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Mental imagery scanning in autism spectrum disorder

Katie L. Maras [a,*], Marina C. Wimmer [b], Elizabeth J. Robinson [c], Dermot M. Bowler [d]

[a] University of Bath, United Kingdom
[b] Plymouth University, United Kingdom
[c] University of Warwick, United Kingdom
[d] City University London, United Kingdom

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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.

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

* Corresponding author. Tel.: +44 01225 383137.
E-mail address: k.l.maras@bath.ac.uk (K.L. Maras).

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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 memorised 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;