

**Supporting Information – Saccade dysmetria indicates attenuated visual exploration
in autism spectrum disorder – by Bast *et al.***

Table S1. Site ethics.

Site	Ethics committee	ID / reference
King's College London University of Cambridge	London Queen Square Health Research Authority Research Ethics Committee	13/LO/1156
Radboud University Medical Centre University Medical Centre Utrecht	Quality and Safety Committee on Research Involving Human Subjects Arnhem-Nijmegen	2013/455
Central Institute of Mental Health	Medical Ethics Commission II of the Medical Faculty Mannheim, Heidelberg University	2014-540N-MA
Universita Campus Bio- Medica De Roma	Medical Ethics Committee	18/14 PAR ComET CBM
Karolinska Intitute	Central Ethical Review Board	32-2010

Table S2. Stimuli characterization.

Download Link: <https://hessenbox-a10.rz.uni-frankfurt.de/dl/fi2rRR2ceLHc2dSPrin1tLx3>

human videos:

<i>50faces.mov</i>	Different people are interviewed on the street. Mainly close-up faces
<i>artist.m4v</i>	An excited crowd cheers the protagonist. Scene from the movie “The Artist (2012)”
<i>dollhouse.m4v</i>	A teenage girl tries to find a spot in the school cafeteria and interacts with another girl –Scene from the movie “Welcome to the dollhouse (1995)”
<i>musicbooth.mov</i>	A man and a woman are nonverbally interacting with each other while listening to a song. Scene from the movie “Before Sunrise (1995)”

non-human videos:

<i>birds.m4v</i>	various bird species are moving on tree branches
<i>coralreef.mov</i>	scenic camera ride over a coral reef with a small plane
<i>flowerstaars.m4v</i>	A spangled sky turns into a sea of flowers
<i>pingul.mp4</i>	Two cartoon penguins write together on a slate
<i>pingu_doctors.m4v</i>	Two cartoon penguins are playing together in a house

Table S3. Preprocessing parameters.

We estimated various quality related metrics in the raw datasets (see below: Table S3a). We used principle component analysis to reduce quality-related metrics to four quality dimensions (Flicker, Precision, Accuracy and Binocular Disparity). The four quality dimension were then used to cluster the datasets in terms of their relative level of quality (see below: Table S3b). We observed that Cluster 1 (“Flicker”) had flickery data with periods of missing data, but otherwise good quality. Cluster 2 (“Good”) had the best average quality dimension scores; and Cluster 3 (“Medium”) had intermediate precision and accuracy. Cluster 4 (“Insufficient”) had the highest variation and the worst average quality dimension scores, and thus was not further pre-processed. We estimated fixations using predefined parameters according to each quality cluster using GraFIX (see below: Table S3c).

Table S3a. Metrics calculated based on each dataset gaze buffer to index data quality levels.

Duration (in seconds):	Total duration of the session, from the first sample timestamp to the last sample timestamp (protocol and additional breaks included).
Proportion of data (in %):	Proportion of data in which no eyes were tracked (Prop No Eyes); in which only one eye was tracked (Prop One Eye); and in which both eyes were tracked by the eye-tracker (Prop Both Eyes). Proportion was calculated based on the eye-tracker validity code (e.g. Prop No Eyes is the number of samples with eye validity code “no eyes” over total number of samples).
Proportion of data (in %):	Proportion of data in which one eye was tracked with gaze position recorded inside the stimuli screen boundaries (Prop One Eye Gaze on Screen); and in which both eyes were tracked by the eye-tracker with gaze position recorded inside the stimuli screen boundaries (Prop Both Eyes Gaze on Screen).

Duration Fragments (in seconds):	Average duration of all the fragments in the data buffer that do not have missing samples.
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Flicker (0 to 1 ratio) :	Correlation between consecutive samples validity code (no eyes/ eyes detected); a value close to 1 is indicative of having many samples consecutively tracked without losing eyes.
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Fixation RMS:	Average Root Mean Square (RMS) of the inter-sample Euclidean distances between samples of fixations estimated using a rough velocity-based algorithm.
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Disparity:	Difference between left and right eye gaze samples for the X axis (Disparity X) and for the Y axis (Disparity Y) – left and right eyes gaze position should be very similar and so disparity should approximate 0.
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Post-hoc calibration:	Precision and accuracy calculated for the fixations made upon presentation of up to 6 gaze-contingent post-hoc target points (post-hoc target points were assumed to trigger stable gaze in the target location). The measures calculated to index accuracy were: drift (absolute difference between mean point of gaze and point of target) for the X axis (PC Drift X) and for the Y axis (PC Drift Y), the Euclidean distance between mean point of gaze and point of target (PC. E. Distance); and to index precision were: standard deviation of the valid coordinates in the X axis (PC STD X) and in the Y axis (PC STD Y), and the RMS of the inter-samples Euclidean distances.
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Table S3b. Quality clusters with number of participants and scaled quality dimension mean scores.

	1 (N=167)	2 (N=251)	3 (N=214)	4 (N=40)
ASD	108	125	136	29
TD	59	126	78	11
Quality dimensions mean (SD)				
Precision	-0.27 (0.05)	-0.54 (0.04)	0.38 (0.05)	2.41 (0.11)
Flicker	-1.07 (0.05)	0.69 (0.04)	0.32 (0.04)	-1.62 (0.10)
Binocular disparity	-0.25 (0.07)	-0.25 (0.06)	0.44 (0.07)	-0.01 (0.15)
Accuracy	-0.01 (0.06)	-0.51 (0.05)	0.22 (0.06)	2.12 (0.13)

Table S3c. Predefined parameters for fixation/saccade estimation.

	Cluster 1	Cluster 2	Cluster 3
Sampling Rate:	N	N	N
60 Hz	1	4	3
120 Hz	131	181	177
300 Hz	35	66	34
Smoothing:			
Smoothing ‘Space’ (mm)	8		20
Smoothing ‘Time’ (samples)	20		30
Use another eye		True	
Interpolation:			
Velocity threshold (° / second)	20		30
Interpolation latency threshold (ms)		100	
Interpolation displacement threshold (°)		1	
Post hoc validation:			
Merge consecutive fixations in similar location (°)		0.5	
Root mean square per fixation is lower than (°)		1°	
Minimum fixation duration (ms)		100	

Table S4. Linear mixed models overview: oculomotor features – 1/3.

dependent variable	feature mean					feature variation				
	df	Sum Sq	F-value	p-value	p-adj	df	Sum Sq	F-value	p-value	p-adj
fixation duration										
group	1	0.05	0.13	0.723	0.867	1	0.05	0.09	0.764	0.972
video	1	0.87	2.14	0.145	0.338	1	0.33	0.56	0.454	0.794
IQ	2	0.25	0.30	0.740	0.867	2	0.03	0.03	0.974	1.000
age	2	6.14	7.55	0.001	0.005	2	1.92	1.65	0.195	0.454
sex	1	0.43	1.05	0.306	0.612	1	1.94	3.33	0.070	0.301
pre quality	1	0.04	0.11	0.743	0.867	1	0.22	0.38	0.536	0.834
post quality	2	8.05	9.89	0.000	0.001	2	17.97	15.43	0.000	0.000
sampling rate	1	3.75	9.22	0.003	0.013	1	7.30	12.53	0.001	0.007
ADHD_inatt	1	2.83	6.97	0.009	0.031	1	1.03	1.77	0.185	0.454
group x video	1	0.13	0.32	0.569	0.867	1	0.42	0.72	0.397	0.794
group x IQ	2	3.16	3.88	0.022	0.062	2	2.89	2.48	0.086	0.301
group x age	2	0.06	0.08	0.927	0.998	2	0.37	0.32	0.727	0.972
group x sex	1	0.13	0.31	0.576	0.867	1	0.01	0.01	0.926	1.000
fixations per second										
group	1	0.06	0.16	0.692	0.920	1	0.58	0.84	0.361	0.777
video	1	9.53	26.59	0.000	0.000	1	42.35	61.38	0.000	0.000
IQ	2	0.12	0.17	0.847	0.920	2	2.78	2.01	0.136	0.477
age	2	2.39	3.33	0.038	0.105	2	0.86	0.62	0.536	0.835
sex	1	0.31	0.86	0.355	0.701	1	0.52	0.75	0.388	0.777
pre quality	1	7.03	19.62	0.000	0.000	1	20.54	29.78	0.000	0.000
post quality	2	33.23	46.34	0.000	0.000	2	18.57	13.46	0.000	0.000
sampling rate	1	3.85	10.73	0.002	0.007	1	0.01	0.02	0.899	0.986
ADHD_inatt	1	0.01	0.03	0.854	0.920	1	0.33	0.47	0.492	0.835
group x video	1	0.03	0.08	0.782	0.920	1	0.15	0.22	0.637	0.892
group x IQ	2	1.16	1.61	0.202	0.470	2	0.31	0.23	0.797	0.986
group x age	2	0.65	0.91	0.405	0.701	2	0.12	0.09	0.915	0.986
group x sex	1	0.20	0.57	0.451	0.701	1	1.10	1.59	0.209	0.585

Note. Analysis of Variance with Satterthwaite's method. Sum Squares are Type III. p-adj = p-values adjusted by the number of estimated models by false-detection-rate correction.

Table S5. Linear mixed models overview: oculomotor features – 2/3.

dependent variable	feature mean					feature variation				
	df	Sum Sq	F-value	p-value	p-adj	df	Sum Sq	F-value	p-value	p-adj
relative pupil dilation										
group	1	0.45	0.81	0.368	0.501	1	0.43	0.63	0.427	0.675
video	1	12.62	22.70	0.000	0.000	1	0.00	0.00	0.955	1.000
IQ	2	1.04	0.94	0.394	0.501	2	2.71	1.97	0.141	0.330
age	2	10.49	9.44	0.000	0.001	2	46.31	33.70	0.000	0.000
sex	1	0.46	0.83	0.362	0.501	1	0.37	0.53	0.467	0.675
pre quality	1	6.01	10.81	0.001	0.004	1	0.27	0.39	0.530	0.675
post quality	2	9.55	8.59	0.000	0.001	2	5.55	4.04	0.019	0.132
sampling rate	1	1.61	2.89	0.097	0.273	1	1.82	2.65	0.106	0.330
ADHD_inatt	1	0.72	1.29	0.257	0.501	1	0.01	0.02	0.892	1.000
group x video	1	0.02	0.03	0.864	1.000	1	1.65	2.40	0.122	0.330
group x IQ	2	0.03	0.03	0.971	1.000	2	0.99	0.72	0.488	0.675
group x age	2	1.32	1.19	0.306	0.501	2	1.28	0.93	0.397	0.675
group x sex	1	0.92	1.66	0.199	0.463	1	1.72	2.51	0.115	0.330
saccade duration										
group	1	5.68	12.13	0.001	0.004	1	3.43	6.09	0.014	0.050
video	1	0.16	0.34	0.563	0.606	1	0.57	1.01	0.316	0.633
IQ	2	0.95	1.01	0.366	0.537	2	1.15	1.02	0.363	0.635
age	2	2.52	2.68	0.071	0.243	2	2.29	2.03	0.134	0.376
sex	1	0.59	1.26	0.262	0.537	1	0.24	0.43	0.512	0.716
pre quality	1	0.30	0.65	0.422	0.537	1	0.00	0.00	0.981	1.000
post quality	2	20.37	21.73	0.000	0.000	2	16.64	14.75	0.000	0.000
sampling rate	1	1.94	4.14	0.051	0.238	1	7.72	13.69	0.001	0.004
ADHD_inatt	1	0.42	0.89	0.346	0.537	1	3.55	6.30	0.013	0.050
group x video	1	0.57	1.21	0.272	0.537	1	0.00	0.01	0.927	1.000
group x IQ	2	2.32	2.47	0.087	0.243	2	0.80	0.71	0.492	0.716
group x age	2	0.85	0.91	0.404	0.537	2	1.32	1.17	0.312	0.633
group x sex	1	0.20	0.42	0.518	0.604	1	0.00	0.00	0.960	1.000

Note. Analysis of Variance with Satterthwaite's method. Sum Squares are Type III. p-adj = p-values adjusted by the number of estimated models by false-detection-rate correction.

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Table S6. Linear mixed models overview: oculomotor features – 3/3.

dependent variable	feature mean					feature variation				
	df	Sum Sq	F-value	p-value	p-adj	df	Sum Sq	F-value	p-value	p-adj
saccade amplitude										
group	1	4.30	7.55	0.006	0.045	1	0.51	0.75	0.386	0.742
video	1	0.05	0.08	0.777	0.907	1	5.28	7.74	0.006	0.027
IQ	2	0.06	0.06	0.945	1.000	2	1.18	0.86	0.424	0.742
age	2	2.14	1.88	0.156	0.364	2	7.22	5.29	0.006	0.027
sex	1	0.35	0.61	0.437	0.730	1	0.07	0.10	0.753	0.878
pre quality	1	0.22	0.39	0.531	0.744	1	1.43	2.10	0.148	0.414
post quality	2	8.67	7.60	0.001	0.009	2	10.43	7.64	0.001	0.009
sampling rate	1	3.31	5.80	0.025	0.117	1	0.89	1.30	0.258	0.602
ADHD_inatt	1	0.05	0.08	0.775	0.907	1	0.02	0.03	0.852	0.918
group x video	1	1.89	3.32	0.070	0.244	1	0.19	0.28	0.596	0.835
group x IQ	2	2.73	2.40	0.093	0.262	2	0.47	0.35	0.708	0.878
group x age	2	0.87	0.76	0.469	0.730	2	0.77	0.57	0.568	0.835
group x sex	1	0.53	0.94	0.334	0.668	1	2.07	3.04	0.083	0.289
peak saccade velocity										
group	1	0.22	1.10	0.294	0.687	1	0.01	0.09	0.768	0.977
video	1	0.26	1.33	0.249	0.687	1	0.00	0.00	0.957	1.000
IQ	2	0.00	0.01	0.990	1.000	2	0.29	1.41	0.246	0.861
age	2	0.02	0.06	0.943	1.000	2	0.12	0.56	0.572	0.977
sex	1	0.00	0.00	0.951	1.000	1	0.03	0.30	0.584	0.977
pre quality	1	0.03	0.15	0.702	1.000	1	0.02	0.20	0.659	0.977
post quality	2	5.43	13.68	0.000	0.000	2	39.49	190.47	0.000	0.000
sampling rate	1	33.36	168.09	0.000	0.000	1	37.36	360.45	0.000	0.000
ADHD_inatt	1	0.74	3.74	0.054	0.254	1	0.21	2.07	0.152	0.708
group x video	1	0.59	2.98	0.086	0.299	1	0.01	0.13	0.715	0.977
group x IQ	2	0.14	0.35	0.708	1.000	2	0.14	0.68	0.510	0.977
group x age	2	0.04	0.10	0.907	1.000	2	0.00	0.01	0.990	1.000
group x sex	1	0.00	0.01	0.919	1.000	1	0.03	0.30	0.586	0.977
velocity mainsequence										
group	1	0.19	1.85	0.176	0.475	1	0.51	1.22	0.270	0.505
video	1	0.01	0.09	0.761	0.887	1	0.06	0.14	0.711	0.829
IQ	2	0.02	0.11	0.899	0.968	2	0.38	0.46	0.633	0.805
age	2	0.33	1.60	0.204	0.475	2	1.51	1.81	0.166	0.505
sex	1	0.12	1.15	0.285	0.498	1	0.21	0.49	0.483	0.751
pre quality	1	0.06	0.57	0.452	0.633	1	0.65	1.56	0.213	0.505
post quality	2	2.76	13.22	0.000	0.000	2	12.87	15.41	0.000	0.000
sampling rate	1	29.17	279.26	0.000	0.000	1	51.02	122.20	0.000	0.000
ADHD_inatt	1	0.42	4.04	0.046	0.213	1	0.12	0.28	0.598	0.805
group x video	1	0.03	0.31	0.580	0.739	1	0.47	1.13	0.289	0.505
group x IQ	2	0.19	0.93	0.396	0.616	2	1.06	1.27	0.283	0.505
group x age	2	0.30	1.43	0.241	0.481	2	0.18	0.22	0.804	0.866
group x sex	1	0.35	3.38	0.067	0.235	1	0.70	1.67	0.197	0.505

Note. Analysis of Variance with Satterthwaite's method. Sum Squares are Type III. p-adj = p-values adjusted by the number of estimated models by false-detection-rate correction.

Table S7. Age effects.

	adolescent – adult		adolescent – child		adult – child	
	Diff	CI	Diff	CI	Diff	CI
relative pupil dilation variation	0	[-0.23, 0.24]	0.82	[0.6, 1.04]	0.82	[0.58, 1.06]
saccade amplitude variation	0.11	[-0.16, 0.39]	0.42	[0.16, 0.68]	0.31	[0.02, 0.59]
fixation duration mean	-0.07	[-0.36, 0.22]	-0.53	[-0.82, -0.24]	-0.46	[-0.78, -0.15]
relative pupil dilation mean	-0.09	[-0.37, 0.19]	-0.56	[-0.83, -0.29]	-0.47	[-0.76, -0.18]

Note. Pairwise post-hoc comparison of predicted marginal means ordered by effect size of adolescent- child contrast, diff = predicted marginal mean difference, CI = 95% confidence interval.

Table S8. Video content effects.

Diff	CI
relative pupil dilation mean	0.35 [0.2, 0.49]
saccade amplitude variation	-0.22 [-0.38, -0.07]
fixations per second mean	-0.3 [-0.42, -0.19]
fixations per second variation	-0.7 [-0.87, -0.52]

Note. Pairwise post-hoc comparison of predicted marginal means ordered by effect size, contrast = human - non-human, diff = predicted marginal mean difference, CI = 95% confidence interval.

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Table S9. Descriptive correlations with clinical measures in ASD.

	ADI SA	ADI COM	ADI RRB	CSS total	CSS SA	CSS RRB	SRSp	SRSs	RBS-R	SSP
Means										
fixation duration	-0.03 (134)	0.03 (134)	-0.08 (134)	0.06 (142)	0.06 (142)	-0.05 (142)	-0.12 (118)	-0.06 (66)	-0.08 (120)	0.15 (84)
fixations per second	-0.08 (134)	-0.13 (134)	-0.01 (134)	-0.16 (142)	-0.15 (142)	0.06 (142)	0.03 (118)	0.22 (66)	-0.04 (120)	0.1 (84)
relative pupil dilation	0.11 (134)	0.17 (134)	0.14 (134)	-0.08 (142)	-0.02 (142)	-0.03 (142)	0.16 (118)	0 (66)	0.13 (120)	-0.03 (84)
saccade duration	0.14 (134)	0.05 (134)	-0.06 (134)	0.09 (142)	0.07 (142)	0.04 (142)	0.1 (118)	-0.15 (66)	0.03 (120)	-0.2 (84)
saccade amplitude	-0.04 (134)	0 (134)	-0.03 (134)	0.21 (142)	0.23 (142)	0.01 (142)	0.09 (118)	0.19 (66)	0.07 (120)	0.08 (84)
peak saccade velocity	0.03 (134)	0.01 (134)	0.18 (134)	-0.02 (142)	-0.01 (142)	0.08 (142)	0.11 (118)	0.25 (66)	0.16 (120)	-0.1 (84)
velocity main sequence	-0.01 (134)	0 (134)	0.26 (134)	-0.12 (142)	-0.14 (142)	0.12 (142)	0.07 (118)	0.12 (66)	0.16 (120)	-0.15 (84)
Standard deviations										
fixation duration	0.11 (134)	0.1 (134)	-0.03 (134)	0.1 (142)	0.09 (142)	-0.04 (142)	-0.08 (118)	-0.18 (66)	-0.03 (120)	0.19 (84)
fixations per second	-0.15 (134)	-0.11 (134)	-0.01 (134)	-0.11 (142)	-0.12 (142)	-0.04 (142)	0.02 (118)	-0.11 (66)	0 (120)	0.03 (84)
relative pupil dilation	0.11 (134)	0.03 (134)	0.05 (134)	0.07 (142)	0.04 (142)	0.03 (142)	-0.09 (118)	-0.11 (66)	-0.08 (120)	-0.02 (84)
saccade duration	0.22 (134)	0.08 (134)	0.03 (134)	0.1 (142)	0.04 (142)	0.11 (142)	0.1 (118)	-0.23 (66)	0.13 (120)	-0.24 (84)
saccade amplitude	0.04 (134)	0.04 (134)	0.05 (134)	0.09 (142)	0.11 (142)	-0.04 (142)	0.18 (118)	0.15 (66)	0.13 (120)	-0.02 (84)
peak saccade velocity	0.04 (134)	-0.05 (134)	0.12 (134)	-0.05 (142)	-0.04 (142)	0.02 (142)	0.08 (118)	0.15 (66)	0.12 (120)	-0.01 (84)
velocity main sequence	0.13 (134)	0.08 (134)	0.2 (134)	0.03 (142)	0.02 (142)	0.07 (142)	0.08 (118)	-0.07 (66)	0.22 (120)	-0.32 (84)

Note. Pearson-Coefficient (number of observations); ADI SA = ADI-R - Social, ADI COM = ADI-R - Verbal Communication, ADI RRB = ADI-R - Restricted and Repetitive Behavior, CSS total = ADOS-2 Calibrated Severity Score - Total, CSS SA = ADOS-2 Calibrated Severity Score - Social Affect, CSS RRB = ADOS-2 Calibrated Severity Score - Restricted and Repetitive Behavior, SRSp = Social Responsiveness Scale - parent rating total, SRSs = Social Responsiveness Scale - self rating total, RBS-R = Repetitive Behavior Scale - Revised, SSP = Short Sensory Profile.