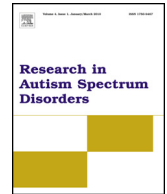




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Brief report

Difficulties predicting time-to-arrival in individuals with autism spectrum disorders



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ABSTRACT

Background: Previous research suggests people with ASD may have various difficulties in processing and interacting with motion in the environment. We investigated whether individuals with ASD have difficulty judging the location of moving objects in a driving context using a time-to-arrival task.

Methods: Participants with and without ASD viewed scenes that simulated self-motion towards a junction, while another car approached on a side road. Scenes terminated prior to either car reaching the junction and participants were required to decide which car would reach the junction first.

Results: Participants with ASD made fewer correct responses although this was only true when self-motion was on a straight road.

Conclusions: This difficulty in judging the location of moving objects could contribute to difficulties people with ASD experience in learning to drive.

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1. Introduction

Research suggests that individuals with Autism Spectrum Disorders (ASD) have difficulties processing moving objects (e.g. Koldewyn, Weigelt, Kanwisher, & Jiang, 2013). These issues may manifest in a range of contexts such as playground games (Robison, 2006), sports (Morin & Reid, 1985), and road environments. For instance, it has been reported that many individuals with ASD are unable to drive (Feeley, 2010), although further data is needed on this matter. Additionally, those with ASD face significant challenges in attaining a driver's license, as well as in driving after obtaining a license (Cox, Reeve, Cox, & Cox, 2012; Daly, Nicholls, Patrick, Brinckman, & Schultheis, 2014). While survey studies suggest these challenges are likely to be manifold, some of the difficulties reported are at least consistent with a difficulty in judging trajectories of other road users (Daly et al., 2014). For instance, in Daly et al. (2014), survey respondents with ASD were more likely than comparison participants to report being in accidents where they hit someone or something.

Various areas of previous research support the notion that people with ASD may have difficulties judging the movement of objects (see Simmons et al., 2009; for a review). Several studies have reported elevated motion coherence thresholds in ASD (e.g. Milne et al., 2002; Pellicano, Gibson, Maybery, Durkin, & Badcock, 2005), although some have not (e.g. Del Viva, Iglizzi, Tancredi, & Brizzolara, 2006). There is also evidence for atypical responses to optic flow in individuals with ASD (Gepner, Mestre, Masson, & de Schonen, 1996; Price, Shiffrar, & Kerns, 2012), and some suggestion of abnormalities in speed perception, although this may be an enhancement rather than a deficit (Chen et al., 2012). Alternatively, difficulties with prediction could result in problems processing moving objects. Sinha et al. (2014) argue that people with ASD may have a

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general impairment in predictive abilities which may give rise to problems with anticipating an object's future position based on current perceptual information.

The ability to predict the location of objects has been investigated in individuals of typical development using time-to-arrival tasks (e.g. Berthelon & Mestre, 1990). These tasks typically involve presenting participants with scenes where an object is moving at a constant speed towards a specified location. The scenes are occluded prior to the object reaching the location and viewers are required to predict when the object would have reached it. Accuracy of time-to-arrival judgments is influenced by various factors including the angle of approach of the object (e.g. Schiff and Oldak, 1990), and self-motion (Van Loon, Khashawi, & Underwood, 2010). Moreover, judgments are improved by the presence of a static reference point close to the moving object (Berthelon & Mestre, 1990), perhaps because participants use the relative optical velocity between reference point and approaching object as a guide in their judgments (Berthelon & Mestre, 1993). Perceptual style affects participants' use of the reference point. Berthelon, Mestre, Pottier, and Pons (1998) found that individuals who are Field-Independent, who have a tendency to process local details without contextual information, responded faster in the presence of the local reference point than Field-Dependent participants, who tend to process stimuli in a more holistic fashion taking the context into account.

Given the difficulties those with ASD experience in driving, the current research used a time-to-arrival judgment task to explore whether individuals with ASD are impaired in judging the movement of objects within a driving context. Participants with and without ASD viewed short computer-generated sequences which simulated self-movement towards a road junction and the movement of another car towards the same junction along a side road. The sequences terminated before either car reached the intersection, and participants judged whether the other car would have arrived at the junction before or after them. On some trials, small posts were positioned along the road of the approaching vehicle leading up to the junction, to act as a local reference point. It was predicted that participants with ASD would be less accurate than comparison participants at judging which car would arrive at the junction first. As it has previously been suggested that individuals with ASD have a local processing style, similar to Field-Independence (Happé & Frith, 2006), it was also predicted that they would be more influenced by the presence of a reference point, that the difference between the groups would decrease in the presence of road posts.

2. Methods

2.1. Participants

Twenty-three males with ASD were recruited from colleges in the West Midlands and South of England. They had all received a formal diagnosis of autism ($N = 7$) or Asperger Syndrome ($N = 16$) by a mental health professional (a psychiatrist or clinical psychologist employed by the National Health Service, using DSM-IV, American Psychiatric Association, 1994). The Wechsler Abbreviated Scale of Intelligence (WASI) was carried out with all participants to establish levels of verbal and non-verbal ability.

A comparison group of 21 males was recruited from colleges of Further Education in the Nottinghamshire area. Details of the groups are provided in Table 1. The groups were matched on chronological age, verbal, performance and full-scale IQ (all $p > 0.25$), and were enrolled in a range of academic or vocational courses.

Table 1

Participant details (ASD = Autism Spectrum Disorders; CA = chronological age; VIQ = verbal IQ; PIQ = performance IQ; FSIQ = full scale IQ; AQ = Autism Spectrum Quotient score).

	ASD ($N = 23$)	Comparison ($N = 21$)
CA (years) mean	18.55	18.83
sd	1.79	2.25
range	16.25–22.00	16.92–23.25
VIQ mean	99.00	99.48
sd	12.15	15.48
range	79–122	74–131
PIQ mean	100.09	103.48
sd	11.38	7.61
range	75–124	89–120
FSIQ mean	99.52	101.76
sd	11.01	10.98
range	86–124	80–122
AQ mean	25.26	14.95
sd	7.93	5.21
range	8–38	7–25

All participants completed the Autism Quotient (AQ; Baron-Cohen, Wheelwright, Skinner, Martin, & Clubley, 2001) and the groups differed significantly in their scores, $t(42) = 5.138, p < 0.001$. None of the participants held a driving license. Non-drivers were recruited because we were specifically interested in any difficulties faced by those with ASD prior to obtaining a license. Individuals were also excluded from the study if they reported any visual or motor impairment. All participants were tested in a familiar setting within their college, and informed consent was obtained. The procedures used in this study were subject to ethical review within the School of Psychology, University of Nottingham, and were judged to comply with ethical standards.

2.2. Design

A $2 \times 2 \times 2 \times 2 \times 2$ mixed design was employed. The between-participants factor was participant group (ASD/comparison), with four within-participants factors: observer trajectory (straight/curved); approach angle of the other vehicle (perpendicular/obtuse); arrival time of the other vehicle (before/after the observer); and reference point close to the junction (present/absent). Thus, there were 16 different sequences, each of which was presented three times, resulting in 48 trials (see Fig. 1 for examples).

2.3. Apparatus

Virtual driving sequences were generated and presented on an Apple (Powerbook) G4 laptop computer by a C program using OpenGL, based on those used in Van Loon et al. (2010). Participants were seated 60 cm from the 17inch screen, creating a visual angle of $28 \times 20^\circ$. Each sequence lasted 6.5 s and simulated self-motion of a driver on either a straight or curved road (curvilinear to the right; radius: 150 m) towards an intersection with a road on the left. Another vehicle approached the same junction rectilinearly from the side road, which was at either a perpendicular or obtuse angle to the starting position of the road of the observer. The simulated main road was 7 m wide with two lanes separated by a central line. The observer approached the junction with a constant speed of 37.8 km/h and the other vehicle approached at a constant speed of 26.5 km/h. On each trial the approaching vehicle was programmed to arrive either 700 ms before or after the observer. Each sequence stopped 2.5 s before the observer would have reached the junction. On half of the trials 15 small posts were programmed at 5 m intervals along the road of the other vehicle leading up to the intersection.

2.4. Procedure

Participants were seated in front of the computer screen. In each trial one of the sequences was shown, followed by the question: 'Will the red car arrive at the junction before or after you?' Participants were asked to assume that both cars continued moving at the same speed after the sequence terminated. They responded using the mouse to click on either the 'before' or 'after' icon on the screen. There was no time limit for responding. Four practice trials were given to familiarise participants with the displays and the procedure. No feedback was given about the accuracy of responses.

3. Results

The proportion of correct responses was calculated for each trial type for each participant, and means and standard deviations are shown in Table 2.

There were several main effects and interactions that replicate previous research with typically developing adults (e.g. Schiff & Oldak, 1990; Berthelon & Mestre, 1990). There was a main effect of observer trajectory, $F(1,42) = 10.55, p < 0.005, \eta_p^2 = 0.20$, where participants were more accurate judging curved ($M = 0.83, SD = 0.08$) than straight roads ($M = 0.78$,

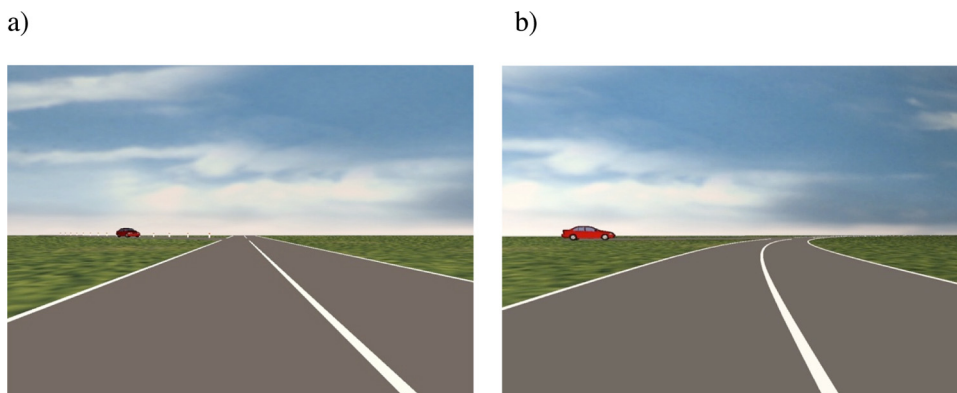


Fig. 1. Still images taken from two sequences: (a) straight road, obtuse approach, signs present; (b) curved road, perpendicular approach, no signs.

Table 2

Mean (standard deviations in brackets) proportion of correct responses made by participants with ASD and comparison participants for each display type.

Approach angle	Observer trajectory	Arrival time	Local cue	ASD	Comparison
Obtuse	Straight	Before	Present	0.85 (0.28)	0.93 (.18)
			Absent	0.86 (0.20)	0.95 (0.12)
		After	Present	0.36 (0.22)	0.54 (0.33)
			Absent	0.46 (0.30)	0.56 (0.27)
	Curved	Before	Present	0.75 (0.31)	0.68 (0.29)
			Absent	0.68 (0.26)	0.70 (.26)
		After	Present	0.80 (0.22)	0.86 (.17)
			Absent	0.85 (0.24)	0.71 (0.34)
Perpendicular	Straight	Before	Present	0.91 (0.14)	0.94 (0.13)
			Absent	0.70 (0.29)	0.79 (0.34)
		After	Present	0.87 (0.22)	0.97 (0.10)
			Absent	0.80 (0.24)	0.86 (0.20)
	Curved	Before	Present	0.81 (0.22)	0.86 (0.20)
			Absent	0.84 (0.24)	0.97 (0.10)
		After	Present	0.88 (0.19)	0.94 (0.20)
			Absent	0.94 (0.13)	0.92 (0.18)

$SD = 0.10$). There was also a main effect of approach angle of the other vehicle, $F(1,42) = 88.16$, $p < 0.001$, $\eta_p^2 = 0.68$, whereby participants were more accurate when the other car approached perpendicularly ($M = 0.88$, $SD = 0.08$) than at an obtuse angle ($M = 0.73$, $SD = 0.09$).

There was a main effect of arrival time, $F(1,42) = 4.63$, $p < 0.05$, $\eta_p^2 = 0.10$, indicating participants were more accurate when the approaching vehicle was due to arrive before ($M = 0.83$, $SD = 0.11$) than after them ($M = 0.77$, $SD = 0.10$). Arrival time interacted with both the observer trajectory $F(1,42) = 50.56$, $p < 0.001$, $\eta_p^2 = 0.55$, and angle of approach of the other vehicle, $F(1,42) = 26.41$, $p < 0.001$, $\eta_p^2 = 0.39$, and there was also a three-way interaction between these variables, $F(1,42) = 65.39$, $p < 0.001$, $\eta_p^2 = 0.61$. This was because the effect of arrival time was only significant when the other vehicle approached at an obtuse angle to a straight road, $t(42) = 10.94$, $p < 0.001$, $d = 2.40$. In this condition, participants tended to respond 'before' on both 'before' and 'after' trials resulting in good performance when the other vehicle was due to arrive prior to the observer ($M = 0.91$, $SD = 0.14$) but poor performance when it was due to arrive afterwards ($M = 0.47$, $SD = 0.22$).

Participants were more accurate in the presence ($M = 0.82$, $SD = 0.08$) than absence ($M = 0.78$, $SD = 0.09$) of posts along the road of the approaching car, $F(1,42) = 8.76$, $p < 0.01$, $\eta_p^2 = 0.17$. The presence of posts interacted with angle of approach of the car, $F(1,42) = 9.45$, $p < 0.005$, $\eta_p^2 = 0.18$, and there was a three-way interaction between the presence of posts, angle of approach and observer trajectory, $F(1,42) = 6.20$, $p < 0.05$, $\eta_p^2 = 0.13$. Posts resulted in greater accuracy for perpendicular approaches to straight roads, $t(42) = 4.44$, $p < 0.001$, $d = 0.88$, but not the other road types.

Finally, there was a main effect of participant group, $F(1,42) = 5.74$, $p < 0.05$, $\eta_p^2 = 0.12$, with participants with ASD ($M = 0.77$, $SD = 0.08$) less accurate than those without ($M = 0.82$, $SD = 0.06$). Participant group also interacted with observer trajectory, $F(1,42) = 6.00$, $p < 0.05$, $\eta_p^2 = 0.13$, depicted in Fig. 2. Participants with ASD were less accurate than comparison participants for straight, $t(42) = 3.06$, $p < 0.005$, $d = 0.94$, but not curved roads. Only the group of participants with ASD was less accurate for straight than curved roads, $t(22) = 3.91$, $p < 0.005$, $d = 0.97$. All other main effects and interactions were non-significant.

It is possible that the observed interaction between group and trajectory arises because the comparison group was performing at ceiling in the task, hence masking any effect of trajectory in this group. To address this possibility the analysis was repeated by comparing the group with ASD with a group including only the 10 comparison participants with the lowest overall% accuracy across conditions (82% or lower). This analysis gave rise to very similar effects as the main ANOVA, although there was no longer any main effect of participant group ($p > 0.9$) and in fact the group mean was 77.5% which was almost identical to the ASD mean of 77.3%. The interaction between trajectory and group remained significant, $F(1,31) = 4.23$, $p < 0.05$, $\eta_p^2 = 0.12$, again due to poorer performance on straight than curved roads in participants with ASD but not the comparison participants.

Some of the participants with ASD in our sample did not report having high levels of autistic traits, despite having a confirmed diagnosis. Is it possible that the findings above could be explained by the inclusion of such individuals – specifically the failure to find any group differences for curved roads? To address this, we repeated the analysis with only those individuals with ASD who scored 26 or over ($N = 13$; using the threshold score proposed by Woodbury-Smith, Robinson, Wheelwright & Baron-Cohen, 2005). This gave rise to all of the same effects as the original ANOVA, including the significant group by trajectory interaction, which again resulted from poorer performance on straight than curved roads in

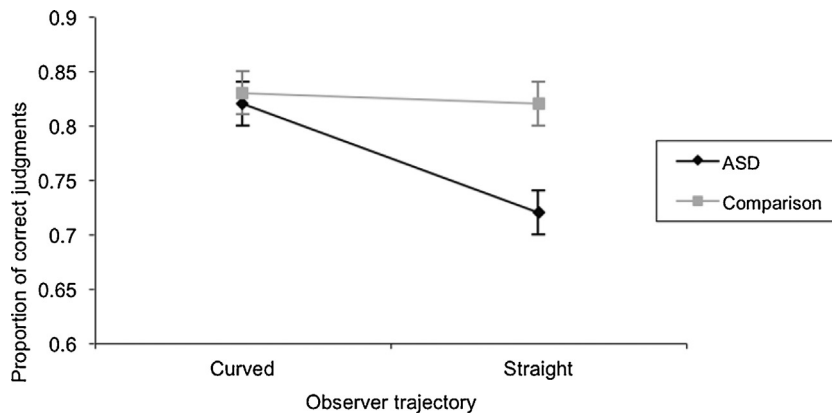


Fig 2. Mean proportion of trials correct for curved and straight roads.

participants with ASD. AQ scores in the whole sample did not correlate with overall accuracy or with accuracy for either curved or straight roads (all $p > 0.1$).

4. Discussion

Participants with ASD were less accurate than comparison individuals at predicting which of two cars (self or other) would arrive first at an intersection. However, further analyses showed that those with ASD were impaired only for judgments where the observer trajectory was straight, while their performance was similar to comparison individuals when the self-motion was simulated along a curved road. Additional analyses implied that these results were not due to inclusion of some individuals with ASD who had relatively low AQ scores, as the same pattern emerged when only performance of higher AQ scorers with ASD was taken into account. It is also unlikely that the effect arose due to ceiling effects in the comparison group, as the same findings were observed when comparing the ASD group with a subgroup of comparison participants that were matched on overall accuracy across conditions. The findings suggest that difficulties judging time to arrival may only be apparent under certain circumstances in those with ASD.

The finding of poorer performance in judging time-to-arrival on straight roads in the ASD group is consistent with [Sinha et al.'s \(2014\)](#) theory that individuals with ASD have an impairment in predictive abilities. However, it is difficult to explain why problems with prediction would arise only for straight and not for curved roads. Alternatively, poorer performance on this task could have arisen from lower-level perceptual demands which may differ between the two road types. Individuals with ASD have been found to have difficulties with coherent motion perception and interpretation of optic flow (e.g. [Pellicano et al., 2005](#); [Price et al., 2012](#)), the contribution of which could be considered in future research using control tasks that measure these skills directly. Displays with straight and curved trajectories differ in the nature of the optic flow pattern involved, although it is not clear why some types of optic flow pattern would be processed differently by those with ASD and not others.

Another related difference is the way in which the visual information presented in the sequence changes over time. On curved trajectory approaches, the angle of the observer is constantly changing, hence the relative locations of all aspects of the display update continuously. In contrast, on the straight trajectory approaches the angle of the observer remains constant, resulting in a different distribution of transformations in the image as the car moves nearer to the junction. This means that participants need to draw upon somewhat different information when making judgments for these two road types. [Van Loon et al. \(2010\)](#) investigated eye movements of typically developing individuals during this task and observed a greater horizontal spread of fixations for displays involving curved than straight roads. If the visual information in the scene required for making the judgment occupies a smaller area for straight than curved road displays, performance on such trials might be more influenced by failure to attend to the appropriate part of the scene. Therefore, it seems reasonable to suggest that different attentional patterns in those with ASD might account for the findings here. Future research could use eye tracking to determine whether differences in performance on straight roads are associated with different patterns of attention.

Participants had a greater tendency to judge the other vehicle would arrive before than after themselves. This bias towards saying 'before' only occurred for displays involving obtuse approaches to straight roads, which was also the scene type with the poorest overall performance. The bias may reflect a cautious approach which is adopted under conditions of higher uncertainty: in real driving scenarios, if in doubt it is better to assume that another vehicle will arrive before you and take appropriate evasive action (such as slowing down) rather than assume it will arrive after and risk collision. Notably this pattern of responding occurred in those with ASD as well as the comparison participants. Nevertheless future research could look at how the tendency to make 'before' judgments varies as a function of arrival time discrepancy between self and other.

Participants were more accurate in their predictions when there was a series of small posts along the side road on which the car was approaching. Berthelon and Mestre (1993) argue that the posts act as an anchor point against which to judge the relative optical velocity of the approaching car. The current study implies this may only be useful for perpendicular approaches to straight roads. This may be because for this trial type, the posts all appear in the same depth plane making them an informative guide to the distance of the vehicle, whereas on the other trial types the posts appear along a road which recedes into the distance.

Contrary to prediction, the groups were equally affected by the posts, although it has been found previously that people who are better at processing locally, as indexed by performance on the Embedded Figures task, make greater use of the reference point when making time-to-arrival judgements (Berthelon et al., 1998). However, previous research has focused on those of high field-independence, who may show a different kind of local processing than observed in ASD. Happé and Frith (2006) argue that people who are field-independent see but are able to resist gestalts, whereas those with weak central coherence do not spontaneously attend to gestalts. Hence, according to Happe and Frith, for field-independent individuals, like field-dependent individuals, the default is to process at the global level while for people with weak central coherence the default is to process at the local level. Perhaps it is this ability to strategically (or ‘analytically’) prioritise local information shown by field-independent individuals that enables them to make optimal use of local cues in this kind of task.

4.1. Implications

This paper provides preliminary evidence that at least in some situations, prediction of future position of objects may be impaired in ASD (Sinha et al., 2014). This could have important consequences as in everyday life we need to make such predictions to guide action and avoid collisions with other objects in space. This has implications for both car users and pedestrians, who must make such judgments to negotiate road environments successfully. However, it should be noted that as this study recruited non-drivers exclusively these observations may not generalise to people with ASD who have successfully learned to drive. It is possible that individuals with ASD who do learn to drive might have different cognitive skills than those who do not, and it is also possible that the ability to make judgments about trajectories of vehicles improves with driver training. Therefore future research could compare groups of driving license holders with and without ASD on the same task.

As this study involved simulated self-motion in a graphically generated environment, using a single display screen, further research will be needed to determine how any difficulties may translate to a real road environment. While research has reported similar findings from driving tasks conducted on computers, in a simulator, and on the roads (Underwood, Crundall, & Chapman, 2011), it is still possible that different results would be observed during actual driving, given a much broader field of view and other processes taking place simultaneously. Given that previous research has found some problems with visuo-motor integration (Paton, Hohwy & Enticott, 2012) as well as challenges associated with multitasking aspects of driving (Reimer et al., 2013) in those with ASD, one might speculate that difficulties in judging time-to-arrival may be more pronounced in real world driving, where it is necessary to carry out moment-to-moment adjustments in speed and steering as a consequence of such judgments. On the other hand, in our task the scenes are occluded prior to arrival at the junction while in real driving situations visual information is available up until the point of arrival, so it could be this mitigates the difficulties shown by those with ASD in this task in the lab.

Conflicts of interest

The authors have no conflicts of interest.

Acknowledgments

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