Short report: Mental imagery scanning in autism spectrum disorder

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Running Head: ASD mental image scanning

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Abstract

Navigational impairments have previously been reported in autism spectrum disorder (ASD). The present study examined the ability of individuals with ASD to generate and scan their mental image of a previously viewed map. Twenty-one ASD adults and 20 age- and IQ-matched comparison adults memorised a map of a fictitious island containing a number of landmarks. They then mentally imagined the map and were timed as they imagined a character walking between the various landmarks. Consistent with previous mental imagery research with typical individuals, there was a linear relationship between the time that participants took to mentally scan between the landmarks and the actual distance between the landmarks on the picture, and this was the case for both typical and ASD participants. ASD and comparison participants' mental image scanning times were both also influenced by misleading signposts in the picture that indicated different distances between landmarks, thus providing evidence that their mental images were penetrable by top-down information. Although ASD and comparison participants showed very similar mental imagery scanning performance, verbal IQ and working memory were significantly and positively associated with image scanning performance for the ASD, but not the comparison group. This finding furthers the notion of a compensatory reliance on different strategies in ASD to achieve similar surface performance to individuals from the general population. Findings have practical implications for supporting navigation strategies in ASD.

Key words: Autism spectrum disorder; mental imagery; scanning, navigation; maps; visuo-spatial processing; IQ; working memory

1. Introduction

Autism spectrum disorder (ASD) is characterised by impairments in social communication and interaction, as well as restricted and repetitive patterns of behaviour or interests (American Psychiatric Association, 2013). An example of the latter is the numerous anecdotal reports that people with ASD have a strong desire stick to familiar, well-known and well-rehearsed routes. However, Lind, Williams, Raber, Peel, and Bowler (2013) have recently argued that, rather than being due to behavioural inflexibility, this insistence on always travelling the same route may actually be associated with ASD-related difficulties in generating cognitive maps and a greater reliance on route-based, egocentric (and thus less flexible) navigation strategies. In support of this contention, the limited work to date that has examined navigation abilities in ASD indicates that route-based, egocentric navigation is intact in the disorder (Caron, Mottron, Rainville, & Chouinard, 2004), whilst survey-based navigation – i.e. that requiring allocentric (topographical), flexible representations of the layout of the environment appears to be impaired (Lind et al., 2013).

An egocentric representation of the environment involves perceptual impressions gathered from a first-person perspective, whereas allocentric representation incorporates angular and metric relationships with a frame of reference on the environment itself and landmarks within it, for example from a topographical perspective (Klatzky, 1998). To calculate new routes and shortcuts one needs to process the spatial layout and temporal order of the environment to create a mental survey-based representation, or 'cognitive map' by generating an allocentric representation from egocentrically-acquired information about the environment (O'Keefe & Nadel, 1978; Siegel & White, 1975; Tolman, 1948). To test spatial navigation in ASD Lind et al. (2013) utilised a virtual island environment, whereby participants used a joystick to find their way to target locations on the island. They did so first in a visible phase where the target locations were marked with flags, before completing the task again when the flag markers were no longer visible. Successful navigation in the latter nonvisible trials thus necessitated a survey-based, allocentric navigation strategy requiring the generation of a cognitive map of the environment to represent the spatial relationships of the landmarks to one another (see Mellet et al., 2000; Shelton & Gabrieli, 2002). The finding that individuals with ASD were impaired only on the survey-based navigation phase indicates a specific difficulty in generating a topographical, survey-based map from a ground-based perspective, which is likely to cause uncertainty regarding location and diminished ability to assess viable alternatives and flexibly adapt the route. Indeed, Lind and colleagues suggest this might go some way in explaining the high levels of anxiety that ASD individuals often experience if they are required to take a new or different route (Lind et al., 2013).

The route-based style of navigation reportedly favoured by individuals with ASD can be performed inflexibly using on-the-ground-based procedurally memorized sequences of turns or stimulus-response associations (for example in a corridor maze paradigm, Caron et al., 2004), without forming a topographical cognitive representation or *mental map*. Mental maps are important, however, if navigation is to be flexible, for example to compute a novel route when the old route is blocked. As a potential remedy, Lind et al. (2013) have suggested that training strategies that utilise external maps might be effective in supporting individuals with ASD to consider their journey from a topographical, survey-based perspective. For such strategies to be transferable and effective in everyday life, it is important to understand the ability of individuals with ASD to mentally generate and manipulate a map-based image when external aids and cues are no longer available.

One way to examine the formation of mental maps is via mental imagery. Visual mental imagery or "seeing with the mind's eye" is when we "see" an event, an object or a scene in our mind in the absence of immediate sensory input (Kosslyn, 2006). Mental imagery is important for thought processes in everyday life; it allows us to plan for future events by visualising what would happen in an actual physical situation (Shepard & Cooper, 1982). Mental image scanning – when we systematically shift our attention over an object or scene in the mental image (see Denis & Kosslyn, 1999) – is a particularly important aspect of this with relevance to navigation. For example, in order to plan a different route home from usual you might generate a mental map and mentally shift your attention along a particular path to see if it links up to the location that you wish to get to. Simulating these sorts of scenarios allows one to be more prepared; and an impaired ability to generate and scan a mental image means that unfamiliar journeys are associated with a degree of uncertainty and inflexibility.

Little is known of ASD ability to simulate navigation from a topographical, map-based perspective. Research to date indicates that individuals with ASD are unimpaired on tasks where route- or ground-based navigation strategies are required (Caron et al., 2004) but that they show impairments when successful performance requires survey-based strategies, i.e., generating a topographical representation from an initial egocentric route-based perspective (Lind et al., 2013). It is unclear, however, whether this difficulty is solely the result of an impaired ability to *construct* a scene (e.g., Lind, Williams, Bowler, & Peel, 2014) topographically from a ground- or route-based perspective, or if difficulties also lie in the generation and simulation of a previously seen map in mental imagery *per se*. If ASD mental image scanning abilities *per se* are unimpaired then this has positive implications for the development of training interventions that utilise external representational aids such as maps in order to foster survey-based navigational strategies in ASD. If, however, individuals with ASD have difficulty generating and scanning a mental topographical map in the first instance, the development of more concrete navigational support tools for use by people with ASD may be required.

The 'island task' (Kosslyn, Ball, & Reiser, 1978) is a mental image scanning paradigm whereby participants study an island map with several landmarks, before mentally scanning their mental image of the map from one landmark to another (e.g., tree to lake) in the absence of any visual input. The time that participants take to mentally scan across the island increases linearly with the distance to be scanned in real space, a finding that has been replicated using different stimuli such as faces and geometric shapes (Beech, 1979; Kosslyn et al., 1978; Pinker & Kosslyn, 1978). Thus, participants preserve spatial properties (i.e., distance) in their mental images. The current interesting question is whether this is also the case in adults with ASD. If they preserve spatial properties of a map then this would suggest that their ability to generate mental maps from a topographical perspective as such is unimpaired and therefore, maps could be used as training tools aiding survey-based navigation. The island scanning paradigm provides a useful test of topographical representational ability as it removes the demand of switching between ground-perspective and topographical representations (e.g., Lind et al., 2013).

An additional question is how information on a map (i.e., on distance) affects its representation. Bottom-up processing refers to stimulus-driven processing of physical properties, whereas top-down processing is driven by goals and intentions. In typical individuals it has been shown that mental scanning is affected by top-down processing (e.g., Mitchell & Richman, 1980; Richman, Mitchell, & Reznick, 1979; Pylyshyn, 1981, 2003). For example, in an adaptation of the island task, if one distance is labelled on a signpost as being longer than another (e.g., 80 versus 20 miles), participants will take longer to scan it in their mental imagery, even though the two distances are actually the same length (Richman et al., 1979). This finding suggests that our mental scanning of a map is influenced by top-down conceptual information on distance. A yet unanswered question is whether this is also the case for adults with ASD. Thus, in addition to important practical implications in the context of map reading and navigation, examining mental imagery scanning in ASD using Richman et al's island scanning paradigm can add to our understanding of the effect of top-down information on map representation in adults with ASD. A top-down processing style indicates more goal-driven processing but at the expense of diminished sensitivity and flexibility to details in the visual environment, whereas a bottom-up processing style equates to more accurate processing of the visually perceived stimulus but at the expense of utilising top-down guidance when stimuli that are irrelevant to the environment are present.

Two contrasting predictions can be made regarding the penetrability of mental imagery to top-down information in ASD. On the one hand, evidence that people with ASD use more visual rather than verbal styles of processing (e.g., Kana, Keller, Cherkassky, Minshew, & Just, 2006) and rely more on bottom-up styles of processing (Mottron, Dawson, Soulieres, Hubert, & Burack, 2006) suggests they may also be less susceptible to top-down information such as signpost distance information in their mental imagery. In support of this contention, some studies have reported that people with ASD are less susceptible to visual illusions (e.g., Bölte, Holtmann, Poustka, Scheurich, & Schmidt, 2007; Happe´, 1996) and that they show reduced interference of top-down information or prior knowledge on processing a stimulus or scene (e.g., Loth, Gomez, & Happé, 2008; Mottron & Belleville, 1995; Mottron, Belleville, & Ménard, 1999; Wang, Mottron, Peng, Berthiaume, & Dawson, 2007). Alternatively, ASD scanning times may be affected by signpost distance information since not all studies have reported reduced influence of top-down information in ASD. There is evidence that individuals with ASD integrate information in its visual context (Ropar & Mitchell, 2001a,) and that they can show typical top-down modulation in the visual perception of objects (Loth, Gómez, & Happé 2010). Moreover, people with ASD are as susceptible to schema-related eyewitness misinformation as people without the disorder (Maras & Bowler, 2011), and not all studies have reported diminished susceptibility to visual illusions (Ropar & Mitchell, 1999, 2001b; Wimmer & Doherty, 2010). It remains to be tested, however, whether the scanning of a mental map is penetrable to top-down information in ASD.

To summarise, the aim of the present study was to examine the abilities of individuals with ASD to recreate and scan a previously seen map in mental imagery using an adaptation of Richman et al's (1979) island task. To examine this we used a novel perspective borrowing from the mental imagery literature: the linearity of participants' time-distance scanning slope. If participants are accurately depicting the previously viewed map in mental imagery then they should show a significant time-distance linear relationship when they scan this mental image. This would suggest that the survey-based navigation difficulties previously observed in the disorder (Lind et al., 2013) are not related to the ability to generate and scan a mental map *per se*, but rather the generation from different, route-based perspective. If, on the other hand, participants with ASD show impaired mental image scanning this would indicate the problem also extends to generating and simulating a (previously seen) map in itself. The study also aimed to examine whether ASD mental imagery scanning is influenced by top-down information. Research to date has reported mixed findings regarding top-down modulation in perception, attention and memory in ASD; by examining susceptibility to top-down misinformation in mental imagery the present study aimed to shed further light on this issue in the context of goal-driven processing of navigational information. Finally, since previous work indicates that people with ASD often show a different association of IQ with task performance from typical individuals (e.g., Happé, 1995; Lind & Bowler, 2009; Loth, Gomez, & Happé, 2011; Soulières et al., 2011; Williams, Jarrold, Grainger, & Lind, 2014), the present study explored whether subtests of the WAIS (Wechsler, 1997) were similarly associated with mental image scanning for both ASD and typical comparison participants.

2. Method

2.1. Participants

Twenty-one participants with ASD (18 males and 3 females) who were formally diagnosed by qualified clinicians were recruited predominantly in London and the South East of the UK from autism support groups and societies, and from word of mouth. All ASD participants were diagnosed by experienced clinicians with local health authorities according to DSM-IV (American Psychiatric Association, 2000) criteria for Autistic Disorder or Asperger Disorder and diagnoses were confirmed for all participants by assessment with the Autism Diagnostic Observation Schedule (ADOS; Lord, Rutter, DiLavore, & Risi, 1999).

Twenty comparison participants were recruited through local newspaper advertisements and comprised 17 males and 3 females. They had no known psychiatric, developmental or neurological disorders. Groups did not significantly differ on age, VIQ, PIQ or FIQ as measured by the WAIS-R or WAIS-III UK (Wechsler, 1997) or age (all ts < 1.22, ps > .23). Table 1 summarises these data. Participants also completed the Autism Spectrum Quotient (AQ, Baron-Cohen, Wheelwright, Skinner, Martin, & Clubley, 2001). None of the comparison participants exceeded the minimum cut off score for ASD of 32 (M = 16, Range = 4-25), and as expected the ASD group scored significantly higher (M = 34, Range = 20-45) than the comparison group on this measure, t (38) = 8.23, p < .001, Cohen's d = 2.60. Participants provided their informed consent and ethical approval for the study was obtained from the Research Ethics Committees at City University London and Plymouth University.

INSERT TABLE 1

2.2. Materials and procedure

Following Kosslyn et al. (1978) and Richman et al. (1979), a map of a fictitious island was constructed on a standard 17.3 inch laptop screen and contained a Lighthouse, Volcano, Hut, Pond and Tree (Appendix A). There were also two signposts, pointing between the Lighthouse-Volcano and the Hut-Volcano (both of which were equal distances), one signpost indicated 20 miles and the other 80 miles. The positions of the signposts were counterbalanced between the two pairs of landmarks between participants.

Participants were tested individually. They were introduced to a 'Percy the Pirate Parrot' character, which they first watched walking across a map of a fictitious park on the laptop screen. They were told that Percy always walked in this way, in a straight line and at the same speed. Participants carried out three practice trials, whereby they were asked to close their eyes and, on the experimenter's 'Start' command, imagine Percy walking between specified landmarks in the park, and to say 'Stop' when he had arrived at the second landmark. After each imagery attempt they then watched Percy walking between said landmarks on the screen, with the instruction to compare this to how they imagined him walking.

Participants were then presented with the island map for 45 seconds. They were instructed to name everything on the island and memorise it as best they could. After 45 seconds the landmarks disappeared to leave an empty island. To ensure that participants had encoded the landmarks positions properly, using the computer mouse they dragged and dropped each landmark (including the two signposts) that appeared in the corner of the screen in turn into its correct position on the island. Once the participant placed the landmark within a 30 pixel radius of its correct location it locked into its original place. The island then disappeared, and participants were instructed to close their eyes and imagine the island, and imagine Percy standing at the Lighthouse. Participants then imagined Percy walking to various landmarks on the island in the following order (actual distances between each landmarks are denoted in parentheses): Lighthouse-Tree (262mm), Lighthouse-Volcano (81mm), Lighthouse-Pond (154mm), Lighthouse-Hut (70mm), Hut-Lighthouse (70mm), Hut-Pond (100mm), Hut-Volcano (81mm), Hut-Tree (260mm). The time taken by participants to mentally scan between each of the landmark pairs was recorded by the computer. Finally, participants completed 'perception control' trials, where this process was repeated, but with the island visible on the screen. Participants were instructed to follow with their eyes the track between the landmarks to imagine Percy walking between them.

3. Results

3.1. Mental imagery scanning times over different distances

To control for any effects of the signposts on the time-distance linear relationship, the two distances (both 81mm) which had a signpost between each of them were excluded from analyses. A 2 (Group) x 6 (Distance) mixed ANOVA revealed no difference between groups in mean scanning times F (1, 38) = .01, p =.91, ηp^2 <.001: ASD and comparison participants took the same length of time to mentally scan between different landmarks on their mental image of the island. There was a main effect of distance, F (3, 99) = 36.37, p <.001, ηp^2 =.49, whereby scanning times increased as a function of distance on the map. A lack of Group x Distance interaction, F (3, 99) = 1.05, p =.39, ηp^2 = .03, however, indicates that both groups showed a similar effect of distance on their scanning times (Figure 1).

To examine whether both groups showed a linear increase in scanning times with increasing distance, we calculated the best-fitting linear function by the method-of-least-squares within each group separately. As can be seen in Figure 1, scanning times increased linearly with increasing distance for both ASD, R^2 = .13, F (1, 124) = 17.93, p < .001, and comparison groups, R^2 = .13, F (1, 119) = 17.46, p < .001. Further, scanning times and distance were positively correlated for both groups (*r*s > .35, all *p*s < .001).

To examine the similarity of the time-distance-scanning relationship between ASD and comparison groups, we calculated the steepness of the slopes of the best fitting lines (i.e., scanning rates) for each participant, and then compared group means using a *t* test. The mean slopes did not significantly differ between ASD and comparison groups, t (39) = .36, p < .72, Cohen's d = .11. ASD participants' slopes (B = 40.80 ms/mm) were just as steep as comparison participants' (B = 37.73 ms/mm).

We carried out similar analyses on participants' scanning performance on perception control trials and found a similar pattern of findings to imagery trials. Again, a 2 (Group) x 6 (Distance) mixed ANOVA revealed no difference between groups in mean scanning times F (1, 39) = .98, p =.33, ηp^2 <.03): ASD and comparison participants took the same length of time to visually scan between different landmarks on the island. There was again a main effect of distance, F (2, 70) = 49.29, p <.001, ηp^2 =.56, whereby scanning times increased as a function of distance on the map. A lack of Group x Distance interaction, F (2, 70) = 1.07, p

=.38, ηp^2 = .03 indicates that both groups showed a similar effect of distance on their visual scanning times. Both ASD, R^2 = .18, F (1, 124) = 27.35, p < .001, and comparison groups, R^2 = .19, F (1, 119) = 28.09, p < .0.001, also showed a significant time-distance linear relationship in their perception control scanning trials. Further, comparison of slopes did not reveal a difference between groups, t (39) = .99, p = .33, Cohen's d = .27.

INSERT FIGURE 1

3.2. IQ and working memory correlations with scanning performance

In order to examine whether IQ was associated with the mental image scanning time-distance effect we ran separate Pearson's correlations within ASD and comparison groups. For the ASD group, steepness of slopes correlated with Verbal IQ (VIQ), r(19) = .45, p < .05, and Full-Scale IQ (FIQ), r(19) = .44, p < .05. Performance IQ (PIQ) was also associated with the time-distance scanning slopes, although the relationship just failed to reach conventional levels of statistical significance, r(19) = .41, p = .066. Comparison participants showed a different pattern of results, with no significant correlations between VIQ, PIQ or FIQ and slopes (all rs < .03, ps > .91). We also examined the association between participants' verbal working memory index scores taken from the digit span and arithmetic subtests of the WAIS and their scanning slopes. Steepness of slopes correlated with verbal working memory for the ASD group, r(18) = .49, p <.05, but not the comparison group, r(20) = .02, p =.93. Verbal working memory index scores did not differ between groups, t(36) = 1.94, p =.31.

3.3. Effect of signposts on scanning times

Finally, we examined the effect of the two signposts on scanning times. A 2 (Sign: 20 vs. 80 miles) x 2 (Group) mixed ANOVA revealed a main effect of Sign, F (1, 39) = 6.77, p < .01, ηp^2 = .15. Participants showed longer scanning times for the 80 miles sign M = 10810, SD = 6801) compared to the 20 miles sign (M = 9252ms, SD = 5904). There was not a main effect of Group, F (1, 39) = .001, p = .97, ηp^2 < .001, nor was there a Sign x Group interaction, F (1, 39) = .03, p = .86, ηp^2 = .001. Thus, both ASD and comparison groups' scanning times were similarly affected by the misleading signpost information.

4. Discussion

The aim of the present study was to examine mental imagery scanning in ASD in the context of generating and mentally scanning a previously seen map. Limited work to date has examined mental imagery abilities in ASD, and none has examined the nature of these abilities in mental image scanning, yet this is pertinent for shedding new light on the rigid navigational strategies often reported in the disorder (e.g., Lind et al., 2013). Although visual-spatial abilities are largely reported to be intact or even enhanced in ASD (Falter, Plaisted, & Davis, 2008; Soulières et al., 2011, and see Mitchell & Ropar, 2004) a key question was whether this is also the case for visuo-spatial mental imagery scanning. Overall, we found a very similar pattern of performance between ASD and comparison participants: The ASD group showed a similar time-distance scanning relationship and were just as susceptible to top-down signpost information.

The finding that the ASD group showed the typical time-distance scanning relationship suggests that they are unimpaired in generating and scanning a mental map. This finding is in line with a large body of work demonstrating intact or even superior visual-spatial abilities in ASD (e.g., Caron et al., 2004; Falter et al., 2008; Mitchell & Ropar, 2004; Ozonoff, Pennington, & Rogers, 1991; Shah & Frith, 1993; Soulières et al., 2011). Indeed, previous work by Caron et al. (2004) has reported preserved spatial abilities in ASD in route mapping, route map reversal and survey mapping. The present linear time-distance scanning effect adds to this by showing that individuals with ASD preserve the spatial layout in their mental images when their task is to generate and scan a map from a previously seen topographical perspective. This finding supports the notion recently proposed by Lind et al. (2014) that ASD difficulties lie specifically with 'scene construction' – that is, mentally generating and maintaining a coherent, multimodal spatial representation involving the integration and binding together of multiple elements of an imagined scene (Hassabis & Maguire, 2007) rather than the generation of map *per se*.

A limitation of the present study is that the task used did not also test survey-based generation of map from an egocentric to allocentric perspective; the map was always presented topographically so participants were not required to generate their own based on an initially route-based perspective. According to Lind et al. (2014) novel scene construction is particularly problematic for individuals with ASD, and future research would be valuable in exploring support for tasks that require the generation of maps from a novel (previously unseen) perspective. The present findings do however indicate that the ability to mentally generate and scan a previously viewed map is unimpaired in ASD. This finding suggests that maps may be useful as a training tool fostering flexible navigation-strategies.

The ASD participants' similar susceptibility to the signpost information (80 versus 20 miles) adds to the mixed pattern of findings to date regarding the influence of top-down information in the disorder. This finding furthers the notion that ASD is not exclusively associated with a specific bias towards bottom-up processing at the expense of top-down influence (e.g., Loth et al., 2010; Maras & Bowler, 2011; Mitchell & Ropar, 2004; Ropar & Mitchell, 2001a; Wimmer & Doherty, 2010). Moreover, previous work indicates that representational deficits in ASD do not extend to non-social tasks that do not require an understanding of others' mental states, such as pictorial representation (Leekam & Perner, 1991; Leslie & Thaiss, 1992; Wimmer & Doherty, 2010). Current findings add that adults with ASD are susceptible to top-down information in map representation, indicating a goal-driven processing style similar to the typical population. This indicates the potentially usefulness of maps as training tools with conceptual information such as indicative distance between two landmarks to further facilitate flexible navigation in ASD.

An unanticipated finding was that the ASD group showed a very different pattern from the comparison group in terms of IQ correlations with scanning performance. IQ, and particularly verbal IQ, predicted the time-distance scanning relationship for the ASD group, whereas there was no such association between IQ and scanning performance for comparison participants. This finding is consistent with previous work reporting different patterns of IQ correlations with task performance in ASD (e.g., Happé, 1995; Lind & Bowler, 2009; Loth et al., 2011; Soulières et al., 2011). Moreover we found that verbal working memory also correlated with scanning performance for ASD but not comparison participants. In order to achieve the linear time-distance scanning relationship when mentally scanning a previously seen image, it seems that ASD participants were relying heavily on verbal strategies and working memory to hold the image in mind whilst mentally scanning between locations. Although we found no difference between ASD and comparison participants in verbal working memory as measured by the digit span and arithmetic subtests of the WAIS, people with ASD are widely reported to have specific spatial working memory difficulties (e.g., Steele, Minshew, Luna, & Sweeney, 2007; Williams, Goldstein, Carpenter, & Minshew, 2005). Moreover, Williams et al. (2014) recently showed that whereas visual working memory was associated with event-based prospective memory in comparison participants, verbal working memory was associated with prospective memory for ASD participants. Williams et al's findings suggest that aspects of working memory that depend on the storage of visual information may be impaired in ASD, which might explain the apparent reliance on verbal strategies in our ASD sample. In terms of ASD navigational strategies the present findings indicate that, although individuals with ASD are able to generate a previously seen map, their ability to mentally scan their image may be more reliant on verbal strategies and working memory capacity. Taken alongside Williams et al. (2014) this suggests that the provision of support for learning navigational strategies in ASD needs to take into account demands on verbal IQ and working memory.

4.1. Conclusion

To conclude, findings from the present study indicate that individuals with ASD, notwithstanding working memory impairments, can achieve similar mental image scanning task performance to people without ASD. This has positive implications for the development of training interventions that utilise external representational aids such as maps in order to foster survey-based navigational strategies in ASD. The different patterns of IQ and working memory correlations with task performance in ASD furthers the notion that individuals with the disorder may go through rather different underlying cognitive processes when performing cognitive tasks (e.g., Barbeau, Soulières, Dawson, Zeffiro, & Mottron, 2013). Specifically, ASD participants in the present study appeared to rely more on verbal strategies and working memory to scan their mental images. This indicates that minimising demands on working memory may be particularly beneficial when developing appropriate support for ASD navigational deficits where mental image representations of the layout of the environment are required (e.g., Lind et al., 2013). Future work should extend the present findings to mental image scanning of a previously *unseen* topographical map generated from a different perspective.

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Table 1.

Mean age and IQ data for ASD and comparison participants (standard deviations in parentheses)

	ASD (N = 21)	**Comparison (N= 20)**
Age (years)	40.19 (10.39)	44.45 (11.90)
AQ[a]	33.5	16.20
	(Range: 20-45)	(Range = 4-25)
VIQ[b]	105.05 (16.50)	108.20 (12.24)
PIQ[c]	101.43 (16.87)	104.50 (12.25)
FIQ[d]	103.29 (17.73)	106.95 (12.19)

a Autism Spectrum Quotient (Baron-Cohen et al., 2001); b Verbal IQ; c Performance IQ; d Full-scale IQ (WAIS-R UK or WAIS-III UK)

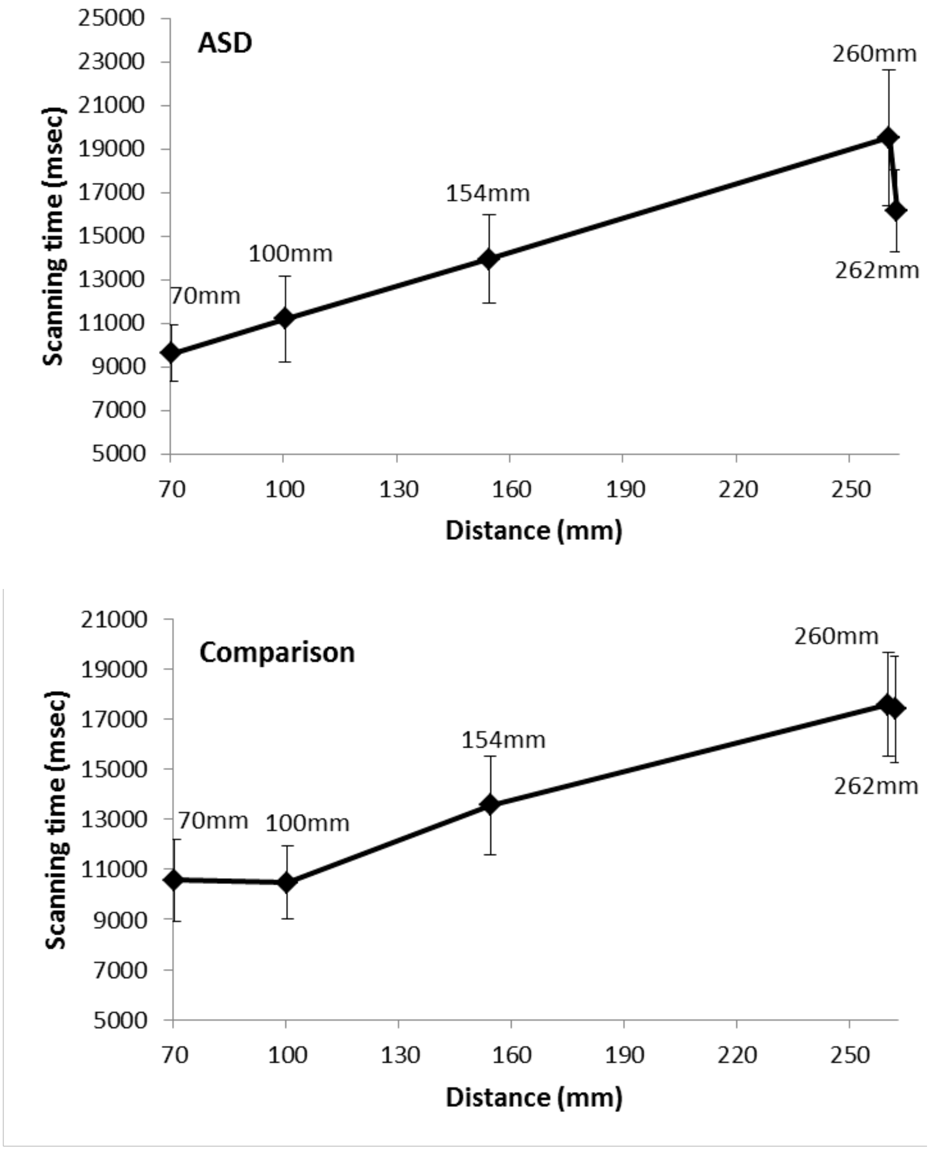

Figure 1

Time taken to scan the different distances by ASD and comparison groups

Appemdix A

Island map with landmarks and signposts