one lies closer to the ASD group, while the other one is closer to the TD group. This finding suggests that the group is not uniform.

ASD - TD comparison

The algorithms classified children diagnosed with ASD from TD children with up to 93% accuracy. Both sensitivity and specificity of the test were reasonably high (Tab. 1, Fig. 3).

Algorithm	Validation Sensitivity	Validation Specificity	Test Sensitivity	Test Specificity
Gradient Boosting Machine (GBM)	0.86	0.87	0.85	0.80
Stacking	0.89	0.88	0.84	0.81

Table 1. The algorithms which were the most successful in identifying movement patterns differentiating ASD group from TD group. (The results for the Sharing Creativity game).

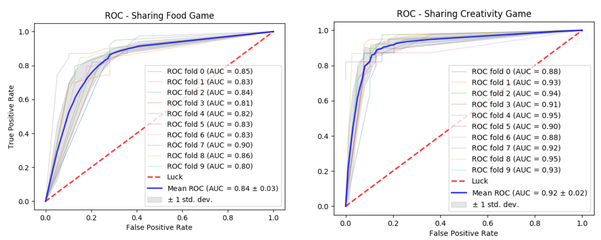

Figure 3. Receiver Operator Characteristic for the two games: (**A**) Sharing Food and (**B**) Sharing Creativity. Results for each of the 10 cross-validation folds is displayed in the legend. For each fold training dataset was split into training and validation part. Each validation part consisted of proportional number of samples from each classified group.

OND - TD comparison

The algorithms classified children diagnosed with OND from TD children with up to 95% accuracy. Sensitivity and specificity were over 90% (Tab. 2). Due to the imbalance in group sizes, additional measures were taken to ensure the reliability of results [3, 4].

The results suggest that movement patterns of typically developing children are different than patterns exhibited by children diagnosed with neurodevelopmental disorders other than autism.

Algorithm	Validation Sensitivity	Validation Specificity
Random Forest (RF)	0.96	0.94
Gradient Boosting Machine (GBM)	0.96	0.91

Table 2. The algorithms that were the most successful in identifying movement patterns differentiating ASD group from TD group. (The results for the Sharing Creativity game.)

ASD - OND comparison

The algorithms classified children diagnosed with ASD from OND children with up to 93% accuracy. Both sensitivity and specificity were high (Tab. 3). This result suggests that ASD is characterised by movement patterns that can be differentiated from patterns related to other neurodevelopment disorders.

Algorithm	Validation Sensitivity	Validation Specificity
Random Forest (RF)	0.96	0.90
Gradient Boosting Machine (GBM)	0.97	0.89

Table 3. The algorithms that were the most successful in identifying movement patterns differentiating ASD group from OND group. (The results for the Sharing Creativity game.)

Conclusions

These findings support the view that children with ASD can be differentiated from TD children by movement patterns analysis. We also provide evidence suggesting that patterns characteristic of ASD children are different from patterns exhibited by children with OND. However, the latter result is not particularly strong due to the small sample of OND children participating in the study. Thus, further research is needed to provide better evidence.

References

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