Using a 3-D multiple object tracking (MOT) task to assess attentional abilities in autism

Bianca Levy[1], Domenico Tullo[1], Laurent Mottron[2], Jocelyn Faubert[3], & Armando Bertone[1]

[1]Department of Educational and Counselling Psychology, McGill University, [2]Centre d'excellence en troubles envahissants du développement (CETEDUM), Université de Montréal, [3]École d'optométrie, Université de Montréal

BACKGROUND

Autism spectrum disorder (ASD) is characterized by differences in visuo-spatial perceptual and attentional abilities. Multiple object tracking (MOT) paradigms are useful in assessing these abilities, as they demand the use of sustained, selective, and distributed attention to dynamic visual information.

As suggested by the load theory of attention [1], attentional capacity is increasingly taxed as the number of items tracked (task difficulty) increases. Individuals with ASD are hypothesized to have greater perceptual capacity than those without ASD and thus may be more susceptible to processing distractor items at higher cognitive loading levels [2]; resulting in poorer performance [3].

Although trial-by-trial feedback is generally hypothesized to benefit task performance and learning, it inadvertently decreased performance in typically-developing participants completing the first session of our 3D-MOT task [4], possibly by taxing attentional resources [5].

AIMS & HYPOTHESES

Using a 3D-MOT task, we aimed to assess dynamic visual attention in adolescents and adults with ASD as a function of cognitive load (Study 1), and feedback (Study 2). We hypothesized that:

1. The ASD group would process distractors more than the TD group (whose loading capacity may be exhausted), resulting in poorer 3D-MOT performance (Study 1). This would be most evident at higher loading levels.
2. ASD participants who received trial-by-trial feedback would perform worse on the 3D-MOT than those who did not receive it, due to its additional demand on attentional resources (Study 2).

METHOD

Participants

***ASD groups*.** Participants with an ASD diagnosis were recruited through and tested at the Clinique d'évaluation des troubles envahissants du développement at Rivière-des-Prairies Hospital; and at Summit School; in Montreal, QC (n_{Study1} = 15; n_{Study2} = 12).

***TD group*.** Typically-developing (TD) participants for Study 1 were recruited and tested at the PNLab at McGill University (n= 15).

Table 1. Participant demographic information

Study 1	ASD_F (12 males, 3 females)			TD_F (10 males, 5 females)			*p*
	Mean	SD	Range	Mean	SD	Range	
Age (yrs)	22.1	5.2	15-30	23.6	3.1	19-30	0.33
FSIQ	102.1	18.3	65-134	107.7	11.4	81-124	0.32
VCI	101.8	22.6	70-147	106.0	14.3	76-128	0.55
PRI	103.3	19.9	65-133	106.9	12.0	81-131	0.55
CPT *d'*	43.2	7.6	31-57	51.7	5.1	43-60	<0.01*
Study 2	ASD_F (12 males, 3 females)			ASD_{NF} (8 males, 4 females)			*p*
	Mean	SD	Range	Mean	SD	Range	
Age (yrs)	22.1	5.2	15-30	20.1	4.0	15-29	0.28
FSIQ	102.1	18.3	65-134	98.5	8.8	84-110	0.54
VCI	101.8	22.6	70-147	96.3	9.1	82-112	0.45
PRI	103.3	19.9	65-133	105.9	12.4	80-120	0.70
CPT *d'*	43.2	7.6	31-57	46.6	9.5	31-62	0.36

Note. Means, SDs, and *p* values are shown. CPT *d'* measures signal-to-noise detection, with lower scores representing better performance. *D'* scores ≥ 60 are clinically elevated. FSIQ = Full-Scale Intelligence Quotient, VCI = Verbal Comprehension Index, PRI = Perceptual Reasoning Index. F/NF = feedback/no feedback given on 3D-MOT.

3D multiple object tracking (3D-MOT) task

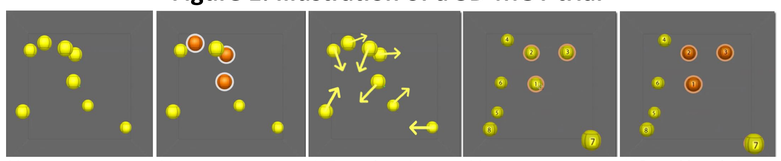
Participants tracked two blocks each of 1, 2, 3, and 4 target spheres (of 8 total spheres) in 3D space while wearing a Sony HMZ-T1 head-mounted display.

Study 1: All participants received trial-by-trial feedback (F).

Study 2: Half the participants received feedback (F), while half did not (NF).

3D-MOT task performance was defined as the average speed at which all target items were identified per loading level (# targets) across both trial blocks. These speed thresholds (STs) were calculated using an adaptive staircase procedure (see Figure 1).

Figure 1. Illustration of a 3D-MOT trial



(a) All 8 spheres are displayed in the visual field. (b) The target spheres are highlighted orange. (c) Target spheres change back to yellow and all spheres move randomly throughout the visual field for 8 seconds. (d) Spheres stop moving. Numbers (1-8) appear on the spheres and the participant attempts to identify the target spheres. (e) For participants in the Feedback groups only, feedback on performance is provided by way of highlighting original target spheres in orange once again.

Cognitive and attention measures

Wechsler intelligence scales (WASI-II, WAIS-IV, and WISC-IV)

All participants completed the Wechsler Abbreviated Scale of Intelligence, 2nd Ed. (WASI-II) [6] or had a valid Wechsler IQ scores upon testing (WAIS/WISC-IV [7/8]).

Conners Continuous Performance Task (CPT-II and CPT-3)

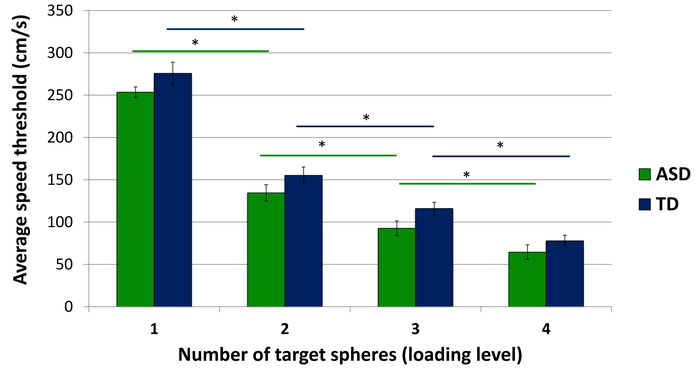
All participants completed a computerized measure of attention (CPT-II [9] or CPT-3 [10]) to screen for clinically significant attention difficulties.

RESULTS

Study 1: Effect of cognitive load on 3D-MOT performance

- Two separate repeated measures ANOVAs revealed significant differences across all levels of cognitive load for both the ASD_F ($F_{(3, 42)}$ = 263.47, p < 0.001, partial η^2 = 0.95) and TD_F ($F_{(3, 42)}$ = 171.19, p < 0.001, partial η^2 = 0.92) groups. All loading level comparisons were significant within groups (Figure 2).
- A 4 x 2 mixed model ANOVA did not find a significant interaction between loading level and diagnostic group ($F_{(3, 84)}$ = 0.27, p = 0.61). No significant difference was found between diagnostic groups when ST was collapsed across all loading levels ($t_{(28)}$ = -1.93, p = 0.06).

Figure 2. Study 1: 3D-MOT performance by cognitive loading level

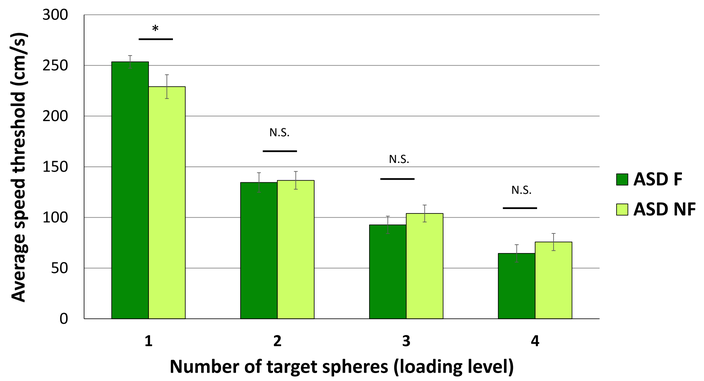


Note. Average speed thresholds (STs) in cm/s are shown for ASD_F (n = 15) and TD_F (n = 15). Higher average ST scores reflect better performance on the 3D MOT task. *p < 0.01.

Study 2: Effect of feedback on 3D-MOT performance in ASD

- A 4 x 2 mixed model ANOVA revealed a significant interaction between loading level and feedback group ($F_{(3, 75)}$ = 3.78, p = 0.01, partial η^2 = 0.13), with a simple main effect of feedback group on ST_1 only ($F_{(3, 25)}$ = 4.25, p = 0.05, partial η^2 = 0.15).
- A significant difference in ST_1 from the first and second blocks was found between groups ($t_{(25)}$ = -3.01, p < 0.01), with the F group appearing to show a positive effect of feedback on task performance (M_F = 21.3; M_{NF} = -42.1)

Figure 3. Study 2: 3D-MOT performance by feedback condition in ASD



Note: Average speed thresholds (STs) in cm/s are shown for ASD_F (n = 15) and ASD_{NF} (n = 13). Higher average ST scores reflect better performance on the 3D MOT task. *p < 0.05.

3D-MOT performance and cognitive ability

- STs were positively associated with PRI for most load conditions in the ASD group only (Table 2). No significant correlations between ST and VCI were found in either the ASD or TD groups.

Table 2. Correlations between speed threshold and Wechsler IQ scores

	ASD_F (n = 15)			TD_F (n = 15)		
ST	**FSIQ**	**VCI**	**PRI**	**FSIQ**	**VCI**	**PRI**
1	0.404	0.320	0.387	0.320	0.215	0.277
2	0.321	0.060	**0.582***	0.137	0.019	0.235
3	**0.559***	0.394	**0.597***	0.342	-0.081	**0.724****
4	**0.664****	0.501	**0.682***	0.412	0.220	0.414

Note. Two-tailed Pearson correlations are shown. * p < 0.05 ** p < 0.01

DISCUSSION

- **(Study 1)** STs at higher levels of cognitive loading were not relatively decreased for the ASD group. This result does not support the notion that individuals with ASD have a greater perceptual capacity as per the load theory of attention.
- **(Study 2)** Feedback did not significantly impair 3D-MOT performance for the ASD NF group; and actually enhanced it when task difficulty was lower (1 target item). Improvement in performance (learning) at this level was seen in the ASD F group only. This suggests that individuals with ASD may not be as attentionally taxed by feedback on our task.
- 3D-MOT performance was linked to PRI in the ASD group only, suggesting that perceptual reasoning abilities are associated with visuo-spatial attention in ASD; especially when task difficulty is high.

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