Spatial Navigation in Autism Spectrum Disorders

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ABSTRACT

Autism Spectrum Disorder (ASD) is a complex pervasive developmental disorder that is characterized by core impairments in social, communication and imaginative functioning. The neuropsychology of ASD is a field that features lively debate; for instance, the question of whether autistic children have impaired, intact, or superior spatial cognitive abilities remains unanswered due to inconsistent findings from several recent empirical studies. This study used a comprehensive battery of neuropsychological tests to assess general spatial ability and spatial cognition (including spatial navigation) in 10 low-functioning autistic (LFA) children, 10 high-functioning autistic (HFA) children, and 10 age- and sex-matched typically developing (TD) children. Results showed that, for the most part HFA participants performed similarly to TD children on tests of spatial navigation and cognition. These data suggest that, contrary to theories of weak central coherence, ASD individuals have intact but not superior spatial cognitive abilities.

Keywords: autism spectrum disorder; spatial cognition; low-functioning ASD; high-functioning ASD; allocentric; egocentric.

BACKGROUND

Autism is a complex and diverse biological disorder that is defined by various behavioural symptoms and deficits that affects the development of an individual. It is "one of several pervasive developmental disorders (PDD's) that are caused by a dysfunction of the central nervous system leading to disordered development" (Kabot, Masi, & Segal, 2003, p. 26). According to the Diagnostic and Statistical Manual of Mental Disorders (Fourth Edition, Text Revision; DSM-IV-TR; American Psychiatric Association, 2000), autism is characterised by three core deficits: in social interaction, communication and imagination. There are various other characteristics of autism spectrum disorder (ASD) aside from the core deficits, such as restricted repetitive behaviour (see Appendix A for the full DSM-IV-TR diagnostic criteria). In order for a positive diagnosis to be made, the three core impairments of ASD must be present before an individual is 3 years old; however, diagnoses are often only made at a later stage.

A certain set of behaviours or symptoms can be used to describe autistic individuals; these behaviours can range from mild to severe. All these symptoms "fit into the overall diagnosis of ASD". Aside from the core deficits, all the symptoms or only a select few, may or may not be present in each individual (National Institute of Mental Health (NIMH), 2007, p. 4). Therefore the various symptoms may be present in different combinations in each ASD individual (Kabot et al., 2003).

The symptoms of autism may be either positive or negative. Negative symptoms are impairments in specific domains of social and communicative functioning. Examples are; failing to form a relationship with a peer that is suitable to their developmental level or lacking spontaneous, make believe, imaginative playing. Positive symptoms are characteristics that an autistic individual may posses that a typically developing individual may not. Such symptoms include the restricted repetitive behaviours and interest or a fixed interest in specific parts of objects (Bonnel et al., 2003).

Autism is viewed a spectrum disorder due to the fact that there are a variety of behaviours and symptoms associated within the disorder and each individual can have varying levels of intelligence and language ability (Hill & Frith, 2003). Low-functioning autistic individuals (LFA) usually have IQ scores of either 70 or below and are often likely to display mentally retarded qualities. In the autistic population, 70 % of autistic individuals have been reported to have an IQ of below 70 (Brosnan, Scott, Fox, & Pye, 2004). High-functioning autistic individuals (HFA) usually have an IQ score of higher than 80. High-

functioning autistic individuals have higher adaptive functioning than other low-functioning autistic individuals. Therefore low-functioning and high-functioning autism both form part of the autism spectrum disorders.

As can be seen from the above, it is hard to distinguish each separate group within the spectrum of autistic disorders. Various studies may only make use of low functioning autistic individuals or high functioning autistic individuals. In particular, behavioural studies usually only use high-functioning individuals due to their better adaptive functioning and because individuals with severe mental dysfunction (i.e., LFA) often have a "limited repertoire and range of observable behaviour" (Hill & Frith, 2003, p. 282). A problem occurs when trying to link behavioural impairment in ASD with the brain as both types of studies involve either high- or low-functioning autistic individuals yet often not both. Therefore it is hard to try and generalise findings from behavioural studies to low functioning autistic individuals.

Neuropsychological Theories of ASD

A variety of theories are used to explain social, communication and imagination problems in ASD. These theories try to bridge the gap between the brain and behaviour as they try to give explanations as to the complex behavioural patterns that are present in autism disorders (Happe & Frith, 1996).

The Weak Central Coherence (WCC; Frith, 1989) theory is one dominant framework that attempts to explain and understand the neuropsychological profile in ASD. 'Central coherence' is the ability of a person to view and process information as a whole. Weak central coherence, then, refers to the fact that autistic individuals focus on specific stimuli; they process information from a detail-specific perspective, at a local rather than a global level (Brosnan et al., 2004).

Weak central coherence theory predicts that on specific tasks that require breaking down of a whole structure and focusing on detailed, individual parts of the structure, autistic individuals will have intact and sometimes an even better performance than typically developing children of the same age. Data collected from tests that require local-level focus, such as the Children's Embedded Figures test (CEFT) and the Wechsler Block Design test, have shown that ASD individuals have intact, and even superior local-level processing (Baron-Cohen, 2004; Edgin & Pennington, 2005). Yet, this is an area of question as some studies have shown that autistic individuals do not perform better on these tasks than typically developing individuals (Burnette, Mundy, Meyer, Sutton, Vaughan, & Charak, 2005). In contrast, WCC also predicts that ASD individuals should have inferior or even

impaired performance on tasks that require a global-level focus. For example, autistic individuals are less susceptible to visual illusions, which suggest that they do not view the visual object from a global-level and are not affected by the broader context of the vision (Frith, 1997). Therefore there are inconsistent findings about the ability of an autistic individual's performance on both types of tasks, and is an area that needs to be explored further.

When navigating the environment, an individual can use both a local- and a global-level perspective. Certain spatial tasks require a local-level focus where as others, such as the navigating of novel environments; require a more global-level focus. Previous studies of spatial abilities in autism have shown that autistic individuals have superior abilities in undertaking those spatial tasks that require local-level focusing. This superior cognitive ability of autistic individuals in certain tasks is labelled as "islets of ability" (Ring, Baron-Cohen, Wheelright, Williams, Brammer, et al., 1999). The opposing prediction of WCC about autistic individuals' inferior performance on tasks involving global processing predicts that autistic individuals should perform poorly on spatial tasks involving global-level processing. Wainwright and Bryson (1996) provided evidence in support of this prediction, showing that autistic individuals have difficulty in processing spatial information on a global-level and often only responded to a small part of an overall picture.

A set of recent studies has, however, disconfirmed both directions of prediction made by WCC theory. Specifically, these studies suggest that autistic individuals do have intact, but not have superior abilities, on spatial tasks (Caron, Mottron, Rainville, & Chouinard, 2003; Edgin & Pennington, 2005). Because spatial navigation is both the culmination of a series of lower-level spatial processing abilities and an evolutionarily significant cognitive ability (O'Keefe and Nadel, 1978), the way in which autistic individuals navigate an environment is an area of ongoing debate within this field.

Spatial Navigation

The knowledge of where an object is in order to make use it or to avoid it is important for every human being (Newcombe, Huttenlocher, Drummey, & Wiley, 1998). Spatial navigation is based around this knowledge. Individuals navigate environments through the use of their perceptions, maps or language. Through their own viewing and moving around environments, individuals collect information about the environment, which, once encoded, creates a mental representation of the environment (Avraamides, Loomis, Klatzky, & Golledge, 2004). The information collected is about the relations individuals have with the

objects within the environment (Mou, McNamara, Valiquette, & Rump, 2004). The mental representation of the environment is a cognitive map, a guide that each individual makes use of when navigating a spatial environment. Cognitive mapping is the "process by which an individual acquires, codes, stores, recalls and decodes information about the relative locations and attributes of the spatial environment" (Caron et al., 2003, p. 468). Therefore there are various ways that information can be encoded to create a cognitive map, reference system, for navigating the environment.

Individuals use a variety of reference systems when processing spatial information (Wang, Johnson, Sun, & Zhang, 2005). Objects and locations become associated with the various reference systems and these systems enable a person to navigate novel environments. Allocentric and egocentric frames of reference are the two most common types of reference or coding strategies a person may use when navigating novel environments. Individuals may choose, depending on the context, which frame of reference to use for each different task (Wang et al., 2005). Allocentric referencing is a viewer-referenced perspective, which is the viewing of an object in relation to external landmarks and other external objects and therefore is independent of the relation between the self and other people. By using landmarks as a reference system, allocentric way finding allows individuals to identify locations from any starting point (Pentland, Anderson, Dye, & Wood, 2003). Egocentric referencing, on the other hand, is an externally referenced perspective, which is the viewing of an object in relation to the self (Frith & Vignemont, 2005; Newcombe et al., 1998). Therefore both allocentric and egocentric coding strategies allow an individual to both create an image of the environment as well as develop a certain type of knowledge about the environment.

Each individual has their own spatial knowledge acquired through applying the above coding strategies when trying to navigate environments (Thorndyke & Hayes-Roth, 1982). The two main types of knowledge that are a part of an individual's cognitive mapping ability are survey and route knowledge. Each type of knowledge has its own characteristics and both differ with regards to the type of tasks they are suited to and type of aspects they represent in an environment (Caron et al., 2003).

Survey knowledge is acquired through the use of allocentric coding strategies. This form of knowledge is from an external perspective that looks at the global layout of an environment. This type of knowledge looks at objects within the environment from a "general and fixed frame of reference" and does not locate objects through learned routes (Caron et al., 2003, p. 468). Survey knowledge helps in trying to find novel routes in an already known environment (McNamara & Shelton, 2003).

Route knowledge, on the other hand, is acquired through egocentric coding strategies. This form of knowledge refers to the layout of an environment from the perspective of the individual. Route knowledge is acquired through actually navigating through an environment and not just observing the general global layout. Individuals who use route knowledge usually follow a sequence of actions, a learned response to a route used when navigating an environment (Caron et al., 2003). Therefore route knowledge is applied when a route has been remembered and learnt, whereas survey knowledge provides individuals a general outline of an environment. Therefore the type of knowledge acquired by an individual depends on the type of coding strategy used when processing information.

There are various studies that have been done in which tests performed have shown that the hippocampus is linked to the use of allocentric spatial memory. The cognitive mapping theory proposes that the hippocampus plays an important role in developing representations of a place or object within an environment in relation to external landmarks (allocentric coding strategy) and not in relation to the individual self (egocentric coding strategy). A study by Schumann et al. (2004) found that high-functioning and low-functioning autistic individuals have a larger right and left hippocampus compared to typically developing individuals. Other studies, such as the study by Abrahams, Morris, Polkey, Jarosz, Cox, Graves et al., (1999), have shown a link between the right hippocampus and spatial memory, specifically examining how patients with right hippocampus damage perform poorly on spatial memory tests. A large number of scientists have supported the theory that proposes the hippocampus to play a role in the spatial processing and spatial memory (Abrahams, Pickering, Polkey, & Morris, 1997). According to Holdstock et al. (2000) studies that link the hippocampus to allocentric spatial memory is only limited evidence, because majority of the studies have not included egocentric spatial memory tasks to use as a comparison to test whether the hippocampus has a role in egocentric spatial memory. Therefore various studies have shown the link between allocentric spatial memory and the hippocampus yet further research is needed to establish whether there is a link between egocentric spatial memory and the hippocampus.

Previous Studies of Spatial Navigation in ASD

There are many inconsistent findings with regard to spatial navigation and autism. One of the main questions asked in spatial research in autism, based on the predictions of the WCC, is how the spatial abilities of autistic individuals compare, both longitudinally and cross-sectionally, to those of typically developing individuals. Edgin and Pennington (2005)

showed, for instance, that high-functioning autistic individuals have intact, but not superior, general spatial abilities compared to typically developing controls. They also showed that autistic individuals do not develop their spatial skills any faster than typically developing controls. More research is needed, however, to better understand the spatial abilities of autistic individuals, particularly on spatial navigation tasks.

How individuals perform on certain spatial tasks, such as tasks that measure an individual's spatial perception, visuoconstruction, planning, organising and visual memory, are important in spatial navigation research as individuals make use of the same abilities used in these tasks in spatial navigation tasks. Therefore the measures of these spatial abilities may provide information as to how an individual might perform on spatial navigation tasks.

Various studies that have used spatial tasks involving spatial perception, visuoconstruction, visual memory, have provided contradictory findings. As already seen, some studies have shown that ASD individuals have superior performance on certain tests such as the Children's Embedded Figures test and the Block Design test (Jarrold, Gilchrist, & Bender, 2005); other studies, however, suggest that ASD individuals perform poorly on a specific spatial memory test (Finger Windows) compared to a typically developing control group (Williams, Minshew, & Goldstein, 2006). These studies are examples of the inconsistency in the findings in autism research regarding the various spatial abilities of autistic individuals.

SPECIFIC AIMS

The current study aimed to produce further findings concerning spatial navigation in ASD. More specifically, the study was designed to achieve these three goals: (1) obtain data on the spatial ability of low-functioning autistic individuals, as there is a limited amount of information for that group as most previous studies have used high-functioning and AS individuals; (2) test whether autistic individuals have intact or even superior spatial abilities in comparison to typically developing individuals; and (3) better understand that type of strategies and reference systems autistic individuals use when navigating an environment.

DESIGN AND METHODOLOGY

Design

The study was a cross-sectional, quasi-experimental design as it observed subjects of different ages at the same time. I compared ASD participants with typically developing children on a variety of tests assessing different aspects of general spatial ability.

Participants

Thirty children, all between ages 6 and 16 years, were selected for the sample. One group of participants ($n = 10$) consisted of low-functioning autistic children. Following the diagnostic criteria of the DSM-IV-TR, the low-functioning autistic children had an IQ between 55 and 75 with social, behavioural and intellectual deficits. The second group ($n = 10$) consisted of high-functioning autistic children. The high-functioning autistic individuals had an IQ of higher than 75, with better adaptive functioning than low-functioning autistic individuals. All participants were volunteers recruited from schools that specialise in teaching autistic individuals from Cape Town and Johannesburg. Prior to being enrolled in the study, all of these participants were independently diagnosed as having autistic disorder, by the specialised schools, according to criteria found in the DSM-IV-TR (APA, 2000).

The third group ($n = 10$) consisted of typically developing (TD) children. All of these children were physically healthy, had not taken any psychoactive medications, and did not have a history of head injuries, psychiatric disorders, or neurological insult. These participants were recruited from local schools that were involved in existing research projects in our laboratory.

Across the three groups, participants were matched on sex (they were all male), age, and socio-economic status and home language (they were all English speaking). Participants were excluded if their home language was not English because all of the tests presented to the participants were in English. Patients with any sensory impairments or psychological or medical problems were also excluded. Basic demographic characteristics of participants in the three groups are presented in Table 1.

Ethical approval for the study procedures was granted by Research Ethics Committee of the University of Cape Town's Department of Psychology and the Research Ethics Committee of the University of Cape Town's Faculty of Health Sciences. Permission to recruit participants from public schools was granted by the Western Cape Education Department and the Gauteng Department of Education.

Table 1
Demographic Characteristics of the Sample

Variable	LFA (*n* = 10)	HFA (*n* = 10)	TD (*n* = 10)
Age	9.67 (2.86)	11.88 (3.06)	9.57 (1.96)
PIQ	65.90 (6.24)	84.30 (8.26)	99.88 (7.66)
Handedness			
(R:L:X)	8:1:1	9:0:1	7:3:0
Computer Use			
Never	2	1	0
Daily	2	5	3
Weekly	3	2	5
Monthly	2	1	1
Yearly	1	1	

Note. PIQ = WASI Performance IQ. For Age and PIQ, means are presented with standard deviations in parentheses. For handedness, R:L:X means ratio of right- to left- to cross-handedness.

General Measures

Parents/guardians of participants were asked to complete a demographic questionnaire. This questionnaire was designed to obtain information, such as the participant's age, sex, date of birth and other information about the participant's life that might be used as the basis for covariate data analyses. The *Edinburgh Handedness Inventory* (Oldfield, 1971) measured the participant's hand preference.

Participants were administered a test of general intellectual functioning and several tests of various spatial abilities. The set of tests, which includes both computer based and pencil-and-paper instruments, is presented in Table 1.

The *Wechsler Abbreviated Scale of Intelligence* (WASI; Psychological Corporation, 1999) is be used to test the participants intellectual functioning. It is a robust and standardised method of testing. There are four subsets to the WASI: Vocabulary, Similarities, Block Design and Matrix Reasoning. The Verbal IQ of participants is measured using Similarities and Vocabulary subsets and Performance IQ is measured using the Block Design and Matrix Reasoning subsets. The Block Design (BD) subset is a robust measure of general intelligence (Edgin & Pennington, 2005). The current proposed study only uses the tests that measure Performance IQ due to the poor language ability that is often present in autism spectrum disorders. As well as a correlated measure of Performance IQ, the BD subset is also used separately as a measure of visual and spatial abilities. Autistic individuals have been reported, in previous studies, to have superior abilities on the BD test (Caron et al., 2004). Other

studies, to the contrary, have shown that autistic individuals have intact but not superior abilities with regard to the block design.

Measures of General Spatial Ability

The *Rey-Osterrieth Complex Figure* (ROCF; Rey, 1941) is a standardized measure of visual memory, visuo-constructional ability, as well as organization and planning. This test has been used in various clinical research studies (Happe & Frith, 2006). The ROCF involves the copying of a two-dimensional image changing pencil colours every 30 seconds. Once the copy is made, the card is removed from the participant's view, and the participants are asked to redraw the image from memory after a 3 minute delay. After a 30-minute delay, the participants are again asked to redraw the image from memory.

There are various scoring systems of the ROCF. The scoring system used in this study is the Rey (1941) 36-point scoring system which measures how accurately the participants were able to copy and recall the figure. According to this scoring system, 18 details of the figure is used to score the participants drawings. The participants are awarded 2 points if the details of the figure are correctly drawn and placed; points are taken away for incomplete or incorrectly placed figures. The copying and recall of the figure tests the visuo-spatial construction and memory abilities of the participants. The WCC theory predicts that ASD individuals should have intact and possible superior abilities on tests requiring a detail specific perspective, showing that autistic individuals have visuo-construction and memory abilities. Therefore ASD individuals should have similar or even superior abilities on the copy and recall aspects of the test according to this scoring system.

The *Children's Embedded Figures Test* (*CEFT;* Witkin, Oltman, Raskin, & Karp, 1971) is used to test central coherence. The test involves finding a familiar object (usually a triangle) that has been embedded within a complex design. The participants are allowed to practice by observing simple shapes and then trying to identify the shapes within design. After the practice rounds, the participants are shown 25 complex designs one after the other, and are asked to give a description of the design. This task helps the participants encode the design themselves. The hidden object is then shown to the participants for 10 seconds. After they have seen the object they are shown the complex design and are asked to try and identify the simple object within the design. Once the object has been found by the participant the time is recorded (Jolliffe & Baron-Cohen, 1997). Participants make use of local-level processing when identifying an object within a complex figure making this test a good test of weak central coherence. Studies have shown that autistic individuals perform better than

typically developing individuals in tests that use local processing therefore making the CEFT a good test of weak central coherence in autistic individuals (Edgin & Pennington, 2005).

Measures of Allocentric Spatial Ability

The *Nine Box Maze Test Child Version* (*NBMT-CV*; Pentland et al., 2003) was created to ensure that certain aspects of the NBMT, such as the vocabulary, style and length, are changed to make the test suitable for children. This test is based on the cognitive mapping theory and is a test of allocentric spatial coding abilities of the right hippocampus. Therefore the test measures the ability of the participants to locate objects by relating them to other objects and not in relation to themselves. This test consists of three stages. The first stage is the Object Familiarisation stage, the second is the Five Box Maze and the last stage is the Nine Box Maze.

The Object Familiarisation stage involves showing 10 common objects to the participants while making sure each participant is aware of what the object is. The items were presented to the participants in a fixed order. After a 1 minute delay the participants are asked to recall as many objects as possible. One point is awarded if the participant was able to correctly recall the object. If any of the participants in the ASD group were non-verbal, they were asked to select which objects were shown to them from a card that contained pictures of the object shown as well as some pictures of objects that were not shown.

The Five Box Maze involves placing five containers in equal positions from each other in front of the participants. The participants are clearly shown that two of the objects are placed into two of the containers in front of them. The participant is then moved to a different position and asked to identify which objects have been hidden. If the participant answers correctly one point is awarded and they are asked to identity which locations have been used. If they are unable to identity which objects have been used, the participants were shown a booklet containing pictures of all the objects and asked to select which objects are hidden. If the child is still unable to identify the objects no points are awarded. The participant is then asked to identify which containers have been used. One point is awarded for correctly identifying the containers used. Lastly, the participants are asked to identify which objects were hidden in which containers. If the participants were able to complete this task they proceed to the Nine Box Maze. If there are unable to, two more trails are conducted using the same procedure. If they are still unable to complete the task, the participants are not asked to proceed any further.

The Nine Box Maze follows the same instructions as the Five Box Maze except that nine containers are used and four objects are hidden. Four trials are completed regardless of whether the objects and containers are recognised or whether a connection between the two is made. During each trial, two of the objects remain in the same location whereas the other two objects locations changed. At the end of all the stages, the participants are asked what type of strategies they used to help find the hidden objects (Pertini, 2004).

Measures of Spatial Navigation

The last spatial task is the *Computer-Generated Arena* (CG Arena; Jacobs et al., 1998), which is a test of general spatial ability. This task is an overall measure of spatial place learning and memory. The test is a virtual reality spatial navigation task. The CG Arena is an analogue of the Morris Water Maze, which has been used, in spatial learning studies involving animals. The first task is a set of trials allowing the participants examine the computer generated room and all the cues (pictures) available in order to locate a square platform on the floor. The representations of the distal cues presented in the room help the participants form a cognitive map of the CG Arena. The room consists of circular arena within a square room. The aim of the task is to locate the blue square platform within the room. The square platform is visible for the first few practice trials and then is removed for testing. In the practise trials the participants are required to locate the platform and move towards it. The participants need to remember where the platform is hidden as the test trials involve finding an invisible platform that is always in the same place within the arena. The platform becomes visible once the participant has located it (Thomas et al., 2001).
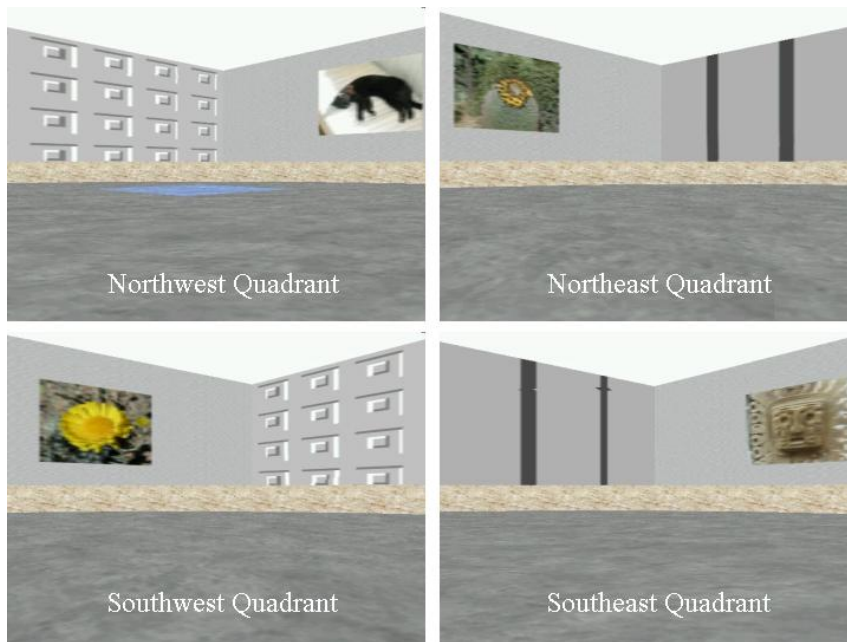
Figure 1. Four views from within the experimental room of the CG Arena. The target toward which participants had to navigate in the Visible Trials condition is represented as a blue square in the upper left panel of the figure.

Once the computer task is completed the participants are asked to complete the Object Recognition Task (ORT) and then the Arena Reconstitution task (ART). In the ORT the participants are asked to identify which pictures they remember being present in the CG Arena. A card containing all the pictures that were present on the Arena walls as well as various pictures that were not present in the Arena is shown to the participants. The researcher then records the number of correctly and incorrectly identified pictures.
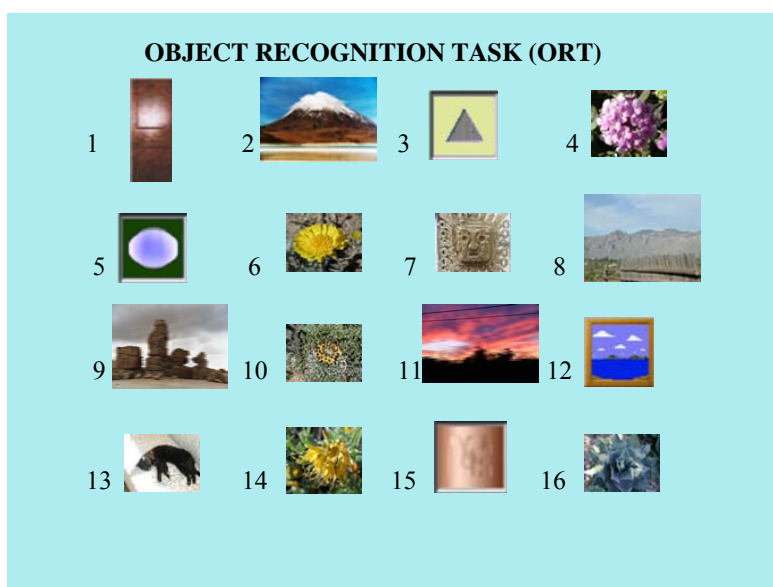
Figure 2. Object Recognition Task (ORT) stimulus sheet. Participants must decide whether each of the items shown on the sheet was present in the CG Arena experimental room.

In the ART the participants are given an image of a topographic view of the computer-generated room with no details or cues present. The participants are then given various icons, those representing the four walls as well as the images from the walls, and are asked to place the icons in the correct locations from memory. This involves the reconstructing of the layout of the arena. The participants are also asked to identify which of the four squares on the page is the location of the target. This measure tests the participant's cognitive map of the CG Arena (Thomas et al., 2001).
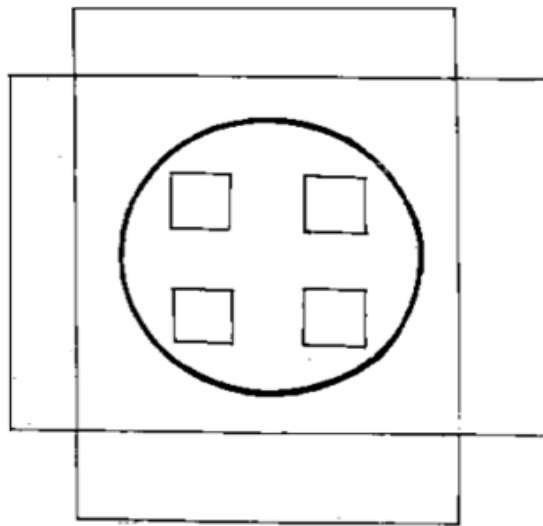
ARENA RECONSTITUTION TASK (ART)

Figure 3. Arena Reconstitution Task (ART) stimulus sheet.

Table 2
Tests Used in the Current Study

Test Name	Domain Tested	Autism Study in Which Test was Used
WASI	General intellectual functioning	Daniels (2006)
ROCF	Visual memory, visual spatial ability, visuoconstruction executive function	Schoolz et al. (2006)
CEFT	Weak central coherence, local processing vs. global processing	Jolliffe & Baron-Cohen (1997)
NBMT	Non-verbal spatial processing and orientation	Pentland et al. (2003)
CG Arena	Overall spatial place learning and navigation	Edgin & Pennington (2005)

   Note. WASI = Wechsler Abbreviated Scale of Intelligence; ROCF = Rey-Osterrieth Complex Figure; CEFT = Children's Embedded Figures Test; NBMT = Nine Box Maze Test; CG Arena = Computer-Generated Arena

Procedure

Before the testing began, written consent was obtained from the parent/guardian of each participant. Demographic questionnaires were also filled in by the parents or guardians before testing so as to ensure that all participants met the inclusion criteria. At the beginning of each test session, the participants signed an assent form. The tests listed above were completed over two sessions, with each session lasting no longer than 90 minutes. All the tests were administered according to conventional procedures outlined in the literature and in the various test manuals. Testing took place at the participant's school.

Data Analysis

Descriptive statistics from the study were analysed first. This stage of the analysis allowed for derivation of measures of central tendency and measures of variation. This analysis allowed me to describe the distribution of the various dependent variables (i.e., scores on the various cognitive tests), to detect the presence of outliers, and to determine whether the assumptions underlying subsequent inferential analyses are met.

The major inferential analyses involved between-group comparisons to assess the differences between the LFA, HFA and TD individuals on the various cognitive tests. Chi-squared analysis was done on the categorical data to determine group differences. No

analyses of covariance (ANCOVAs) were used because the groups were selected based on their PIQ scores, making the use of PIQ as a covariate confounding. An alpha level of $p = 0.05$ was used in all decisions regarding statistical significance.

RESULTS

All measures were analysed using ANOVA. For most of the measures all the assumptions underlying ANOVA were met; in those tests where Levene's test for homogeneity of variance was significant, all other assumptions were upheld and therefore the analysis proceeded using ANOVA.

Demographic and Intelligence Measures

One-way ANOVA was performed to determine if there were any between-group differences on demographic and intelligence variables. With regard to age, there were no statistically significant between-group differences, $F(2, 27) = 2.38$, $p = 0.111$. There was also no statistically significant association between group membership and frequency of computer use, $\chi^2(8, N = 30) = 5.30$, $p = 0.725$. With regard to intelligence, there were, as expected, statistically significant between-group differences, $F(2, 27) = 56.12$, $p = 0.001$.

Measures of General Spatial Ability

Table 3 shows the results of one-way ANOVAs comparing the performance of participants in the LFA, HFA, and TD groups on measures of general spatial ability (ROCF, CEFT, and Block Design). As can be seen, the omnibus F was large and highly statistically significant in each case, with at least 60% of the variance in performance explained by group membership.

Planned contrasts using Tukey's test (see Table 4) showed that participants in the LFA group performed statistically significantly more poorly than did participants in the HFA group and in the TD group. There were no statistically significant differences on these measures between participants in HFA and TD groups.

Table 3
Measures of General Spatial Ability: ANOVA results

Variable	M (SD)	df	F	p	η²
ROCF	17.73 (12.91)	2	12.17	< 0.001***	0.47
CEFT	12.65 (6.35)	2	16.07	< 0.001***	0.60
Block Design	41.00 (11.12)	2	20.31	< 0.001***	0.60

** $p < .01$, *** $p < .0001$

Table 4
Measures of General Spatial Ability: Tukey's post-hoc test results

Test / Comparison #	Group			
	LFA	HFA	TD	*p*
ROCF				
1	5.70 (6.44)	21.30 (11.89)	----	0.004
2	5.70 (6.44)	----	26.20 (9.98)	0.001
3	----	21.30 (11.89)	26.20 (9.98)	0.505
CEFT				
1	6.40 (4.53)	14.80 (5.69)	----	0.001
2	6.40 (4.53)	----	17.22 (1.92)	0.001
3	----	14.80 (5.69)	17.22 (1.92)	0.466
Block Design				
1	29.80 (4.24)	42.90 (10.31)	----	0.001
2	29.80 (4.24)	----	50.30 (5.91)	0.001
3	----	42.90 (10.31)	50.30 (5.91)	0.077

Measures of Allocentric Spatial Ability

Table 5 shows the results of one-way ANOVAs comparing the performance of participants in the LFA, HFA, and TD groups on the measure of NBMT Object Familiarity subtest and on the FBMT. As can be seen, in both cases the omnibus *F* was large and highly statistically significant, with at least 48% of the variance in performance explained by group membership.

Planned contrasts using Tukey's test (see Table 6) showed that participants in the LFA group performed statistically significantly more poorly than did participants in the HFA group and in the TD group. There were no statistically significant differences on these measures between participants in HFA and TD groups.

Most LFA participants did not progress beyond the FBMT and into the NBMT itself because they were not able to complete the FBMT despite repeated trials. The HFA and LFA participants who completed the FBMT were therefore merged into one group labelled ASD (*n* = 11). A one-way ANOVA was then conducted on the Nine-Box Maze Test Total score,[1] comparing the performance of the ASD group and the TD group. The results, as shown in Table 5, indicate that there was a statistically significant between-group difference, with the TD group (*M* = 54, *SD* = 3.59) performing better than the ASD group (*M* = 34, *SD* = 12.30). The effect size shows that 56% of the variance is explained by the groups.

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[1]This score included the number of correct objects freely recalled, number of objects correctly recognised, number of correct locations recalled, and the number of correct object-location associations made.

Table 5
Measures of Allocentric Spatial Ability: ANOVA results

Variable	*M* (*SD*)	*df*	*F*	*p*	η²
NBMT					
Object Familiarisation	4.83 (2.18)	2	13.89	< 0.001***	0.51
FBMT	19.27 (7.65)	2	12.71	< 0.001***	0.48
NBMT total	43.52 (13.65)	1	24.42	< 0.001***	0.56

Note. FBMT = Five-Box Maze Test. NBMT Total = total score on Nine-Box Maze Test.
*** $p < .0001$

Table 6
Measures of Allocentric Spatial Ability: Tukey's post-hoc test results

	Group			
Test / Comparison #	LFA	HFA	TD	*p*
NBMT Object Familiarisation				
1	2.70 (2.00)	5.60 (1.65)	----	0.001
2	2.70 (2.00)	----	6.20 (0.92)	0.001
3	----	5.60 (1.65)	6.20 (0.92)	0.679
FBMT				
1	11.90 (9.09)	22.30 (3.59)	----	0.001
2	11.90 (9.09)	----	23.60 (1.26)	0.001
3	----	22.30 (3.59)	23.60 (1.26)	0.867

Measures of Spatial Navigation

A one-way ANOVA was used to examine the group differences with regard to the participant's average path length on the four visible trials (see Figure 4). There were no significant between-groups differences (see Table 7). This measure tested the participants' egocentric spatial abilities; the results indicate that participants in both the LFA and HFA groups have intact motor and visuoperceptual ability and intact (but not superior) egocentric spatial ability compared to the TD group.

The first analysis of data from the invisible target trials focused on the number of times the participants was successfully located that target across those trials. Results of a one-way ANOVA (see Table 7) indicate there were no statistically significant between-group differences, suggesting that participants in all groups located and re-located the invisible target equally successfully.

The next analysis of data from the invisible target trials focused on the path length participants took to go from their starting position to the target on each of those trials. A repeated-measures ANOVA examined performance across invisible target trials among participants in the three groups (see Figure 5). The analysis revealed no statistically significant main effect of trials, $p = 0.259$, of group, $p = .312$ or of Group X Trials

interaction, $p = 0.949$. These data, together with those reported in the paragraph above, seem to suggest that both participants in both the LFA and HFA groups perform just as well as participants in the TD group on an allocentric task of spatial navigation.

Analysis of data from the probe trial suggested, as shown in Table 7, that there were statistically significant between-group differences in the amount of time the participants spent searching for the invisible target in the correct quadrant (the NW quadrant) during that trial. The effect size estimate shows that 21% of the variance is explained by the groups. Post-hoc analyses using the least-significant difference (LSD) procedure showed that participants in the TD group spent significantly more time in the NW quadrant ($M = 57.12$, $SD = 31.82$) compared to both the HFA ($M = 31.58$, $SD = 20.01$) and the LFA ($M = 33.22$, $SD = 16.18$) groups, $p = .32$ and $p = .23$, respectively.

Analyses of CG Arena data thus far tell us that participants from both the LFA and HFA groups successfully find the target as many times as do participants from the TD group over the course of the invisible target trials. Additionally, they find the target using similar path lengths to the TD group. The results of probe trial performance suggested, however, that both LFA and HFA participants may have been finding the invisible target by chance: They spent less time exploring the NW quadrant, where the target had previously been located, than did the TD participants. Thus, further examination of the types of strategies used by both LFA and HFA groups is needed to better understand how these individuals are successfully negotiating the Arena in order to find the target.

Table 7
CG Arena: ANOVA results

Variable	Mean (SD)	df	F	p	η^2
Visible Trials: Path Length	76.34 (21.59)	2	3.12	0.060	0.19
Times Target Found	4.40 (0.77)	2	2.19	0.131	0.14
Dwell Time	40.64 (25.70)	2	3.66	0.039*	0.21
ORT	1.91 (2.35)	2	7.79	0.002**	0.37
ART	21.86 (7.29)	2	6.74	0.004**	0.34

* p < .05, ** p < .01

CG Arena Path Length (Visible Trials)

Mean Score of Path Lengths

LFA   HFA   TD
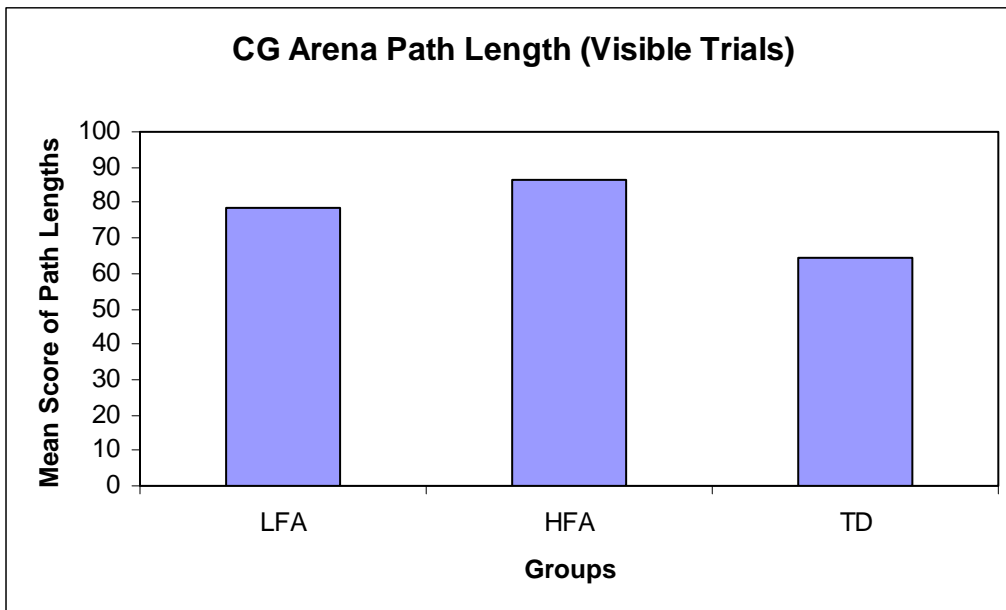
Groups

Figure 4. Performance on the CG Arena Visible Target trials across the three groups

CG Arena Path Length (Invisible Trials) by Group by Trial
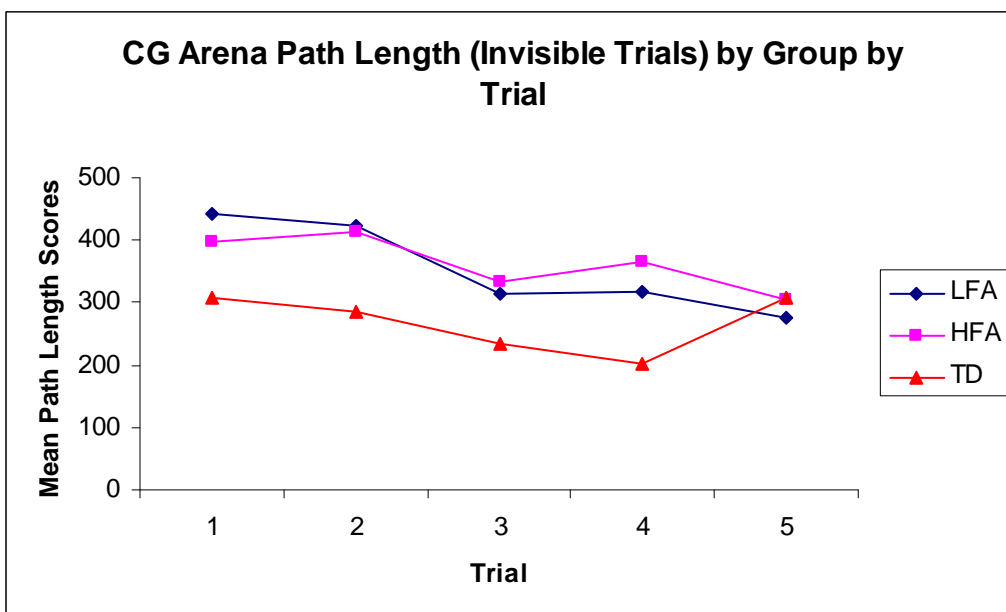
Mean Path Length Scores

LFA
HFA
TD

Trial

Figure 5. Performance on the CG Arena Invisible Target trials across the three groups

I examined and analysed the types of search strategies that the participants used while navigating the CG Arena during the invisible target trials. The strategies were classified using a taxonomy described by Kallai, Makany, Karadi, and Jacobs (2005). Therefore the participants' search paths across all five invisible target trials were classified as being predominantly one of these strategies: Thigmotaxis, Circle, Visual Scan and Enfilading. Thigmotaxis strategy is a circular path that is passed along close to the wall of the arena.

Circle strategy is an arch shaped path that occurs inside the arena but does no involve the use of the wall. Visual Scan strategy is used when an individual stands in a fixed position and turns around to examine the distal cues. Enfilading strategy involves small position corrections and non-strategic motions. Examples of each of these strategies, taken from participants in the current study, are shown in Figure 6.

Chi-squared tests were used to examine whether there were any associations between group membership and the type of strategies used. The analysis showed that there was no significant association, $\chi^2(6, N = 30) = 11.5, p = 0.741$.

To further explore associations between the use of particular search strategies and group membership, pairwise comparisons, again using chi-square tests, were completed. An analysis of the association between membership in either the LFA or TD groups and search strategy employed revealed statistical significance, $\chi^2(3, N = 20) = 8.67, p = 0.341$ Examination of the results showed that a larger percentage of the LFA individuals used the thigmotaxis strategy as well as the circle strategy than the TD group, whereas a larger percentage of the TD group than the LFA group used the enfilading strategy. The same percentage of LFA and TD individuals used the visual search strategy.

A similar analysis of the association between HFA/TD group membership and search strategy used showed that there was no statistical significance in this relationship, $\chi^2(3, N = 20) = 4.48, p = 0.214$). Similarly, there was no statistical significance in the association between HFA/LFA group membership and search strategy used, $\chi^2(3, N = 20) = 2.14, p = 0.543$.

The first analysis of data from the invisible target trials focused on the number of times the participants was successfully located that target across those trials. Results of a one-way ANOVA (see Table 7) indicate there were no statistically significant between-group differences, suggesting that participants in all groups located and re-located the invisible target equally successfully.

The analysis of data from the Object Recognition Test focused on the ORT d'scores. Results of a one-way ANOVA (see Table 7) indicate there were statistically significant between-group differences. Planned contrasts using Tukey's test (see Table 8) showed that participants in the LFA and HFA group performed statistically significantly more poorly than did participants in TD group. This shows that TD individuals have better recognition memory than both LFA and HFA participants.

The analysis of the data from the Arena Reconstitution Task focused on the ART Total score. Results of a one-way ANOVA (see Table 7) indicate there were statistically significant between-group differences. Planned contrasts using Tukey's test (see Table 8) showed that participants in the LFA and HFA group performed statistically significantly more poorly than did participants in TD group. This shows that TD individual's cognitive mapping ability is stronger than both LFA and HFA participants.
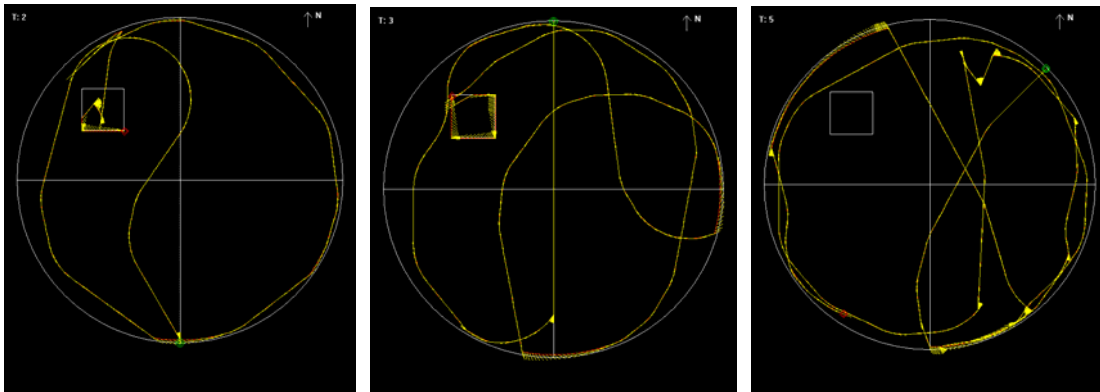
Table 8

Measures of Allocentric Spatial Ability: Tukey's post-hoc test results

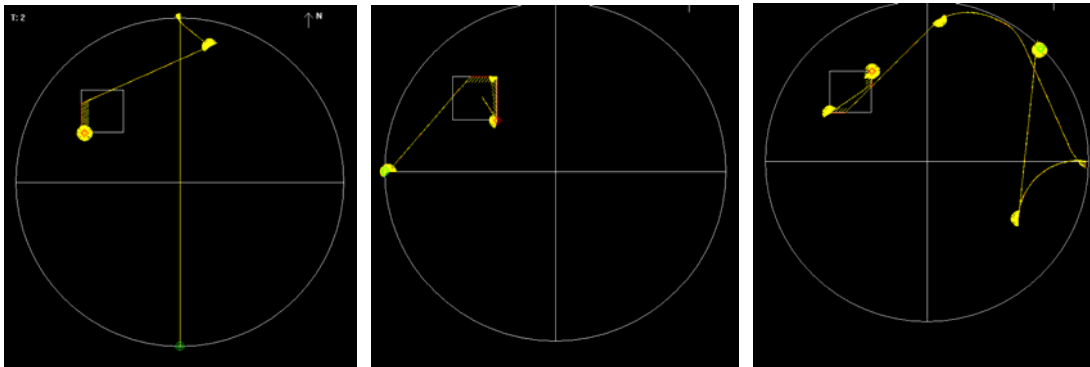| | Group | | | |
Test / Comparison #	LFA	HFA	TD	*p*
ORT				
1	0.60 (2.20)	0.59 (1.69)	----	0.999
2	0.60 (2.20)	----	3.66 (2.09)	0.006
3	----	0.59 (1.69)	3.66 (2.09)	0.006
ART				
1	24.60 (4.81)	25.22 (4.89)	----	0.974
2	24.60 (4.81)	----	16.10 (8.03)	0.013
3	----	25.22 (4.89)	16.10 (8.03)	0.0.009

Thigmotaxis: #18, #8, #53
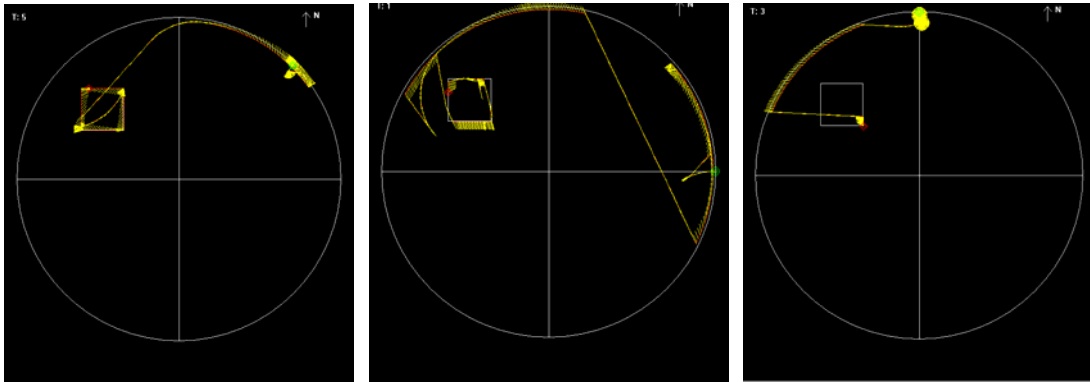
Circle: #81
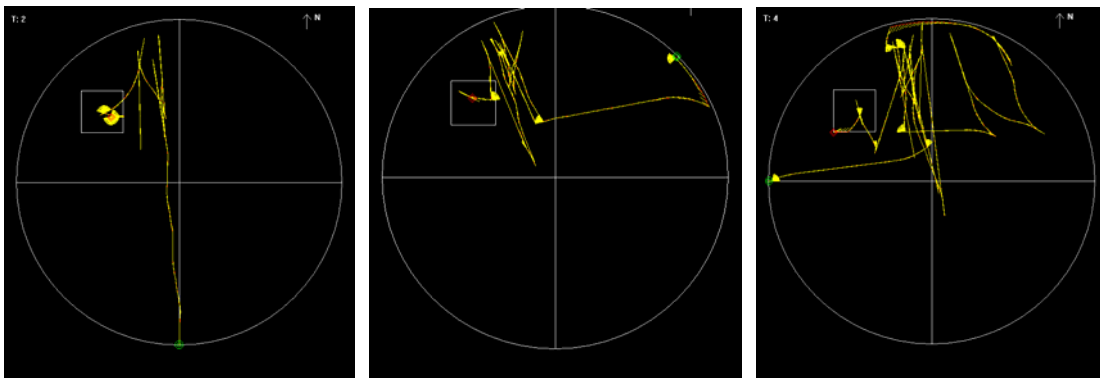

Visual: #53

Enfilading: #15

Figure 6. Search strategies used by participants in the current study. The top panel shows the Thigmotaxis strategy, as employed by participants number 18 (LFA group), number 8 (HFA), and number 53 (LFA). The next panel down shows the Circle strategy, as employed by participant number 81 (HFA). The next panel down shows the Visual strategy, as employed by participant number 53 (LFA). The next panel down shows the Enfilading strategy, as employed by participant number 15 (HFA).

Discussion

Previous research within spatial research has provided conflicting results regarding autistic individual's spatial abilities. Various findings have shown that autistic individuals have superior abilities on certain spatial tasks where as others have shown that autistic individuals have intact but not superior spatial abilities on certain spatial tasks (Caron et al., 2003; Edgin & Pennington, 2005; Jarrold, Gilchrist, & Bender, 2005). The findings from the present study do not support the predictions made by the WCC as they show that the autistic individuals, specifically HFA individuals, have intact and not superior spatial abilities on certain aspects of spatial cognition. The results of this study will therefore be discussed in terms of how they relate to the Weak Central Coherence theory.

Measures of General Spatial Ability

The results of the study have shown that on tasks requiring local level processing and a detail-specific focus, HFA individuals display intact but not superior spatial abilities where as LFA individuals display poor spatial abilities. These results therefore contradict the predictions made by the WCC as well as the results from previous studies. The results from the present study, specifically from the Block Design, CEFT and ROCF measures have shown that the 'weak central coherence' theory does not provide a sufficient understanding and explanation of the visuo-spatial processing in ASD populations. The weak central coherence theory has been used in autism research to provide an understanding for the superior performance of ASD participants in visuo-spatial tasks requiring local-level processing. This dominant theory has provided a way of understanding ASD individuals 'islets of ability' but the results from the present study questions the predictions on which the WCC is based on. Reported superior performance in the ROCF and BD has not been confirmed in the present study as the HFA individuals displayed intact but not superior abilities on both tasks. Therefore the results regarding general spatial ability ASD individuals has shown that do not present superior abilities on tasks requiring local level processing, as predicted by the WCC.

Measures of Allocentric Spatial ability

Allocentric spatial coding involves the use of global-level processing when locating an object within the environment. The results from the NBMT which focuses on testing the individuals allocentric spatial coding ability, has shown that ASD individuals have difficulty in employing this form of spatial coding. These results do however confirm the opposing

prediction of the WCC regarding inferior performance by ASD individuals on tasks requiring global-level focusing. The differences between the performance of the TD group and ASD group in the present study show that while HFA participants have intact abilities on tasks requiring local-level focus, their abilities on a specific task requiring global-level focus, is inferior to that of the TD participants.

ASD individuals have on the other hand been shown to have intact egocentric spatial coding abilities (Pertini, 2004). The practice trials on the CG Arena task provide a measure of the participant's egocentric abilities. The ability of both the HFA and LFA groups on this test showed that both LFA and HFA individuals have intact egocentric spading coding ability. The ability to locate the visible target within the arena involves the use of egocentric spatial coding as no external landmarks or cues are needed. These results from the CG Arena test therefore shows that both LFA and HFA participants are able to locate an object within the environment using egocentric spatial coding.

The poor performance by the LFA group on most of the measures may be explained by their poor intellectual functioning. The studies that do make use of low-functioning match the ASD individuals to individuals with learning difficulties so that the groups will be matched on PIQ or VIQ (Brosnan et al., 2004). In doing so it controls the possibility of intelligence being a confounding variable. In this study the LFA group was not matched on intellectual functioning to the HFA and TD groups because the selection of the groups was based on the individuals PIQ. The poor performance by the LFA individuals on both the measures of general spatial ability and allocentric spatial ability may be accounted for by their poor intellectual functioning.

Measures of Spatial Navigation

The results from the CG Arena show that individuals from both LFA and HFA groups have intact spatial navigational abilities, regardless of their intellectual functioning. The results from the invisible trials show, that the participants from both the LFA and HFA groups were able to successfully locate the target using similar path lengths to the TD group. These results suggest that the individuals have intact allocentric as well as egocentric spatial abilities as they are able to navigate the arena. The results of the probe trial however suggest that both LFA and HFA individuals may be finding the target by chance. Further analysis was done to examine whether an alternate type of strategy was used by the participants in both the LFA and HFA group that enabled them to find the targets.

When navigating an environment, individuals normally make use of allocentric spatial coding to remember the locations of an object. The CG arena requires a form of allocentric spatial coding as it requires that individuals to locate an invisible target within the arena using external cues. As already seen in the previous measures, ASD individuals have difficulty in employing allocentric spatial coding when navigating the environment. The results of the invisible trials however suggest that both LFA and HFA individuals have intact allocentric spatial coding abilities. These results therefore suggest that possible alternate strategies were used when navigating the arena. Therefore the types of search strategies used by the participants from all three groups were examined to better understand how these participants are locating the invisible target.

The analysis showed there is a difference between the types of search strategies used by the LFA and TD groups, with participants in the LFA group using Thigmotaxis and Circling search strategies more than the TD group. The TD group on the other hand made use of the enfilading strategy more than any of the other strategies. There was no significant difference between the HFA and TD group, or between the LFA and HFA group regarding the search strategies. These results show that possible intact spatial navigational ability by the LFA group may be explained by use of the thigmotaxis and circling strategy when trying to locate the invisible target within the arena. No difference between the HFA and TD group as well as between the HFA and LFA group on the types of search strategies used shows that HFA individuals are using a combination of both the strategies used by the LFA and TD individuals. These results show the need for further research regarding the use of search strategies.

The results from the ORT and ART analysis showed that both LFA and HFA individuals have poor recognition memory as well as poor cognitive mapping ability compared to TD individuals. The poor cognitive mapping ability of the LFA and HFA individuals' suggests that these individuals should have poor spatial navigational abilities which, shown by the above results, is not true. The results provided by the present study shows that even though the LFA individuals have poor general spatial abilities as well as poor allocentric abilities, they have intact spatial navigation abilities. These results therefore show the need for further research regarding the types of search strategies used by ASD individuals to better understand how these individuals navigate the environment.

Directions for Future Research

One of the main limitations of the present study that needs to be addressed in future research is the small sample size. The small sample can not provide an accurate representation of the larger ASD population. To further examine the type of strategies used by ASD individuals during navigation, a larger sample size is needed as a larger sample will provide a larger set of search strategies to be examined. Therefore future research on the spatial navigational abilities of ASD individuals should ensure that a large sample of indivudlas is selected.

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Appendix A

299.00 Autistic Disorder

- Diagnostic criteria for 299.00 Autistic Disorder
- Diagnostic Features
- Associated Features and Disorders
- Associated descriptive features and mental disorders.
- Associated laboratory findings.
- Associated physical examination findings and general medical conditions.
- Specific Age and Gender Features
- Prevalence
- Course
- Familial Pattern
- Differential Diagnosis