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Visual Information Processing by High Functioning Individuals with Autistic Spectrum Condition

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Abstract

People with Autistic Spectrum Condition (ASC) have sometimes been found to show a local-processing bias on certain visual tasks. This bias has been associated with superior task performance on tasks where it confers an advantage. However, this finding is far from universal; especially when the research participants with ASC have an average to above average level of general intellectual functioning. This thesis comprises a literature review of research examining the processing of visual information by people with ASC, and an empirical paper examining the performance of people with ASC on the Rey-Osterrieth Complex Figure. The literature review considers various models of ASC with the predictions they make for processing of complex visual stimuli. The evidence which supports or refutes these theories is described. Several methodologies have been used to explore visual processing in people with ASC and the information and understanding which each methodology has provided is discussed. Finally, the literature review considers what still remains unknown, and potential directions for future research. The empirical paper is a quantitative study using the Boston Qualitative Scoring System and eye tracking methodology to investigate the potential presence of a local-processing bias, evidenced by increased lower level cognitive processing during completion of the Rey-Osterrieth Complex Figure. A local-processing bias was not found. This study does not support the presence of this bias in high functioning individuals with ASC. The study findings are discussed in relation to the existing literature and the Underconnectivity Hypothesis of ASC.

Contents

Table of Tables

Table of Figures

Table of Abbreviations

AQ = Autism Quotient

AS = Asperger Syndrome

ASC = Autism Spectrum Condition

BD = Block Design

BQSS = Boston Qualitative Scoring System

CI = Confidence interval

DSM = Diagnostic and Statistical Manual of Mental Disorders

DSS-ROCF = Developmental Scoring System for the Rey-Osterrieth Complex Figure

EF = Executive Function

EFT = Embedded Figures Test

EQ = Empathy Quotient

E-S = Empathising-Systematising

fMRI = Functional Magnetic Resonance Imaging

HF = High-functioning

IQ = Intelligence Quotient

NICE = National Institute for Health and Clinical Excellence

PIQ = Performance Intelligence Quotient

ROCF = Rey-Osterrieth Complex

ROI = Region of interest

SQ = Systematizing Quotient

TD = Typically developed

ToM = Theory of Mind

VIQ = Verbal Intelligence Quotient

WASI = Wechsler Abbreviated Scale of Intelligence

WCC = Weak Central Coherence

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The Visual Processing of Complex Stimuli by People with an Autistic Spectrum Condition

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Abstract

This literature review aims to explore the processing of visual information by people with an Autistic Spectrum Condition (ASC). The various models of ASC will be outlined with the predictions they make for visual processing of complex visual stimuli. The evidence which supports or refutes these theories will be described. Several methodologies have been used to explore visual processing in people with ASC. The information and understanding which each methodology has provided will be discussed. Finally, this review will consider what still remains unknown, and potential directions for future research.

Keywords: Autistic Spectrum Condition; Eye tracking; Visual processing; Rey-Osterrieth Complex Figure

1. Autistic Spectrum Condition

The term ‘autism’ was first used by Dr Leo Kanner to describe what is now considered to be ‘classic’ autism (Kanner, 1943). Infantile Autism first became an official diagnosis in the third edition of the diagnostic and statistical manual (DSM-III). Symptoms included a pervasive lack of responsiveness to other people; bizarre responses to various aspects of the environment; and gross deficits in language development or peculiar speech patterns (American Psychiatric Association, 1980). Currently an individual must show impairments in social interaction and communication, and at least one symptom of restricted or repetitive behaviour to be diagnosed with autism (American Psychiatric Association, 2000). The diagnosis of Asperger Syndrome (AS) also requires impairments in social interaction and the presence of restricted or repetitive behaviour. However, there must be no significant delay in language or cognitive development (American Psychiatric Association, 2000). Both Autism and AS fall within the umbrella term Autistic Spectrum Condition (ASC).

Despite their absence from the diagnostic criteria, factors such as sensory hypersensitivity (Ben-Sasson et al., 2009) and a tendency toward bottom-up, detail focussed, processing of the environment (Mottron, Dawson, Soulieres, Hubert, & Burack, 2006; Neumann et al., 2011) can also be indicative of an ASC (Baron-Cohen, Wheelwright, Skinner, Martin, & Clubley, 2001). The tendency to process information using a ‘local-processing bias’ (Pellicano, Maybery, Durkin, & Maley, 2006) was noted by Dr Kanner as a main feature of autism (Kanner, 1943), and is a focus of many theories of autism today.

ASC can be diagnosed by a single clinician. However, for the diagnosis of ASC in young people, the NICE guidelines recommend that ASC should be diagnosed by a multidisciplinary team. An ASC diagnostic assessment should include details of an individual’s home life, education and social care; a developmental and medical history; and an assessment of social and communication skills and behaviours (National Institute for Health and Clinical Excellence, 2011). Estimates suggest that there are currently approximately 433 000 people with ASC living in the UK. It has been estimated that ASC in adults costs the UK economy approximately £25.5 billion every year, accounted for by service use, lost unemployment for the individual with ASC, and by family expenses (Knapp, Romeo, & Beecham, 2007).

Despite their average to above average levels of intellectual functioning, high functioning people with ASC can still experience pronounced difficulties in their everyday life. A recent report by the National Audit Office notes that whilst people with ASC use a wide range of public services, the effectiveness of these services at meeting their specific needs could be improved (National Audit Office, 2009). The report highlights the need for good information about ASC. This information should then be used to better plan service delivery strategy and to raise the knowledge levels and awareness of the needs of people with ASC. The report also specifically highlights the potential for better targeted support for high functioning people with ASC, who can find themselves without a service because they are not eligible for either learning disability services or mental health services, unless they have a comorbid diagnosed mental health problem. The National Audit Office report suggests that a key focus of services specialising in ASC would be to help high functioning individuals to live more independently and to obtain and retain employment (National Audit Office, 2009). It is clear from this report that whilst high functioning individuals with ASC can function normally in many domains, subtle differences in how they process and navigate the world around them can cause pronounced difficulties in their life.

1.1. Brain Development Differences in ASC

Children born with ASC show differences in brain development from an early age. During the first years of life, head circumference correlates well with brain size in both typically developed (TD) children and children with ASC (Bartholomeusz, Courchesne, & Karns, 2002). At birth, infants with ASC have typically normal or slightly small head circumference (Webb et al., 2007). However, by one to two years of age, children with ASC demonstrate brain overgrowth and abnormally large head circumferences (Dawson et al., 2007). This increased head size occurs to accommodate the rapidly growing autistic brain. Overgrowth in two to four year old children particularly occurs in the frontal and temporal lobes and amygdala (Courchesne & Pierce, 2005). By the time children with ASC approach adolescence, the disturbances in white matter are evident, particularly in the frontal lobe (Herbert et al., 2004) and this is associated with reduced functional connectivity between brain regions (Rudie et al., 2012). As children with ASC age, they may acquire skills which require functional connectivity between brain regions more slowly than their TD peers (Baron-Cohen, 1989). The differences in local and long range connectivity can mean that whilst people with ASC can match or even exceed the performance of their TD peers on simple tasks, they may perform more poorly on tasks which require a high level of functional connectivity across different brain regions, particularly between frontal and posterior brain regions (Just, Keller, Malave, Kana, & Varma, 2012).

2. Theories of Information Processing in ASC

Several cognitive models have been proposed which attempt to explain the manner in which people with ASC process information. The main current theories will be discussed in turn below, along with the evidence which supports or refutes them. This will be followed by a critique of the current methods for assessing visual processing and the evidence that these methods have provided.

2.1. Mind-Blindness Theory

The mind-blindness theory was proposed by Baron-Cohen, Leslie and Frith (1985) and posits that social difficulties in people with ASC stem from a deficit in theory of mind (ToM). They found that 80% of their sample of children with autism failed a theory of mind task requiring participants to report that a character in a scenario held a false belief regarding the location of an object (Wimmer & Perner, 1983). They concluded that the children had a ToM deficit. These findings were replicated using other assessments of false belief (Perner, Frith, Leslie, & Leekam, 1989). The mind-blindness theory was criticised for its lack of universality as 20% of children with autism passed tests of false belief (Happe, 1994). Baron-Cohen (1989) addressed this concern using a more complex second-order false belief task, which 90% of TD children passed. None of the children with autism passed this test. Baron-Cohen concluded that whilst a few children with autism could pass a first-order ToM task, they did not demonstrate a fully representational ToM. He thus amended his theory to state that ToM was delayed in children with autism, and this amendment was supported by meta-analytic data showing a strong association between autistic children's verbal mental age and their ability to pass a false belief task (Happe, 1995). In more recent years, the manner in which ToM is assessed has expanded to include an individual's ability to infer another's mental state from their eye expression, using the 'Eyes Task' (Baron-Cohen, Jolliffe, Mortimore, & Robertson, 1997); and the ability to infer an emotion or intention from another's tone of voice (Golan, Baron-Cohen, Hill, & Rutherford, 2007). People with autism typically perform below the level achieved by TD individuals.

Whilst there is much evidence to support the mind-blindness theory of autism, it has been superseded by newer theories. This is mainly because whilst the theory explains many of the social difficulties people with ASC can experience, it does not explain several other aspects of autism, such as a need for routine or order in the environment; the local-processing of information bias; difficulty switching attention; or sensory hypo and hyper sensitivities (Tager-Flusberg, 2007). This theory is therefore limited in its predictive usefulness, and in the potential habilitating strategies it could suggest to help people with ASC navigate their environments and their lives.

2.2. Executive Dysfunction Theory

This theory originated from the observations of some researchers that some symptoms of autism showed similarities with symptoms of the Dysexecutive Syndrome that follows specific brain injury (Baddeley & Wilson, 1988; Ozonoff, Pennington, & Rogers, 1991). These researchers defined executive functioning (EF) as including behaviours such as planning, organisation of behaviour, inhibition of task irrelevant stimuli or responses, impulse control and cognitive flexibility. Research into the EFs of people with ASC has shown varied results. Whilst Ozonoff, Pennington and Rogers (1991) found that 96% of their participants with autism performed worse than the control group, Pellicano et al. (2006) found that only 50% of their participants with autism showed executive difficulties. Ozonoff (1997) later updated the executive dysfunction theory by hypothesising that autism entails a specific cognitive flexibility deficit. In contrast, inhibition abilities remain relatively unaffected (Ozonoff & Jensen, 1999).

The executive dysfunction theory has suffered from variability in experimental findings. Researchers have struggled to replicate the findings of others, even when using the same methods and tasks (Hill & Bird, 2006). Performance on EF tasks have been found to be mediated by verbal intelligence (VIQ) in several studies (Hill, 2004). Finally, executive dysfunction is not unique to ASC; it is present in other disorders, meaning that the executive dysfunction theory fails to uniquely describe or explain cognitive functioning in autism. Research into the executive performance of people with ASC continues; however the executive dysfunction theory has been somewhat superseded by the newer theories described below.

2.3. Weak Central Coherence Theory

Weak Central Coherence (WCC) theory posits that whilst TD individuals process information by extracting the overall meaning or the ‘big picture’, people with ASC characteristically show absent or weak drive for global coherence of information (Frith & Happe, 1994). Instead, people with ASC process stimuli in a detail-focused way, processing the component parts, not the global whole. This is also known as a local-processing bias. Evidence for this bias comes from people with ASC showing both weaknesses in tests of global processing, but also strengths in local processing, when compared to TD individuals. Shah and Frith (1993) found that participants with autism could produce block designs (Wechsler, 1997) faster than TD individuals. People with ASC have also performed the Embedded Figures Test (EFT) faster than TD individuals, whilst retaining the same accuracy (Jolliffe & Baron-Cohen, 1997). Further evidence for a local-processing bias comes from studies of visual illusions, to which participants with autism have shown reduced susceptibility (Happe, 1996). This finding has not always been replicated (Ropar & Mitchell, 2001), which has led to a debate as to whether individuals with ASC can use attentional control to choose to process information at a global level, as opposed to TD individuals who would be expected to initially process information at a global level by default (Mottron et al., 2006). Researchers have found that the phrasing of the research question which participants with ASC are asked has affected the manner in which they respond (Brosnan, Scott, Fox, & Pye, 2004). It has also been argued that people with autism may show a local-processing bias due to spatially over-focused visual attention coupled with a deficit in broadening their visual attention (Mann & Walker, 2003). In a similar manner to previous theories, the WCC theory has been called into question because not all individuals with ASC show deficits in central coherence (Norbury, 2005). Over time this theory has evolved from attempting to explain all aspects of autism to explaining the processing of information in ASC (Happe & Frith, 2006).

The WCC theory would make specific predictions about the processing of visual information by people with ASC. They would be expected to perform optimally on tests requiring participants to ignore the global context in order to use local information, such as the embedded figures test (Witkin, Oltman, Raskin, & Karp, 1971). They might also perform well on tasks such as Block Design from the Wechsler tests (Wechsler, 1997) which require a design to be created from component parts. This task requires participants to imagine the overall design as broken down into segments. When scanning or copying complex visual information, people with ASC would be expected to examine and recreate individual details without first looking for or imposing an overall structure. This could be apparent on tests such as the Rey-Osterrieth Complex Figure (Osterrieth, 1944).

2.4. *Empathising-Systematising Theory*

Empathising-Systematising (E-S) theory highlights the importance of two dimensions or skills, empathising and systematising (Baron-Cohen, 2009). These are measured using the Empathy Quotient (EQ) and the Systematizing Quotient (SQ) (Baron-Cohen, Richler, Bisarya, Gurunathan, & Wheelwright, 2003; Baron-Cohen & Wheelwright, 2004). A person who scores highly on empathising is considered motivated to understand the thoughts and emotions of others, and to respond appropriately to these. A person who scores highly on systematizing is considered motivated to understand or construct systems, defined as anything that follows repeatable and lawful patterns, or rules. Examples of systems include mechanical, abstract, collectible and natural. E-S theory seeks to explain the stereotypically different profiles of strengths and weaknesses seen in men and women. On average, women tend to score higher on the EQ than on the SQ. Men tend to show the reverse pattern (Baron-Cohen, Knickmeyer, & Belmonte, 2005). People with ASC tend to experience deficits in the skills defined as empathising (such as ToM) and strengths in systematising skills, even when compared to the average man. For this reason, E-S theory has been extended into the 'Extreme Male Brain' theory (Baron-Cohen, 2010). Further evidence for this theory comes from neuroimaging. Several regions of the brain such as the anterior cingulate, the prefrontal cortex, the superior temporal gyrus and the thalamus are, on average, smaller in men than in women; and smaller still in people with autism (Baron-Cohen et al., 2005). In contrast, regions such as the amygdala and the cerebellum, which are typically larger in men than in women, are larger still in people with autism.

E-S theory shares some similarities with WCC theory and draws on much of the same supporting literature. Both theories focus on the cognitive styles used by people with ASC, compared to those used by TD people. Both theories hypothesise that people with ASC should show better attention to detail than attention to the overall gestalt. However, whilst WCC theory sees the local-processing bias as due to an inability to integrate the details in the environment into a global gestalt, E-S theory sees this same behaviour by people with ASC as a highly purposeful attempt to understand the world around them (Baron-Cohen, 2009). E-S theory has proved useful in the generation of habilitation techniques and strategies. These techniques tend to exploit a person's systematizing strengths to compensate for their empathising weaknesses, for example, by presenting emotions in an autism-friendly format (Ryan & Ni Charragain, 2010).

E-S theory would make similar predictions for performance on visual processing tasks as the WCC theory, with one exception. Whilst people with ASC would still be expected to choose to examine the details of a complex figure instead of focussing on the global structure, they would still be expected to have the ability to notice and examine this global structure. This may be evident in their scanning path of a visual scene or complex figure, and would also suggest that some people with ASC might impose a global structure on an image or figure they produced, rather than producing groups of details.

2.5. The Underconnectivity Hypothesis

Minshew and Payton (1988) proposed a fundamentally different theory of autism. They focused on the aetiology of autism, rather than the cognitive result of that aetiology, and thus developed a neurobiological model of autism. Since this time, their research group has generated evidence to support this theory of autism as a neurodevelopmental disorder. Minshew recently described five key levels to ASC and these have provided potential areas for research (Minshew, Williams, & McFadden, 2008). ASC is described as originating from abnormalities in the genetic code for brain development. These abnormalities in DNA then create abnormal mechanisms of brain development, starting from an individual's conception. This then leads to structural and functional abnormalities in the brain. These create the cognitive and neurological abnormalities which the theories discussed above have focused on. Finally, these cognitive and neuronal abnormalities cause the behavioural syndrome known as ASC.

Minshew hypothesises that in low ability individuals, ASC is the result of failed development of functional connections between sensorimotor cortices and association cortices. In high-functioning (HF) adults, ASC is described as the result of disordered development of the white matter connective tissues which connect neocortical systems, especially those involving heteromodel cortex, such as the frontal cortex (Minshew et al., 2008). This underdevelopment of cortico-cortical connections is coupled with an increase in the amount of white matter connections within localised regions of the brain which support basic cognitive processes. This leads to wide ranging impairments in higher order cognitive abilities, in the presence of intact or sometimes enhanced processing of lower level information and tasks (Minshew, Goldstein, & Siegel, 1997; Williams, Goldstein, & Minshew, 2006). Minshew et al. (2008) hypothesised that these differences in cortical connections would result in people with ASC being disproportionately affected by increases in task complexity. Complex information processing tasks are defined as those which require integration of multiple features rather than the reliance on one or two individual features. Task complexity is also a function of speed of processing, processing of large amounts of information, or processing of novel material. However, there is not currently a standardised measuring system for evaluating how these various variables of complexity compare individually or how they interact; for example, how high task load compares to high novelty, or the effect of combining high task load on a novel task.

The Underconnectivity Hypothesis is supported by evidence from functional magnetic resonance imaging (fMRI) studies. HF people with ASC can perform at the same level as TD individuals on a range of tasks. However, fMRI studies have found that people with ASC demonstrate different patterns of brain activation to TD individuals whilst completing the same tasks (Philip et al., 2012). They show greater activation of occipital parietal regions, consistent with a reliance on using basic cognitive abilities to complete tasks, and comparatively reduced activation of frontal regions (Luna et al., 2002; Just, Cherkassky, Keller, Kana, & Minshew, 2007). This pattern of information processing results in an accelerated drop-off of performance by people with ASC when task complexity increases (Garcia-Villamisar & Della Sala, 2002), as predicted by the Underconnectivity Hypothesis.

The Underconnectivity Hypothesis provides the most detailed predictions of how people with ASC would process complex visual stimuli. Increased neural connectivity in occipital and parietal regions may make it easier for people with ASC to notice the presence and location of details (Just et al., 2012). They might be expected to reproduce visual stimuli in a detail focussed manner, and they may also remember more details of a complex figure than their TD peers. In contrast, due to reduced connectivity within the frontal lobe and between brain regions, people with ASC could be less likely to utilise higher order reproduction and memory strategies (Just et al., 2012). This could result in their reproducing and remembering less of the global structures of a figure. The Underconnectivity Hypothesis would also predict faster reaction times on EFTs and the Block Design subtest.

3. Methodologies Used to Investigate Information Processing in People with ASC

With the exception of the Underconnectivity Hypothesis, the theories outlined above were largely conceptualised based on behavioural data. Tasks were used which already had known and established normative outcomes based on the performance of TD individuals. People with ASC would be asked to complete these tasks to compare their performance and behaviour to that of the TD population. Later, fMRI techniques have been employed to ascertain the brain activation which correlates with these differences in performance (Gallagher et al., 2000; Rumsey & Ernst, 2000). Finally, studies of eye tracking began to be used to examine the way in which people with ASC were processing visual information (Trepagnier, Sebrechts, & Peterson, 2002) as they were completing tasks. Each of these methodologies will be discussed below with particular focus on the evidence that each of these methodologies can provide regarding the manner in which people with ASC process complex information.

3.1. Behavioural Experiments

Behavioural experiments have focused on two areas of exploration. Firstly, the performance of people with ASC on standardised tasks such as subtests from neuropsychological test batteries has been compared to the performance of TD people, in order to describe the relative strengths and weaknesses of people with ASC. Secondly, researchers have attempted to manipulate the way in which participants complete a task by changing task instructions or varying task complexity; in order to examine any differences in the resulting alteration of performance between TD people and people with ASC. The results of both of these approaches are described below.

3.1.1. Strengths and Weaknesses

One of the first noted strengths in information processing exhibited by people with ASC was shown by their faster and more accurate performance on the block design subtest of the Wechsler intelligence scales (Wechsler, 1997). People with ASC often perform better on this subtest than any other, showing a 'visuospatial peak' in performance (Shah & Frith, 1993; Shah & Frith, 1983). This strength seems particularly pronounced when perceptual coherence of the design interferes with task performance in TD individuals. People with ASC show reduced susceptibility to this interference (Caron, Mottron, Berthiaume, & Dawson, 2006). This strength is hypothesised as resulting from a local-processing bias (WCC theory); high levels of systematising abilities (E-S theory); or increased information processing at a perceptual level (Underconnectivity Hypothesis).

These theories posit similar hypotheses to explain performance on the Embedded Figures Test. This test requires participants to detect a target shape hidden within a complex background (Witkin et al., 1971). Reaction time is the main index of performance. People with ASC show similar or faster performance on the EFT, without a reduction in accuracy (Pellicano et al., 2006; Ropar & Mitchell, 2001; Jarrold, Gilchrist, & Bender, 2005; Kaland, Mortensen, & Smith, 2007). Similar results have been found when grouping the general population by their Autism Quotient (AQ; Baron-Cohen et al., 2001) scores. Participants scoring high on the AQ have performed significantly better on various embedded figure tasks than participants who score low on the AQ (O'Riordan, 2004; Almeida, Dickinson, Maybery, Badcock, & Badcock, 2010).

The Rey-Osterrieth Complex Figure (ROCF) is a test of visuo-spatial perception and construction, and memory. It was first created in 1941 by Andre Rey (Rey, 1941) and further standardised in 1944 by Paul-Alexandre Osterrieth (Osterrieth, 1944). The individual being tested is required to copy the figure, which is displayed in front of them. Both the figure and the copy are then removed and the individual is asked to reproduce the figure from memory, both immediately and 20-30 minutes later. This test measures visuo-spatial abilities, but also planning ability and visual memory (Meyers & Meyers, 1995). The ROCF is one of the most commonly used tests in the field of neuropsychology (Camara, Nathan, & Puente, 2000) and is ranked among the top 10 tests used by Neuropsychologists (Rabin, Barr, & Burton, 2005). The measures of performance typically used include a copy score, and immediate and delayed recall scores. These scores are derived by assessing the number of figure elements which have been correctly produced. Over time, a number of systems for evaluating qualitative features of the reproduction have been created. These systems measure several aspects of performance, such as how a participant organises their ROCF reproduction, what style they use (detail or Gestalt focused), and how many of the main structural elements or attached details are present. For children the most widely used qualitative scoring set of criteria is the ‘Developmental Scoring System for the Rey-Osterrieth Complex Figure’ (DSS-ROCF). For adults, the most well-normed and commonly used system is the Boston Qualitative Scoring System (BQSS) (Stern et al., 1999). The BQSS divides the ROCF into six main configural elements, nine clusters and six remaining details. The BQSS measures 13 different aspects of ROCF copy and recall and gives an additional six summary scores. However, researchers who have recently begun to use this system with people with ASC have tended to use the measures of Presence, Accuracy and Planning; as well as the summary score Organisation (Kuschner, Bodner, & Minshew, 2009; Tsatsanis et al., 2011). This is because these four measures are most relevant to the measurement of a potential local processing bias, whereas other measures such as Perseveration or Confabulation are rarely present in the ROCFs produced by TD individuals or people with ASC.

The ROCF has been used in studies of ASC to assess overall accuracy and the manner in which the ROCF is reproduced. Two small sample studies of children and adolescents with ASC found that copy accuracy and element placement was not significantly different to TD controls (Prior & Hoffmann, 1990; Gunter, Ghaziuddin, & Ellis, 2002). However, other studies have found that people with ASC show poorer accuracy on the ROCF than when copying more simple designs. This reduction in performance shows a greater drop than expected from the TD population (Rumsey & Hamburger, 1988; Minshew et al., 1997; Kenworthy et al., 2005). Minshew and Goldstein (2001) tested adolescents and adults with ASC on the immediate and delayed memory trials of the ROCF, but did not report scores for the copy condition. They found that people with ASC remembered significantly less of the ROCF on both memory trials than TD controls. Minshew and Goldstein hypothesised that the participants with ASC used less organisational strategies during copy of the ROCF and that this may have reduced the depth of encoding and therefore amount remembered. Unfortunately they did not use the BQSS to assess the organisation of ROCF copy or reproduction and so did not produce supporting evidence for this hypothesis. Ropar and Mitchell (2001) examined the strategies used by children and adolescents with ASC to reproduce the ROCF. They did not find evidence that the participants with ASC used a more detail-oriented reproduction strategy. However, they measured drawing strategy using the general judgement of two raters who dichotomously rated the drawings as either globally or locally reproduced, rather than using a standardised rating system of organisation, such as the BQSS. This limits the conclusions that can be drawn from this study. Schlooz et al. (2006) used a standardised scoring system, the DSS-ROCF (Bernstein & Waber, 1996) to compare children with ASC to children with Tourette syndrome and TD children. The children with ASC achieved a lower mean organisation score, evidenced a detail-focused style, and recalled fewer structural elements than the other groups. This study supports a local-processing or detail-oriented bias in children with ASC.

It is possible that the disagreements found between many of the early studies using the ROCF have been caused by the use of children as participants. There is evidence that TD children show a detail oriented manner of ROCF reproduction and later change to a more strategic global manner of organising their ROCF reproduction as they get older (Akshoomoff & Stiles, 1995a; Akshoomoff & Stiles, 1995b) and as their frontal lobes develop (Anderson, 2002). Earlier studies may have found no difference between children with ASC and TD children because all of the children are, on average, likely to use a detail-focused style of reproduction. Kuschner, Bodner and Minshew (2009) addressed this issue by comparing both children and adults with ASC to age, IQ, and gender matched TD controls. Both the adult TD and ASC groups achieved better Presence and Accuracy summary scores than their child counterparts, suggesting that both TD and ASC individuals may improve their ROCF reproduction with age. These authors also reported an interaction between diagnostic group and age for the Organisation score calculated for the ROCF copy condition. Children with ASC, TD children, and adults with ASC all achieved similar scores on the Organisation measure. However, TD adults achieved significantly higher Organisation scores, suggesting TD individuals improve on this ability with age, whilst adults with ASC do not. Kuschner et al. (2009) found the same pattern of results for the Planning score although this interaction was only marginally significant (p=0.06). Interestingly, these results were not repeated on the Block Design subtest which participants also completed. No group difference or interaction was found on this subtest; although Block Design subtest scores did positively correlate with the Detail Presence scores on the ROCF. Better block design scores by people with ASC have previously been found to correlate with greater tendency towards detail-focused processing. This suggests that an increased ability to notice detail positively affects accuracy on both detail presence on the ROCF and the block design task.

In a recent large scale study Tsatsanis et al. (2011) compared 50 people with ASC, to 49 TD controls and also 71 clinical controls with either Obsessive Compulsive Disorder, Tic Disorder, and/or Attention-Deficit Hyperactivity Disorder. The three diagnostic groups were matched for age, sex, verbal IQ, performance IQ and full scale IQ. The ASC group showed a more detail-focused style to reproducing the ROCF than the TD and clinical control groups; scored using the DSS-ROCF (Bernstein & Waber, 1996). When the sample was split into children (six years to 13 years) and adolescent/adults (14 years to 42 years) this difference was still significant. In the younger age group the difference was only significant between children with ASC and TD controls, with a moderate effect size. A far more significant difference was seen within the older age range. Participants with ASC showed a more detail-focused than both the TD controls and the clinical controls. This difference showed a large effect size. Interestingly, the participants with ASC reproduced significantly less incidental details or structural elements of the ROCF than TD controls in the Copy condition. This would suggest that a detail-focused style did not help the participants with ASC reproduce more incidental details. However, this analysis was not split into an older and younger group and so any potential differing effect of age cannot be ascertained. The authors considered these results to support WCC theory. This is partially supported, as WCC theory would predict that people with ASC would produce less structural elements of the ROCF than TD controls. However, WCC would be likely to predict equivalent performance on incidental detail production between the two groups, as this is not an area people with ASC are expected to show a weakness in, and so this particular study finding does not support WCC.

Finally, in TD controls, better organisation of ROCF copy was linked with a more configurational reproduction approach. However, participants with ASC showed an ability to draw the ROCF in a part-oriented but still well organised manner (Tsatsanis et al., 2011). This suggests that two types of detail-focused styles are possible. Where detail-focus is organised, individuals with ASC appear to perceive the gestalt as a complex collection of parts. However, where detail-focus lacks organisation, it may be that individuals perceive only separate components without any overarching context. If two different forms of detail-focused style exist, this may explain the subtle differences in the literature which fuel the ongoing debate between WCC theory and E-S theory. WCC theory would expect people with ASC always to see the parts and not the whole. E-S theory would expect the same people to primarily perceive the parts, but given enough time, to construct these parts into a well understood and detailed whole (Baron-Cohen, 2009).

People with ASC have also shown weaknesses in some aspects of information processing. They often disengage their attention slower than TD individuals (Landry & Bryson, 2004; Courchesne et al., 1994; Maes, Eling, Wezenberg, Vissers, & Kan, 2011). This has been hypothesised as due to cerebellar maldevelopment (Courchesne et al., 1994), a reduction in novelty processing (Maes et al., 2011; Orekhova et al., 2009), or a difficulty in broadening their spread of attention resulting in difficulty shifting attention to peripheral targets (Mann & Walker, 2003). If people with ASC do struggle to broaden their attention to include all the useful available stimuli they are attending to, this may contribute to the local processing bias. These difficulties are the particular focus of the Executive Dysfunction theory, which focuses primarily on these cognitive skills. These difficulties may also contribute to the style of reproduction used by people with ASC on the ROCF, and would also suggest some amelioration strategies. For example, perhaps if people with ASC are asked to reproduce a larger simple figure before drawing the ROCF, their spread of attention may be primed to encompass larger configural elements of the ROCF, reducing the use of a local processing bias.

Difficulties with some aspects of attention may lead to a difference in how well people with ASC are able to remember information compared to TD individuals. When comparing implicit and explicit memory abilities, adults with ASC showed similar performance on an unanticipated word memory task and an explicit memory task, with the exception of making more false recalls of words that were not actually presented (Gardiner, Bowler, & Grice, 2003). It has recently been shown that whilst contextual cueing facilitates learning for people with ASC, exposure to repeated contexts which bias attention towards local, rather than global, sections of a visual display makes it more difficult for people with ASC to adapt to new trials (Kourkoulou, Leekam, & Findlay, 2012). This supports earlier findings from research on attention which concluded people with ASC struggle to broaden their area of attention. This means if they have been focusing on a small physical area in the environment, they will struggle to change to attending to a larger area of space. This attention expanding difficulty appears to potentially have a secondary effect on memory abilities. If a stimulus is not attended to and encoded, it cannot be recalled.

Spatial memory may also be affected in people with ASC. Steele, Minshew, Luna and Sweeney (2007) found that participants with ASC made more errors than matched TD controls on the CANTAB computerised test of spatial working memory (Sahakian & Owen, 1992). Participants with ASC were also less likely to use a specific organised search strategy when attempting the task. The authors concluded that HF people with ASC are more likely to show deficits in working memory when tasks exceed a certain level of difficulty or complexity. More recently, the same research group has found similar deficits when people with ASC visually process dynamic scenes (O'Hearn, Lakusta, Schroer, Minshew, & Luna, 2011).

The behavioural experiments described above show that people with ASC may perform differently than TD individuals on a variety of information processing tasks, for a number of reasons that may have some underlying connection. When initially attending to stimuli, their attention may be more focussed on a small area of the available information, which may result in a difference in the manner in which they interact with the stimuli and thus how they complete a task. This difference can result in reduced (e.g. divided attention tasks), similar or improved (e.g. block design) task performance compared to TD individuals. This difference also appears to be partially dependent on task complexity, as defined by Minshew et al. (2008) as tasks requiring integration of multiple features; high processing speed; processing of large amounts of information; or the processing of novel material. It is possible that the increased use of globally focussed strategising sometimes used by TD individuals when completing a task gives them an advantage when task complexity or demands exceed a certain level. However, a quantitative measurement of 'complexity' remains to be defined; as does the level of complexity required to cause TD individuals to switch from the use of bottom-up processing strategies to top-down executive guided processing strategies. Finally, the manner in which people with ASC process information appears to affect how much information they are later able to recall. Often HF individuals with ASC can perform at similar levels to their TD peers. However, there again appears to be an effect of task complexity, with performance dropping faster for people with ASC than their TD peers as task complexity increases.

3.1.2. Attention Cueing Paradigms

Attention cueing experiments allow researchers to manipulate the manner in which participants complete a task. They can be particularly useful in exploring the underlying mechanisms to differences in the performance of people with ASC and TD individuals. However, like the behavioural experiments above, they are not able to elucidate how a participant attempts the task or achieves the task performance that they do. In eye-gaze cueing experiments participants are usually asked to report the presence of a stimulus which appears to the left or the right hand side of a computer screen, as quickly and accurately as they can. The impending stimulus location can be 'cued' or hinted at in many ways, but typically an arrow pointing, or a symbol of an eye looking, have been used in studies of people with ASC (Pruett et al., 2011) in order to ascertain potential differences created by using a standard cueing symbol (arrow) or a social cue (eye looking) which encourages shared gaze. These experiments indicate that people with ASC orient in the same way in response to arrow and eye cues to the forthcoming location of a target. In contrast, the TD individuals show a greater response to eye gaze cues than to arrows (Ristic et al., 2005), although this difference has not always been found (Kuhn et al., 2010). Further research has suggested that people with ASC orient to these cues using a different process to TD individuals. It has been suggested that intact cueing in people with ASC is motion induced through the sudden transients present in the stimuli often employed in cueing experiments (Swettenham, Condie, Campbell, Milne, & Coleman, 2003; Senju, Tojo, Dairoku, & Hasegawa, 2004). Other authors have suggested that gaze cueing is intact in people with ASC, but that their reaction times to the resulting stimuli are slowed because they make more eye saccades during the task than TD individuals (Pruett et al., 2011). These experiments show that the manner in which people with ASC process visual scenes during a task may differ, even when their behavioural performance in some studies has matched that of TD controls. However, these experiments have produced little evidence of exactly how either group attempts the task; what cognitive processes and abilities are utilised, or what brain regions are activated.

3.2. fMRI Experiments

In an effort to investigate why people with ASC show the behavioural and potential processing differences discussed above, researchers have used fMRI to examine the patterns of brain activation which correlate with behavioural performance. Imaging experiments must be designed with the limitations of the scanning environment in mind. The participant must keep their head still during scanning. They can move their fingers and hands to use button press equipment, however arm movement is limited and talking will disrupt the scan, due to the head movement it causes (Friston, Williams, Howard, Frackowiak, & Turner, 1996). Ring et al. (1999) first adapted the EFT for use in an MRI scanner by asking participants to press a keypad button when they had located the simple target shape inside the complex figure. They found no significant differences in task accuracy between people with ASC and TD controls, although reaction time was not recorded. Both groups showed similar activation of the middle and inferior temporal gyri; supramarginal gyrus; precuneus; inferior frontal gyrus and middle occipital gyrus whilst completing the task, suggesting these areas are commonly involved in processing the task across both groups. A two-way ANOVA found that the autism group showed greater activation within the inferior and middle right occipital gyri than the TD controls. In contrast, the TD control group showed greater activation than the group with autism within several regions, including the right inferior and middle frontal gyri; the left middle and superior occipital gyri; the right supramarginal gyrus; and the right superior parietal lobule. These results supported the assertions of the Underconnectivity Hypothesis (Minshew & Payton, 1988) which hypothesised that HF people with ASC could achieve similar task performance to TD individuals; but by using a more bottom-up information processing strategy, rather than imposing a top-down strategy (Siegel, Kording, & Konig, 2000). Bottom-up processing would require more activation in the occipital lobe and other brain areas involved in lower level cognition (Corbetta & Shulman, 2002), whereas top-down processing requires the generation of specific problem solving strategies. This strategy generation is an executive functioning task requiring activation of the frontal lobe and activation of connections between the frontal lobe and brain areas involved in lower level processing (Ozonoff, 1997). These results thus suggest that despite functioning at a high level, the participants with ASC may be compensating for difficulties in using executive functioning, with a greater use of lower level processes. This could help to explain why people with ASC show a greater decrease in performance than TD individuals do as the complexity of a task increases. Unfortunately, the researchers did not use any method of checking that participants were being truthful or correct in their button press response, which somewhat limits the conclusions that can be drawn from this study.

Further fMRI studies attempted to correct some of the methodological issues of Ring et al's study. Reaction times were measured, and participants were given a two button choice to indicate which of two simple figures was embedded in the complex figure, or whether the simple figure was present or absent (Lee et al., 2007; Manjaly et al., 2007; Damarla et al., 2010). Lee et al. (2007) used fMRI to test children aged seven to 12 with ASC, and age and IQ matched controls on the EFT. There were no differences between the two groups for accuracy or reaction time. However, the two groups did show activation in different brain regions when completing the EFT, compared to completing a control task. TD children demonstrated activation in the left dorsolateral, medial and dorsal premotor regions of the frontal cortex, whereas children with ASC only showed activation in the dorsal premotor region of the frontal cortex. Similarly, bilateral ventral temporal activation was found in TD children but not in children with ASC. These children also did not show the right superior parietal and left occipital cortical activation found in TD children. However, these differences in activation did not reach significance when the two groups were compared to each other. The authors concluded that this was due to increased variability in brain region activation within the group of children with ASC.

Manjaly et al. (2007) used fMRI to test adolescents with ASC and TD controls with an average age of approximately 14.4 years. There was no significant difference between the two groups on reaction time or accuracy for the EFT. The two groups did show some differences in the pattern of activation for the EFT over and beyond that shown for a control task. The TD group showed increased activation in the left posterior parietal and dorsal premotor cortex. In contrast, the adolescents with ASC showed increased activation in the right calcarine sulcus; right cerebellum and bilateral extrastriate cortex. Similar to the study conducted by Lee et al., there were no significant differences in brain region activation between the groups. The authors concluded that their results suggest people with ASC do not have an absolute advantage for local visual processing over TD individuals, but that they have a relative advantage for local processing over Gestalt processing. This relative advantage is likely to be due to people with ASC using different functional brain networks than TD individuals to complete visual tasks (Liu, Cherkassky, Minshew, & Just, 2011). It is also possible that the participants with ASC did not show an absolute advantage over their TD counterparts because they were HF. The local processing bias may be more pronounced in lower functioning individuals with ASC, who show even greater local connectivity and more reduced cortico-cortical connectivity than their HF peers (Minshew et al., 2008). This study adds to a body of evidence which suggests that whilst there is no uniform effect of abnormal brain connectivity on cognitive functioning, recruitment of functional networks during completion of tasks is organised differently in people with ASC to TD individuals (Vissers, Cohen, & Geurts, 2012).

Proponents of a local processing bias in ASC have noted that people with ASC often achieve their peak performance on the Block Design subtest of the Wechsler intelligence scales. Bolte et al. adapted the Block Design subtest for use inside an MRI scanner by asking participants to report the number of black triangles indicative of a single block as quickly and accurately as possible (Bolte, Hubl, Dierks, Holtmann, & Poustka, 2008). They found no difference between adolescents/adults with ASC and TD controls on accuracy or reaction time. However, the fMRI analysis suggested that Block Design task completion was associated with altered responses from V2 grating and angle-selective neurons in the occipital lobe. The authors concluded that these results suggest that the performance of people with ASC could be due to differences in basic visual processing within the occipital lobe, compared to TD individuals.

Finally, the most recent study to use fMRI to examine the performance of people with ASC on visual processing tasks was conducted by Damarla et al. (2010). Like the previous studies, they found no significant differences in the EFT behavioural performance of their adolescent and adult group of participants with ASC and a group of age, IQ, and socioeconomically matched TD controls. Again though, differences in the brain regions showing increased activation were found between the two groups. Participants with ASC demonstrated less activation in the left inferior parietal and dorsolateral prefrontal areas and greater activation in visuospatial areas than TD controls. The authors considered this difference in pattern of activation to indicate reduced use or reliance on executive functions and increased reliance on more basic visual processes to complete the task; thereby indicating a difference in the use of cognitive strategies by the two groups. However, it is important to note that this difference in ‘strategy’ use does not refer to a conscious choice made by either group of participants. Participants with ASC show a reduced ability to engage the frontal lobe because of the developmental underconnectivity between their frontal lobes and other brain areas. This therefore requires the increased use of lower level processing to complete the task. Finally, in a new finding not explored by the previous fMRI studies of EFT performance, a positive correlation was found between the size of the corpus callosum, and functional connectivity between frontal and posterior brain areas, for participants with ASC. This correlation was not found for TD participants. Damarla et al. concluded that this correlation demonstrates a possible biological substrate for some of the behavioural characteristics of ASC. This conclusion was based on the frequent finding that corpus callosum size is reduced in people with ASC (Frazier & Hardan, 2009). Damarla et al. considered that decreased corpus callosum size could constrain the communication among cortical areas. Conversely, their current participants with ASC who had larger corpus callosums showed greater functional connectivity between frontal and parietal areas. However, the authors did not report on how this intra ASC group variance may or may not have affected behavioural performance.

A recent meta-analysis (Philip et al., 2012) amalgamated the results of 12 studies of visual processing. Within these 12 studies, children, adolescents and adults with ASC were tested against matched controls on such tasks as the modified block design (described above); visual checkerboard; an emotion recognition task; visual search; the EFT; mental rotation of matching shapes; and visually guided saccades. Across these amalgamated task results, significant group differences were found between participants with ASC and TD controls. Participants with ASC showed greater activation in the higher level processing areas of the left thalamus and left medial frontal gyrus than TD controls. In contrast, TD controls showed greater activation than participants with ASC in the lower-level processing areas of left precentral gyrus; the occipital lingual gyrus and the middle occipital gyrus. The authors concluded that the greater activation of visual areas by TD controls might reflect more efficient processing of visual stimuli by people with ASC; whilst TD controls showed more efficient higher level processing and therefore less activation in the left thalamus and medial frontal gyrus (Philip et al., 2012; Soulieres, Zeffiro, Girard, & Mottron, 2011).

All of the studies discussed above are in agreement that people with ASC can show a different pattern of brain activation to TD controls on visual processing tasks, in the presence of similar behavioural performance. However, authors have differed in the theory of autism they have discussed in relation to their results. Several authors (Ring et al., 1999; Lee et al., 2007; Manjaly et al., 2007) concluded their results supported WCC theory; however, their results could also be used as evidence to support E-S theory or the Underconnectivity Hypothesis. Damarla et al. (2010) conducted a somewhat different data analysis by examining what their participants' pattern of activation during the task suggested about the functional connectivity between different brain areas. They concluded that their results supported the Underconnectivity Hypothesis, however their results could also support WCC theory, because their participants showed equivalent (not enhanced) behavioural performance in the presence of reliance on lower level processing suggestive of a local processing bias.

3.3. Eye Tracking Experiments

Eye tracking offers a unique way to investigate real time visual information processing whilst an individual is completing a task. Behavioural results such as reaction time to complete a task or accuracy of task completion can only tell us what people do, not how they do it. In contrast, fMRI experiments can tell us which brain regions are involved in completing a task but is unable to offer real time information because the BOLD response is delayed behind task activity by approximately six seconds (Liao, Worsley, Poline, Duncan, & Evans, 2001). Eye tracking may be particularly useful for investigating the online processing of people with ASC, who often struggle with deciding how to complete a complex task, especially if something unexpected happens such as a sudden change or if they make a mistake (Gaus, 2007). Problem solving strategies can be taught to people with ASC (D'Zurilla, 1986); however, it is not known how they were originally attempting and struggling to achieve a task, or what changed in the way they approach information after intervention.

Eye movements are comprised of saccades and fixations. 'Saccade' refers to the movement of the eye from one location to another, and 'fixation' refers to a place or view point on which the eye stops and looks at directly. Eye saccades and fixations can be tracked using cameras which record both the eye and the scene it surveys. The recording of the eye and the recording of the scene are then matched together. Capturing eye movements and gaze gives a good measure of attention, because it has been shown that covert and overt orienting using eye movements are inextricably linked (Kowler, Anderson, Dosher, & Blaser, 1995). This means that where a person attends is where they look, and vice versa, unless they are attempting to deliberately attend to something in your parafoveal or peripheral visual field without looking at it. Eye movements have been shown to reflect on-line cognitive processing for a multitude of tasks across many domains (Rayner, 2009).

A number of eye tracking paradigms have been used to explore the cognitive processes of people with ASC. Anti-saccadic tasks require participants to suppress the learned response of looking at a stimulus as it appears on a computer screen, and instead to look away to the opposite side of the screen. People with ASC have found it harder to look away from the appearing stimulus than TD controls. This has been hypothesised as being due to difficulties in higher-order volitional attention shifts (Minshew, Luna, & Sweeney, 1999). Further evidence for this hypothesis comes from scene viewing tasks. When given two different sets of instructions, TD individuals significantly modify the way they visually scan the same image. In contrast, people with ASC have not shown the same difference, meaning they scan an image in a similar way regardless of the instructions (Benson, Piper, & Fletcher-Watson, 2009).

Eye-tracking is a very popular methodology for investigating the manner in which people with ASC survey naturalistic scenes and videos. People with ASC spend less mean total time fixating on the eyes of people in the scenes they view compared to TD individuals (Klin, Jones, Schultz, Volkmar, & Cohen, 2002; Jones, Carr, & Klin, 2008). This differing manner of facial scanning can also lead people with ASC to have greater difficulty remembering faces than TD individuals (Snow et al., 2011). In social scenes and videos people with ASC spend less time looking at the people present and more time observing objects and the environment than TD controls (Riby & Hancock, 2009). However, other studies have not found these results (Kuhn et al., 2010; Fletcher-Watson, Leekam, Benson, Frank, & Findlay, 2009). It has been suggested that differences in visual scanning by people with ASC are likely to increase with task complexity; for example, the addition of sound or characters in video interacting (Speer, Cook, McMahon, & Clark, 2007). These additional factors increase both working memory load, and the processing speed required by the task, thereby increasing complexity (Minshew et al., 2008).

3.3.1. Eye Tracking Experiments Using Complex Figures

Compared to the exploration of social scene scanning and emotion recognition, eye tracking experiments of how people with ASC process complex two-dimensional line drawing figures or shapes are relatively rare. However, this type of test is frequently used in Neuropsychological testing and may offer a more quantitative way of measuring complexity, both for load of information and novelty. Keehn et al. (2009) published the only study to date to use eye tracking to examine the manner in which people with ASC completed a modified version of the EFT developed by Manjaly et al. (2007). The use of this modified version allowed Keehn et al. to compare the relative differences between TD people and HF people with ASC on a baseline control condition and the EFT. They attempted to elucidate the underlying processing mechanism by which people with ASC have often shown enhanced performance on the EFT. Children and adolescents with ASC were found to perform the EFT significantly faster than TD controls, without demonstrating a concurrent reduction in accuracy. No group difference was found on the baseline control condition. Comparison of eye tracking data showed no group differences for fixation frequency, however, children and adolescents with ASC made significantly shorter fixations than the TD controls. Further analysis of this data revealed that the children and adolescents with ASC made significantly shorter fixations on the figure, but not the target, indicating the young people with ASC spent less time identifying or being distracted by non-target information than the TD controls. Participants with ASC also made significantly shorter initial and final fixations than the TD controls during the test condition, but not in the baseline condition. The authors concluded that this longer latency to first saccade shows that the TD controls found the test condition more challenging than the baseline condition. In contrast, the young people with ASC showed similar initial times to first saccade during both conditions. This suggests that the target shape was equally salient to them in both conditions. Keehn et al. concluded that these results supported both WCC theory and a model of enhanced perceptual processing (Mottron et al., 2006); however, they could also support both E-S theory, which sees the local processing bias as a strength or advantage in people with ASC; and the Underconnectivity Hypothesis which would argue the group differences were due to increased lower-level perceptual processing by the children with ASC, which results from a lack of higher level cognitive input to the task.

Despite its popularity with clinicians (Rabin et al., 2005), the ROCF has received little attention from researchers working with eye tracking methodology. This may be due to the requirement for using mobile head mounted eye tracking equipment to allow people to move and draw, instead of the usual wall or computer mounted systems used for computer based button press tasks. These wall or computer mounted systems are not suitable for drawing as they require the participant to remain completely still and only focus on a set area directly in front of them. Only two studies have examined the manner in which people visually process the ROCF. The first study examined how 20 TD individuals processed the ROCF when it was presented on a computer screen for 20 seconds. They were then asked to reproduce the ROCF from memory (Manor, Gordon, & Touyz, 1995). Eighty percent of the sample made their first fixation to a circle and its contents located in the top right quadrant of the ROCF. The authors concluded that this may be for two possible reasons. Firstly, it may be due to the circle being the most unique feature of the figure, as it is the only non-straight line. Secondly, it may be due to the circle and three dots partly resembling a line drawing of what could be perceived as a schematic face. This would preferentially draw the attention of TD individuals (Caldara et al., 2006; Stein, Peelen, & Sterzer, 2011). Manor, Gordon and Touyz (1995) reported that after the first saccade, participants made a median of 41 further saccades, with a median fixation duration of 0.32 seconds. Patterns of eye movements were found to widely differ between participants, without any apparent common pattern, although the authors did not report any quantitative analysis of the scan path following initial fixation. During recall, 95% of participants started by drawing the outer main box shape, as described by Osterrieth as the ‘Type 1’ style of reproduction (Osterrieth, 1944). There was no correlation between the number or duration of fixations and the reproduction score. However, there are several issues in generalising these results to the clinical usage of the ROCF. Normally participants are expected to start by copying the ROCF whilst it stays in front of them, and no time limit is imposed. Clinicians also frequently don’t warn their patients or clients in advance that they will be expected to produce the ROCF from memory. Participants in this eye tracking study might alter their scanning strategy in response to the altered presentation, time limit and instructions.

The second study to examine the reproduction of the ROCF used the figure as a control comparison when examining the visual processing of faces (Manor et al., 1999). Twenty five TD individuals were recruited as control comparisons to a group of people with a diagnosis of schizophrenia. Manor et al. showed each participant the ROCF for 10 seconds and examined their visual scan paths. TD controls made their first fixation to the right side of the ROCF significantly more than their clinical group, who showed greater tendency to start by examining the left side of the figure. No other analysis was reported and no reproduction of the figure was requested from participants. This methodology differs greatly from the clinical use of the ROCF and so does not provide any predictions on how people might be expected to process the ROCF when reproducing it under test conditions. In summary, virtually no evidence exists on how people visually process this widely used and longstanding test of visuospatial construction and memory.

4. Conclusions

Altered information processing is one of the most studied areas of ASC, evidenced by the focus it receives from many current major theories of ASC, especially the WCC and E-S theories. The Underconnectivity Hypothesis attempts to explain the aetiology of ASC, with the behaviour which characterises ASC seen as a product of this aetiology. These theories have influenced the focus and methodology of research studies in recent years. Behavioural experiments have been supplemented by fMRI, and more recently by the use of eye tracking. These methodological advances have been pivotal in expanding our understanding of the more subtle differences between people with ASC and TD individuals in information processing. It is now evident that whilst HF individuals with ASC can often perform tasks to the same ability as their TD peers, they may do so in a different manner, using different strategies and recruiting brain regions to a different degree. It appears that people with ASC may have difficulties in widening their focus of attention, leading to difficulties attending to stimuli in their peripheral space and perhaps resulting in the often reported local processing bias. However, a local processing bias can confer some advantages when tasks require a focus on detail.

Functional imaging studies have often demonstrated increased activation of occipital and parietal brain regions and decreased activation of the frontal regions in people with ASC whilst completing visual tasks, compared to their TD peers (Philip et al., 2012). This has been interpreted to reflect people with ASC processing information to an increased degree at a basic level, using bottom-up processing. This style of information processing appears to allow people with ASC to achieve equivalent task performance to their TD peers until task load exceeds a certain level, when performance deteriorates more rapidly for people with ASC than for TD individuals, who may be able to adopt a more top-down strategy based information processing style. People with ASC may not have the capacity to utilise this style due to differences in their cortico-cortical white matter connections (Minshew et al., 2008).

Finally, eye tracking methodology is starting to bridge the gap between information processing and the behavioural performance produced for many cognitive processing tasks. Eye tracking allows a greater focus on how people attend to the stimuli in order to process it and complete the task. It has been found that people with ASC may show difficulty with higher order volitional attention shifts and may struggle to attend to complex social interactions involving more than one person conversing. This is potentially partly due to the increased working memory requirements of the situation. When viewing complex figures or completing the EFT, people with ASC execute a similar number of saccades to their TD peers, but it has also been found that their fixations are shorter which leads to an overall reduction in reaction time to complete a task, and therefore a task advantage. However, despite these recent findings, our understanding of the attentional processes which underlie visual processing of tasks remains limited.

5. Future Directions for Research

Whilst fMRI studies have shown that people with ASC show a different profile of brain activation to TD individuals whilst performing visual processing tasks, it is not known how this affects the manner in which people with ASC attend to visual stimuli. They could attend to the stimuli in a similar manner but process the information differently after acquisition, leading to different strategies of task performance, or they might show fundamental differences in the way they approach and view a task, by focussing on different aspects of the stimuli to TD people and therefore encoding different amounts or information before any strategy to act upon that information is used. These two potential mechanisms could suggest different habilitation strategies to help people with ASC manage tasks they report finding difficult. For example, if people with ASC show difficulty in spreading their attention, an intervention that helps them to consider the widest area they need to include might be helpful, or to consider the task without the stimuli in front of them in order to attempt to form a strategy to complete the task in hand in a more targeted manner. Alternatively, if people with ASC attend to visual stimuli in a similar manner but then act upon it differently, higher order EF strategies may be helpful (D'Zurilla, 1986; Gaus, 2007). However, until these two potential mechanisms are examined using eye tracking, the most effective starting point for skills training will remain unknown.

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An Eye Tracking Investigation of the Visual Processing of the Rey-Osterrieth Complex Figure by People with Autistic Spectrum Condition

Abstract

People with Autistic Spectrum Condition (ASC) have previously achieved superior performance on tasks which require an attention to detail, or local-processing bias, coupled with reduced task performance when an overview of the Gestalt is required. However, this finding is far from universal; especially when study participants with ASC have an average to above average level of general intellectual functioning. The current study used both the Boston Qualitative Scoring System and eye tracking methodology to investigate the potential presence of a local-processing bias, evidenced by increased lower level cognitive processing during completion of the Rey-Osterrieth Complex Figure. Eleven participants with ASC and 11 typically developed participants matched for age, sex, and general intellectual functioning participated in the study. A local-processing bias was not found. This study does not support the presence of this bias in high functioning individuals with ASC. The study findings are discussed in relation to the existing literature and the Underconnectivity Hypothesis of ASC.

1. Introduction

Autistic Spectrum Condition (ASC) is the current umbrella term used for the neurodevelopmental conditions of Autism and Asperger Syndrome (AS; Baron-Cohen, 2009). People with ASC experience impairments in social interaction and communication, coupled with at least one symptom of restricted or repetitive behaviour (American Psychiatric Association, 2000). An individual will be diagnosed with Asperger Syndrome (AS), instead of autism if they show no significant delay in language or cognitive development (American Psychiatric Association, 2000). Despite their absence from the diagnostic criteria, factors such as sensory hypersensitivity (Ben-Sasson et al., 2009) and a tendency toward bottom-up, detail focussed, processing of the environment (Mottron, Dawson, Soulieres, Hubert, & Burack, 2006; Neumann et al., 2011) can also be indicative of an ASC (Baron-Cohen, Wheelwright, Skinner, Martin, & Clubley, 2001). This tendency to process information using a 'local-processing bias' (Pellicano, Maybery, Durkin, & Maley, 2006) is a focus of many current theories of ASC.

Estimates suggest that there are currently approximately 433 000 people with ASC living in the UK and that ASC in adults costs the UK economy approximately £25.5 billion every year (Knapp, Romeo, & Beecham, 2007). High functioning people with ASC can experience pronounced difficulties in their everyday life, despite having low average to above average levels of intellectual functioning. A recent report by the National Audit Office indicates that whilst high functioning (HF) individuals with ASC can function normally in many domains of their lives, subtle differences in how they process and navigate the world around them can cause pronounced difficulties in other areas (National Audit Office, 2009).

1.1. Theories of ASC

There are currently three main theories of ASC. These are Weak Central Coherence (WCC) theory (Frith & Happe, 1994); Empathising-Systematising (E-S) theory (Baron-Cohen, 2009) and the Underconnectivity Hypothesis (Minshew, Williams, & McFadden, 2008). The WCC and E-S theories share a focus on how people with ASC process information. WCC theory posits that people with ASC show either a reduced or lack of ability to extract overall meaning from their environment; instead processing the constituent parts of a stimulus or environment (Frith & Happe, 1994). Support for this theory comes from research demonstrating the 'local-processing bias' by people with ASC (Brosnan, Scott, Fox, & Pye, 2004; Happe & Frith, 2006), coupled with difficulty benefiting from the context of information (Happe, 1994; Gallagher et al., 2000).

In contrast to WCC theory, E-S theory depicts the local-processing bias shown by people with ASC as a purposeful attempt to understand their environments (Baron-Cohen, 2009). This focus on the details of stimuli is seen as an innate preference and cognitive style rather than an inability to see the gestalt and therefore a disability. E-S theory hypothesises that given enough time and access to information regarding the different variables, an individual with ASC would be able to gain an excellent understanding of a system. WCC theory would expect the individual to remain lost in the parts of the system and never be able to integrate them into a whole.

Whilst WCC theory primarily focuses on information processing, the E-S theory also considers the neurological basis behind ASC. Neuroimaging studies show that the deficits that people with ASC tend to experience in empathising skills and the strengths they tend to experience in systematising skills are correlated with the size of the brain regions thought to subserve these skills. For example, brain regions linked to empathising abilities such as the anterior cingulate, the prefrontal cortex, the superior temporal gyrus and the thalamus are smaller in people with ASC than typically developed (TD) individuals. In contrast, regions thought to subserve systematising skills such as the amygdala and the cerebellum are larger in people with ASC than TD individuals (Baron-Cohen, Knickmeyer, & Belmonte, 2005).

In contrast, to the WCC and E-S theories, the Underconnectivity Hypothesis focuses on the aetiology of autism, rather than the cognitive result of that aetiology, and as such, represents a neurobiological model of autism (Minshew, Goldstein, & Siegel, 1997; Minshew et al., 2008). The Underconnectivity Hypothesis describes five key levels to ASC . ASC is thought to originate from abnormalities in the genetic code for brain development, which then create abnormal mechanisms of brain development. These mechanisms result in structural and functional abnormalities in the brain, which in turn create the cognitive and neurological abnormalities seen in ASC.

In HF adults, ASC is considered the result of disordered development of the white matter connective tissues between neocortical systems; especially frontal posterior connections (Minshew et al., 2008). This cortico-cortical underdevelopment is coupled with an increase in white matter connections within localised regions of the brain. This results in wide ranging impairments in higher order cognitive abilities, in the presence of intact or enhanced processing of lower level tasks and information (Minshew et al., 1997; Williams, Goldstein, & Minshew, 2006). Minshew et al. (2008) hypothesised that these differences in cortical connections would result in people with ASC showing greater sensitivity to increases in task complexity. Task complexity is defined as a function of the number of features which must be integrated; speed of processing; processing of novel material; and/or the processing of large amounts of information. However, there is currently no standardised measuring system for evaluating how these variables of complexity compare or interact; for example, how high task load compares to high novelty, or the effect of high task load on a novel task.

The Underconnectivity Hypothesis is supported by evidence from functional magnetic resonance imaging (fMRI) studies. Whilst HF people with ASC can perform at the same level as their TD peers on a range of tasks fMRI studies show that people with ASC demonstrate different brain activation patterns to TD control participants, whilst completing the same tasks (Philip et al., 2012). They exhibit greater activation within occipital parietal regions; consistent with a reliance on using basic cognitive abilities to complete tasks, In contrast, people with ASC show comparatively reduced activation of frontal regions (Luna et al., 2002; Just, Cherkassky, Keller, Kana, & Minshew, 2007). This pattern of information processing results in an accelerated reduction on task performance by people with ASC as task complexity increases (Garcia-Villamisar & Della Sala, 2002).

The Underconnectivity Hypothesis predicts that increased neural connectivity in occipital and parietal regions may make it easier for people with ASC to notice both the presence and location of details (Minshew et al., 2008). They may reproduce visual stimuli in a detail focussed manner, and remember more details of a complex figure than their TD peers. Conversely, people with ASC could be less likely to utilise higher order reproduction and memory strategies, due to reduced connectivity between brain regions (Minshew et al., 2008). This could result in people with ASC reproducing and remembering less of the global structures of a visual stimulus, than their TD peers. The Underconnectivity Hypothesis is the most extensive and theoretically supported theory of ASC, especially from experiments that go beyond behavioural data alone, such as fMRI studies or eye tracking (discussed below). Therefore this hypothesis will be used to discuss the results of the current study and compare the current research to similar studies, also designed using the Underconnectivity Hypothesis as their theoretical basis.

1.2. The Rey-Osterrieth Complex Figure and ASC

The Rey-Osterrieth Complex Figure (ROCF) is a test of visuo-spatial perception and construction, and memory (Rey, 1941; Osterrieth, 1944; Meyers & Meyers, 1995). The individual being tested is first asked to copy the figure. The individual is then required to reproduce the figure from memory, both immediately and 20-30 minutes later. The ROCF is commonly used within the field of neuropsychology (Camara, Nathan, & Puente, 2000) and is ranked among the top 10 tests most frequently used by Neuropsychologists (Rabin, Barr, & Burton, 2005). The measures of performance typically used are the copy score, and immediate and delayed recall scores; as well as the indices provided by any standardised qualitative scoring systems used. These qualitative systems measure several aspects of performance, such as how a participant organises their ROCF reproduction, which style they use (detail or Gestalt focused), and how many of the main structural elements or attached details are reproduced. The most well-normed and frequently used system is the Boston Qualitative Scoring System (BQSS) (Stern et al., 1999). The BQSS divides the ROCF into six main configural elements, nine clusters and six remaining details. The BQSS measures 13 aspects of ROCF copy and recall, and provides an additional six summary scores. Researchers who have used this system with people with ASC have used the measures of Presence, Accuracy and Planning; as well as the Organisation summary score (Kuschner, Bodner, & Minshew, 2009; Tsatsanis et al., 2011), because these measures are theoretically most able to detect a potential local processing bias.

The ROCF has been used in studies of ASC to assess both overall accuracy and the manner in which the ROCF is reproduced. Two small sample studies of children and adolescents found that copy accuracy and element placement did not differ between participants with ASC and TD controls (Prior & Hoffmann, 1990; Gunter, Ghaziuddin, & Ellis, 2002). However, other research shows that people with ASC demonstrate poorer accuracy on the ROCF than when copying more simple designs; showing a greater reduction in performance than the TD participants (Rumsey & Hamburger, 1988; Minshew et al., 1997; Kenworthy et al., 2005). Minshew and Goldstein (2001) tested adolescents and adults with ASC on the immediate and delayed memory trials of the ROCF. Participants with ASC remembered significantly less of the ROCF on both memory trials compared to the TD controls. Minshew and Goldstein hypothesised that the participants with ASC used less organisational strategies whilst copying the ROCF and this may have reduced their depth of encoding and thus the amount they later remembered. Unfortunately, Minshew and Goldstein did not assess the organisation of the ROCF copy or reproduction and so did not produce supporting evidence for this hypothesis. Ropar and Mitchell (2001) examined the strategies used by children and adolescents with ASC to reproduce the ROCF. They did not find evidence that participants with ASC used a more detail-oriented reproduction strategy than their TD peers. However, they did not use a standardised rating system of organisation, such as the BQSS and so this limits the conclusions that can be drawn from their study. Schlooz et al. (2006) used a standardised scoring system, the Development Scoring System (DSS-ROCF; Bernstein & Waber, 1996) to compare children with ASC to children with Tourette syndrome and TD children. The children with ASC achieved a lower mean organisation score, used a more detail-focused style, and recalled fewer structural elements than the other groups. This study supports a local-processing or detail-oriented bias in children with ASC.

The disagreement found between many of the early studies using the ROCF may have been caused by the use of children as participants. There is evidence that TD children show a detail oriented manner of ROCF reproduction and later develop a more strategic global manner of organising their ROCF reproduction as they age (Akshoomoff & Stiles, 1995a; Akshoomoff & Stiles, 1995b). Earlier studies may not have found a difference between the children with ASC and TD children because all of the children are most likely to use a detail-focused style of reproduction. Kuschner, Bodner and Minshew (2009) addressed this concern by comparing both children and adults with ASC to age, IQ, and gender matched TD controls, using the BQSS. Both the adult TD and ASC groups achieved better Presence and Accuracy summary scores than their child counterparts, suggesting that both TD and ASC individuals improve their ROCF reproduction with age. There was an interaction between diagnostic group and age on the copy condition Organisation score. Children with ASC, TD children, and adults with ASC all achieved similar Organisation summary scores, whilst TD adults achieved significantly higher Organisation scores. This suggests that TD individuals improve their ROCF organisation with age, whilst adults with ASC do not. A similar pattern of results was found for the Planning score although this interaction was only marginally significant (p=0.06). This suggests that the ability to plan the ROCF reproduction before beginning to draw also improves with age in TD individuals but not people with ASC. This could mean that the TD adults use a greater level of executive functioning to aid their ROCF reproduction than the other groups (Ozonoff, 1997).

In a recent large scale study Tsatsanis et al. (2011) used the DSS-ROCF (Bernstein & Waber, 1996) to compare 50 children and adults with ASC, to 49 TD controls and also 71 clinical controls diagnosed with either Obsessive Compulsive Disorder, Tic Disorder, and/or Attention-Deficit Hyperactivity Disorder. The three groups were matched for age, sex, and IQ. The ASC group showed a more detail-focused style to reproducing the ROCF than the TD and clinical control groups.. When the sample was split into children (six years to 13 years) and adolescent/adults (14 years to 42 years) this difference remained significant. Participants with ASC showed a more detail-focused than the TD controls in both age groups. This difference showed a large effect size. Interestingly, the participants with ASC reproduced significantly less of the incidental details or structural elements of the ROCF than TD controls in the Copy condition, suggesting that a detail-focused style did not help the participants with ASC reproduce more incidental details. However, this analysis was not split by older and younger age group and so any potential differing effect of age cannot be ascertained. Finally, better organisation of ROCF copy was linked with a more configurational approach to reproduction in the TD controls. However, participants with ASC showed an ability to draw the ROCF in a part-oriented but still well organised manner (Tsatsanis et al., 2011), suggesting that two types of detail-focused style exist. Where detail-focus is organised, individuals with ASC appear to be able to perceive the gestalt as a complex collection of parts. However, where detail-focus lacks organisation, it may be that individuals can only perceive separate components without the overarching context. This study also highlighted the importance of age as a pivotal factor in whether differences in ROCF reproduction are found. This may be linked to frontal lobe development in TD adults, allowing them to choose from and utilise a greater range of strategies when completing the ROCF (Burgess & Simons, 2005).

1.3. Eye Tracking Studies of Visual Processing in ASC

Eye movement tracking provides a non-invasive measurement of online cognitive processing during the completion of visual tasks (Liversedge & Findlay, 2000; Rayner, 2009). Eye movement analysis in ASC allows the moment by moment inspection of what, how, and for how long visual information is sampled during task completion. Previous studies of the eye movements of people with ASC have often examined how they survey naturalistic scenes and videos. These studies have often found that whilst TD individuals significantly modify the way they visually scan the same image when given two different sets of instructions, people with ASC do not, meaning they scan an image in a similar way regardless of the task instructions (Benson, Piper, & Fletcher-Watson, 2009). This means that for simple task instructions the performance of people with ASC equals that of age, sex and IQ matched TD controls. However, when asked to complete a more complex task such as making social judgements about an image, the performance of people with ASC drops significantly below their TD peers (Au-Yeung, Benson, Castelhano, & Rayner, 2011). This indicates that people with ASC may show differences in how they sample visual information before they do any higher level cognitive processing on that information; rather than just using different cognitive strategies to process the same information. This supports the Underconnectivity Hypothesis which states that people with ASC will conduct a greater amount of their information processing within the localised regions of the brain that support basic cognitive processes compared to their TD peers. For people with ASC, a concurrent reduced ability to use frontal-posterior connections to aid in complex task completion becomes more evident as task complexity increases.

Eye tracking research on how people with ASC process complex two-dimensional line drawing figures or shapes is relatively rare. However, figure reproduction tests are frequently used in Neuropsychological testing and may offer a more quantitative way of measuring complexity, both for load of information and novelty. Keehn et al. (2009) have published the only study so far to use eye tracking to examine the manner in which people with ASC completed a modified version of the Embedded Figures Test (EFT) developed by Manjaly et al. (2007). Children and adolescents with ASC were performed the EFT significantly faster than TD controls, without demonstrating a concurrent reduction in accuracy. No group difference was found on the control condition. Comparison of eye tracking data did not show any group differences for fixation frequency. However, participants with ASC made significantly shorter fixations than the TD controls. This was due to the TD controls demonstrating longer first and last fixations during the EFT than the baseline condition, whereas the children and adolescents with ASC did not find the test condition any more challenging than the baseline condition. The Underconnectivity Hypothesis would argue the group differences were due to increased lower-level perceptual processing by the children with ASC.

Despite its popularity with clinicians (Rabin et al., 2005), the ROCF has received little attention from researchers working with eye tracking methodology. Only two studies have examined the manner in which people visually process the ROCF. Both studies examined how TD individuals processed the ROCF when it was presented on a computer screen for 20 seconds. They were then asked to reproduce the ROCF from memory (Manor, Gordon, & Touyz, 1995; Manor et al., 1999). Eighty percent of the sample made their initial fixation to a circle and its contents located in the top right quadrant of the ROCF. This may be due to the circle being the most unique feature of the figure, as it is the only non-straight line; or it may be due to the circle and three dots partly resembling a line drawing of a schematic face. This would preferentially draw the attention of TD individuals (Caldara et al., 2006; Stein, Peelen, & Sterzer, 2011). After the first saccade, patterns of eye movements were found to widely differ between participants, without any apparent common pattern. This methodology differs greatly from the clinical use of the ROCF and so doesn't provide any predictions on how people might be expected to process the ROCF when reproducing it under test conditions. In summary, virtually no evidence exists on how people visually process this widely used and longstanding test of visuospatial construction and memory.

1.4. The Current Study

In the current study, I investigated both task accuracy and speed, and the profile of eye movements during the task by both people with ASC and TD controls. Both groups of participants completed the standard administration of the ROCF and a control condition which was to reproduce a simple two-dimensional shape whilst their eye movements were tracked. The aim of this study was to compare the processing of two different levels of task complexity by the two groups. Better planned and organised ROCF reproduction should occur when participants successfully integrate top-down information from the higher frontal brain regions with bottom-up visual information from the occipital regions. In contrast, no such integration should be required to complete the simple control task.

This study will attempt to test the following hypotheses:

1) Participants with ASC will achieve poorer BQSS Planning and Organisation scores than TD controls. The Underconnectivity Hypothesis suggests this would be because people with ASC are less able to use top-down information from the higher frontal brain regions to guide their reproductions.
2) Participants with ASC will achieve better Cluster and Detail Presence and Accuracy scores on the BQSS than TD controls, thereby demonstrating a local-processing bias and advantage. This will be coupled with lower Configural Presence and Accuracy scores than TD controls.
3) There will be a correlation between the Block Design subtest and the Detail Presence scores, supporting a local-processing advantage to both test performances.
4) Participants with ASC will spend less mean total copy completion time looking at the Configural main elements of the ROCF than TD controls and more mean total copy completion time looking at the Cluster and Detail elements; thereby evidencing a local-processing bias.
5) Participants with ASC will be slower to fixate on ‘Cluster 5’ (see Appendix C), which is the round element in the upper right side of the ROCF because they will be less drawn to look at an element which resembles a schematic representation of a face.

2. Methods

2.1. Participants

Two groups of participants were recruited to take part in this study. The ASC group consisted of men with a diagnosis of either Asperger Syndrome (AS) or high functioning autism, and the control group consisted of typically developed men. Women were not asked to participate for two reasons. Firstly, there is an ongoing debate concerning the diagnosis of women with ASC. Women may show a different pattern of autistic behaviours, demonstrating more social interaction and better imagination (Gould & Ashton-Smith, 2011). The ASC diagnosis criteria were developed with greater reference to symptoms or behaviours more frequently demonstrated by men with ASC, and until this debate is resolved, testing only men with ASC may provide a more homogenous sample and thereby reduce the chance of type II statistical error. Secondly, recruiting women to the control TD group could also increase intra-group variance and chance of type II error. A gender difference has previously been found on both the Autism Spectrum Quotient (AQ) questionnaire (Baron-Cohen et al., 2001) and the Rey-Osterrieth Complex Figure (ROCF; Gallagher & Burke, 2007), with TD men and women scoring significantly differently from each other.

Potential participants were also excluded if they were less than 18 years old; taking psychoactive medication; had a previous head injury resulting in loss of consciousness; had any motor movement problems; or if they had a full scale intelligence quotient (FSIQ) of less than 80, as measured by the Wechsler Abbreviated Scale of Intelligence (WASI; Wechsler, 1999). These exclusions reduced the risk that intra or inter-group differences reflected an influence of these known nuisance variables. Recruiting only participants with an IQ of over 80 was intended to exclude any effect of learning disability on test completion (Gallagher & Burke, 2007) and to increase the probability that the results found could be generalised to both the majority of the male general population (for the TD group) and the majority of the male population of high functioning individuals with ASC.

2.2. Sample

Individuals with ASC were recruited from ASC social groups in Southampton (the National Autistic Society) and London (the adults group run by the Children on the **Autistic** Spectrum Parents Association); from Southampton Solent University Disability Support; or from the University of Southampton Psychology department's Centre for Visual Cognition database of individuals with ASC who have indicated an interest in participating in research (see Appendix A for the Participant Information Sheet). TD controls were recruited from the University of Southampton. The demographic data for the two groups are shown below in Table 1. The mean age of the ASC group was 28.5 years, compared to a mean age of 24.9 years for the TD group. An independent samples t-test showed that the mean age of the two groups was not significantly different ($t = 0.94$, $p = 0.36$).

Table 1: Demographic data for the experimental groups

Group Name	Autistic Spectrum Conditions	Typically Developed
Number of participants	11	11
Participant Age (mean +/- s.d. in years)	28.5 (11.1)	24.9 (5.7)
Participant Age range (years)	18 - 48	19 - 38

2.3. *Measures and Stimuli*

2.3.1. The Wechsler Abbreviated Scale of Intelligence

The WASI (original version) is a measure of general intellectual functioning, or intelligence (Wechsler, 1999). Intelligence may be broadly defined as the ability to deal effectively with the environment (Wechsler, 1944) and is considered as both a global capacity (*g*) and the combination of more specific and varied abilities. The WASI measures both verbal and performance intelligence with a four different tasks that measure skills such as perceptual abilities and abstract reasoning. The WASI was originally trialed on 2245 individuals to create standardised norms for use with people aged 6 – 89 years old. The test gives an overall FSIQ, and can be separated into a two factor model of verbal IQ (VIQ) and performance IQ (PIQ). The 95% confidence interval (CI) of the WASI is approximately four points either side of the obtained FSIQ; the WASI has a test-retest reliability of 0.92 and inter-rater reliability of 0.98 (Wechsler, 1999).

2.3.2. The Autism Spectrum Quotient

The AQ is a 50 item self-report questionnaire designed to measure the traits associated with the autistic spectrum in adults of normal to superior intelligence (Baron-Cohen et al., 2001). The Autism Spectrum Quotient (AQ) has been shown to successfully distinguish people with ASC from TD controls. Studies have shown that 93% of the general population fall within the average range of the AQ, and 99% of the autistic population fall in the extreme (high-end) of the scale (Baron-Cohen, Hoekstra, Knickmeyer, & Wheelwright, 2006; Baron-Cohen et al., 2001). Cronbach's α coefficients for the five domains measured by the AQ range from 0.63 ('Local details') to 0.77 ('Social').

2.3.3. The Rey-Osterrieth Complex Figure

The Rey-Osterrieth Complex Figure (ROCF) is a test of visuo-spatial perception and construction, and memory. It was first created in 1941 by Andre Rey (Rey, 1941) and further standardised in 1944 by Paul-Alexandre Osterrieth (Osterrieth, 1944). The individual being tested is required to copy the figure, which is displayed in front of them. Both the figure and the copy are then removed and the individual is asked to reproduce the figure from memory, both immediately and 20-30 minutes later. This test measures visuo-spatial abilities, but also planning ability and visual memory (Meyers & Meyers, 1995). The figure is scored for the accurate reproduction and placement of 18 specific design elements, giving a maximum possible score of 36 points and has test-retest reliabilities of between 0.85 – 0.97 for the three conditions (Tupler, Welsh, Asare-Aboagye, & Dawson, 1995).

Each participant's copy and reproductions of the ROCF were scored using the Boston Qualitative Scoring System (BQSS; Stern et al., 1994). The BQSS divides the ROCF into Configural Elements, Clusters, and Details. A Configural Element is a large global element such as the main rectangle of the design. A Cluster is a distinguishable component of the total figure, such as the small rectangle containing one diagonal line that appears on the left side, below the large rectangle. A Detail is a smaller, less distinguishable component of the ROCF. These Configural Elements, Clusters, and Details are scored for Presence, Accuracy, Placement, and Fragmentation. These scores contribute to Summary Scores, including Presence and Accuracy for the copy and reproductions, and the Organization of the reproduction. The ROCF is also scored for characteristics of how the reproduction is approached, giving an overall Planning Score. The BQSS shows good to excellent reliability (kappa values range from 0.78 – 0.99; Stern et al., 1994). A Copy of the ROCF and the Configural Elements, Clusters, and Details is shown in Appendix C.

2.3.4. The House

A diagram of a house was used as a simple figure because its configural elements could be matched to the ROCF. For example, the main rectangle of the house matches the main rectangle of the ROCF. The triangular and square elements of the house can also be found in different locations and angles on the ROCF. However, the house lacks the additional details which gives the ROCF its complexity; thereby making it a much more simple shape to copy. The house and its scoring criteria are shown in Appendix B.

2.4. Procedure

Participants attended the University of Southampton Psychology department. They had the opportunity to ask any questions about the information sheet and the procedure to follow, before signing the consent form (see Appendix D). Participants then completed the WASI. For the eye movement recording, participants were seated with their chin on a height adjustable chin rest 55cm from an easel upon which the ROCF or the figure of a house were placed. The easel was angled at 67 degrees. The ROCF measured 19cm x 15.5cm. The House measured 18.5cm x 13cm. Participants completed the copying conditions of the ROCF and the House in counterbalanced order so an equal number of participants in each group started the testing session with each figure. Upon successful calibration with a nine-point matrix that covered the dimensions of both figures, either the ROCF or the House was placed on the easel in view of the scene camera. Participants were then instructed to open their eyes and copy what they saw onto blank paper below the image. When finished they again closed their eyes. The image was changed over and participants again opened their eyes and copied the second image. The trial finished with a recalibration using the nine-point matrix to check correct alignment between the scene camera and the eye camera.

After participants had completed this trial they were then told to draw both the simple and complex shapes from memory, one after the other, onto blank paper. Following a 20 minute break, during which time participants completed the AQ, participants completed the testing session by drawing the House and the ROCF from memory a second time.

2.5. Eye Tracking Apparatus

Eye movement data were recorded onto a Dell Latitude E6420 laptop running Windows 7. The eye tracker was constructed from two cameras: an eye camera and a scene camera. Both cameras were Mino-Cam HD cameras and were mounted onto a set of goggles. The eye camera recorded the actual eye footage that was used for subsequent analyses. To determine eye position, the pupil and first-surface corneal reflection were recorded using the eye camera. The first surface corneal reflection was illuminated by a small infrared LED attached to the eye camera. The scene camera recorded the stimuli placed upon the easel in front of the participant.

Recordings were analysed using EyeCalibratorDX software. This uses two different methods for pupil detection, namely 'blob detection' and the 'starburst algorithm'. These operate on 'dark pupil' footage where the infra-red illumination creates a sharply defined black circle that can be detected. Blob detection first applies an adaptive threshold to the greyscale input image, which reacts to changes in the intensity of certain areas of the image in comparison to other parts. As opposed to traditional thresholding, which considers each pixel individually, a region of pixels of a predetermined size is used instead. This averaged intensity is compared to neighbouring region intensities, and if the difference is positive and larger than a specified threshold then the pixel in the centre of that region is assigned a full intensity value. The output of the blob detection method is used as an initial starting location for the Starburst method (Li, Winfield, & Parkhurst, 2005). A number of rays are sent outwards at regularly spaced angles away from this initial point. If one of these rays encounters a border (i.e. across which the intensity changes significantly) then a feature point is defined where the ray crosses this border. Once this process has been completed for all the rays, the process is repeated for each feature point. The final stage of the algorithm involves data pruning to eliminate the outliers of found feature points, and then fitting an ellipse to a limited number of these feature points. Once the ellipse has been fitted, the centre of the ellipse can either be used as a starting location for another iteration of the Starburst algorithm, or it can be used as the final pupil centre.

The two basic components of eye movements are the movements themselves, which are called saccades, and the fixations. These are the periods of time when the eyes remain fairly still and new information is obtained from the visual array (Rayner, 2009). The Mino-Cam HD cameras operate at 30Hz, taking thirty pictures of the eye and the scene every second. Because saccades are very short in duration, taking approximately 40-50ms (Abrams, Meyer, & Kornblum, 1989), the cameras cannot reliably detect the difference between very short physically close fixations and camera images taken mid-saccade. Therefore, eye 'gaze' is measured instead. 'Gaze' refers to a series of consecutive fixations on a given region of interest (ROI). A minimum of two frames within a ROI are required for the gaze to be verified, and not considered to be a camera picture taken mid-saccade. 'Gaze cycle' is defined as the time lapse between two gazes to the original, during the copy condition (Miall & Tchalenko, 2001).

2.6. Eye Movement Analysis

Eye movement analysis was conducted for the copy condition only. This was because eye movements for the memory trials preceded or coincided with the lines being drawn, and did not give insight into how participants had sampled the ROCF. Eleven Regions of Interest (ROIs) were created for the ROCF. These were based on the BQSS. Regions 1 – 9 matched the Clusters of the BQSS. Region 10 encompassed Details 'b' and 'c'. Region 11 encompassed all the lines of the Configural elements A-F and 3mm either side of a Configural line. Where a fixation fell within an overlap between Region 11 and a Cluster region (e.g. anywhere a Cluster joined a Configural element, this was counted as within Region 11.

3. Results

3.1. General Intellectual Functioning and Self-Reported Autistic Traits

All group comparisons were made using independent samples t-tests, unless otherwise specified. There were no differences between the groups on any measure of general intellectual functioning ($t \leq 1.87$, $p \geq 0.08$) or on any of the four WASI subtests ($t \leq -1.48$, $p \geq 0.16$). However, there was a significant difference between the two groups on the AQ ($t = 5.12$, $p < 0.001$). The ASC group reported a significantly higher mean score on the AQ than the TD group. These results are shown in Table 2.

Table 2: The AQ and IQ scores for each group

Group Name:	Autistic Spectrum Conditions	Typically Developed	t	p(t)
AQ Score (mean +/- s.d)	29.4 (9.0)	12.2 (6.0)	5.12	<0.001
FSIQ (mean +/- s.d)	109.6 (12.5)	119.4 (11.9)	-1.87	0.08
VIQ (mean +/- s.d)	106.5 (12.9)	115.9 (11.7)	-1.81	0.09
PIQ (mean +/- s.d)	112.3 (11.4)	119.0 (10.7)	-1.43	0.17

AQ = Autism Spectrum Quotient; FSIQ = Full Scale Intelligence Quotient; PIQ = Performance Intelligence Quotient ; VIQ = Verbal Intelligence Quotient

3.2. Behavioural Results for the Figures

3.2.1. Figure Copy and Recall – Standard scoring system (Osterrieth, 1944)

There were no significant differences between the groups on the House copy score ($t = -1.81$, $p = 0.09$); the ROCF score ($t = 0.52$, $p = 0.61$); the time taken to complete the House ($t = 0.00$, $p = 1.00$); or the time taken to complete the ROCF ($t = 0.98$, $p = 0.34$). The individual ROCF completion times are shown below in Figure 1. There were also no group differences for the House memory scores ($t \leq -1.36$, $p \geq 0.19$) or the ROCF memory scores ($t \leq -0.82$, $p \geq 0.42$). These results are shown in Table 3. The ROCF was scored by two raters. A Pearson's correlation between the two raters scores showed a high level of agreement for all three conditions (Copy: $r = 0.97$, $p < 0.001$; Immediate memory: $r = 0.995$, $p < 0.001$; Delayed memory: $r = 0.99$, $p < 0.001$).

There was a correlation between the Block Design (BD) subtest and the ROCF copy score for the whole sample (r = 0.51, p = 0.03). However, this was no longer significant when the sample was split into the ASC and TD groups ($p \geq 0.09$).

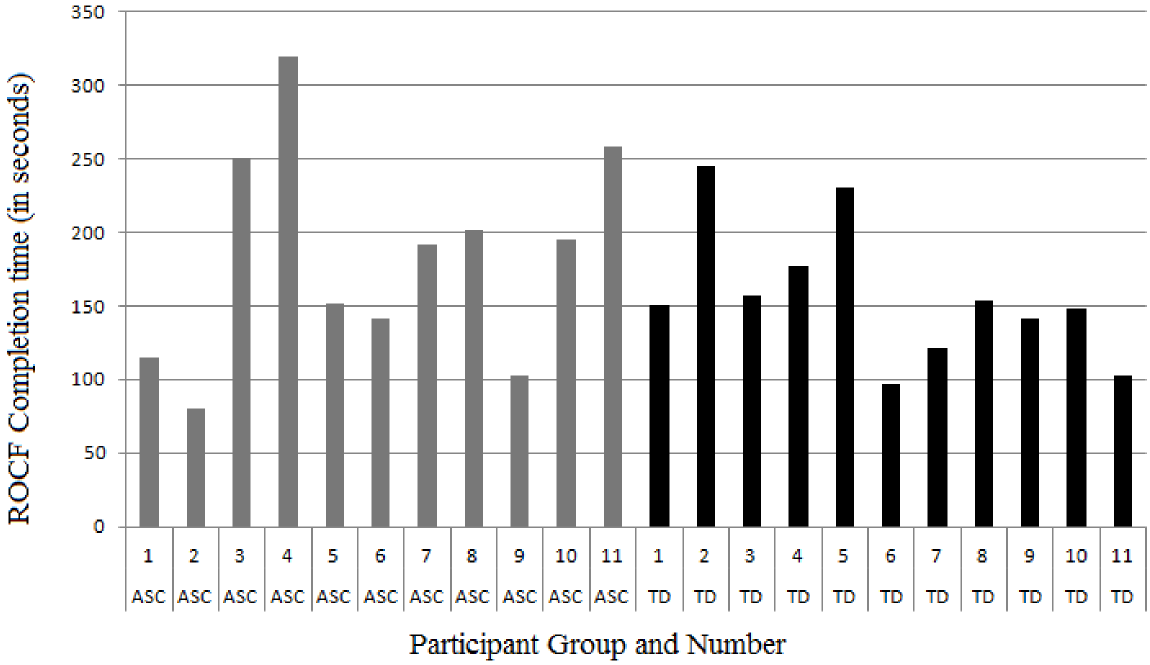

Figure 1: The ROCF completion time of each participant

Table 3: The figure copy and memory recall results for each group

Group Name:	Autistic Spectrum Conditions	Typically Developed	t	p(t)
House Copy (mean +/- s.d)	10.5 (0.9)	11.1 (0.7)	-1.81	0.09
House Immediate Recall (mean +/- s.d)	9.7 (1.3)	9.7 (1.8)	0.00	1.00
House Delayed Recall (mean +/- s.d)	9.4 (1.0)	10.1 (1.4)	-1.36	0.19
House copy time (in seconds)	52.9 (25.5)	46.7 (22.9)	0.60	0.56
ROCF Copy (mean +/- s.d)	34.5 (1.4)	34.1 (2.5)	0.52	0.61
ROCF Immediate Recall (mean +/- s.d)	18.8 (7.7)	21.0 (7.5)	-0.68	0.51
ROCF Delayed Recall (mean +/- s.d)	18.2 (7.4)	20.9 (7.9)	-0.82	0.42
ROCF copy time (in seconds)	182.3 (73.3)	156.7 (46.6)	0.98	0.34

3.2.2. Figure Copy and Recall - BQSS

There are three hypotheses relating to the ROCF BQSS results. These will be discussed in order.

1) **Participants with ASC will achieve poorer BQSS Planning and Organisation scores than TD controls.**

Contrary to Hypothesis 1, there were no differences between the two groups on the Planning score (ASC mean = 3.18, s.d. = 0.75; TD mean = 2.64, s.d. = 0.67; t = 1.79, p = 0.09) or the Organisation summary score (ASC mean = 6.27, s.d. = 1.35; TD mean = 5.27, s.d. = 1.70; t = 1.54, p = 0.14).

2) **Participants with ASC will achieve better Cluster and Detail Presence and Accuracy scores and lower Configural Presence and Accuracy scores on the BQSS than TD controls.**

Contrary to Hypothesis 2, there were no differences between the two groups on the Cluster or Detail Presence or Accuracy scores ($t \leq -1.88$, $p \geq 0.08$). There were also no differences on the Configural elements Presence or Accuracy scores ($t \leq 1.00$, $p \geq 0.34$) or the Presence and Accuracy summary scores for the Copy (t = 0.79, p = 0.44), Immediate memory (t = -0.35, p = 0.73), or Delayed memory (t = -1.27, p = 0.22) conditions. These results are shown in Table 4

Table 4: The Configural, Cluster and Detail Presence and Accuracy Scores

Group Name:	Autistic Spectrum Conditions	Typically Developed	t	p(t)
Copy Configural presence score (mean +/- s.d.)	4.0 (0.0)	3.8 (0.6)	1.00	0.34
Copy Configural accuracy score (mean +/- s.d.)	3.7 (0.5)	3.6 (0.7)	0.37	0.72
Copy Clusters presence score (mean +/- s.d.)	3.8 (0.4)	3.9 (0.3)	-0.60	0.56
Copy Clusters accuracy score (mean +/- s.d.)	4.0 (0.0)	3.9 (0.3)	1.00	0.34
Copy Details Presence score (mean +/- s.d.)	3.7 (0.5)	3.6 (0.5)	0.44	0.67
IM Configural presence score (mean +/- s.d.)	3.2 (1.2)	3.0 (1.1)	0.38	0.71
IM Configural accuracy score (mean +/- s.d.)	3.8 (0.4)	3.7 (0.6)	0.40	0.70
IM Clusters presence score (mean +/- s.d.)	2.2 (0.9)	2.9 (1.0)	-1.78	0.09
IM Clusters accuracy score (mean +/- s.d.)	2.9 (0.9)	2.8 (0.6)	0.27	0.79
IM Details Presence score (mean +/- s.d.)	1.1 (0.7)	1.2 (0.8)	-0.29	0.77
DM Configural presence score (mean +/- s.d.)	3.3 (1.1)	3.2 (0.9)	0.21	0.83
DM Configural accuracy score (mean +/- s.d.)	3.6 (0.5)	3.7 (0.6)	-0.37	0.72
DM Clusters presence score (mean +/- s.d.)	2.2 (0.8)	2.9 (1.0)	-1.88	0.08
DM Clusters accuracy score (mean +/- s.d.)	2.4 (1.0)	3.0 (0.9)	-1.55	0.14

DM Details Presence score (mean +/- s.d.)	0.8 (0.6)	1.2 (0.8)	-1.25	0.23

DM = Delayed Memory; IM = Immediate Memory

3) **There will be a correlation between the Block Design subtest and the Detail Presence scores.**

In support of Hypothesis 3, there was a correlation between the BD subtest and both the ROCF Copy Detail Presence score (r = 0.47, p = 0.04), and the ROCF Delayed memory Detail Presence score (r = 0.48, p = 0.04). The correlation did not reach significance for the ROCF Immediate memory Detail Presence score (p = 0.13). When the sample was split into the ASC and TD groups only the correlation between the BD subtest and the ROCF Copy Detail Presence score remained significant and only for the TD group (r = 0.66, p = 0.03).

3.3. Eye Tracking Results for the Figures

3.3.1. General Eye Tracking Measures

Despite large mean differences, there were no differences between the two groups for the number of gazes for the House (t = 1.10, p = 0.29) or the ROCF (t = 1.01, p = 0.33). This was due to large within group differences shown by the standard deviations of each mean. There were also no differences between the two groups for the mean length of each gaze for either the House (t = 0.69, p = 0.50) or the ROCF (t = 0.60, p = 0.55). Finally, there were no differences between the two groups for the mean number of cycles between the original figure and the participant drawn reproduction during the Copy condition for either the House (t = 0.96, p = 0.35) or the ROCF (t = 0.01, p = 0.99). These results are shown in Table 4.

Table 5: The mean number of gazes and gaze length for each group

Group Name:	**Autistic Spectrum Conditions**	**Typically Developed**	**t**	**p(t)**
House number of gazes (mean +/- s.d)	85.7 (46.9)	65.4 (37.9)	1.10	0.29
ROCF number of gazes (mean +/- s.d)	271.6 (92.6)	236.1 (64.5)	1.01	0.33
House gaze length in seconds (mean +/- s.d)	0.70 (0.32)	0.78 (0.20)	0.69	0.50
ROCF gaze length in seconds (mean +/- s.d)	0.66 (0.14)	0.70 (0.11)	0.60	0.55

House Cycles/Min (mean +/- s.d)	25.29 (10.89)	21.19 (8.63)	0.96	0.35
ROCF Cycles/Min (mean +/- s.d)	24.69 (3.66)	24.68 (4.83)	0.01	0.99

ROCF = Rey-Osterrieth Complex Figure

3.3.2. Specific Eye Tracking Measures for the ROCF

There are two hypotheses relating to the eye tracking results. These will be discussed in order.

4) **Participants with ASC will spend less mean total copy completion time looking at the Configural main elements of the ROCF than TD controls and more mean total copy completion time looking at the Cluster and Detail elements.**

Contrary to Hypothesis 4, there were no differences between the two groups on the mean percentage of time spent looking at the Configural main elements or the Cluster and Detail elements of the ROCF during copy completion (ASC mean = 11.2, s.d. = 4.0; TD mean = 11.3, s.d. = 2.6; $t = -0.05$, $p = 0.96$).

5) **Participants with ASC will be slower to fixate on 'Cluster 5' (see Appendix A), which is the round element in the upper right side of the ROCF.**

Despite large mean differences, there were no differences on a Mann-Whitney U test between the two groups for the number of gazes made before the participant fixated on Cluster 5 (ASC mean = 26.5, s.d. = 42.5; TD mean = 4.8, s.d. = 7.5; $U(10) = 42.0$; $p = 0.36$). This was due to large differences within the ASC group, but not the TD group, shown by the standard deviations of each mean. Because of this intra-group variability a post-hoc analysis was conducted to examine any relationship between the AQ scores and the number of gazes taken to fixate on Cluster 5. This correlation was significant ($r_s(20) = 0.43$, $p = 0.04$), showing that the higher a participants AQ score, the more gazes it took them before they fixated on Cluster 5.

4. Discussion

This study aimed to test hypotheses mainly regarding a potential local-processing bias in the ROCF copy and reproduction. Hypotheses predicting group differences were not supported. The first study hypothesis predicted that participants with ASC would show poorer Planning and Organisation BQSS scores. However, participants with ASC actually scored better on these measures than the TD controls, although not significantly so. Kuschner, Bodner and Minshew (2009) published the only prior group to compare adolescents and adults with ASC to TD controls on the BQSS for the ROCF. They also found no significant differences between adolescents/adults with ASC and TD adolescents/adults on the Copy Planning score or the Organisation summary score. Of note, their Planning and Organisation scores were considerably lower than in the current study. This may because their adolescent/adult groups included participants as young as 14 years old whereas the current study tested only participants aged 18 years and above. The mean FSIQs of their adolescent/adult groups were also 13 to 20 points below the current study and this may have affected the ROCF scores which can correlate with FSIQ (Gallagher & Burke, 2007). As both the current and prior study to compare Copy Planning and the Organisation summary score did not find a difference between groups of adult participants, this may mean that these scores do not consistently highlight a local-processing bias in people with ASC, or it may mean that a local-processing bias is not a universal symptom of ASC and is therefore not experienced by everyone with an ASC diagnosis.

The second study hypothesis predicted that the participants with ASC would produce more Cluster and Detail elements than the TD participants and would produce less Configural elements. This hypothesis is somewhat linked with the fourth hypothesis which stated that people with ASC would spend proportionally less time fixating on the Configural elements of the ROCF and more time looking at the Cluster and Detail elements. Neither hypothesis was supported. It is possible that the participant groups achieved similar Copy and Memory scores for Configural elements, Clusters and Details because they spent similar amounts of time fixating on each of these components. Kuschner, Bodner and Minshew (2009) also found no between group differences for their adolescents/adults on any of the Presence or Accuracy Scores, or the Presence and Accuracy summary scores. Keehn et al. (2009) found fixation differences using eye tracking and the EFT. They found that children with ASC had shorter mean fixations to distracter stimuli than the target. However, it is not possible to compare their study with the current research for two reasons. Firstly, Keehn et al. tested children and not adults. Secondly, they did not separate their ROIs based on whether the region contained a global or local picture element. Thus, these results cannot inform the current findings of similar gaze ratios to global and local elements across the TD and ASC groups. The current finding may therefore be due to reasons specific to this study sample, such as higher IQs than participants in past research using the ROCF, or it may actually be representative of the majority of people with ASC. Unfortunately, the current literature is not able to offer predictions on the meaning of this finding.

The third hypothesis predicted a correlation between performance on the BD subtest of the WASI and the BQSS Detail Presence scores because a local-processing bias has previously been shown to confer an advantage on both test performances (Mottron et al., 2006). This hypothesis was partly supported. Across the whole sample BD performance positively correlated with the Copy and Delayed Memory Detail Presence scores. Surprisingly, this was not the case for the Immediate Memory Detail Presence score. There seems to be no theoretical reason for this difference and it may be that the number of participants in the current study was too low for this correlation to consistently reach significance across conditions. When the sample was split into the ASC and TD groups, only the Copy Detail Presence score remained significantly correlated with the BD subtest for the TD group. This is also surprising for two reasons. Firstly, indications of a local-processing bias are usually expected in participants with ASC, not TD controls. Secondly, Kuschner, Bodner and Minshew (2009) previously found the opposite pattern of results, with a correlation between the BD subtest and the Detail Presence scores for participants with ASC, but not for TD controls. However, Kuschner, Bodner and Minshew did group their child and adult participants for this analysis which limits its applicability to the current study. The current result may indicate two points of interest. Firstly, if the current TD participants are demonstrating a local-processing bias, then this may explain the lack of group differences found on other hypotheses. Secondly, if TD participants show a local-processing bias, then this tendency may not be specific to people with ASC but could also be present in highly systematising men who do not show the triad of impairments found in ASC (Robinson et al., 2012).

Finally, in order to compare the current study to a previous study examining eye tracking I examined how soon participants with ASC fixated on BQSS Cluster 5 compared to TD participants. Previously, Manor, Gordon and Touyz (1995) found that 80% of their TD participants made their first fixation to Cluster 5. It is thought that they may do this because the circle and three dots could partly resemble a schematic face, and that this would preferentially draw the attention of TD individuals (Caldara et al., 2006; Stein et al., 2011). It was hypothesised that participants with ASC would take significantly more gazes before fixating upon Cluster 5 than the TD controls. This hypothesis was partly supported. No group differences were found on this measure; however, this was largely due to considerably greater intra-group variance for the ASC group than the TD group. Therefore, a post-hoc analysis was conducted to examine whether differences in AQ scores could better predict the number of gazes taken to fixate Cluster 5 than group membership. Participants with higher AQ scores took longer to fixate Cluster 5 suggesting that the higher a person's self-reported symptoms of ASC, as measured by the AQ, the less likely they are to have their attention preferentially drawn to Cluster 5. This result highlights that diagnosis alone may not be the best method of grouping participants, in order to ascertain the causes of performance variance.

There are four main reasons which might explain why significant differences were not found during this study. The first two reasons pertain to study design, the third to participant recruitment and the final potential reason is theoretical. Firstly, group differences may have reached significance for gazes taken to reach Cluster 5 if the number of participants in the current study had been greater. However, the other group comparisons were either not approaching significance or were approaching significance in an unexpected direction, showing a greater likelihood of a local-processing bias from the controls. For this reason, the small sample size of this study is unlikely to have been the cause of some of the non-significant results. In contrast, the increased variability within the ASC participants compared to the TD participants may have resulted in some of the results not reaching significance. As previously considered, people with ASC can form a very heterogeneous group, and thus in future it may be necessary to reconsider whether diagnosis alone is enough to partition adults with ASC into groups. AQ score or the cluster of symptoms people with ASC experience may be more appropriate grouping variables.

The second reason more significant results may not have been found in this study relates to the ROCF itself. This figure was used as a complex task, in comparison to the much simpler figure of a house. The ROCF was intended to show increased complexity over the House on two levels. Firstly, it lacks the familiarity of the House, which is a highly recognised symbolic representation, and therefore the ROCF shows high levels of novelty. Secondly, the load requirement of the ROCF is much higher than the House. Whilst it shares the same rectangle structure, it has far more Clusters and Details to be copied and remembered, thereby increasingly the load requirement and thus the complexity. However, there is no time limit on the ROCF, meaning that the required processing speed of the task is low. Participants can take as long as they want to complete the ROCF, and whilst there was no significant differences between the groups on completion time, figure 1 demonstrates that some participants in both groups took a considerable amount of time to copy the ROCF. This low processing speed requirement may have resulted in the ROCF being experienced as a lower complexity task than intended. This would result in the participants with ASC not showing the expected accelerated drop-off in performance compared to the TD controls or compared to their own performance on the House. Future researchers may wish to consider if the ROCF is able to offer a high enough level of complexity to be used with adults of average to above average general intellectual functioning.

Participant recruitment may have contributed to the lack of group differences in this study. Most of the participants in both of the groups were University students. Many were studying degrees such as Engineering or Computer Science. It may be that this affected the results because a large number of the sample may be likely to show a systematising approach, and possibly local-processing bias, in both groups; regardless of whether those participants had a diagnosis of ASC.

Finally, this study intended to investigate the presence of increased lower level cognitive processing of this visual task by participants with ASC compared to TD controls. The lack of significant results may simply not support this hypothesis. A local-processing bias was also not found by Kuschner, Bodner and Minshew (2009), or again in the current study. This does not undermine the entire Underconnectivity Hypothesis. However, it does suggest that if increased lower level cognitive processing is present in HF individuals with ASC, it does not greatly influence their task performance on the ROCF; nor does it confer an advantage in noticing or remembering the smaller details of the ROCF. It is possible that any local-processing advantage seen in people with ASC who also have a learning disability is not present or pronounced in HF individuals with ASC.

The main limitations of this study and the effects of these have been discussed above, and can be summarised as potentially a too low sample size and a predominance of University students. Future research may consider recruiting a greater number of older participants. Furthermore, it would be advisable to pilot the control task for a number of reasons. Firstly, to check that both the instructions to participants were clear enough that they appreciated the level of precision required to achieve the maximum score; secondly pilot data would have allowed inter-rater reliability to be assessed to ensure that it was at least as high as the level usually achieved on the ROCF; and thirdly to ascertain whether participants find the House task significantly less complex than the ROCF task. This may also have demonstrated that the ROCF was not experienced as comparatively highly complex by individuals with above average intelligence before main data collection began; and therefore highlighted that highly intelligent people with ASC were unlikely to show greater reduction in performance on the task than their TD peers. It may also be advantageous to design studies and group participants with ASC based on their self-reported problems. These are commonly considered to be due to difficulties using executive strategies (Gaus, 2007); however, it could prove very informative to better understand why a HF person with ASC struggles with a daily living task such as choosing and making their own dinner, or coping with an unexpected change in their schedule from the moment they are confronted with the information necessary for the task. In time, such knowledge may better guide the choice of which interventions are likely to help different HF people with ASC.

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List of Appendices

Appendix A

Participant Information Sheet

Processing and Production of Visual Figures

Dear Sir/Madam,

I am Alana Tooze, a Trainee Clinical Psychologist at the University of Southampton. This project will investigate people's eye movements whilst reproducing line drawings. To examine what people attend to, we are going to record the eye movements of participants whilst they copy line drawings and later reproduce them from memory. The aim of our work is to understand the processes of visual attention during these tasks.

Why have I been chosen?

I am investigating how people with an autistic spectrum condition process visual information. I will be asking people with an autistic spectrum condition to participate and also aged matched controls.

What would be involved?

To understand where people look when presented with visual information we will use a very sophisticated machine that records your eye movements while you look at a picture presented on an easel and draw it out on plain paper. The eye tracking machine is completely harmless. You will just sit in a normal chair whilst wearing the eye tracking glasses. The machine will record your eye movements but you won't even realise it is happening. If at any point you feel uncomfortable or tired we will stop for a break and if you decide that you don't wish to carry on, we can stop altogether.

The session would take approximately 1 hour and 30 minutes. There are some other parts to the project, as well as the eye-tracking, that we would try to do during that time. For example, we would ask you some questions about words and puzzles, which is something you might have done before. The measures that we take will be treated in complete confidence and will be released to no-one without your permission. In any scientific reports that we prepare, we will ensure your anonymity is protected.

What are the benefits of participation?

We believe that what we will learn from this study will greatly improve our understanding of how people process visual information. This will eventually allow us to learn more about how people with or without an autistic spectrum condition process what they see. The data that you will provide can help us with this longer-term process. There will be no benefits to you personally.

What if I wish to make a complaint about the research?

If you are not happy at any point in the research you are welcome to discuss this with me and I will aim to address your concerns as best I can. If you are not satisfied with my responses or wish to speak to someone independent of the project, please contact:

The Chair of the Ethic Committee, School of Psychology, University of Southampton.
Phone: 023 8059 5578

What should I do next?

I very much hope that you will volunteer to participate in the study.

If you would like to participate, please complete and sign the enclosed consent form. If you are uncertain and would like to talk to us about the study before deciding, please feel free to contact us:

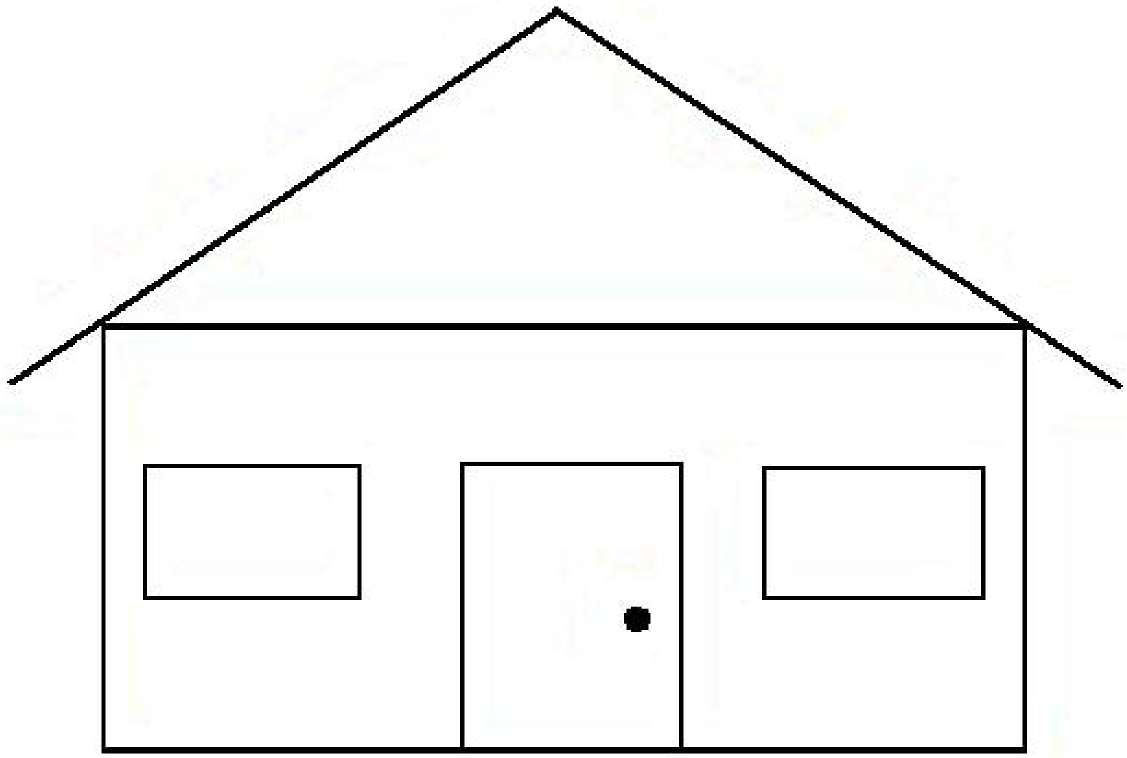
- Dr Alana Tooze, Trainee Clinical Psychologist (023 80595576), at2g09@soton.ac.uk

I am always happy to talk about this work. Many thanks for your support.

Appendix B

House Scoring Criteria

House Scoring Criteria



1. Large Rectangle.
2. Triangle above 1. Sides of triangle attached to 1 and ends of triangle extend past point of attachment (deduct one point if ends do not extend past point of attachment).
3. Small rectangle within lower 70% of 1, attached to 1 around the centre of the horizontal lower line.
4. Small dot within central right of 3 (deduct one point if circle is hollow and not filled in).
5. Small rectangle, within central left of 1.
6. Small rectangle, within central right of 1.

Appraise the accuracy of each unit and relative position within the whole design as follows:

Correct and placed properly = 2 points

Correct and placed poorly = 1 point

Distorted or incomplete but recognisable, and placed properly = 1 point

Distorted or incomplete but recognisable, and placed poorly = 1/2 point

Absent or not recognisable = 0 points

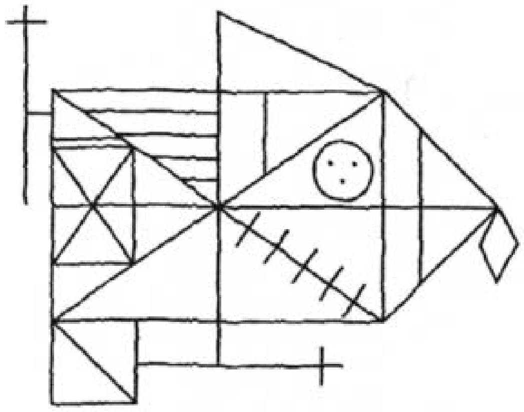
Maximum = 12 points

Appendix C

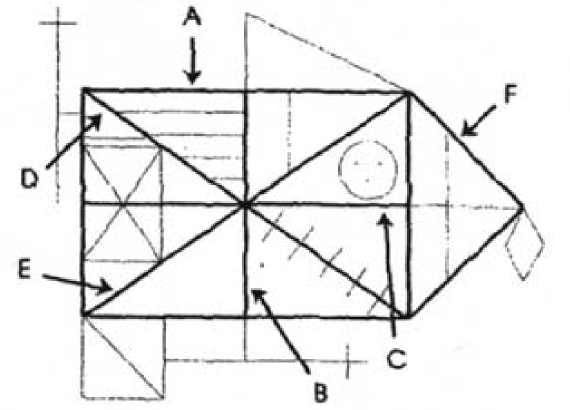
Scoring Units for the Boston Qualitative Scoring System

Scoring Units for the Boston Qualitative Scoring System

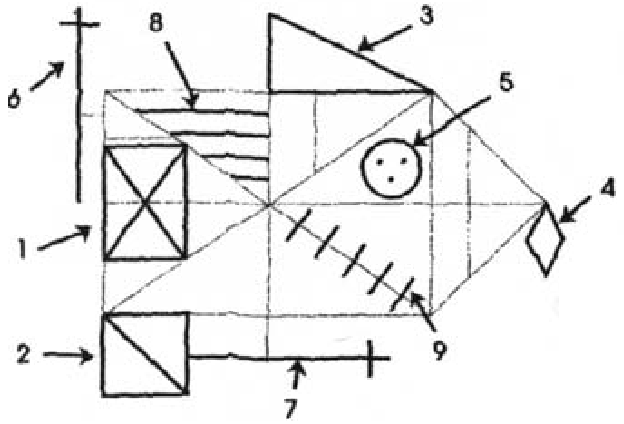
Complete Figure



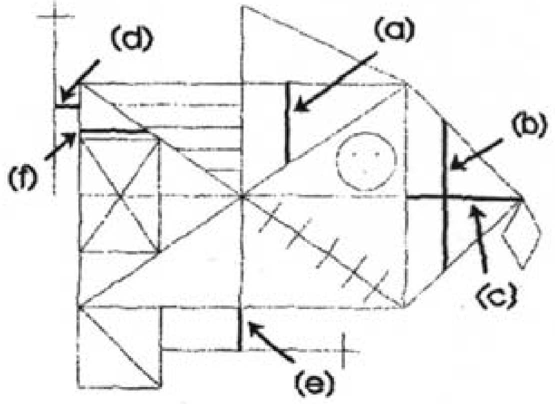
Configural Elements A – F



Clusters 1 – 9



Details (a) – (f)



Appendix D

Participant Consent Form

CONSENT FORM (Version 2, dated 04.09.11)

Study title: Processing and Production of the Rey Complex Figure

Researcher name: Alana Tooze
Study reference: 514
Ethics reference: 514

Please initial the box(es) if you agree with the statement(s):

I have read and understood the information sheet (dated 04.09.11/version 2) and have had the opportunity to ask questions about the study ☐

I agree to take part in this research project and agree for my data to be used for the purpose of this study ☐

I understand my participation is voluntary and I may withdraw at any time without my legal rights being affected ☐

Name of participant (print name)…………………………………………………

Signature of participant………………………………………………………..

Date...