Adherence to the Two-Thirds Power Law and Kinematic Differences in Children with Autism during Ellipse Drawing and Tracing Activities on a Smart-Tablet

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INTRODUCTION

- Autistic individuals often demonstrate atypical motor control of purposeful action[1], especially in the area of fine motor skills.
  - Studies assessing writing and drawing reveal larger peak velocities and greater sizing variability in autistic participants.[2]
  - During swiping gestures on a tablet, those with autism show atypical kinematics compared to typically-developing (TD) controls.[3]
- The emergence of these atypical kinematic features require further investigation.
- One method used to characterize motor control is the two-thirds power law (⅔ PL), a law of motion involving a covariation between the velocity and curvature, in which velocity decreases in more curved parts and increases in less curved parts of movement, as specified by the equation:
  - *Tangential Velocity = K * Radius of Curvature*$^{1/3}$
  - The ⅔ PL governs many types of human movement, including of the arm[4], foot[5] and eyes.[6]
  - It is present in early in development[7] and the velocity-curvature coupling appears to progress with age.[8]
- The goal of this study is to assess adherence to the ⅔ PL and kinematic features during drawing movements in autistic and TD children ages 4 through 8.
  - The law has yet to be studied in autism.
  - It may offer insight into atypical motor development and provide a better metric by which to assess motor kinematics.

PARTICIPANTS

- The final sample included 33 TD and 24 autistic (ASD) participants, matched on age (p = .3) and non-verbal IQ (p = .06), but not on verbal IQ (p < .0001).

	ASD	TD
Age (months)	84.46 (15.49)	80.12 (15.11)
NVIQ	101.67 (19.20)	110.51 (12.27)
VIQ	98.54 (16.51)	118.33 (14.15)

METHODS

- The study used an innovative approach by capturing movement kinematics through an iPad activity that was both accessible and appealing to children.
- Participants were instructed to first draw and then trace ellipses, chosen in order to elicit varying degrees of curvature.
- The bespoke application recorded these movements on the screen, in the form of x and y coordinates of finger location over time.
- For each continuous segment of movement, radius of the curvature and tangential velocity were computed for each data point and linearly regressed to assess their relationship, based on the equation:
  - *Tangential Velocity = K * Radius of Curvature* [6]
  - The exponent β quantifies adherence to the 2/3 PL, with a value of 0.33 representing perfect adherence.
- Jerk and acceleration values were also calculated.
- Mann-Whitney U tests were used to test for group differences.

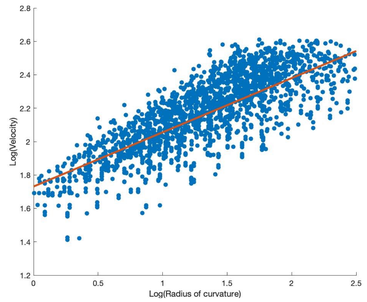


Figure 1: Plot of the logarithms of radius of curvature and tangential velocity for a tracing trial of a TD participant. The red line represents the slope of relationship between the variables (β=.32).

RESULTS

- Beta values (β) for each continuous segment are displayed in Figure 2.
- On drawing trials, the ASD group showed greater beta values (*M* = .33) than the TD group (*M* = .29), *p* < .01.
- On tracing trials, there was a trend toward significance (*p* = .09), with the ASD group demonstrating greater beta values (*M* = .36) compared to the TD group (*M* = .33).
- For tracing trials, autistic participants demonstrated greater individual variability across segments (*M* = .099), compared to TD participants (*M* = .063), *p* = .01.
- Variability on drawing trials did not significantly differ by group (*p* = .4, TD = .077, ASD = .093).

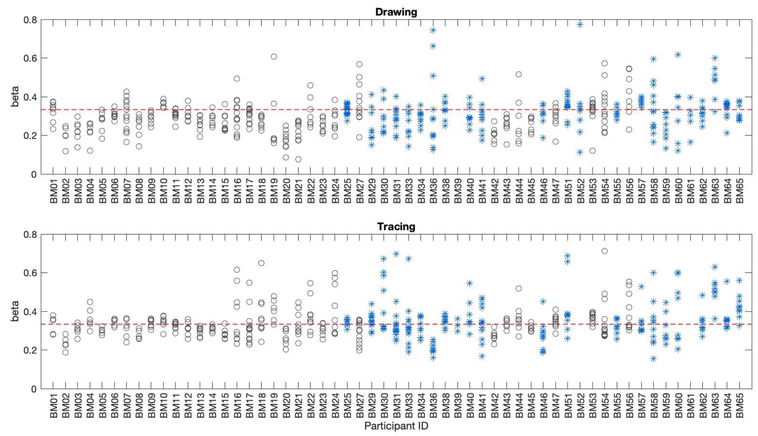
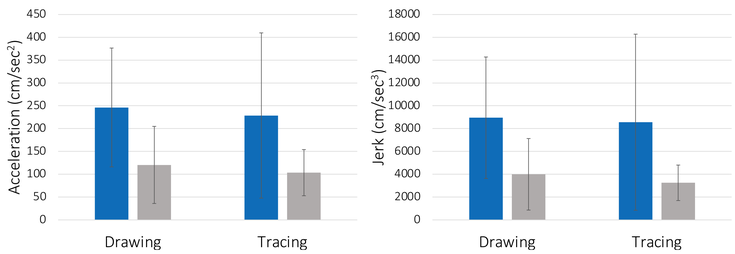


Figure 2: Plot of the beta value of each continuous movement



- The movements made by autistic participants showed significantly greater levels of acceleration during drawing (*p* < .001) and tracing trials (*p* = .002), as well as greater levels of jerk on both drawing (*p* < .0001) and tracing trials (*p* = .02).

ASD TD

Figure 3: Average acceleration and jerk for drawing and tracing trials by group (errors bars = SD)

DISCUSSION

- This novel iPad methodology revealed group differences, with ASD participants showing greater beta values, more individual variability, and greater levels of acceleration and jerk.
- On the more constrained tracing task, the TD group's beta value suggests close adherence to the ⅔ PL, while the increased beta in the ASD group points to an atypical velocity-curvature coupling.
- On the drawing task, the ASD group demonstrated closer adherence to the 2/3 PL, however individual differences and inter-individual heterogeneity require further exploration.
- We plan to assess the quality of the movement performed and whether curved or straight portions are driving the group differences.
- Future investigation will examine the relationship between these kinematic variables and other measures of social and motor functioning.
- This approach may provide a useful method for studying kinematics and help to expand our understanding of motor atypicality in autism, a growing area of interest and focus.

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