Variability in Movement and Visual Attention During a Behaviorally Adaptive Eye-Tracking and EEG Paradigm with Children with ASD

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Background

- Much neuroscience research requires participants to remain extremely still, maintain fixed visual attention, and comply with complex instructions.
- This methodological approach has limited the scope of prior research by excluding participants who have difficulty following verbal directives, such as minimally verbal children with ASD.
- This problem could be addressed by reactive paradigms that shape behavior and encourage compliance without the need for verbal instructions.
- The present study is the first application of a novel eye-tracking (ET) and electroencephalography (EEG) data acquisition approach designed to monitor and respond to participant movement to shape behavior in real-time.

Objective: To examine the behavior profiles of children with cognitive impairment and ASD during a novel ET and EEG paradigm designed to adapt to participant behavior in real time to improve data acquisition success.

Methods

Participants

- This pilot study included five children (7-11 years, *M*=9.2, *SD*=2.0) with ASD and cognitive impairment.

Clinical Measures

- ASD diagnoses were confirmed with the *Autism Diagnostic Observation Schedule (ADOS-2)* and clinician endorsement of DSM-5 criteria for ASD.
- ASD symptom severity was measured by the ADOS-2 comparison score (CS).
- Cognitive ability was measured by the *Differential Ability Scales-II (DAS-II)* or *Mullen Scales of Early Learning (Mullen)*.
  - Full-scale, verbal, and nonverbal ratio IQs were calculated using age equivalent scores from the DAS-II or Mullen.

Paradigm

- Participants interacted with a co-registered ET-EEG paradigm with simultaneous eye and head movement tracking.
- Paradigm progression was compliance dependent; experimental administration remained paused when a participant's eye gaze was off screen (*inattention pause*) and when head movement exceeded baseline threshold determined during participant's initial viewing of a preferred video (*movement pause*).

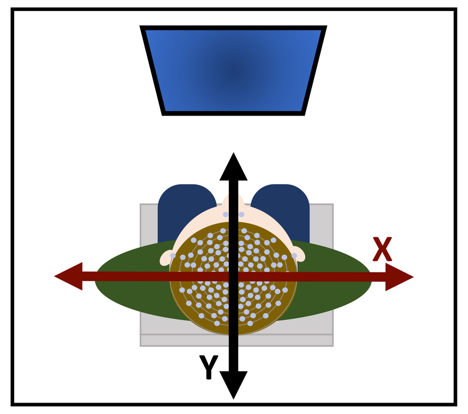


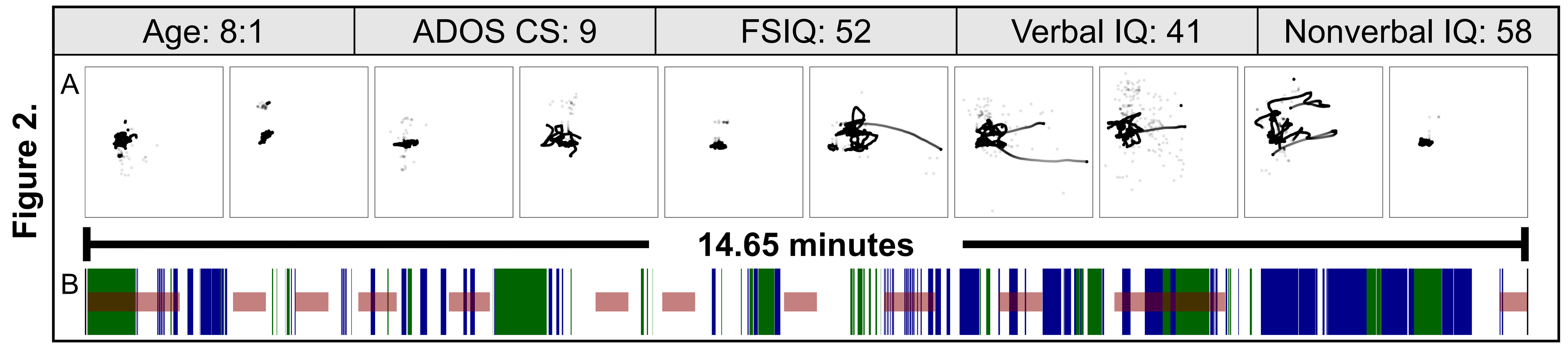
Figure 1. Participant location in front of monitor and axes of head location coordinates.

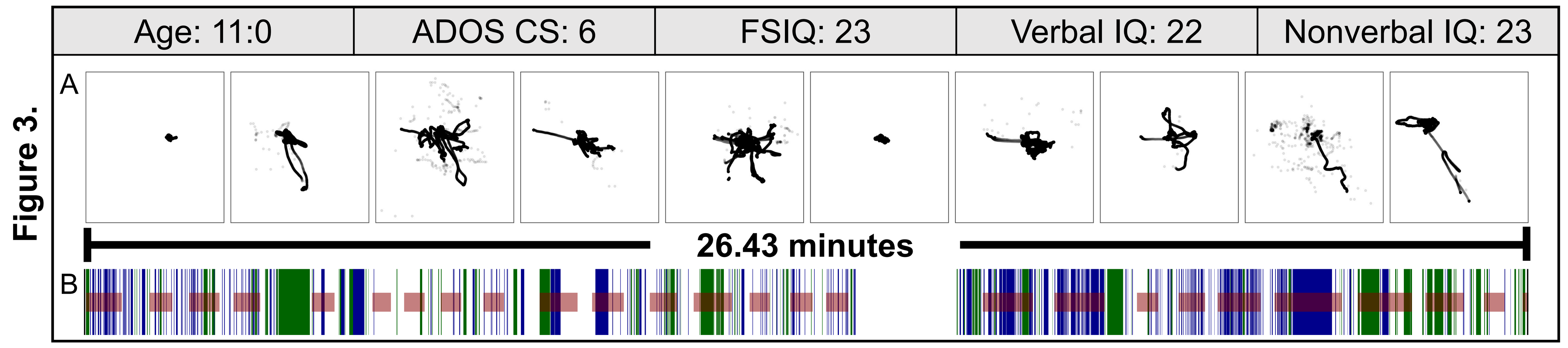
- Movie breaks were both automatic based on paradigm progression and manually triggered by experimenters as needed.

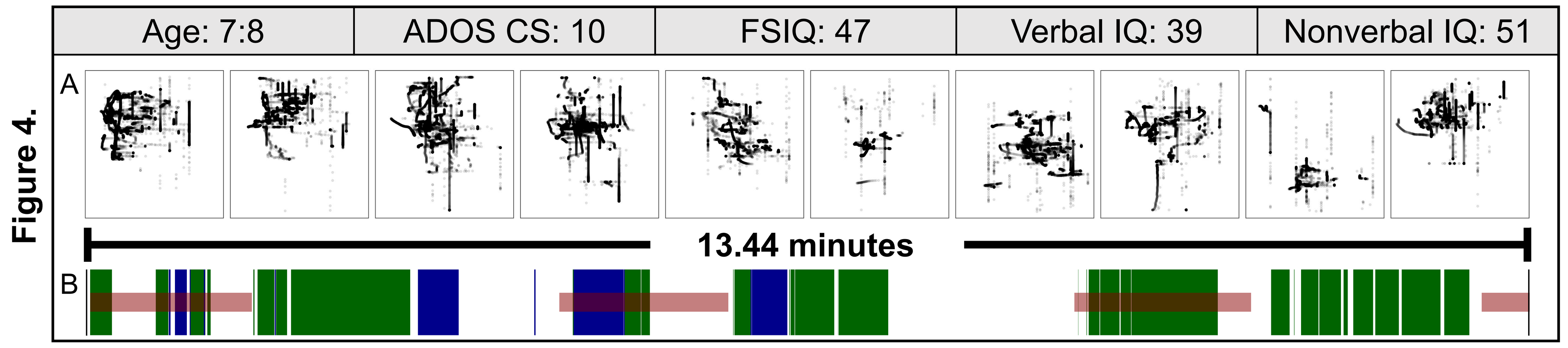
Acquisition and Analysis

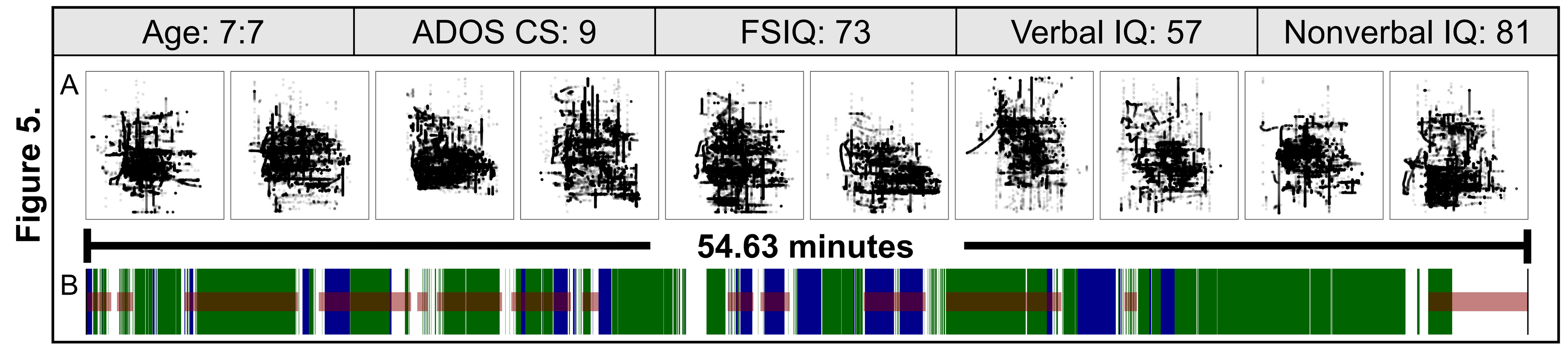
- Movement and eye tracking data were acquired at 500Hz using the SR Eyelink 1000 Plus eye tracker.
- Movement was derived from forehead target sticker location samples along the X and Y (horizontal) axes (see Fig. 1).

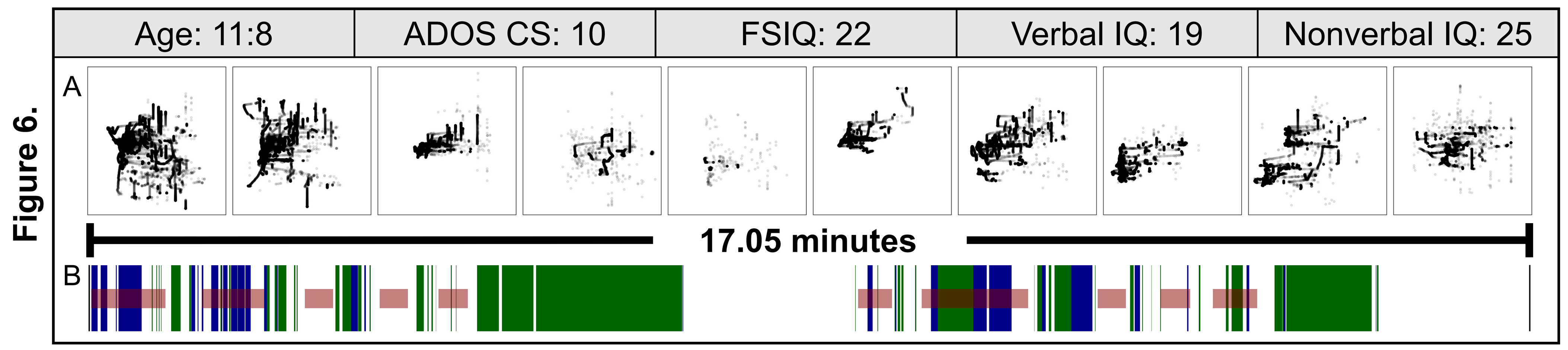
Results

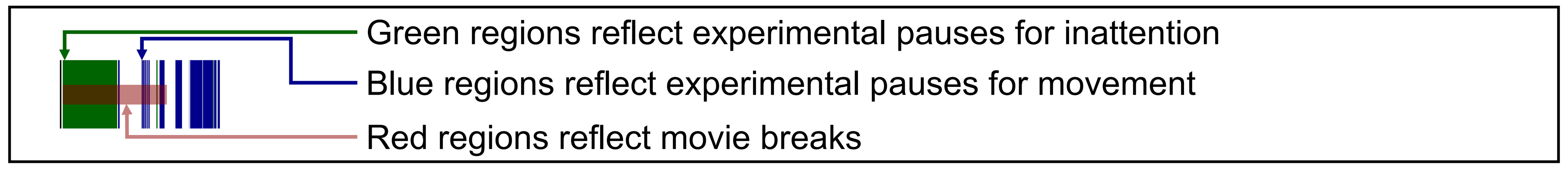












Figures 2-6. Characteristics and visual representation of EEG sessions for five unique participants. (A) Head position (X and Y dimensions; see Fig. 1), in which each point represents a head location sample, during 10 equally divided, continuous timeframes spanning the entire session. Note: sample coordinates are comparable within subjects but are not comparable between participants. (B) Timing and duration of behavior-dependent pauses (inattention and movement pauses) and pre-determined or experimenter-initiated movie breaks.

Results

- Overall, EEG session length ranged from 13.4 to 54.6 minutes (*M*=25.2, *SD*=17.2).
- Behavior-dependent pauses ranged from .01 to 208.83 seconds long (*M*=4.56, *SD*=14.74).
  - Inattention pauses (*M*=7.23, *SD*=20.06) were longer than movement pauses (*M*=2.55, *SD*=7.57; $t(519.18)=4.34$, $p<.001$).
- Variation between participants emerged in the number of pauses during the session, ranging from 45 to 446 (*M*=187.60, *SD*=159.21).
  - Number of eye-gaze pauses ranged from 34 to 176 (*M*=84.40, *SD*=62.25) and movement pauses ranged from 11 to 324 (*M*=103.20, *SD*=127.12).
  - Frequency of inattention and movement pauses remained stable over the course of the session.
- There was more movement during breaks than trials for four participants (all $ps<.001$) and for the other participant, movement was greater during the trials than breaks ($p<.001$).
- As the session progressed, movement decreased for two participants ($r_s=-.04$, Fig. 4; $r_s=-.14$, Fig. 6; $ps<.001$) and increased for three participants ($r_s=.15$, Fig. 2; $r_s=.02$, Fig. 3; $r_s=.06$, Fig. 5; $ps<.001$).

Conclusions

- Variability in individual behavioral responses highlights the heterogeneity within the subset of children with ASD and cognitive impairment and underscores the potential benefit of adaptive experimental paradigms for this understudied population.
- Decreased movement across the EEG session demonstrated by some, but not all, participants suggests that understanding individual differences in behavior is crucial for effectively integrating automated behavior modification into data acquisition.
- Aside from increasing EEG data quality, movement and eye tracking data acquired during this paradigm can be used to quantify behavior. For example, these results suggest that movement increased during breaks for some children, which may inform the relationship between reinforcement and attentiveness.
- Ongoing data acquisition will allow for detection of more nuanced patterns of movement and visual attention in response to this novel, reactive paradigm and inform future application of adaptive experimental paradigms.
- These results hold promise for and underscore the importance of increasing representation of minimally verbal populations in neuroscience research.

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