Investigating ASD-Specific Visual Search Patterns Using Discriminative Modeling: Results from the ABC-CT Interim Analysis

C. Carlos[1], A. Naples[1], K. Chawarska[1], R. Bernier[2], S. Jeste[3], C.A. Nelson[4], G. Dawson[5], S.J. Webb[2], M. Murias[6], F. Shic[7], C. Sugar[3], J. McPartland[1]

(1)Child Study Center, Yale University School of Medicine, New Haven, CT, (2)Psychiatry and Behavioral Sciences, University of Washington, Seattle, WA, (3)University of California, Los Angeles, Los Angeles, CA, (4)Boston Children's Hospital, Boston, MA, (5)Department of Psychiatry and Behavioral Sciences, Duke University Medical Center, Durham, NC, (6)Duke University, Durham, NC, (7)Center for Child Health, Behavior and Development, Seattle Children's Research Institute, Seattle, WA

Background

- Autism spectrum disorder (ASD) is marked by atypical visual attention to socially meaningful visual stimuli[1].
- ”Attention to socially meaningful stimuli” is designated as an *a priori* derived variable, but collected eye-tracking (ET) data may contain other discriminative characteristics with less straightforward lexical descriptions.
- By treating ET data as a high-dimensional input for machine learning models, the variability in these latent characteristics can train models to discriminate effectively between groups and also elucidate psychometric factors that drive gaze behavior.

Objective: To explore latent, conceptually abstract ET data patterns that have predictive power for diagnostic grouping or given clinical variables.

Methods

ABC-CT Study Details

- Methodologically rigorous, multi-site evaluation of potential biomarkers in a large sample of children with and without ASD.
- Longitudinal study evaluating children across 6 months, including clinical assessment, video-tracking during play, electroencephalogram (EEG), and eye-tracking.

Inclusion/Exclusion Criteria

- ASD Group: Age 6-11; met criteria for ASD based on ADOS-2, ADI-R, and DSM-5; IQ 60-150; stable medication for 8 weeks; no sensory or motor impairments; no epilepsy; no genetic or neurological conditions.
- Typically Developing (TD) Group: Age 6-11; IQ 80-150; stable medication for 8 weeks; no sibling with ASD; no sensory or motor impairments; no epilepsy; no genetic or neurological conditions; no clinically significant score on the *Child and Adolescent Symptom Inventory, 5th Edition* (CASI-5).

Participant Demographics

	n (Female)	Age (*SD*)	IQ (*SD*)
TD	64 (22)	8.73 (1.77)	114.64 (13.53)
ASD	161 (30)	8.71 (1.62)	95.80 (18.91)

- Diagnostic groups did not differ on age but were significantly different on sex (F(1223)=6.514, p=0.01) and IQ (F(1223)=52.746, p=0.001).

ET Acquisition & Experiment

- Binocular ET data were collected at 500 Hz using SR Eyelink 1000 Plus.
- Children were presented with trials of static images (S1, S2) images and sets of 5 images equidistant from the center of the screen (P1).

Figure 1. Stimulus images from which ET trial data were analyzed; designated from left to right as S1, S2, and P1.

variable	description
age	Participant age in months
casi_hyp	CASI-5 Hyperactivity score
casi_inatt	CASI-5 Inattention score
fsiq	Full Scale IQ score
nviq	Nonverbal IQ score
viq	Verbal IQ score
srs_rrb	SRS Restrictive & Repetitive Behaviors score
srs_tot	SRS Total score

Table 1. Clinical variables investigated.

Analysis

Consistency of Gaze (CoG)

- Defined as the ratio of the most looked at location to the total number of samples per single participant trial.
- A two sample *t*-test was used to determine difference of means between ASD and TD group CoG measures.

Models for Classification by Diagnostic Group

- Convolutional Neural Networks (trained on S1 stimulus ET data)
  1. *CNN*: input of ET data overlaid as mask onto stimulus image (only the image data where participant viewed is preserved).
  2. *eCNN*: input of ET data mask overlaid onto white image.
- Gaussian Processes on Principal Components (trained on S1, S2, and P1 ET data)
  1. *G*: input of ET data with PCA applied
  2. *G_NoSoc*: input of PCA ET data with all data corresponding to social features of image (i.e. eyes, hand) removed.
  3. *G_OnlySoc*: input of PCA ET data with exclusively social features data present.
- Metric for classification: Brier score, defined as the largest possible difference between a predicted probability and the actual outcome (lower score indicates better predictive capability; ranges from 0 to 1).

Model for Regression on Clinical Variables

- The Gaussian Process/PCA model *G* was applied to continuous clinical variables (see Table 1 for variables investigated).
- Metric for regression: Explained variance score, measures the quality of the regression (best possible score is 1.0, a model that guesses the expectation of the variable without any learning scores a 0).
- Trained on S1, S2, and P1 ET data.

Results

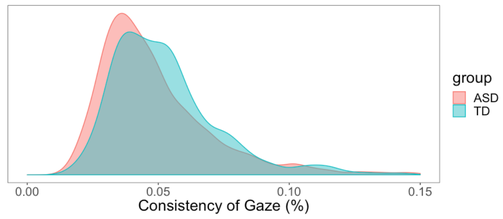

Figure 2. CoG distribution by diagnostic group; Significant difference in means, t(1333.7)=-3.76, p=1.8e-4.

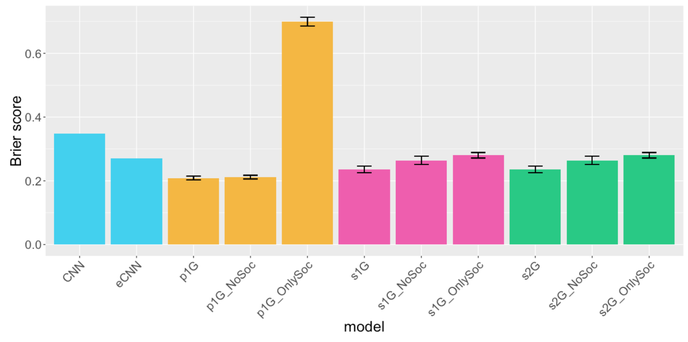

Figure 3. Mean Brier scores for all classification models.

Results, cont.

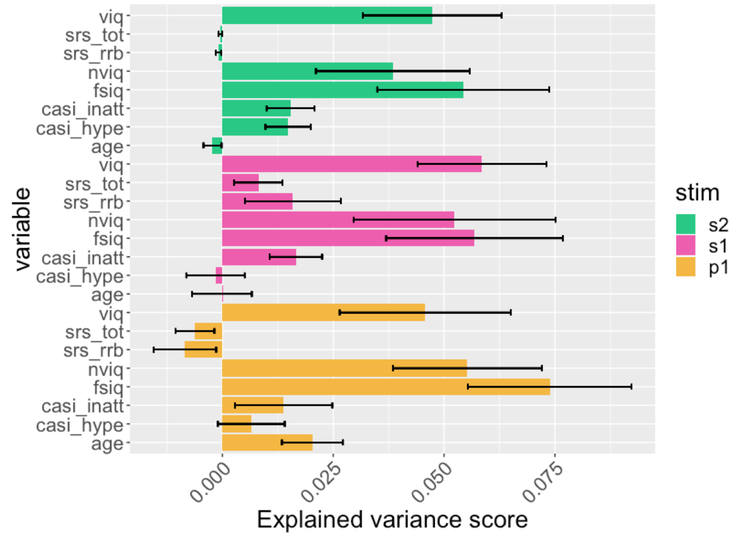

Figure 4. Mean explained variance scores of all regression models across all stimuli.

Discussion

- The significant mean difference in CoG shows that there are ET data characteristics not specific to regions of interest that differ between groups, indicating that there may be other latent measures in the ET data useful for discrimination other than attention to social stimuli.
- The *eCNN* model had a lower Brier score than its *CNN* counterpart, suggesting that the inclusion of the stimulus image’s data only serves to increase the complexity of the input data without benefit to discriminative ability.
- Both the ”NoSoc” and “OnlySoc” models of all three stimulus image sets scored as less accurate than their counterpart that contained all possible ET data from the trial. While these two methods do decrease the complexity of the input data, they fail to utilize data with high learning utility.
- The *p1G_OnlySoc* model was the worst, far outranking the others in its inability to learn differences in diagnostic groups. This may be because the collected data for this model is from a very small subset of the initial ET data.
- In the regression models, across all stimuli, the IQ measures (fsiq, viq, nviq) scored highest. Additionally, across all stimuli, the CASI-5 Inattention score also ranked relatively high in ability to be learned.
- Age was able to be predicted relatively well only in the P1 dataset, suggesting that age-related ET patterns are more likely to appear in this stimulus design versus the stimulus designs of S1 and S2.

References

[1] Murias, M. , Major, S. , Davlantis, K. , Franz, L. , Harris, A. , Bardin, B. , Sabatos-DeVito, M. and Dawson, G. (2018), Validation of eye-tracking measures of social attention as a potential biomarker for autism clinical trials. Autism Research, 11: 166-174. doi:10.1002/aur.1894

ABC-CT
abc-ct@yale.edu
medicine.yale.edu/ycci/researchers/autism/

McPartland Lab
mcp-lab.org
mcp.lab@yale.edu

Funding Source: NIH U19 MH108206 (McPartland).