Disruption to Motor Intentions in Children with Autism: Kinematic evidence for brainstem timing errors

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Jonathan T. Delafield-Butt[1], Krzysiek Sobota[2], Ania Anzulewicz[2,3], Szu-Ching Lu[1], Lindsay Millar[1] and Phil Rowe[1]

[1] Laboratory for Innovation in Autism, University of Strathclyde, Glasgow, United Kingdom
[2] Harimata, Krakow, Poland
[3] Jagiellonian University, Krakow, Poland

Abstract

Human movements are prospective (Delafield-Butt et al., 2018). They must anticipate ahead of time their lawful consequences (Delafield-Butt & Gangopadhyay, 2013; Trevarthen & Delafield-Butt, 2017a, 2017b). In children with autism, evidence indicates a common disruption to prospective movement may underpin its early pathogenesis (Trevarthen & Delafield-Butt, 2013) and may be a cardinal feature of autism (Fournier et al., 2006). Yet, more work is required to better characterize this possible 'autism motor signature' and to probe its neurodevelopmental origins. In this study, we employed smart tablet computers with touch-sensitive screens and embedded inertial movement sensors to ecologically record the subsecond motor kinematics of purposive, prospective movements made by children developing with and without autism.

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.duckiedeck.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 with code for collecting inertial sensor and touch screen data (Play.Care, Harimata) was employed. Previous machine learning analysis demonsrated 93% classification accuracy based on motor kinematic features (Anzulewics, Sobota, & Delafield-Butt, 2016).

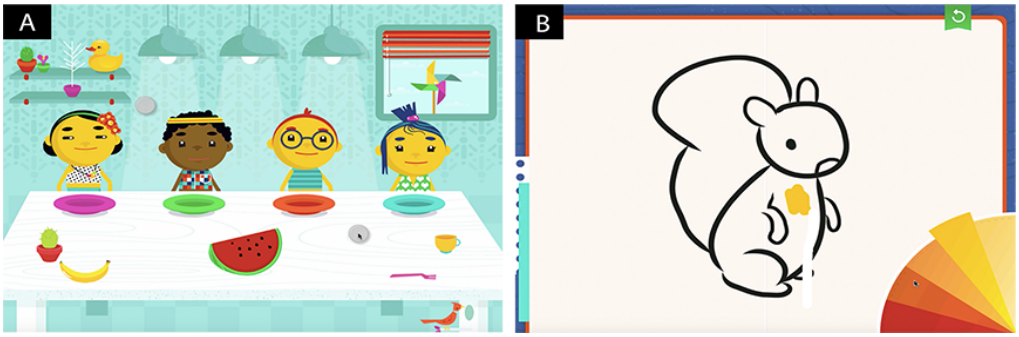

Figure 1. (A) Sharing consisted of dividing a piece of food and distributing it evenly among four cartoon children present on the screen. When the food was distributed, all children exclaimed, "Yipee!" and proceeded to munch the food in a delightful manner for 3 seconds. Then, the trial repeated. (B) Creativity was a colouring game with no 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 unobstructed.

Data Acquisition. (A) Touch Screen coordinate data (x,y) recorded at 60Hz and (B) Inertial Movement Unit sensor (tri-axial accelerometer, tri-axial gyroscope) data collected at 20Hz were obtained during gameplay.

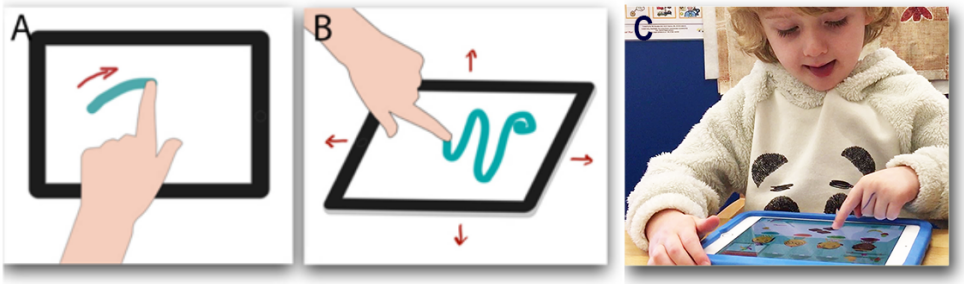

Figure 2. Data were collected on gesture (A) kinematics from the touch screen and (B) impact and and pressure from the intertial sensors during (C) children's gameplay at the table.

Results

1. Serious Game Kinematic of Purposeful Movement. 2D positions of touch data were collected from gameplay session and food-to-plate trajectories identified by those with a start swipe start point located in the food area and the end point located in the plate area. These are goal-directed, purposive movements requiring prospective organisation.

Figure 3. Example trajectories (x,y coordinates) of purposive food-to-plate gestures (n=58) from a single TD child.

Faster, Jerkier Movements by Children with ASD.

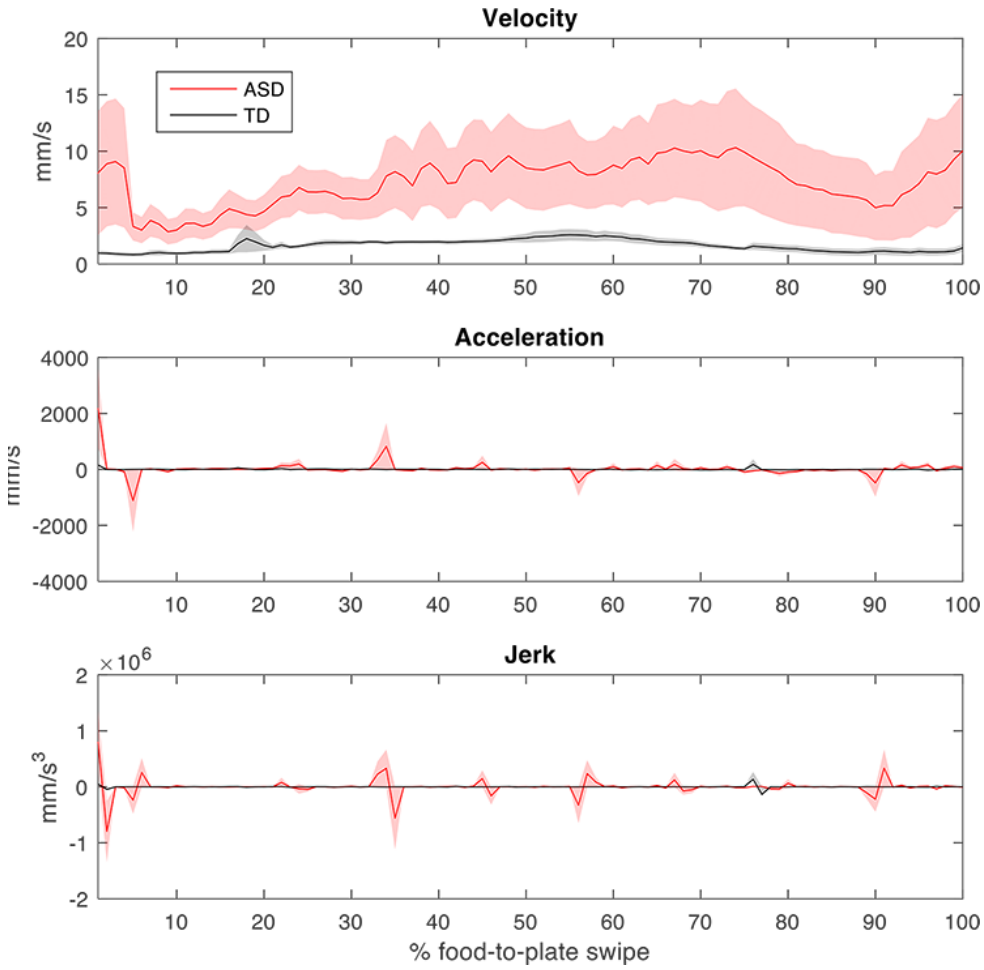

Figure 4. Mean velocity, acceleration, and jerk for all purposive food-to-plate gestures. A total of 1096 swipes were identified from 34 ASD children, and a total of 2182 wipes were collected from 45 TD children. 3 ASD children did not complete any food-to-plate trajectories. 2D coordinates of each food-to-plate swipe were time-normalised by resampling to a fixed rate (100/duration) using linear interpolation. Velocity, acceleration, and jerk were derived from the resampled data. Shaded regions are standard errors of the mean. These data are first draft and require further cleaning and verification.t

Table 1. Mann-Whitney Test of the middle 31-70% trajectory data demonstrates significantly greater maximum velocity, acceleration and deceleration, and jerk.

	Vel_max	Vel_avg	Acc_max	Acc_min	Acc_mag_max	Acc_mag_avg	Jerk_max	Jerk_min	Jerk_mag_max	Jerk_mag_avg
Mann-Whitney U	551.000	602.000	506.000	498.000	504.000	476.000	530.000	532.000	526.000	552.000
Wilcoxon W	1586.000	1637.000	1496.000	1059.000	1494.000	1466.000	1565.000	1093.000	1561.000	1587.000
Z	-2.119	-1.614	-2.265	-2.347	-2.285	-2.573	-2.149	-2.129	-2.190	-1.927
Asymp. Sig. (2-tailed)	.034	.107	.024	.019	.022	.010	.032	.033	.029	.054

2. Impact Force on Screen Contact. Accelerometer data record movement to the iPad and were collected as a proxy measure of impact force to indicate residual velocity, and therefore force put into the device at the start of a gesture.

Greater Force at Impact in ASD

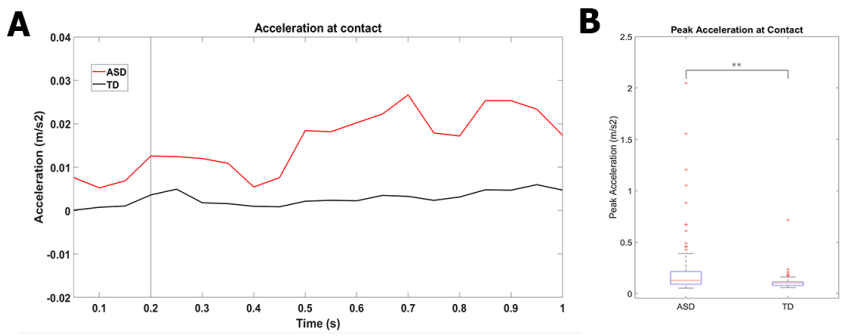

Figure 5. (A) Mean modulus over time of the tri-axial accelerometer values at point of contact (vertical line) and the proceding second during Sharing gampeplay. This is a measure of displacement forces put into the device on contact. (B) Boxplot of peak accelerometer values at point of contact for all gestures in Sharing and Creativity. All children participated. 14,908 screen contacts for ASD and 11,020 for TD children were identified. Asterisks indicate $p<0.001$ (Mann-Whitney U Test).

Conclusions

- Kinematic analysis is feasible and fun with an iPad serious game.
  a potential game changing (excuse the pun) paradigm for autism research and assessment.
- Prospective motor kinematics are disrupted in children with ASD.
  with significant implication for development of anticipatory knowledge and social communication, and well-being.
- Children with ASD exhibit faster, jerkier goal-directed movements.
  these novel data in young children 3-5 years old corroborate with published data in older children (Torres et al, 2013) and adults (Cook at al, 2013) and suggest a motor invariant, but these particular data require further analysis for verification.
- Children with ASD touch the screen with greater force.
  indicative of functional disruption of inferior olive-cerebellar sensorimotor integration

Evidence for Brainstem Timing Errors

- Faster, Jerkier, Greater Impact purposive movements appear to indicate a fundamental, brainstem-mediated disruption to timing and integration and proprioception, not cortical

control (Delafield-Butt & Trevarthen, 2017) with implications for learning and development (Delafield-Butt & Trevarthen, 2015; Trevarthen & Delafield-Butt, 2013).

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