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PHD

An Investigation of Non-Social Cognition across the Autism Spectrum

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An Investigation of Non-Social Cognition across the Autism Spectrum

Clarence Jeopardy Singleton

A thesis submitted for the degree of Doctor of
Philosophy

University of Bath

Department of Psychology

June 2018

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Abstract

Autism Spectrum Disorder (ASD) is a pervasive developmental disorder characterized by two distinct features; the social, including impairments in communication and social functioning (empathizing), and the non-social, including preoccupation with restricted interests and repetitive behaviours (systemizing). This thesis investigated non-social cognition in the autism spectrum by undertaking six studies, three with neurotypical participants from the general population and three with an ASD group and matched neurotypical controls. These studies measured autonomic arousal to social and non-social stimuli and stimuli associated with the participant's own special interest or hobby, and change blindness tasks that utilized both social and non-social changes, along with measures of attention to detail and anxiety in an attempt to understand some of the cognitive and affective mechanisms that underlie non-social cognition in ASD and in the wider autism spectrum. A further study assessed 'drive to systemize' along with an objective behavioural assessment of logical thinking ability and a measure of preference for deliberative or intuitive thinking style, to try to further elucidate connections between drive to systemize and ability to systemize, and the modes of cognition that relate to systemizing.

Findings included the relationship between autistic traits and stronger physiological responses to non-social stimuli in the neurotypical sample, and a significantly stronger response in the ASD group to non-social stimuli related to personal special interest than in controls. Participants with a larger number of autistic traits showed enhanced change blindness when changes were social in nature. Self-reported high systemizers report that they prefer slow, deliberative styles of thinking and provide more accurate responses to questions that should involve logical thinking—yet they are less able to provide sound logical reasoning for their correct answers than those who are low systemizers. Together, the results suggest that non-social cognition, or systemizing, in autism is motivated by bottom up perceptual and affective processes that share features with conventional social and emotional cognition, or empathizing.

Chapter 1

The Autism Spectrum: Features and Theories

1.1 Overview

This chapter characterizes the two key features/dimensions of autism spectrum disorder that comprise its diagnostic criteria—the social and the non-social. The concept of the autistic spectrum and the broad autism phenotype are presented and explored, along with measures of subclinical autistic traits in neurotypical populations. Key cognitive theories of autism spectrum disorder are reviewed, with an emphasis on those that provide the theoretical underpinning of the current thesis. This chapter will focus on some of the evidence from neuroscience that suggests physiological causes of the social deficits of ASD and hints at possible neurobiological explanations for its non-social component. The literature on repetitive behaviours and restricted interests in ASD will be reviewed, and some of the most prominent theories of autism will be discussed, with particular reference to the Empathizing-Systemizing theory, which will form the basis for this thesis.

1.2 Definitions of Autism

1.2.1 Diagnostic Criteria and Prevalence

Since autism was first described by Leo Kanner in 1943, it has been understood as a disorder that involves the manifestation of two kinds of behavioural symptoms; the social and the non-social. Kanner noted that the children in his case studies had a “good relation to objects” and would respond emotionally to them—for example with affection or anger—along with a marked indifference in their relations to people, ignoring others as though they were part of the furniture (Kanner, 1943). Although the specific diagnostic criteria for autism have changed over the years, the inclusion of both these social and non-social symptoms, broadly defined, has remained. Current criteria for diagnosis of autism spectrum disorders (ASDs)

include persistent and pervasive impaired social communication and non-social repetitive and inflexible behaviours and interests, with the broader diagnosis of ASD intended to recognise that these symptoms represent a continuum or spectrum ranging from mild to severe (American Psychiatric Association, 2013; World Health Organisation, 2018).

The social aspects of ASD include an inability to sustain reciprocal social-emotional interactions, difficulties with non-verbal communication—including abnormalities in eye contact and body language—deficits in the development and understanding of social relationships, a lack of interest in peers and reduced sharing of emotions, interests or affect. The non-social diagnostic criteria for ASD incorporate repetitive or stereotyped movements or behaviours, including echolalia, an insistence on sameness or resistance to change that may manifest as rigid adherence to—and distress at any changes to—routines, ritualized patterns of behaviour, intense and circumscribed interests and hypo- or hyper-arousal to sensory inputs or atypical interest in sensory aspects of the environment (American Psychiatric Association, 2013).

ASD is a developmental disorder, so a diagnosis of ASD also recognises that these symptoms typically emerge during childhood. Due to the range of severity of symptoms across the spectrum, full manifestation of ASD may appear later in some individuals at a point at which the demands of social interaction exceed their capabilities to handle them (WHO, 2018). ASD is diagnosed by a trained clinician, against standardized diagnostic criteria (e.g. the Diagnostic and Statistical Manual of Mental Disorders (DSM–5) or International Classification of Diseases (ICD-11)) using diagnostic tools and measures alongside observation of the patient and with input from the parent/caregiver on the patient’s history and behavioural symptoms. The most commonly used tools for the diagnosis of ASD include the Autism Diagnostic Observation Schedule, a semi-structured standardized assessment of social interaction, communication, play and imagination— a later version of the ADOS was developed to enable assessment of adults—(ADOS; Lord et al., 1989; 2000) and the Autism Diagnostic Interview–Revised, which is used to assess ASD in children and adults, focusing on reciprocal social interaction, communication and language, and restricted interests and repetitive behaviours (ADI–R; Lord, Rutter & Couteur, 1994).

In their most recent incarnations, both the DSM–5 and the ICD–11 have collapsed a range of previously distinct developmental disorders under the diagnosis of Autism Spectrum Disorder (APA, 2013; WHO, 2018). Previously, the DSM–4 had listed Autistic Disorder, Asperger’s Disorder (AS) and Pervasive Development Disorder Not Otherwise Specified (PDD–NOS), and the ICD–10 had listed Childhood Autism, Atypical Autism, Asperger Syndrome, and PDD-NOS, as separate conditions. The change to bring all these categories under a broader diagnosis of Autism Spectrum Disorder reflects a move away from the ‘triad’ of autistic impairments—which separated social impairment from language and communication difficulties, and included restricted and repetitive behaviours and interests (RRBs; Wing & Gould, 1979)—to two core dimensions (social impairment and restricted interests and behaviours) that the previously separate diagnoses shared. This distillation to two behavioural dimensions (the social and the non-social) of autism is based on the wealth of literature that has found little meaningful distinction between social and communication impairments (Gotham et al., 2007) and the fact that language/communication impairments occur in the absence of autism (Bishop & Norbury, 2002) while not all children with autism experience language delays (Kjellmer et al., 2012). The broader diagnosis of Autism Spectrum Disorder, encompassing these two cognitive/behavioural dimensions, also recognises that research into the neurobiological underpinnings of autism has produced heterogeneous findings, failing to find a single genetic cause for the condition, despite its strong genetic heritability (Veenstra-VanderWeele, Christian & Cook, 2004; Ronald et al., 2006; Geschwind, 2011) and therefore that behavioural diagnosis and conceptualizations of autism are essential for clinicians, people with autism, and for the basis of future research into the aetiology of the condition (Lord & Jones, 2012).

The prevalence of ASD has been rising (Matzon, Koslowski, 2011; Zahorodny et al., 2012; van Bakel et al., 2015). A study by Baird et al. (2006) found a prevalence of autism of approximately 11.6 per 1000 in the South Thames area of the UK; in 2011, a study on school-age children found a prevalence of approximately 26.4 per 1000 (Kim et al., 2011), in 2012 a study in New Jersey found a prevalence of around 17.4 per 1000 (Zahorodny et al., 2012) and a recent study by the Centres for Disease Control in the United States found an overall prevalence of ASD of 16.8 per 1000

(Baio et al., 2018). Estimates therefore put the occurrence of ASD in the general population at somewhere between 1% and 2.64%. Suggested reasons for the increasing prevalence of ASDs includes the impact of increasing traffic-related air pollution (Volk et al., 2013; Dawson, 2013), that prevalence rises whenever diagnostic methods change (King & Bearman, 2009), that increased awareness among the population leads to an increase in people seeking a diagnosis (Kogan et al., 2009), and various other suggestions and theories (see Waterhouse, 2008).

The prevalence of ASD in males appears to be significantly higher than in females, with male to female incidence ratios ranging from 2.69:1 (Baker, Milivojevich et al., 2014) to 3:1 (Loomes, Hull, & Mandy, 2017) to 4:1 (Ehlers & Gillberg, 1993; Fombonne, 2009; Baio et al., 2018). It has been suggested that this discrepancy may be related to a sex bias in the diagnosis of ASD, with clinicians failing to spot autism in female patients, leading to under- and misdiagnosis (Giarelli et al., 2010; Lehnhardt et al., 2016; Loomes, Hull, & Mandy, 2017). One possible reason for this may be that females with ASD are comparably more socially skilled than their male counterparts (Koenig & Tstsanis, 2005; Lai et al., 2011; Wing, 1981) or engage in fewer RRBs (Mandy et al., 2012; Shefcyk, 2015; Wilson et al., 2016) and it has been suggested that there may be two distinct ASD phenotypes for males and females. Related to this idea, research found that females are subject to a genetic ‘protective effect’ whereby a larger abnormal genetic load is necessary for ASD to manifest, leading to fewer females developing ASD or possibly leading to a different expression of ASD symptoms (Jacquemont et al., 2014) and that chromosomal genes and sex hormones may modulate the impact of genetic variation on the ASD phenotype (Werling & Geschwind, 2014).

1.2.2 The Autism Spectrum

The re-classification of various related developmental disorders under the term ‘Autism Spectrum Disorder’ in both the DSM–5 and the ICD–11 reflects the fact that the symptoms and behaviours within the two dimensions (social and non-social) affected, while similar in type, vary greatly in severity across individuals. The concept of the Autism Spectrum therefore represents the existence of certain socially and non-socially related traits that may appear together with varying degrees of severity, ranging from being mild to having a serious impact on daily functioning. This continuum of autistic traits is thought to run from those with severe forms of low

functioning ASD to those with milder, higher functioning forms of autism, all the way into the neurotypical population, in which some people will experience high levels of autistic traits that do not reach clinical significance (Baron-Cohen, Wheelwright, Skinner, Martin & Clubley, 2001; Posserud, Lundervold & Gillberg, 2006).

Evidence suggests that subclinical autistic traits are more prevalent in those who are related to someone with a diagnosis of ASD. In his initial case studies describing autism for the first time, for example, Kanner makes a point of noting some of the rigid behaviours and preoccupation with routines of the parents of his child patients (Kanner, 1943). Folstein and Rutter (1977) discovered that the siblings of those diagnosed with autism had a much greater risk of developing the disorder themselves, and that they were also genetically predisposed to acquiring a 'lesser variant' of it that involved language and communication impairments. Le Couteur et al. (1996) conducted a twin study and found that concordance for the manifestation of a broader autism phenotype—identified by social/communication deficits—was much greater for monozygotic twins than in dizygotic twins, suggesting a strong genetic component for autistic-like traits. Bolton et al. (1994) also found evidence for this 'lesser variant' of autism, or broad autism phenotype, reporting that first degree family members of individuals with ASD exhibited an increased number of autistic-like symptoms (communication difficulties, RRBs etc.) compared with the relatives of individuals with Down syndrome. Piven et al. (1997) followed up this study, using the same criteria and interview schedule, in families with multiple-incidence autism and found that, in these families, both first and second-degree relatives to those with ASD exhibited more autistic-like symptoms (i.e., increased social/communication deficits, stereotyped behaviours etc.) than did relatives of those with Down syndrome. Similarly, Losh et al. (2008) found that families with multiple-incidence of ASD were more likely to express characteristics of the broad autism phenotype—which included symptoms/behaviours related to social/language impairments, rigidity and anxiety—than single incidence families or families with multiple incidence Down syndrome.

The term broad autism phenotype (BAP) is thus used to describe the presence of mild autistic-like symptoms in the relatives of those with an ASD diagnosis (Piven et al., 1997). These symptoms do not reach clinical significance, but their presence

indicates the heritability and genetic foundations of ASD and therefore the study of these traits and behaviours, and their neurobiological origins, can help understanding of the aetiology of ASD and identify genes associated with it. As mentioned above, the notion of the Autism Spectrum has also been proposed to extend beyond those with a diagnosis, or those with a relative diagnosed with the disorder, and across the entire neurotypical population more generally (Baron-Cohen et al., 2001; Posserud, Lundervold & Gillberg, 2006). Constantino and Todd (2003) administered the Social Responsiveness Scale (Constantino et al., 2002), a measure of autistic traits, to the parents of 788 pairs of twins, none of whom had ASD, and found that these traits were moderately to highly heritable, suggesting that measuring subclinical autistic traits in the neurotypical population is useful for genetic research into ASD. A later study by the same authors investigated the heritability of autistic traits in neurotypical adults by collecting partner/spouse and parent reports on the autistic traits of 285 pairs of twins and their parents, finding again that autistic traits were highly heritable, and that those whose parents both reported a high number of autistic traits were more likely to display a larger number of subthreshold autistic traits, and were eleven times more likely to experience clinically relevant levels of autistic traits (Constantino & Todd, 2005). Other studies have also found high heritability of autistic traits in the neurotypical population, for example Hoekstra et al. (2007) conducted a twin study and found high heritability of self-reported autistic traits, and Ronald & Hoekstra (2011) provided a review of similar twin studies on ASDs and autistic traits, concluding that the aetiology of autistic traits in the general population is similar to that of ASD.

Research on subclinical autistic traits in neurotypical populations has therefore grown over the past two decades, and various self-report methods for measuring autistic traits in neurotypical samples have been developed. The Broad Autism Phenotype Questionnaire (BAPQ) was developed to measure traits such as aloofness, pragmatic language and rigidity in the subclinical population, developed with family members of those with an ASD (Hurley, Losh, Parlier, Reznick, & Piven, 2007). The Social Responsiveness Scale (SRS) was developed to distinguish between those with and without ASD and focuses largely on autistic traits related to the social dimension of ASD (Constantino & Gruber, 2002). The Subthreshold Autism Trait Questionnaire (SATQ) was developed to provide a self-report measure for adults of a broader range of subclinical autistic traits than had been included in previous

measures (Kanne, Wang & Christ, 2012). The Autism Spectrum Quotient (AQ), possibly the most widely used measure, was developed as a self-report questionnaire to assess both social and non-social autistic traits in the neurotypical population (Baron-Cohen, Wheelwright, Skinner, Martin & Clubley, 2001; see Chapter 3 for further detail on this measure).

Investigating subclinical autistic traits and their relationship to various cognitive, affective and attentional processes can therefore help to illuminate the behavioural, neurobiological and cognitive mechanisms underlying the development and manifestation of ASD (Elsabbagh et al., 2009a; 2009b), can facilitate experimental designs in neurotypical samples that may cause distress or anxiety in clinical groups (Kanne, Wang & Christ, 2012) and can allow for hypothesis testing in neurotypical individuals prior to the recruitment of clinical samples. This thesis includes studies that measure autistic traits in neurotypical (NT) samples to study the relationship between autistic traits and aspects of non-social cognition, as well as follow up studies with ASD groups and NT controls, which allows for the assessment of any similarities and differences in non-social cognition between those on either side of the threshold for ASD diagnosis.

1.3 Theories of Autism

Autism research in the fields of neuroscience, genetics and cognitive psychology attempts to explain how both the social and non-social behavioural symptoms of ASD manifest at genetic, biological and cognitive levels, and the current thesis focuses on cognitive and affective aspects of interaction with non-social stimuli in order to contribute to the understanding of this core dimension of ASD. Within the two dimensions of ASD (social and non-social), symptoms vary widely across the spectrum and between individuals, making it a challenge to identify a single cause of the disorder, with some conceding that one distinct explanation of ASD and its heterogeneous manifestations may never be possible (Happé, et al., 2006). Despite both being necessarily present for a diagnosis of ASD, it is not yet clear how its social and non-social symptoms relate to one another. Twin studies indicate that these social and non-social behaviours, though both highly heritable, may in fact be genetically independent of one another and therefore benefit from being considered separately (Ronald, Happé and Plomin, 2005; Happé, Ronald and Plomin, 2006). A

review of research on the relationship between the social and non-social features of ASD also found a stark lack of evidence that the two dimensions are correlated with one another and suggests that these symptoms may have distinct underlying causes (Mandy & Skuse, 2008). Many theoretical attempts to elucidate the cognitive profile of ASD have, however, focused on finding unitary explanations, while neurobiological studies have tended to focus on one or other of these two general diagnostic criteria. One of the main issues with most theories of autism is that they fail to account for *all* aspects of autistic symptomatology, and fail to explain the heterogeneity in the disorder. Although there is, as yet, no overall consensus on a grand unified theory of autism, several of the key neurobiological and cognitive theories that have contributed to the theoretical underpinning of this thesis are detailed below.

1.3.1 Cognitive Theories

1.3.1.1 Theory of Mind

The Theory of Mind (ToM) account of autism suggests that those with ASD suffer from a type of ‘mind blindness’ whereby they are unable to understand or gauge the perspectives, feelings or motivations of others (Baron-Cohen, Leslie & Frith, 1985). A perspective-taking task performed with autistic children found that the majority of them were unable to imagine themselves in another person’s position, and the authors concluded that the inability to develop a theory about what others might be thinking, feeling or planning would lead to difficulties predicting behaviour resulting in difficulties with social interactions (Baron-Cohen et al., 1985). These results and subsequent theory later led to the development of the Reading the Mind in the Eyes Task (RMET), whereby participants are presented with emotionally expressive eyes and must choose which of four emotions the eyes are conveying (Baron-Cohen, Jolliffe, Mortimore & Robertson, 1997). Results of experiments using the RMET have consistently found that those with ASD perform worse than controls (Baron-Cohen, Wheelwright, Hill, Raste & Plumb, 2001; O’Riordan, Stone, Jones, & Plaisted, 1999; Heavey, Phillips, Baron-Cohen, & Rutter, 2000), yet while the ToM account may illuminate a underlying factor that explains the social deficits seen in ASD, it does not explain how such ‘mind blindness’ arises, nor does it account for the other, non-social aspects of ASD.

1.3.1.2 Executive Dysfunction

Executive functioning refers to the cognitive processes involved in controlling behaviour, including planning, working memory, inhibition of inappropriate or irrelevant responses, attention shifting and flexibility of thought. Executive Dysfunction (ED) theory suggests impaired frontal lobe function in ASD, resulting in an inability to switch attention from one task to another, resulting in an abnormally heightened focus for a restricted number of interests or features in a given environment (Ozonoff, Pennington & Rogers, 1991). Ozonoff et al. (1991) administered tasks testing ability to empathize, emotional processing and executive functioning to participants with ASD and age, sex and IQ matched controls. They found that the ASD participants performed less well on all tasks, and that deficits in emotion understanding and executive function were related to one another in the ASD group, concluding that executive dysfunction is a primary deficit in both high and low functioning ASD. Problems with ED theory include the fact that not all individuals with ASD exhibit executive dysfunction (predominantly in high-functioning autism (HFA)), suggesting that it cannot be a core feature of the condition (Baron-Cohen et al., 1999), and that executive dysfunction is not specific to ASD, with reports of executive function difficulties in conditions such as ADHD (Shang, Wu, Gau & Tseng, 2013), depression (Lockwood et al., 2002) and even in menopause (Epperson et al., 2015).

1.3.1.3 Weak Central Coherence Theory

Weak Central Coherence (WCC) theory was put forward by Frith and Happé (1994) as an attempt to explain not only the deficits seen in ASD, but also the aspects of cognition that appear to be preserved or even enhanced. Central coherence refers to the ability to process information as a whole, that is, in context and including the assimilation of semantically relevant features. WCC suggests that autistic individuals are unable to process information at this global level, instead focusing on local details, which leads to both an inability to grasp the wider context and 'black-and-white' thinking. This local information processing style, however, also yields an enhanced aptitude for attention to detail, supported by studies showing that ASD participants perform as well as, or better than, neurotypical controls on tasks that measure attention to detail, such as the Embedded Figures Task (EFT) (Shah & Frith, 1983; Frith, 1989; Jarrold, Gilchrist, & Bender, 2005; Happé & Frith, 2006).

The fact that weak central coherence accounts for strengths in ASD as well as weaknesses means that it is seen as a cognitive difference rather than as a deficit (Happé, 1999). WCC, in conjunction with reduced Theory of Mind, is suggested to account for the full range of ASD characteristics (Happé & Frith, 2006). One problem with WCC theory is that it predicts that those with ASD will be unable to grasp ‘wholes’ that are made up of many parts, yet many with even low functioning ASD are able to derive overarching general rules from complex parts, and apply these rules in certain ways to predict or calculate outcomes, for example performing calendrical calculation or factorising vast numbers without prior mathematical education (Saks, 1985; Baron-Cohen et al., 2007). It therefore seems that WCC theory is unable to account for the affinity for, and ability to understand, systems in ASD (Baron-Cohen, 2004).

1.3.1.4 Enhanced Perceptual Functioning

While the WCC theory proposes that those with ASD possess an enhanced local processing style along with difficulties processing information globally, the Enhanced Perceptual Functioning (EPF) theory of autism posits that this aptitude for local details is the result of superior visual processing and an ‘overfunctioning’ of certain regions in the brain responsible for primary perceptual functions (Mottron & Burack, 2001; Mottron, Dawson, Soulières, Hubert & Burack, 2006). EPF theory accounts for the ability of those with ASD to process global information, such as mathematics as mentioned above, or a piece of music, by suggesting that there is not a deficit in global processing, but that enhanced perceptual processing prompts adaptive responses that manifest as restricted interests or as extraordinary abilities in people with ASD and savant syndrome (Mottron et al., 2006). EPF also explains repetitive behaviours in ASD by suggesting that the overstimulation of sensory input leads to a mitigating response such as tapping, rocking, etc., in order to try to reduce what would otherwise be an overwhelming sensation.

There is evidence to support EPF theory, such as the finding that local processing enhancement in those with a talent for observational drawing was related to an ability to successfully filter global information, rather than a deficit in global processing (Chamberlain et al., 2013). Additionally, Bertone et al. (2005) administered a task to an ASD group and controls whereby they had to distinguish

the orientation of a stimulus that was determined by either texture or luminance contrast. The luminance discrimination task is simple and involves processing in only one receptive field—area V1—of the visual cortex and can be determined by a single neuron in that area, whereas the more complex texture discrimination task requires integration from more than one receptive field. They found that those with ASD performed significantly better than controls at distinguishing orientation by luminance contrast than by texture, and worse than controls on the texture discrimination task. Bertone et al. (2005) suggest that these results provide evidence that the strengths in local processing seen in ASD are related to enhanced perceptual functioning for simple stimuli, that the deficits seen in global processing are related to poorer perceptual functioning for complex stimuli and that these differences are contingent on the complexity of the neural network that is required to process each type of stimuli and atypical neural connectivity, rather than on an inability to process meaning globally (as suggested by WCC theory).

1.3.1.5 Social Motivation Theory

The Social Motivation Theory (SMT) suggests that the socially-related symptoms of ASD arise from a lack of interest in social information. The background to this theory includes research that has shown that people with ASD will show reduced fixation on eyes compared to controls and that this reduced attention to eyes is related to social deficits (Klin et al., 2002); hypoactivation in ASD in areas of the brain usually specialised for processing faces (the fusiform face area (FFA)) when presented with images of faces (Schultz, 2005); and evidence from face processing studies in ASD, which indicates impaired face recognition and discrimination, reduced attention to the eyes and slower face processing, which is suggested to be due to a primary deficit in motivation to attend to social stimuli (Dawson, Webb & McPartland, 2005). Based on this evidence, the Social Motivation Theory proposes that the social difficulties in ASD arise from reduced or absent motivation to attend to social information, leading to reduced exposure to faces and other social stimuli, which in turn leads to reduced opportunity for developing social understanding, resulting in the social deficits characteristic of autism (Chevallier, Kohls, Troiani, Brodtkin & Schultz, 2012).

There is much evidence suggesting reduced attention and orienting towards social stimuli in ASD, for example, a study using social orienting tasks found that NT children exhibited a preference for orienting to social information, where children with ASD did not (Burnside, Wright & Poulin-Dubois, 2017); a study investigating orienting to social stimuli found atypical gaze cue and face processing in children with ASD and children with a diagnosis of ASD and ADHD, compared with those with a diagnosis of ADHD alone and controls, suggesting that reduced social attention is specific to autism (Groom & Kocher et al., 2017); an eye tracking study looking at social orienting in children with ASD during dyadic interactions in naturalistic settings found that those with ASD oriented towards faces to a lesser extent than NT controls, and that they are much slower to attend to speaking faces (Magrelli et al., 2013). The Social Motivation Theory suggests that while social motivation seems to be an innate feature of neurotypical individuals, with most people seeking out relationships with others and preferentially orienting towards faces and social stimuli, even in the first months of life (Mares, Smith, Johnson, & Senju, 2016; Tomalski, Csibra, & Johnson, 2008), in ASD the atypical social orienting and reduced attention to social stimuli reflects a diminished drive towards the social that appears at an early age and may therefore have a knock-on effect on social functioning later on.

Results of studies investigating social attention in ASD have not been consistent, however. A change blindness task (see Chapter 5 for further detail on change blindness paradigms) found no differences between an ASD group and controls in attending to people and animals in naturalistic scenes (New et al., 2010); a study on infants at risk for autism (by virtue of having an older sibling who had been diagnosed with ASD) found that those who later went on to develop autism showed clear orienting towards faces and typical social attention patterns (Elsabbagh et al., 2013); and research on orienting towards protoface stimuli (e.g. black dots where the eyes and mouth would appear on a face) found that the orienting response to these face-like configurations was intact in individuals with ASD (Shah, Goule, Bird & Cook, 2013).

These conflicting results may be due to the fact that it is not that individuals with ASD lack motivation for social stimuli, but simply that they prefer or are more motivated towards non-social stimuli. Sasson & Touchstone (2014) found that

children with ASD attended to social information as much as NT controls unless there was a competing image of an object related to typical autistic circumscribed interest, in which case they attended significantly less to faces. Similarly, an eye tracking study in adolescents with ASD and NT controls found that the presence of a non-social object alongside social stimuli within a scene was associated with reduced preference for attending to the social image and suggest that atypicalities in social motivation in autism may be context dependent (Unruh, Sasson & Shafer et al., 2016). It may therefore be that social motivation in ASD is modulated by non-social motivation and that a preference for, or stronger orienting response towards, non-social information interferes with social attention in certain contexts but not in others. The aim of the present thesis is to explore this non-social attention and motivation in ASD and the subclinical autism spectrum.

1.3.1.6 Empathizing-Systemizing & Extreme Male Brain

The Empathizing-Systemizing (E-S) theory of autism attempts to explain both the social and non-social characteristics of ASD by postulating that restricted interests and repetitive behaviours (RRBs) represent a form of extreme ‘systemizing’, that is, an overdeveloped drive to construct and analyse rule-based systems (Baron-Cohen, 2009). Baron-Cohen’s Empathizing-Systemizing and Extreme Male Brain (EMB) theories of autism posit that the spectrum of autistic traits extends from those with few autistic symptoms (good social communication, no repetitive and restrictive behaviours) right across the neurotypical population to those with mild, and then severe, ASD (Baron-Cohen, 2009; Baron-Cohen, 2002). These theories therefore account for the evidence for the broad autism phenotype and the presence of autistic traits in the general population (as discussed in Section 1.2.2).

The development of the self-report Systemizing Quotient (SQ; Baron-Cohen, Richler, Bisarya, Gurunathan & Wheelwright, 2003) and Empathizing Quotient (EQ; Baron-Cohen & Wheelwright, 2004) to measure both drive to systemize and drive to empathize, allowed for the investigation of sex differences in the neurotypical population in terms of these two cognitive dimensions. Along with behavioural assessments to measure systemizing and empathizing abilities more objectively, studies found that females tend to outperform males on empathizing tasks while scoring higher on the EQ, and males show the opposite pattern, outperforming females on systemizing tasks while self-reporting higher systemizing drive (Baron-

Cohen et al., 2003; Baron-Cohen & Wheelwright, 2004; Carroll & Chiew, 2006; Nettle, 2007). These sex differences led to the hypothesis that the repetitive behaviours and restricted interests of ASD represent an exaggeration of typically 'male' cognitive attributes in the form of heightened systemizing ability and fewer typically 'female' abilities, such as empathizing (possessing a 'theory of mind' that enables the understanding and successful navigation of the social environment).

The theory that ASD represents the extreme of a typically male cognitive style is supported by evidence from various studies including one that tested empathizing and systemizing ability in males with Asperger Syndrome (AS) and NT males and females, and found that females outperformed both AS and NT males on the empathizing task, with NT males outperforming the AS males, while both NT and AS males outperformed females on the systemizing task (Lawson, Baron-Cohen, & Wheelwright, 2004). Other research also supports these findings—in a study by Wakabayashi et al. (2007), people with ASD and neurotypical controls were administered both the SQ and the EQ, and the results showed that those with ASD scored lower on the EQ and higher on the SQ than controls. Further evidence suggests that cognitive ability associated with both empathizing and systemizing are linked to levels of testosterone, both pre- and post-natally. Research has found that higher pre-natal exposure to testosterone correlates with social communication difficulties in female children and restricted interests in male children (Whitehouse, et al., 2010; Knickmeyer et al., 2005), and that a proxy for circulating testosterone correlates with systemizing ability (measured using the intuitive physics test) (Brosnan et al., 2010).

While there is evidence to support the Extreme Male Brain theory of autism, the Empathizing-Systemizing (E-S) theory (Baron-Cohen, 2009) may provide a better approach. Although empathizing and systemizing can very generally be thought of as female and male attributes respectively, it may be more useful to consider the autistic spectrum in terms of the abilities themselves, to allow for the occurrence of female high systemizers and male high empathizers, of which there are many. For example, a recent study found that scores on the Empathizing and Systemizing quotients were a better predictor of degree subject than gender, with those scoring highly on the SQ more likely to be taking a science degree, and those scoring higher on the EQ more likely to be studying a subject from the arts and humanities (Manson &

Winterbottom, 2012). More recent research also suggests that females with ASD may be underdiagnosed and that there may be two distinct ASD phenotypes for males and females respectively, so it makes sense to discuss autistic traits in terms of their qualities rather than in terms of their maleness (Mandy et al., 2012; Bargiela, Steward, & Mandy, 2016; Lehnhardt et al., 2016; Loomes et al., 2017). There is an established link between empathizing and systemizing abilities; those that are very good at one tend to be challenged when it comes to the other (Baron-Cohen, 2009), so this way of framing the social and non-social dimensions of ASD is useful for the purposes of this thesis.

1.3.1.7 Dual Process Theories

There is evidence that Theory of Mind cognition is an automatic process, for example, a study showed that adults are significantly slower to spot the location of a ball if an onlooker has a false belief about where the ball is located, even when that belief is irrelevant to the task, suggesting that the tracking of others' beliefs is automatic (Kovacs et al., 2010), and other studies reveal automatic identification of what others perceive (Samson et al., 2010; Qureshi et al., 2010). However, there is conflicting evidence, suggesting that ToM cognition involves slower processes that involve working memory and attention, for example Back and Apperly (2010) found that participants were significantly slower answering questions about the beliefs of another person compared to questions about reality. Additionally, while infants as young as 18-months can typically pass false-belief tests to assess ToM (measuring eye gaze behaviour), children up the age of 4 typically do not pass verbal false-belief tests (Onishi & Baillargeon, 2005). Conversely, individuals with ASD will pass an explicit verbal false-belief test but, on implicit false-belief tasks, will not exhibit eye gaze behaviour consistent with false-belief understanding (Senju, 2009). This conflicting evidence suggests that ToM and social cognition more broadly, may involve two separate processes or styles, one automatic and one slower that involves a processing cost (Butterfill & Apperly, 2013). These two conjectured styles of social cognition are consistent with classic dual process theories of cognition, which propose two different domain-general reasoning and decision-making styles or systems (Stanovich & West, 2000; Evans, 2008) and investigating ToM and social understanding within this framework is thought to be promising (Happé, Cook & Bird, 2017).

Beyond Theory of Mind, Brosnan et al. (2014) suggest that the two distinct cognitive styles proposed by dual process accounts of cognition parallel the concepts of empathizing and systemizing. The first thinking style (Type 1) is characterized as a fast, low effort, automatic, intuitive and unconscious processing style that is independent of working memory and general intelligence, and has been linked to emotion and the rapid attribution of emotional/mental states and intention to others (Stanovich & West, 2000; Epstein, 1994; Hassin et al., 2004). It is also argued that as Type 1 processes do not require controlled attention, they can be involuntarily triggered by certain stimuli but can also be mediated by higher level reasoning processes (Stanovich, 2009; Evans & Stanovich, 2013). Type 2 is characterized as a slow, analytical, reflective, conscious and controlled deliberative processing style that is dependent on general intelligence and working memory and is linked to the representation of rules and underlying principles (Stanovich & West, 2000).

Brosnan, et al. (2014) suggest that Type 1 type processing is related to empathizing, due to the rapid, autonomic and intuitive nature of emotion recognition that has been conjectured in the literature (Clark, Winkielman, & McIntosh, 2008; Kahneman & Egan, 2011; Tracy, et al., 2011; Oliva & Anikin, 2018). Type 2 type processing, they propose, is related to systemizing, which involves slower, more deliberative and higher-order cognitive processes. Their research on the relationships between self-reported systemizing and empathizing biases (using the Empathizing Quotient (EQ) and Systemizing Quotient (SQ)) and measures of intuitive and deliberative cognitive mechanisms (using the Rational Experiential Inventory (REI; Pacini & Epstein, 1999) and the Cognitive Reflection Task (CRT; Frederick, 2005) found correlations between empathizing and intuition/Type 1 type processes and systemizing and deliberation/Type 2 type processes (Brosnan, Hollinworth, Antoniadou & Lewton, 2014). These findings were explored by Brosnan et al. (2016; 2017) in the autism spectrum to establish whether the cognitive profile of ASD could be understood in terms of dual process accounts of cognition, and discovered that people with ASD produced fewer intuitive responses on the CRT and that a higher number of autistic traits in a pooled sample of NT and ASD participants was related to more deliberative responses and fewer intuitive responses.

Another study also explored the relationships between empathizing–systemizing constructs and the Type 1/Type 2 constructs proposed by dual process accounts of

cognition, by administering the EQ, SQ and various measures of deliberative and intuitive reasoning style to a large NT sample (n=2789) and found that self-reported systemizing drive was significantly positively correlated with deliberative thinking style and significantly negatively correlated with intuition, and that self-reported empathizing drive was negatively correlated with deliberative thinking style but not related to intuition (Svedholm-Häkkinen & Lindeman, 2017). An aim of the present thesis is to explore systemizing as an aspect of non-social cognition, the processes and mechanisms underlying both systemizing drive and ability, as well as attentional and physiological responses to non-social stimuli in ASD and in relation to autistic traits. The Dual Process theory as conceptualised by Brosnan et al. (2014; 2016; 2017) is a useful framework for bringing together, thinking about and analysing the results of the various studies presented here. See Chapters 6 and 9 for further discussion.

1.3.2 Biological Explanations

1.3.2.1 Genetics

There is high heritability of ASD and autistic traits and it is widely accepted that there is a genetic basis for ASD (Woodbury-Smith & Scherer, 2018). However, the genetic findings thus far have been complex and heterogeneous, making elusive yet again the idea of a single underlying cause (Veenstra-Vanderweele et al., 2004; Lord & Jones, 2012). Between 200 and 1000 genes have been implicated in susceptibility for ASD (Chen et al., 2015) and the disorder is associated with many different genetic patterns, sharing them with numerous other disorders and psychiatric conditions, making it difficult to identify a genetic aetiology for the majority of individuals with an ASD diagnosis (Guilmatre et al., 2009). A recent review of the progress in research on the genetics of ASD is hopeful, however, suggesting that new insights into its genetic aetiology may offer opportunities for identifying molecular targets for intervention (Woodbury-Smith & Scherer, 2018).

1.3.2.2 The Social Brain

A great deal of research into ASD has focused on the social aspects of the disorder, due to the negative impact of social deficits on daily functioning, with much attention being paid to the areas of the brain involved in emotion and face

recognition and processing. Brain structures involved in social cognition include the amygdala, the superior temporal sulcus, and the fusiform gyrus, or fusiform face area (FFA), which various studies have shown to be abnormal in ASD (Brothers, 1990; Baron-Cohen et al., 2000; Bookheimer, et al., 2008; Ashwin, et al., 2007; Schultz, 2005; Boucher, et al., 2005; Gaigg and Bowler, 2007; Howard, et al., 2000; Kanwisher, et al., 1997; Pierce, et al., 2001; Critchley, et al., 2000; Schultz, et al., 2003).

The amygdala has been identified as a crucial part of the ‘social brain’ (Brothers, 1990) as there is evidence it plays a role in recognising emotion in facial expressions (Adolphs, Russell & Tranel, 1999) and in orienting to socially salient stimuli (Birmingham et al., 2010). In non-human primate studies, it has been shown that ablation of the amygdala in rhesus macaques results in a withdrawal from social interactions (Kling, 1986). Studies also indicate that the amygdala functions abnormally in ASD, for example Baron-Cohen et al. (2000) discovered that the amygdala is not activated while performing the ‘reading the mind in the eyes task’ and other studies indicate that those parts of the brain activated in controls when processing emotional facial expressions, including the amygdala, are not activated in adults with high-functioning ASD (Bookheimer, et al., 2008; Ashwin, et al., 2007; Schultz, 2005) and that the amygdala is abnormally developed in ASD (Boucher, et al., 2005; Howard, et al., 2000).

There is growing evidence to suggest that autistic individuals are in fact able to recognise both ‘non-social’ (e.g. fear or happiness) and ‘social’ (e.g. guilt or embarrassment) emotions in others under experimental conditions (Williams and Happé, 2010; Hobson, et al., 2006). The authors of these studies acknowledge that while autistic individuals may possess cognitive processes for recognising emotions similar to non-autistic individuals, it is clear that they cannot apply these processes flexibly across a variety of contexts in daily life. For example, it may be that the focused and systematic structure of the experimental tasks facilitates that processing, while the pressures and complexities of real life situations makes social emotional processing particularly difficult for those with ASD. While social emotional processing in ASD is impaired in everyday contexts, the ability to recognise social emotions in experimental conditions, and the ability to identify the appropriate emotional content of music suggest that ASD may not involve a complete deficit in

emotion recognition and processing. In another study, autistic adults and adolescents demonstrated intact learning and perception of emotionally relevant non-social stimuli equivalent to that of NT controls (South et al., 2008). This indicates intact amygdala function for other aspects of emotional processing and decision-making where social stimuli are not involved. This study however did not compare emotional facilitation with social stimuli, and suggests that future research should examine this.

Another area of the brain implicated in ASD is the superior temporal sulcus (STS), which appears to be involved in social perception (Allison, Puce & McCarthy, 2000), including the analysis of biological motion (Bonda et al., 1996) and the interpretation and prediction of the intentions and actions of others (Mosconi et al., 2005). Brain imaging studies with individuals with ASD found atypical activation of the STS when performing social tasks, and that there is reduced grey matter in the STS in ASD subjects (Saitovich et al., 2012). It has been suggested that abnormalities in the early development of the function and anatomy of the STS may trigger a cascade of dysfunction in other neural processes, leading to the social impairments characteristic of ASD (Zilbovicius et al., 2006).

Neurons are remarkably selective and will fire only for specific stimuli that they code for, with neurons in the visual cortex being highly specialised towards certain kinds of stimuli (Quiroga et al., 2005; Quiroga et al., 2008). For example, there are face-selective neurons involved in face perception that only fire when a face appears in the visual field (Afraz et al., 2006), ‘canonical’ neurons that respond to objects (Rajmohan & Mohandas, 2007), neurons that code for specific quantities (Nieder & Miller, 2003) and there are neurons known as mirror neurons (MNs), found in the STS, that are specialised for the visual processing of information about the actions of others (Rizzolatti et al., 1996; Carey, 1996). Mirror neurons are so-called because they code for/are activated by patterns of movement perceived in others and form a kind of pre-motor representation of the same pattern of movement in the observer. It has been suggested that MNs allow for the development of a theory of mind—by internally reconstructing the neural patterns that accompany particular movements and behaviours it may be possible to then experience an impression of the kind of mental and emotional states, and intentions, that are associated with those movements and behaviours (Gallese & Goldman, 1998). It is theorized that MNs are

important for developing imitative behaviour, theory of mind and social understanding and that early dysfunction in the MN system may lead to difficulties interpreting, predicting and understanding the behaviours of others, causing the social deficits characteristic of ASD (Williams et al., 2001). A recent review of 17 studies on mirror neurons in autism found that 13 of them reported that the MN system plays a role in ASD, while 4 studies reported no such influence (Guedes Neta & Varanda, 2016).

A further area of the brain proposed to be dysfunctional in ASD is part of the middle aspect of the right fusiform gyrus, or the fusiform face area (FFA) as it has come to be known due to its activation during facial processing tasks in the typically developing population (Kanwisher, et al., 1997; Puce, et al., 1995, 1997; Sergent, 1992; McCarthy, 1997). Studies have shown that in ASD, however, this area is not activated when viewing faces (Pierce, et al., 2001; Critchley, et al., 2000; Schultz, 2005). Another study discovered that the FFA is also activated by social attribution tasks that involve human like interactions between non-human geometric shapes with no involvement of facial imagery (Schultz, et al., 2003), which suggests that the FFA performs a function when meaning is assigned to socially relevant gestures and stimuli during social cognition in general. The conclusion of this study was that hypoactivation of the FFA in ASD could be indicative of a more general malfunctioning of the larger 'social brain network,' in which the FFA plays a crucial role along with the amygdala.

There is evidence to suggest that dysfunction or abnormal development of these regions of the 'social brain' are not related to ASD symptomatology. For example, a more recent non-human primate study by Emery et al. (2001) found that adult rhesus monkeys with bilateral lesions of the amygdala were still able to engage in social interactions, understand social gestures and initiate and receive social contact. A case study of two patients with a rare disease (Urbach–Wiethe disease) causing bilateral atrophy of the amygdala revealed no association with ASD when they were assessed with standard diagnostic tests for ASD (Paul et al., 2010) and other research has shown more differences between individuals with amygdala lesion and those with ASD than similarities (Birmingham et al., 2011). This conflicting evidence may suggest that it is not solely the amygdala that is responsible for either social proficiency or social deficits, but a more complex 'social brain network' of which the

amygdala forms a part, and which can produce ordinary social functioning even when one of its components fails, perhaps due to compensatory activity by the other parts (Schultz et al., 2003; Hadjikhani et al., 2004).

Further research shows that the amygdala and the FFA are not necessarily damaged or dysfunctional in ASD. One fMRI study found that there were no significant differences in FFA activation between adults with ASD and controls when shown facial stimuli in comparison with non-social stimuli (Hadjikhani, et al., 2004), also suggesting that the social deficits in autism are due to the overall dysfunction of a distributed social processing network in the brain rather than abnormal functioning in a particular area. A more recent study investigated the performance on tasks previously identified as involving engagement of the amygdala of adults and adolescents with ASD (South, et al., 2008). The tasks chosen were not socially related, and involved identifying (non-social) threats, assessing (non-social) risk and affective word memory. They found that there was no difference in performance between the ASD group and controls, suggesting again that impairment of the amygdala in ASD is specific to social information.

Evidence suggesting activation of both the FFA and the amygdala in ASD to non-face stimuli was found in an fMRI study on a child with autism, when he was shown images of Digimon characters, which were an example of his particular restricted interest (Grelotti, et al., 2005). The child did not show activation of these areas when viewing images of faces, suggesting that while the areas of the brain usually associated with social processing may be intact in ASD, they may instead be activated by non-social stimuli, or stimuli specific to a particular obsession or special interest. A study by Rosset et al. (2008) further supports this finding, reporting that children with autism could identify emotions in cartoon faces using the same configural processing strategy as that employed by NT controls when identifying emotion in human faces. When autistic children attempted to identify emotion in real human faces, they used an atypical perceptual strategy that focuses on details rather than the face as a whole. These studies suggest that the brain structures employed for such processing in NT controls are not necessarily defunct in ASD. Although the amygdala is typically associated with response to social stimuli and it is therefore presumed dysfunctional in ASD, evidence such as this implies that in ASD the amygdala is in fact functional, but is responsive to non-social rather than social

stimuli. The current thesis aims to explore this idea by investigating attention and physiological responses to non-social compared with social stimuli across the subclinical autism spectrum and in an ASD sample vs controls.

Chapter 2

Systemizing and Non-Social Cognition in the Autism Spectrum

2.1 Overview

This chapter provides a summary of the non-social features of autism, beginning with a review of the restricted interests and repetitive behaviours that broadly constitute the non-social diagnostic criteria for ASD, before discussing the concept of Systemizing, from the Hyper-Systemizing and Empathizing-Systemizing theories of autism, which is used to describe the cognitive style of individuals with ASD. A summary of Chapters 1 and 2 is provided and the aims of the research are stated.

2.2 Restricted Interests and Repetitive Behaviours

2.2.1 High and Low Level RRBs

The mechanisms underlying the non-social dimension of the core diagnostic criteria for ASD are less frequently studied than the social and communicative deficits, due in part to the perceived comparatively negative impact of social dysfunction on daily life and in part to the considerable challenge of studying such a heterogeneous set of behaviours (Turner, 1999). The restricted interests and repetitive behaviours (RRBs) that constitute key symptoms of ASD encapsulate a wide variety of activities and inclinations, some of which can be harmful or inappropriate, and others of which can be harmless at worst and beneficial or enjoyable at best.

RRBs can be reliably divided into two subtypes: high and low level behaviours (Turner, 1999; Leekam, 2011). Factor analyses of measures of RRBs, such as the Repetitive Behaviour Scale Revised (RBS-R; Bodfish, Symons, Parker & Lewis, 2006), the ADOS (Lord et al., 2000) and ADI-R (Lord et al., 1994) reveal that the low level subtype can be broadly categorised as repetitive sensory motor behaviours, and the high level subtype as insistence on sameness behaviours (Bishop et al., 2013). Low-level behaviours therefore include actions such as arm flapping, rhythmic movements and rocking; and self-injurious actions such as head or face slapping, hand biting or hair pulling (Cuccaro et al., 2003). These behaviours are

more characteristic of low-functioning autism and occur more frequently in younger ASD patients, as well as occurring as symptoms of other intellectual disabilities, developmental or neurological disorders and psychiatric conditions such as Tourette's syndrome, Parkinson's disease and schizophrenia (Bishop & Richler, 2006; Carcani-Rathwell et al., 2006). High-level, or 'insistence on sameness,' RRBs include having restricted interests; repetitive speech (palilalia and echolalia); ritualistic behaviours such as repetitive manipulation and arrangement of objects (e.g. obsessively lining up toys); and an intense dislike of change, which can result in great distress if routines or environments are disrupted. Restricted interests are particularly common in high-functioning autism (HFA) and represent the highest level of RRB, referring to the (often obsessive) pursuit and regurgitation of information about a circumscribed entity or set of entities such as a certain film franchise, a football league, train timetables or a particular make of vehicle, with little desire to engage about anything else. Some analyses suggest a three-factor model of RRBs, in which restricted interests load onto a factor of their own, indicating that restricted interests may have a different pathology to the repetitive behaviour and insistence on sameness RRBs in ASD (Lam, Bodfish & Piven, 2008).

Despite the relative lack of in depth research into the underlying causes of RRBs compared to the social and communicative symptoms of ASD, the importance of researching the non-social features of the autistic cognitive profile in order to better understand the aetiology of the condition has been highlighted and research is growing in this area (South, et al., 2005; Spiker et al., 2012; Jiujiias, Kelley & Hall, 2017). Leekam et.al. (2011) state the need for further integration of the research into RRBs from the disciplines of developmental and cognitive psychology, neuroscience and psychiatry in order to develop a conceptual framework for understanding these behaviours and their role in the broader diagnosis of ASD. Much of the research on RRBs in these various disciplines attempts to understand their underlying causes and what functions they might serve. The fact that these behavioural symptoms are so heterogeneous and are characterised by their apparent lack of purpose, makes these investigations challenging. A thorough review by Turner (1997) of earlier research into RRBs suggests that to explain the presence of these behaviours in autism, a sound theory must account for the variance in symptoms between individuals, the rigidity and inappropriateness characteristic of these behaviours and the reasons for their resistance to treatment or change with time, and their prevalence across all ages

and abilities within the autistic spectrum. Over the past two decades there have been theoretical and empirical developments that have made some progress in attempting to answer these questions and explain what drives restricted and repetitive behaviours in ASD.

2.2.2 Hyper- and Hypo-Arousal in RRBs

There is evidence to suggest that RRBs may be related to hyper-arousal, both in ASD and in other conditions such as obsessive-compulsive disorder (OCD), schizophrenia, Fragile X syndrome and Rett syndrome, as well as in amphetamine users, who attest to finding repetitive motion calming when under the influence of the stimulant (Kinsbourne, 2011). Several studies have shown that abnormal sensory responses are related to RRBs in ASD (Gabriels, et al., 2008; Boyd, et al., 2009; Chen, et al., 2009) but there is as yet no real consensus on the nature of this relationship (Leekam, et al., 2011). One prevalent and longstanding hypothesis related to the Enhanced Perceptual Functioning theory (Motttron et al., 2006) suggests that the simple repetitive motions seen in low-level RRBs provide sensory input that modulates hyper-arousal, displacing the negative feelings associated with an overactive sympathetic nervous system, and that the avoidance of new objects and situations ('insistence on sameness') in ASD is due to the inability to cope with the heightened arousal that is elicited by novel stimuli (Hutt et al., 1964; Hutt & Hutt, 1965; Hutt & Hutt, 1970; Kinsbourne, 1980; Repp et al., 1992).

However, a review by Rogers and Ozonoff (2005) of all research undertaken since 1960 into sensory abnormalities in ASD found that these accounts are likely to be inaccurate, as while the research suggests that sensory abnormalities occur more frequently in ASD than in NT controls, this does not distinguish ASD from other developmental disorders such as Fragile X syndrome, and there is insufficient evidence to support the hyper-/hypo- arousal theory. The majority of findings would suggest that hyper-arousal is not a core feature of ASD, and while some studies found evidence to support a theory of hypo-arousal in ASD, the diversity of methods and the lack of replication across the research render the overall picture of arousal in ASD inconclusive.

2.2.3 Anxiety and RRBs

The presence of restricted interests and repetitive behaviours may interfere with overall functioning in ASD, as an obsessive narrow focus of attention can cause important information in the environment to be overlooked (Attwood, 2003). Indulgence in RRBs has been found to have a negative impact on social interaction as it interferes with the ability to engage in reciprocal communication, and intensity of the expression of RRBs is associated with poorer social outcomes (Klin et al., 2007). Spiker et al. (2012) suggest that this interference of RRBs in social functioning may lead to increased anxiety levels in those with ASD. Clinically significant anxiety symptoms are commonly experienced by people with ASD, with studies finding that between 30-81% of individuals with ASD suffer from some form anxiety, such as general anxiety, social anxiety and separation anxiety, as well as symptoms of Obsessive Compulsive Disorder (OCD), (Rodgers et al., 2012; Wood & Gadow, 2010). Studies have found that anxiety symptoms are related to restricted interests (Lidstone et al., 2014). As restricted interests in ASD are often related to positive affect (Sasson, Dichter & Bodfish, 2012) it is thought that engaging in restricted interests and other RRBs may help to relieve anxiety so the correlation between the two may be due to excessive engagement with RRBs that provoke positive feelings to mitigate already existing anxiety symptoms, which has been suggested before (Jiujiu et al., 2017; Baron-Cohen, 1989).

2.2.4 Motivation for Restricted Interests

Despite evidence that time spent obsessively engaging in restricted interests impacts negatively on social functioning and daily life (South et al., 2005; Turner-Brown et al., 2011), restricted interests are enjoyable and very rewarding for individuals with ASD and may help to reduce anxiety, as mentioned above (Mercier, Mottron & Bellvile, 2008). Research on motivation and reward in ASD has found diminished neural (Kohls et al., 2012) and behavioural (Lin et al., 2012) responses to social stimuli, inspiring the Social Motivation Theory of autism (Chevallier et al., 2012; see Chapter 1, Section 1.3.1.5). Atypical responses to monetary reward have also been reported (Delmonte et al., 2012; Zeeland et al., 2010), which could indicate perhaps a general dysfunction in the reward system in ASD. However, studies have found intact reward processing for objects relating to typical restricted interests in ASD, such as vehicles and trains (Dichter et al., 2012) and enhanced activity of the reward

system when presented with images relating to the individual's own particular special interest (Cascio et al., 2014).

A study by Watson et al. (2015) found that children with ASD were willing to receive less money to view images related to their restricted interest than controls, indicating that restricted interests have reward value in autism. Foss-Feig et al. (2016) conducted a neuroimaging study with children and adolescents with ASD and controls, all of whom reported having a special interest or hobby. Participants were then shown images relating to their own interest while undergoing fMRI, and the results showed a stronger activation of the FFA in the ASD group compared to controls, suggesting that brain regions usually associated with social functioning are not dysfunctional in ASD, but are employed in the attention to, and perception of, non-social stimuli related to restricted interests. Other studies have reported similar findings, with ASD groups exhibiting larger responses to non-social restricted interest-related stimuli than to social stimuli (Benning et al., 2016; Kohls et al., 2016; Clements et al., 2018). Authors tend to suggest that these findings indicate a dysfunction in the reward system in ASD that manifests as diminished social motivation and underlies an increased interest in restricted interests, extending the Social Motivation Theory of autism to include motivational differences in the non-social domain, although explanations for the mechanisms by which this occurs are the subject for further study (Clements et al., 2018).

The evidence outlined here and in Chapter 1 suggests that while those with an ASD diagnosis may have dysfunctional activation of brain areas that are normally engaged in processing social information, these same areas may in fact function for processing different types of non-social information. Research has shown that the FFA may be employed for processing any category in which we have become an expert, faces simply being a category in which most NT humans have naturally acquired expertise (Kanwisher, 2000; Gauthier, et al., 2000; Liu et al., 2003; Mckone, et al., 2005; Xu, 2005). For example, the FFA has been shown to activate in expert chess players when undertaking chess-relevant tasks, suggesting that similar brain functions may underlie automatic and holistic processing of both social and non-social domains of expertise (Bilalić, et al., 2011; Boggan et al., 2012). These findings have relevance for the study of restrictive interests and repetitive behaviours in ASD, as it is commonly accepted that in NT children and adults, repetition of activities

and experiences is a major contributor to the development of expertise in a given area (Piaget, 1952; Gesell, et al., 1974; Ericsson, et al., 1993).

2.3 Systemizing

Systemizing involves focusing on input-operation-output processes, attempting to understand how they work and predict what they will do (see also Chapter 1 Section 1.3.1.6). It is something almost all human beings do, but in extreme ‘hyper-systemizers,’ the drive towards this approach to the world is enhanced, and can lead to the types of repetitive behaviours and restricted interests that form the diagnostic criteria for the non-social dimension of ASD (Baron-Cohen et al., 2003). The neural and cognitive mechanisms underlying the drive to systemize and the cognitive processes involved in systemizing are poorly understood. A recent paper by Baron-Cohen and Lombardo (2017) advocated for more research into systemizing in ASD. They suggest five areas in which additional research could help to elucidate the cognitive and neurobiological means by which systemizing occurs. The first is to clarify how systemizing is implemented in the brain, and how it leads to enhanced skills in autism. They also suggest that components of systemizing, such as drive and ability, should be further explored. Systemizing in ASD, like the condition itself, has heterogeneous manifestations. For example, the drive to systemize can be expressed at a low level by spinning a pencil on a table, and at a high level by engaging in complex mathematics. Baron-Cohen and Lombardo suggest that drive (or motivation) to systemize is probably highly related to ability, and that those with the highest drive to systemize will be motivated to practice more and enhance their skill, but call for additional studies investigating and comparing drive and ability in systemizing. Related to motivation, they propose future research to establish the neural basis of the restricted interests seen in ASD, where a particular topic or ‘system’ is pursued with fervour, and ask whether this process of developing special interests involves a mapping of the laws that govern their chosen system and if it impacts on neural circuitry in such a way that confers expertise. They also suggest that work needs to be done to understand the heterogeneous presentation of systemizing drive and ability in individuals with ASD, and finally ask for additional future brain imaging studies to explore neural activity during systemizing tasks (Baron-Cohen and Lombardo, 2017). The present thesis contributes to work on differentiating systemizing ability and drive (see Chapter 6) and also investigates

attention and physiological responses to restricted interests in order to better understand the cognitive processes underlying motivation towards non-social stimuli and systems.

As described in Section 2.2.4 above, there is evidence from various neuroimaging and psychophysiological studies that non-social stimuli related to special interests elicits stronger affective responses in people with ASD than controls, and stronger responses than do social stimuli. Alongside diminished social motivation, they appear to show increased motivation towards certain non-social stimuli. One possible way of characterizing this non-social motivation is as a drive to systemize. The Empathizing- Systemizing theory is useful for conceptualizing the drive to systemize as analogous to the drive to empathize. While it has long been assumed that the regions in the brain that are responsible for social cognition in the NT population are dysfunctional or impaired in ASD, research indicates that these areas may in fact function correctly, but in response to non-social stimuli (Kanwisher, 2000; Gauthier, et al., 2000; Liu et al., 2003; Mckone, et al., 2005; Xu, 2005; Benning et al., 2016; Kohls et al., 2016; Clements et al., 2018; Foss-Feig et al., 2016; Dichter et al., 2012; Cascio et al., 2014; Grelotti et al., 2005; Sasson & Touchstone, 2013). If those with ASD adopt the social brain network for attending to, understanding and predicting non-social features of the environment then it may be that hyper-systemizers experience a strong affective response in relation to systems-related stimuli and particularly special interest-related stimuli equivalent to the response in an NT individual when meeting a person or seeing the face of their best friend, i.e., when empathizing.

There is evidence to suggest that individuals with ASD and those with high levels of autistic traits in the NT population do experience emotion in response to non-social and systems-related stimuli. Music is a prime example of a rule-based system, and one that frequently elicits emotional responses in the neurotypical population (Levitin, 2006). Research indicates that people with ASD show intact or superior musical pitch processing (Heaton, et al. 1998) and that they are able to identify the emotional content of music, a ‘complex non-social affective stimulus’ (Caria et al., 2011). The fact that while social emotional processing in ASD is invariably affected, the ability to identify the emotional valence of a piece of music is not, suggests that ASD may not involve an overall deficit in emotion recognition and processing.

There is also anecdotal evidence that people who usually score highly on the Autism Quotient derive emotional pleasure from the predictability of physics and patterns in the world and have an emotional response to abstract concepts and systems (Baron-Cohen, et al., 2001a).

Accounts of autistic savants also indicate that there is a strong emotional component to the drive to systemize, and that this emotion has a social quality to it, even though it is directed at the non-social. Savant syndrome is a condition in which individuals with developmental disabilities (usually ASD, Treffert, 2009) also possess an extraordinary ability in some domain, such as a prodigious aptitude for music along with absolute pitch or an ability for calendrical calculation, mathematical calculation or prime number derivation, along with a remarkable memory that is usually narrow in its focus on the individual's area/s of interest (Treffert, 2009). Savant syndrome is rare, but there is evidence that its prevalence is increasing, with a 2009 study on 137 autistic individuals finding that almost 30% of them met the criteria for savant abilities (Howlin et al., 2009). Like ASD, savant syndrome is a very heterogeneous condition, the aetiology of which is poorly understood in terms of the juxtaposition of extraordinary systemizing-related ability with socially-related disability, representing the very extreme end of the Empathizing-Systemizing continuum.

Several autistic savants, and reported observations of such individuals, have expressed their drive to systemize in terms that sound more appropriate for speaking of social relationships. For example, Sacks describes several mathematical savants who claim that numbers are their friends, and the joy experienced by a pair of developmentally disabled autistic savant twins as they factorized large numbers, subitized huge quantities of matchsticks and calculated primes (Sacks, 1985). A rare high-functioning autistic savant with number-colour synaesthesia, who is able to describe his experience, also claims that numbers are his friends and talks about their distinct personalities (Tammet, 2007). It is also suggested by the mathematician Keith Devlin that mathematicians (scoring on average higher on the AQ than other scientists (Baron-Cohen, 2009)) 'view mathematics as a soap opera' and that 'numbers are like gossip' (Devlin, 2000).

Further still, although as yet very under-researched, there is evidence suggesting that there is a higher incidence of paraphilia (forming intense emotional, romantic and sexual bonds with inanimate objects) in those with ASD compared with NT and

other groups (Hellemans, et al., 2007; Hellemans, et al., 2010; see also <http://www.objectum-sexuality.org>). However, there is little research on the nature of the emotional response to the non-social in ASD and whether it is analogous to social-emotional responses in the NT population (Baron-Cohen, 2009).

This all suggests that the drive to systemize in ASD may be rooted in experiences of positive emotion towards, and a strong, innate preference for, certain non-social stimuli, patterns and/or relationships, and that this bias may be influenced by bottom-up, unconscious processes. The current thesis investigates this hypothesis by conducting studies to elucidate any differences in orienting responses to non-social stimuli, non-social stimuli of interest (to the individual) and social stimuli between an ASD group and controls, and in relation to autistic traits across the general population. Further studies are conducted to investigate attentional processes and the salience of non-social stimuli in an ASD group vs controls and in relation to autistic traits in an NT sample. An exploration of cognitive processes underlying systemizing drive, including the intuitive and deliberative thinking styles associated with dual process accounts of cognition, and whether the motivation to systemize translates into ability to perform on objective behavioural assessments of logical/systems reasoning are also carried out.

2.4 Summary and Research Questions

There is little evidence to show how the social and non-social dimensions of ASD (social impairment or lack of Empathizing, and repetitive/restricted behaviours or Systemizing) are related to one another or whether they can even be explained by a single theory (Happé et al., 2006). Cognitive theories of autism (such as the E-S theory), while often able to explain the social deficits of ASD, cannot account for the non-social aspects of the disorder; and those theories that adequately explain repetitive and restricted behaviours are unable to provide a satisfactory account of how they relate to social difficulties. This raises the question of how these co-occurring behaviours interact with each other in ASD, and at what level, if any, they are related, and therefore whether they should be studied separately. Happé et al. (2006) suggest that due to the requirement of both these social and non-social characteristics for a diagnosis of ASD, studies to establish whether these core

features are indeed fractionated or have a unitary explanation need to be carried out on the general population. The aim of this thesis is to explore cognitive, affective and attentional features of the approach to the non-social in ASD, asking whether the drive to systemize is related to ability to understand and manipulate systems; whether the cognitive style of hyper-systemizers is rational and deliberative or if it involves an intuitive grasp of patterns and rules that is analogous to the intuitive grasp of emotions and social situations most typically developing individuals have; and whether drive to systemize is influenced by bottom up perceptual processes involved in orienting attention that bias towards the non-social domain.

Chapter 3

Participants

3.1. Overview

This thesis presents the results of several studies conducted with both neurotypical (NT) participants recruited from the general population and with participants diagnosed with an ASD along with an NT control group matched for age, gender and level of educational attainment. All participants recruited were adults, aged 18 years or older. The present chapter discusses the rationale for the recruitment of these samples, the methods used for recruitment and their demographics and assessment.

3.2. Demographics

Below is a table detailing the basic demographics for participants from each study. These are then discussed in further detail below with reference to participants in general across all studies reported in this thesis, and more specific detail on participants for each study is reported in its corresponding chapter.

Study/ Chapter	Number of Participants	Age Range	Males Total	Females Total	ASD Total	NT Total
1 & 2 (Chapters 4 & 5)	46	18-66 yrs M=26.7 yrs	21	25	N/A	46
3 (Chapter 6)	119	18-66 yrs M=22 yrs	60	59	N/A	119
4 (Chapter 6)	64	18-54 yrs M=22.33 yrs	45 ASD 24 NT 21	19 ASD 6 NT 13	30 Male 24 Female 6	34 Male 21 Female 13
5 & 6 (Chapters 7 & 8)	33	19-67 yrs M=37.67	20 ASD 10 NT 10	13 ASD 7 NT 6	17 Male 10 Female 7	16 Male 10 Female 6

3.2.1. Age

All participants were adults, aged between 18 and 67 years ($M=31.18$ years, $SD=13.23$). Adults were chosen for this research primarily because while the concept of systemizing as a characteristic of ASD does include ‘low level’ RRBs, a greater understanding of systemizing—and particularly of restricted or circumscribed interests—as a whole, both within ASD and the broader autism phenotype, is possible only by conducting research on people with high-functioning autism (HFA), in which high level RRBs are more common. Many people with HFA are misdiagnosed in childhood or only diagnosed with HFA as late as adulthood (NICE, 2012) and this is particularly true of females (Bargiela, Steward, & Mandy, 2016; Lehnhardt et al., 2016; Loomes et al., 2017). Females with ASD have been relatively overlooked both diagnostically and when it comes to autism research, and it has been suggested that biological sex differences may account for much of the heterogeneity in ASD (Lai et al., 2013). Adult participants were therefore chosen for this study to increase the likelihood of recruiting sufficient numbers of people with HFA that would include as close to a balanced male-female sample as possible in order to elucidate any sex differences in systemizing behaviours in ASD. Adults are also increasingly a focus of ASD research due to the previous relative lack of attention on the disorder in adulthood, along with findings from various studies that ASD presents specific and ongoing challenges for people throughout life (Barnhill, 2007; Howlin et al., 2004; Levy & Perry, 2011; Seltzer, Shattuck, Abbeduto, & Greenberg, 2004; Weiss & Fardella, 2018). RRBs are a feature of ASD that persist well into adulthood and can have a negative impact on social functioning (Mercier et al., 2000). However, the circumscribed or ‘special’ interests of adults with ASD have been shown in some cases to help improve quality of life, with a recent study suggesting such interests be considered a resource for coping with the difficulties of navigating adult life with ASD, rather than simply as a symptom (Dachez & Ndobo, 2018).

3.2.2. Sex

Sex differences are explored in the analyses for the several studies reported in this thesis (Chapters 4–8). This includes sex differences in aspects of non-social cognition in neurotypical samples and an exploration of sex differences in an ASD

sample with NT controls. Sex is known to play a part in the autistic spectrum, with males being diagnosed with an ASD four times more than females (Fombonne, 2009) and with differences found between the sexes in the NT population when it comes to subclinical autistic traits, with NT males exhibiting more such traits than NT females, as assessed with the Autism Quotient (AQ), although the sex differences in AQ do not extend to ASD samples (Baron-Cohen et al., 2001; Ruzich et al., 2014). The Extreme Male Brain (EMB) theory of autism explains the sex differences in the NT population that disappear in the ASD population by positing that ASD is an extension or exaggeration of male cognitive attributes, so that both female and males with an ASD diagnosis represent an extreme version of a typically 'male' cognitive profile—i.e. enhanced systemizing and reduced empathizing (Baron-Cohen, 2002). Consistent with this, in the NT sample recruited for the studies in Chapters 4 and 5, the male mean AQ was 18.2 (SD=7.03), which was higher than that of the female mean AQ of 17.2 (SD=6.51) although this difference was not statistically significant ($t(44)=-.591, p=.558$), as found by previous studies (Baron-Cohen et al., 2001). The mean AQ for NT females was higher in this sample than has been reported elsewhere; Baron-Cohen et al. reported a mean NT female AQ of 15.4 in the general population and 16.4 among female undergraduate students (2001) and Ruzich et al. report a mean NT female AQ score of 14.88 (2014). The majority of participants in the NT sample for the current thesis were university students or graduates/postgraduates, which may account for the higher AQ scores among NT females in this sample.

The male bias in ASD prevalence has been consistently reported since the condition was first described (Kanner, 1943), with epidemiological studies and the DSM-5 putting the sex ratio at around 4:1 (American Psychiatric Association, 2013; Fombonne, 2009). More recent research suggests the true ratio may be closer to 3:1 due to a sex bias in the diagnosis of ASD, leaving females who meet the diagnostic criteria at risk of being undiagnosed or misdiagnosed as children and subsequently receiving an ASD diagnosis later than males (Giarelli et al., 2010; Lehnhardt et al., 2016; Loomes, Hull, & Mandy, 2017). There are several possible reasons for this bias in ASD diagnosis, including that females may be better able to compensate for their social and communication impairment than males (Lai et al., 2011; Wing, 1981), that females are subject to a genetic 'protective effect' whereby a larger abnormal genetic load is necessary for ASD to manifest, leading to fewer females developing ASD

(Jacquemont et al., 2014), that the neurobiology of ASD is affected by sex (Lai et al., 2013), and that diagnostic criteria may over-emphasise behavioural symptoms of ASD that are exhibited more strongly in males than in females (Lai, 2011; Shefcyk, 2015). The latter relates to the suggestion that there may be two distinct ASD phenotypes for males and females, with the female ASD phenotype involving a different manifestation of typical ASD symptoms and behaviours, including the internalising of symptoms such as anxiety and depression where males are more likely to exhibit symptoms externally through hyperactivity or impulsivity (Mandy et al., 2012).

Studies have also found evidence that females with ASD exhibit fewer repetitive and restrictive behaviours (Van Wijngaarden-Cremers et al., 2014; Wilson et al., 2016) and others have found that females with ASD perform comparably with neurotypical females in non-social cognitive domains, where neurotypical males outperform their ASD counterparts, suggesting that sex in ASD influences non-social cognition in particular (Lai et al., 2012). There have been calls for more research into females with ASD (Pellicano, Dinsmore, & Charman, 2014) but the ASD sample size recruited for the studies in Chapters 7 and 8 (10 males and 7 females) was too small to be able to make meaningful comparisons between genders within the ASD group alone. It is interesting to note, however, that the male: female ratio of the ASD participants recruited for the study was approximately 1.4:1, which is much lower than the usually cited 4:1 diagnosis ratio (Fombonne, 2009) and the 3:1 (Loomes, Hull, & Mandy, 2017) and 2.69:1 (Baker et al., 2014) ratios reported elsewhere.

3.2.3. Education

Research that uses the AQ as a measure of autistic traits in the NT population is conducted on participants with normal or above-average intelligence (Baron-Cohen et al., 2001; Ruzich et al., 2014), and as mentioned above, the research on an ASD sample presented in this thesis was focused on high-functioning autism (HFA), which is a term often used to describe ASD without intellectual disability (Ghaziuddin & Mountain-Kimchi, 2004). Because the studies presented in Chapters 7 and 8 with the ASD and NT groups involved several long self-report measures along with several computer-based tasks, the control group was matched on educational level instead of administering an IQ test for matching by IQ in order to

reduce study time and potential participant frustration. All participants were asked to report any psychological diagnoses and all ASD participants provided diagnostic reports from their doctor, so it was confirmed that all participants were at least of normal IQ or above (>70). For the study on the ASD sample, controls were matched according to educational attainment and were given the following options: No education; Primary education; GCSEs; A/AS Levels; Undergraduate (studying for a first degree); Graduate (have received a UG degree); Post-Graduate (studying for PG degree); Post-Graduate (have received a PG degree). All participants had attained A/AS levels at a minimum.

3.3. Measuring Autistic Traits

It is theorized that autistic traits are present within the neurotypical population at levels that are not clinically significant, distributed on an 'autistic spectrum,' the extreme end of which results in diagnosis of either high-functioning or low-functioning ASD. Research supports this theory; findings from various studies indicate that the aetiology of autistic traits in the general population is similar to that of ASD (Constantino et al., 2003; Ronald & Hoekstra, 2011). An understanding of how (and whether) these traits relate to one another within the general population can help provide insight into cognitive processes in ASD and in general. The present thesis seeks to contribute to the understanding of the non-social symptoms of ASD and how they may relate to the socially-related symptoms in the context of the broader autism phenotype. It was therefore necessary to measure autistic traits in both NT and ASD samples in order to establish how they related to aspects of non-social cognition. The Autism Spectrum Quotient (AQ) was chosen for this purpose.

The AQ was developed to study the traits that characterise the broader autism phenotype (Baron-Cohen et al., 2001). The AQ is a 50-item self-report measure widely used in research to establish the degree of autistic-like traits in NT samples, as well as in ASD groups and other clinical control groups (e.g., schizophrenia, anorexia nervosa, obsessive compulsive disorder) (Ruzich, 2014; Mito et al., 2014; Spek & Wouters, 2010; Westwood et al., 2016). The AQ consists of 50 statements with which participants either definitely agree, slightly agree, slightly disagree or strongly disagree on a dichotomous scale (0/1). Originally validated with 58 adults

with HFA, 174 NT controls, 840 university students and 16 winners of the UK Mathematics Olympiad, the AQ was found to have good test-retest and interrater reliability and was able to discriminate between ASD and NT groups; 80% of those with an ASD diagnosis scored 32+ versus 2% of NT controls, so Baron-Cohen et al. (2001) established a score of 32 as a clinically relevant cut-off point, with a later study on using the AQ to screen adults for Asperger Syndrome suggesting a threshold score of 26 (Woodbury-Smith, Robinson, Wheelwright, & Baron-Cohen, 2005).

The AQ has been independently validated by several authors since its development; Austin (2005) reported similar results to the original 2001 paper, finding a normal distribution of scores with good internal reliability of the overall AQ score ($\alpha=.82$) and Hurst et al. (2007) produced similar findings with regard to total AQ score ($\alpha=.67$). The traits the AQ measures have been shown to have high heritability (Hoekstra et al., 2007; Scherff et al., 2014; Wheelwright et al., 2010) and the AQ has been validated cross-culturally in many countries, including Italy (Ruta, et al., 2012), the Netherlands (Hoekstra, Bartels, Cath, & Boomsma, 2008), Japan (Wakabayashi, Baron-Cohen, Wheelwright, & Tojo, 2006), France (Sonié et al., 2013), and China (Zhang et al., 2016). The AQ has been used in a variety of research into the broader autism phenotype in the neurotypical population, such as assessing attentional differences between high and low AQ scores in an NT sample (Bayliss & Tipper, 2005), exploring the relationship between AQ, self-categorization and shared-attention (Skorich, Gash, Stalker, Zheng, & Haslam, 2017) and investigating reasoning processes across the autism spectrum (Brosnan, Lewton, & Ashwin, 2016).

While the AQ is the most widely used self-report measure of autistic traits in non-clinical populations, some authors have suggested that it needs improvement (Stewart & Austin, 2009). The 50 questions of the AQ comprise five theoretically-derived subscales of 10 questions each—communication, social skill, imagination, attention to detail and attention switching. The subscales were not empirically validated during the development of the AQ, but marginal–moderate internal consistency was reported for each of them (social skill $\alpha=.77$; imagination $\alpha=.65$; communication $\alpha=.65$; attention to detail $\alpha=.63$; attention switching $\alpha=.67$) (Baron-

Cohen, Wheelwright, et al., 2001). These subscales have not been well validated in the literature, with various authors exploring the factor structure of the AQ and suggesting different factor models to improve upon them. Austin (2005) and Hurst et al. (2007) found similar factor structures, suggesting a three-factor alternative to the AQ of social skills, patterns/details and poor communication. Stewart and Austin (2009) found four factors (Socialness, Pattern, Understanding Others/Communication and Imagination) and Kloosterman et al. (2011) found three- and four-factor solutions that were a better fit than the original five suggested subscales but still did not accurately represent the data. There is yet to be consensus on the best model to use for delineating specific traits within the AQ, due to varying results from factor analyses.

At least one study suggests that other self-report measures may be more reliable and internally consistent than the AQ for measuring autistic traits in the neurotypical population (Ingersoll, Hopwood, Wainer, & Donnellan, 2011). The authors of the latter compare the AQ with two other self-report measures of autistic-like traits—the Broad Autism Phenotype Questionnaire (BAPQ; Hurley, Losh, Parlier, Reznick, & Piven, 2007) and the Social Responsiveness scale (SRS; (Constantino & Gruber, 2002). The BAPQ was developed specifically to measure traits such as aloofness, pragmatic language and rigidity in the subclinical population, developed with family members of those with an ASD. The SRS was developed to distinguish between those with and without ASD and focuses largely on the socially-related traits of ASD. Ingersoll et al. found that while all three measures exhibited satisfactory internal consistency on the overall scores ($\alpha > .70$ for all), in line with the previous research mentioned above, there was low internal consistency for the five theoretical subscales of the AQ whereas the internal consistency of the subscales of the BAPQ and SRS were good (Ingersoll et al., 2011). They conclude that all three measures can be used as reliable self-report measures of autistic traits in non-clinical samples but suggest that the AQ had the weakest performance in terms of factor structure, gender differences and criterion validity. However, for the purposes of this thesis, the AQ was the most suitable measure because the BAPQ is not intended for use in ASD populations (Piven & Sasson, 2014), whereas the follow-up studies (Chapters 7 and 8) were planned with ASD and control samples. The SRS was also not suitable as it focuses on social behaviours and cognition, whereas the AQ includes questions

relating to non-social behaviours and cognition, which were the main focus of this research.

The initial stage of this research (Chapters 4 and 5 in this thesis) investigated systemizing in the NT population as it relates to autistic traits, in order to increase understanding of non-social cognition and behaviours in subclinical samples and across the broader ASD phenotype. The Autism Quotient was used to assess autistic traits in this sample, in order to investigate whether there was any difference in results between those scoring higher on the AQ and those with a low score. If ASD is indeed at the extreme end of a spectrum on which we all lie, it was hypothesised that the results from this study should provide an indication of how people with ASD might respond to social and non-social stimuli. The subsequent studies in Chapters 7 and 8 then explored this further with ASD/NT groups. The AQ was suitable again for these studies, firstly to maintain consistency with the initial study in order to compare results and, because the AQ has been shown to discriminate between those who meet the criteria for an ASD diagnosis and those with subclinical autistic traits (Baron-Cohen et al., 2001; Woodbury-Smith et al., 2005), to support the diagnostic information provided by the participants in the ASD group.

3.4 Diagnosis

One of the inclusion criteria for the ASD sample (in the studies reported in Chapters 7 and 8) was having a verified diagnosis of Autism Spectrum Disorder. This included diagnoses of conditions previously listed in the DSMIV and incorporated under ASD in the DSMV, including Pervasive Developmental Disorder Not Otherwise Specified, Asperger Syndrome and Autistic Disorder. Each participant provided a diagnostic report from a trained clinician, verifying that they had received a diagnosis of ASD according to official international diagnostic criteria. Other methods are available for determining/diagnosing ASD for the purposes of research, the main ones being the Autism Diagnostic Observation Schedule (ADOS; Lord, et al., 2000) and the Autism Diagnostic Interview Revised (ADI-R; Lord, Rutter, & Couteur, 1994). Several studies have however confirmed that diagnosis by trained, experienced professional clinicians that includes taking a thorough history from

patients along with, in many cases, interviewing their parents, teachers, partners and/or caregivers is much more reliable than administering a single instrument such as the ADOS or ADI-R, and the ADI-R in particular has been criticized for missing diagnoses of individuals with HFA (Fitzgerald, 2017; Jones & Lord, 2013; Risi et al., 2006). These instruments also require training to perform and they are time consuming (adding approximately 40 minutes to the overall study time for each participant) and the minimal resources available for this research project meant that this was not practically feasible. Verification of diagnosis by way of checking participants' clinical reports was therefore deemed the most reliable and practical way to ensure inclusion criteria were met for the ASD sample.

As mentioned above, the AQ has been shown to distinguish between individuals with ASD and subclinical autistic traits, with 80% of subjects with confirmed ASD scoring 32 or above on the AQ (Baron-Cohen et al., 2001). The results for the ASD group in this research were more or less consistent with this, with a mean AQ score above 32 (mean=34.7 (SD=8.87)) and scores ranging from 13 to 44, with 76.5% of ASD participants scoring 32 or above. Three participants scored below the clinically relevant cut-off of 26 suggested by Woodbury-Smith et al. (2005), representing 17.6% of the group, a larger percentage than for either of the above-mentioned studies. This is not unexpected due to the larger sample sizes employed in the Baron-Cohen et al. (n=58) and Woodbury-Smith et al. (n=73) studies in comparison with the sample size of 17 in the ASD group for the present study, meaning that the three scores below 26 represented a bigger percentage of the overall group, and this would likely decrease with a larger sample as AQ scores have been found to be normally distributed across the population.

A t-test revealed that the difference between ASD and control groups was statistically significant, as expected ($t(31)=4.84$, $p<0.0001$). The mean AQ of the NT control group was 22.5 (SD=6.5), with a range from 8 to 33, which was higher than most reported scores in nonclinical samples. Baron-Cohen et al. (2001) reported a mean AQ score of 16.4 in an NT control group (n=174) and Ruzich et al. (2015) report a mean AQ score of 16.94 in NT samples from a review of relevant AQ-related research (n=6934). One possible reason for this higher mean AQ score is that the majority of participants were either university students or graduates, and studies have shown that students and graduates tend to score higher on the AQ on

average, particularly in scientific disciplines ($m=17.6$, $(SD=6.4)$; Baron-Cohen et al., 2001). Because the NT control group was matched to the already-recruited ASD group on education level, and the majority of the ASD group were university educated, this potential bias was unavoidable, although it will be considered when analysing and discussing the results of the studies in Chapters 7 and 8.

The NT sample recruited for the initial studies (Chapters 4 and 5) had a mean AQ of 17.74 ($n=46$, $SD=6.7$) with a range from 5 to 35, which is not statistically significantly different to the typically reported average NT AQ scores ($t(45)=1.36$, $p=.182$). All NT participants in both the initial study with AQ as a variable and in the control group were asked whether they had been diagnosed with any psychiatric or neurodevelopmental condition and only those participants who answered this question with 'no' were included in the studies.

3.5 Recruitment

3.5.1 Initial Neurotypical Sample

There is little previous research using the same overall methodology as used in these studies, although research on the AQ and Embedded Figures Test with NT participants (see review by Cribb et al., 2016), studies using electrodermal activity to assess emotional significance in ASD (Mathersul, McDonald and Rushby, 2013) and change blindness experiments with ASD adults (Hochhauser et al., 2017) all reported medium to large effect sizes. A priori power analyses in G*Power using a conservative estimate of a medium effect size (eta squared statistic of 0.4) determined that a sample size of at least 34 would be needed to achieve a power of 0.8 with an alpha level of 0.05, or 46 for an effect size of eta squared 0.35. Forty-six NT participants, aged between 18 and 66 years ($M=26.7$ years), (25 female ($M=26$ years), 21 male ($M=28$ years)) were recruited from the University of Bath population through the Department of Psychology electronic notice board, posters displayed around campus and through the Call for Participants website (Jisc, 2015).

Participants were provided information on the basic background of the study (without mention of ASD) and what participation would involve. Participants provided informed consent before each part of the study and had to complete the online survey before coming to the lab for testing, where they were each paid £5 on completion of the tests.

3.5.2 ASD Group

The sample size for the ASD group was calculated on the basis of the results of the initial studies with the neurotypical population. For the change blindness study (Chapter 5), the effect size of the paired samples t-test was large, with an eta squared statistic of 0.68. Using the G*Power software, a sample size of 15 was calculated using this effect size, for statistical power of 0.8. For the analyses of physiological response and AQ (Chapter 4; Singleton, Ashwin, & Brosnan, 2014), the effect sizes for the correlations were around 0.6, for which a sample size of 15 was also calculated, given statistical power of 0.8. Thus, a clinical sample of a minimum of 15 participants was recruited for the clinical study, along with a matched control group.

Various methods were used to recruit the ASD sample, including putting notices on the University of Bath electronic notice board, posters on the University of Bath campus and around various buildings of the University of Oxford, contacting specific Autism support groups and social groups by email, through volunteering with a social group for people with Asperger Syndrome and through an Autism summer school run at the University of Bath for prospective students with ASD and through the Call for Participants website (Jisc, 2015). The advertisements contained brief information about what the study involved and the inclusion criteria, and those who were interested were sent a detailed information sheet. All participants provided informed consent prior to taking part. As with the first studies with the NT sample, participants initially completed an online survey before being invited to complete the rest of the study in the lab. Participants were each paid £10 on completion of the study. Many more people completed the online survey than followed up with coming for testing, resulting in a total of 17 participants in the ASD group. Due to the difficulty recruiting participants with ASD, funding was obtained to be able to offer reasonable travel expenses in order to widen the geographic region from which suitable participants could be recruited.

3.5.3 Neurotypical Control Group

The NT control group was matched to the ASD group by age, sex and education level. As with the other NT sample, recruitment was carried out through posters and advertisements on the University of Bath campus, the electronic noticeboard and the Call for Participants website (Jisc, 2015). The process was the same as for the ASD

group, with participants providing informed consent prior to taking part and being paid £10 on completion of the study. 17 matched participants were recruited but the data for 1 of them was corrupted upon analysis so the total final number in the NT control group was 16.

3.5.4 Systemizing Studies

The study presented in Chapter 6 focused solely on systemizing traits in general and how these relate to other measures of reasoning style and ability. A similar previous study examining self-report assessments of empathizing, systemizing and the rational-experiential inventory (Brosnan et al., 2013) used a sample size of 68, and a sample size equivalent to, or larger than this was planned for this study. The sample for this study was recruited from the University of Bath population by way of an online questionnaire, which was advertised on the University online noticeboard and emailed to students and staff. There were 119 participants in total who completed the full online survey (60 male, 59 female) and with a range of ages from 18 to 66, and a mean age of 22 (SD=6).

The online systemizing survey was replicated for a study with an ASD and a control group. It was sent to participants who had been part of the ASD group recruited for the studies detailed in Chapters 7 and 8, whose ASD diagnosis had already been verified, as well as to participants who had expressed interest in those studies and had completed the initial online questionnaire, stating that they had an ASD, but had not followed up with coming to the laboratory for testing. The online questionnaire was also sent to specific Autism support groups and social groups by email, and through the Call for Participants website (Jisc, 2015). The inclusion of the AQ on this version of the systemizing survey was considered, for the purposes of supporting self-reported ASD diagnosis, but as the completion rates for the initial survey had been low, with approximately two thirds of those starting the survey abandoning it before completion, it was decided to leave out any additional measures to ensure a larger sample.

Only seven of the participants whose ASD diagnosis had been previously confirmed completed the systemizing questionnaire, but 23 other participants claiming an ASD diagnosis also completed the survey, along with 34 NT controls (who claimed no psychiatric diagnoses). This comprised a total sample of 64 participants, 30 reporting

ASD and 34 NT controls. The ASD group consisted of 6 females and 24 males, with a mean age of 22.33 (SD=3.14) and the NT group was comprised of 21 males and 13 females, with a mean age of 22.45 (SD=8.52). Analysis revealed no significant differences between groups on age ($t(45) = -.55, p = .957$). Because ASD diagnoses could not be confirmed for all ASD participants, this study is reported in Chapter 6 to supplement the initial study with the NT sample rather than in a chapter of its own.

Chapter 4

Study One: Physiological Responses to Social and Non-Social Stimuli

4.1 Overview

This chapter details an initial study investigating the relationship between autistic traits and physiological responses to social and non-social stimuli in an NT sample. Some of the results of this study have been published in the journal *Autism Research* (Singleton, Ashwin & Brosnan, 2014; Appendix A). Co-authors of this paper included Professor Mark Brosnan and Dr Chris Ashwin (University of Bath) and the research was conducted as part of this PhD, with some financial support from The Stapley Trust grant for doctoral students. The following chapter includes and adds to the results of the skin conductance response and AQ experiment published in *Autism Research* by including a more in-depth background review of the relevant literature and by reporting and discussing the additional results of the investigation into the relationship between anxiety, autistic traits and physiological arousal.

Drive towards types of processing may be related to physiological arousal to categories of stimuli, such as social (e.g. faces) or non-social (e.g. trains). This study investigated how autistic traits in an NT population might relate to differences in physiological responses to non-social compared with social stimuli. NT participants were recruited to examine these differences in those with high vs. low degrees of autistic traits. Forty-six participants (21 male, 25 female) completed the Autism Spectrum Quotient (AQ) to measure autistic traits before viewing a series of 24 images while skin conductance response (SCR) was recorded. Images included 6 non-social, 6 social, 6 face-like cartoons and 6 non-social (relating to the participants' personal interests). Analysis revealed that those with a higher AQ had significantly greater SCR arousal to non-social stimuli than those with a low AQ, and the higher the AQ, the greater the difference between SCR arousal to non-social and social stimuli. This is the first study to identify the relationship between AQ and physiological response to non-social stimuli, and a relationship between physiological response to both social and non-social stimuli. These results suggest

that physiological response may underlie the atypical drive toward non-social processing seen in ASD, and that at the physiological level at least the social and non-social in ASD may be related to one another.

4.2 Background

4.2.1 The Relevance of Physiological Response

Various physiological responses, including the skin conductance response (SCR), are an index of the orienting response (OR), which is a mechanism that facilitates information processing through changes in physiological states—such as pupil dilation/constriction, heart rate, and electrodermal activity—in response to a novel stimulus or environmental change (Barry & Furedy, 1993; Filion, Dawson, Shell, & Hazlett, 1991). The somatic marker hypothesis suggests that such autonomic arousal to stimuli plays a crucial role in directing attention and influencing decision-making (Damasio, 1996). Novel stimuli that are of significance to the organism elicit a more extreme orienting response than those that are deemed insignificant, for example a potential threat or the presence of prey (Weiner, 1992) and social information, particularly faces and facial expressions (Mares, Smith, Johnson, & Senju, 2016; Tomalski, Csibra, & Johnson, 2008). The OR can thus be a proxy for what stimuli most capture a subject's interest, i.e., which stimuli have salience for an individual within a particular context (for example, SCRs will be larger for task-relevant stimuli than they are for task-irrelevant stimuli during task performance in experimental settings (Filion et al., 1991)).

Which stimuli provoke such physiological responses therefore vary across species, across individuals and across contexts. For example, the shape of a hawk flying overhead will elicit an escape response from chicks; the stimulus provokes an autonomic response which is translated to a contextually relevant action (Tinbergen, 1951; Schneirla, 1965). In humans and primates, faces and socially-related stimuli provoke greater autonomic arousal, which increases with the salience of the

stimulus—e.g., most infants show a heightened physiological response to photographs of their mother’s face compared to that of a stranger’s; most infants show a heightened physiological response to faces compared to non-social objects (Barrera & Maurer, 1981; Pascalis et al., 1995; Frank, Vul, & Johnson, 2009); adults exhibit increased arousal for scenes with affective valence in which human beings are present compared to similar scenes without a human present (Proverbio, Adorni, Zani, & Trestianu, 2009) and show preferential orienting towards faces and face-like stimuli (Tomalski, Csibra, & Johnson, 2008); and in the animal kingdom, primates such as rhesus macaques show increased attention and sympathetic arousal towards videos with subject-directed social content compared to those with non-social content (Machado, Bliss-Moreau, Platt, & Amaral, 2011). Physiological responses can therefore be used as a measure of which stimuli are attended to most immediately and are processed as being particularly salient, enabling investigation of the potential mechanisms underlying atypical attention or cognitive processes.

4.2.2 Autistic Traits and Social Orienting

It has been theorized that the social deficits of autism may be the result of atypical attention to social stimuli (Dawson, Webb, & McPartland, 2005; Jones, Carr, & Klin, 2008). There is a variety of evidence to suggest that individuals with ASD do not orient to social information such as faces (Kikuchi et al., 2009; Riby & Hancock, 2009), direct partner gaze (Freeth & Bugembe, 2018; Helminen et al., 2017), social/biological motion (Hubert et al., 2007; Klin et al., 2009; Helt, et al., 2010) and speech (Kuhl et al., 2005; Magrelli et al., 2013) compared to controls.

Studies have also found atypical attention to social stimuli in neurotypical samples with subclinical autistic traits. Bayliss and Tipper (2005) found that participants with a higher AQ oriented to scrambled parts/faces while those with lower AQ scores oriented more towards faces and objects attended to by others, suggesting that possessing more autistic traits may be related to an attentional bias towards local details rather than socially-relevant stimuli. Another study found that those with a higher AQ were less likely to look at the direct gaze of an actor on-screen than were those with low AQ (Chen & Yoon, 2011), similar to the results found in more recent studies with ASD samples (Freeth & Bugembe, 2018; Helminen et al., 2017). Freeth et al. (2013) conducted a study on neurotypical adults in which they compared social attention to both video and live interactions with an experimenter, finding that those with high autistic traits attended to the face of the experimenter on the video less

frequently than did those with low AQ, but that there were no differences between high and low autistic traits in attendance to the experimenter in the live situation, indicating the increased salience of in-person social interaction for those with more autistic traits. A recent study found that those with a higher AQ score were less able to accurately identify threatening faces than those with a lower AQ on an attentional blink task, replicating abnormalities seen in those diagnosed with ASD (English, Maybery, & Visser, 2017).

However, findings of atypical social orienting in ASD and the broader autism phenotype have not been consistent. A review of literature on social attention in ASD, focusing particularly on eye-tracking studies, found that social orienting was not impaired in clinical samples (Guillon, Hadjikhani, Baduel, & Rogé, 2014). A version of a dot-probe experiment found no differences between an ASD group and NT controls in orienting to protoface stimuli (Shah, Gaule, Bird, & Cook, 2013). Freeth et al. (2010) found that the gaze direction of a person cues attention and biases preference and memory in both ASD and NT adolescents. A study of infants aged 2-6 months, both those at low risk of ASD and those who had an older sibling already diagnosed with ASD, involved showing them a video of a female and measured their fixation on her eyes (Jones & Klin, 2013). A follow-up three years later then revealed which of the infants had gone on to receive an ASD diagnosis so that the data could be viewed and compared in light of these outcomes. The authors found that at 2 months, infants who went on to be diagnosed with ASD fixated on the eyes just as much as those who did not receive a diagnosis, but that after 2 months fixation patterns began to diverge, with infants in the ASD diagnosis group fixating less on the eyes while those in the non-diagnosis group generally increased or maintained the level at which they fixated on the eyes, suggesting that, in ASD, social orienting may be intact in the first months of life but begins to decline thereafter (Jones & Klin, 2013). The authors suggest that while in NT infants this initial orienting to faces facilitates the specialization of the social brain, in infants that go on to develop ASD this process is somehow disrupted. It has been suggested that the combination of research that evidences intact innate social orienting in ASD indicates that there may be a disruption in the way subcortical processes guiding orientation to social stimuli communicate with the cortical social brain network (Johnson, 2014).

While ASD involves both deficits in social cognition and behaviour and enhanced drive towards non-social cognition and behaviour, few studies of social attention in ASD and in relation to autistic traits in the NT population have investigated social orienting in direct comparison with non-social orienting. A study found that female neonates spent longer looking at faces while male neonates spent longer looking at a mechanical mobile, suggesting that a generally greater drive towards sociability or empathizing in females and a generally greater drive towards physical systems in males may be biologically hardwired (Connellan et al., 2000). In line with the Extreme Male Brain theory of autism (EMB; Baron-Cohen et al., 2002), it is therefore plausible that the development of a stronger orienting response to non-social stimuli (e.g. geometric shapes, patterns, physical systems etc.) disrupts the social orienting and face specialization processes that canalize typical social development at around 2 months of age. Visual acuity improves eight-fold over the first 5 months of life (Adams, 1987), coinciding with the time during which infants can first hold their heads up to look around unsupported (Bayley, 1936), potentially providing the first opportunity at around this age for an initial social orienting response to be supplanted by a greater physiological response to an increase in perceptually available non-social stimuli, thereby interrupting social learning and facilitating an ongoing drive towards systemizing-type behaviours and manifesting the broad autism phenotype. The present study therefore sought to investigate whether there was a relationship between autistic traits in NT adults and physiological responses to social and non-social stimuli.

4.2.3 Autism and Skin Conductance Response

Emotional arousal to presented stimuli can be reliably assessed by measuring SCR (Greenwald, et al., 1989) and there have been several studies investigating SCR in ASD. For example, Hubert et al. (2009) found that adults with ASD exhibited lower SCRs to emotional faces than typical matched controls, while performing similarly on emotional expression judgement tasks. This suggests that while social judgements may be mediated by physiological arousal in the NT population, those with ASD employ different strategies to achieve similar results. SCR could therefore be an important measure of individual differences in the kinds of processing elicited by different categories of stimuli.

Using heart rate as a measure of arousal, Goodwin et al. (2006) compared responses to potentially stressful stimuli in adults with ASD and NT controls, finding that the ASD group only exhibited a significant autonomic response to stressors 22% of the time compared to controls, who responded significantly to 60% of stressors. Similarly, Gaigg and Bowler (2007) demonstrated atypical fear acquisition in ASD, with participants exhibiting attenuated autonomic fear responses in comparison to NT controls, and similar autonomic responses to both conditioned and non-conditioned stimuli. This suggests poor connectivity between the amygdala and other regions of the brain, leading to abnormal processing of the emotional significance of sensory stimuli. The authors suggest this may underlie the behavioural characteristics and social deficits seen in ASD.

A study by Stagg et al. (2013) investigated the relationship between language development and arousal to faces and eye gaze in children with ASD, finding that SCRs to faces differentiated ASD children from the NT control group, and that arousal to faces also differentiated late and normal language onset among the ASD group. These results appear to confirm results from previous studies demonstrating hypoarousal to faces among ASD individuals (Dalton, et al., 2005; Kylliäinen & Hietanen, 2006), as well as providing evidence that there is a relationship between SCR to social stimuli and language development. Stagg et al. explain their results by suggesting that a relationship between higher arousal to faces and the quality of eye contact in early infancy may confer an advantage for language development in children with ASD. However, this study did not use non-social stimuli as a control measure, so these results could alternatively be explained if ASD participants display hypoarousal to all forms of stimuli in general, or alternatively if there are other kinds of stimuli that elicit 'normal-' (in comparison to NT arousal to faces) or hyper-arousal. It is therefore important for studies of this kind to investigate arousal to different kinds of stimuli in order to understand more fully the role of arousal in the social deficits of ASD.

Differences in autonomic arousal to social stimuli have also been found in relation to autistic traits. Nummenmaa et al. (2012) found that neural response to faces was related to self-reported autistic traits in various regions of the brain that are activated for social attention and perception, indicating that differences in the activation of physiological responses to social information extend to subclinical traits in the NT

population. Despite a number of other studies investigating physiological responses to social stimuli in ASD (Blair, 1999; James & Barry, 1984; Baron-Cohen, 2009; Kylliäinen & Hietanen, 2006), as yet no substantial research has been undertaken to assess emotional response to the non-social in ASD. The non-socially-related diagnostic criteria for ASD include restricted interests—an atypical and intense focus on a narrow (usually non-social) topic or subject area. The presence of circumscribed interests is a widespread feature of autism, with an estimated 75%-90% of people with ASD developing at least one topic of intense interest early in life (Klin, Danovitch, Merz, & Volkmar, 2007). Of course, many NT people also develop special interests and hobbies, and it has been suggested that the development, intensity and topic of such interests lie on a continuum, for example with the focused interests of scientists, academics and hobbyists representing a subclinical expression of a drive towards understanding and collecting information on a particular topic that can manifest as the more circumscribed, intense and often obsessive and disruptive interests typical of ASD (Jordan & Caldwell-Harris, 2012).

As well as investigating physiological responses to non-social compared with social stimuli and autistic traits in an NT sample, this study sought to investigate whether there was any relationship between autistic traits and responses to stimuli relevant to the individual's own special interest. The aim of the present study was to investigate the mechanisms behind the non-social features of the broad autism phenotype by analysing physiological responses to both social and non-social stimuli, and to identify the possibility of a relationship between response to these two categories of stimuli in the NT population (and therefore assessing their relatedness as suggested by Happé et al., 2006) as well as the relationship to autistic traits.

The presence of anxiety symptoms is also widespread in those with a diagnosis of ASD (Kim et al., 2000; Leyfer et al., 2006). It has been suggested that circumscribed interests may play a role in comorbid anxiety in ASD due to the negative interference the intense focus on non-social topics may have on social interaction and social outcomes (Klin et al., 2007), as well as that engaging in restricted interests may serve as a method for coping with anxiety and distress (Baron-Cohen, 1989). A study of children with HFA found an association between anxiety symptoms and play-enactment of restricted interests (Spiker et al., 2012). Similar associations have been found in relation to subclinical autistic traits in the NT population. A study by

Liew et al. (2015) made a distinction between socially-related anxiety and more general non-social obsessive-compulsive/worry type anxiety, and investigated mediators between autistic traits in an NT sample and these two manifestations of anxiety. They found that autistic traits were positively correlated with anxiety symptoms, that social competence mediated the relationship between autistic traits and social anxiety, and that being prevented from engaging in repetitive behaviours and frequent aversive sensory experiences mediated the relationship between autistic traits and the non-socially related anxiety symptoms. To explore a potential relationship between anxiety and physiological response to non-social stimuli related to interests, a measure of anxiety—the State Trait Anxiety Index (STAI; Spielberger, 1983)—was taken as part of this study (see Chapter 2 Section 2.3.3 for further information on anxiety in ASD).

4.2.4 Hypotheses

It was hypothesised that, in line with previous research, AQ would be positively correlated with anxiety (Romano et al., 2014; Reed et al., 2016). If restricted interests are indeed related to anxiety in ASD, a relationship would be expected between scores on the STAI and SCR to non-social stimuli of special interest. In line with the Empathizing-Systemizing theory, it was hypothesised that those with a higher number of ASD traits would have a higher physiological response to non-social stimuli and a lower response to social stimuli, and a positive relationship between AQ and SCR to non-social stimuli was predicted. It was also predicted that the difference between arousal to social and non-social stimuli would be larger the higher the AQ, suggesting that the social and non-social are related to one another (and to AQ) in an NT population, and that difference in physiological response to social and non-social stimuli may underlie some aspects of the cognitive profile of ASD.

4.3 Methods

4.3.1 Participants

As participants in this study were recruited from the NT population, the AQ was used to assess whether there was any difference in results between those scoring higher on the AQ and those with a low score. If ASD is indeed at the extreme end

of a spectrum on which we all lie, it was theorized that results from this study should provide an indication of how people with ASD respond to social and non-social stimuli. An a priori power analysis in G*Power using a conservative estimate of a medium effect size (eta squared statistic of 0.4) determined that a sample size of at least 34 would be needed to achieve a power of 0.8 with an alpha level of 0.05, or 46 for an effect size of eta squared 0.35 (see Section 3.5.1). Forty-six NT participants were recruited (as described in Chapter 3, Section 3.5.1) aged between 18 and 66 years ($M=26.7$ years), (25 female ($M=26$ years) and 21 male ($M=28$ years)). All participants reported having normal to corrected normal vision, and no psychiatric diagnoses. Participants were provided information on the basic background of the study (without mention of ASD) and what was involved before giving their consent. The experiment was conducted in two parts; the first part involved completion of an online survey and the second part was carried out in a quiet laboratory on campus. Participants had to complete the online survey before coming to the lab for testing, where they were each paid £5 on completion of the tests.

4.3.2 The Autism Spectrum Quotient

Participants were administered the full 50 item Autism Spectrum Quotient (AQ) questionnaire (Baron-Cohen, et al., 2001) as part of an online survey that also established age, gender and non-social objects of interest. The survey was created and run between December 2011 and August 2012 using Bristol Online Surveys (2012). Answering each question on the survey was mandatory, so there were no missing data for any participants completing it. The results were scored according to Baron-Cohen et al.'s (2001) specifications, resulting in an 'AQ score' for each participant (minimum possible score was 0 and maximum possible score was 50), and scores (minimum score of 0 and maximum score of 10) for each of the theoretical subscales suggested by the original authors—social skill, communication, imagination, attention-to-detail and attention switching. For more detail on the AQ and the subscales, see Chapter 3 Section 3.3.

4.3.3 State-Trait Anxiety Inventory

The State-Trait Anxiety Inventory (STAI Form Y; Spielberger et al., 1983) includes two 20-item questionnaires, one designed to measure trait anxiety (i.e., an individual's general propensity to respond to situations with anxiety) and the other to measure state anxiety (i.e., the present existence of anxiety symptoms within an

individual). Each 20-item questionnaire includes both anxiety–present (e.g., I feel nervous) items and anxiety–absent (e.g., I feel calm) items. Participants mark how much each statement applies to them on a four-point Likert scale, with anxiety–absent items scored in the opposite manner to the anxiety–present items, a minimum–maximum score of 20–80 on each questionnaire, with a total maximum combined STAI score of 160. The STAI has been widely used in psychology to assess anxiety levels in various clinical and non-clinical populations (Bortolon & Raffard, 2015; Muschalla et al., 2010; Simon & Thomas, 1983), to predict anxiety disorder diagnoses (Hishinuma et al., 2001; Kvaal et al., 2005) and with both ASD groups (Corbett et al., 2017; Simon & Corbett, 2013) and the broader autism phenotype (Conner et al., 2013; Horder et al., 2014). Participants completed the STAI-Trait questionnaire as part of the initial online survey, and then completed the STAI-State questionnaire on paper, when they arrived at the laboratory for testing.

4.3.4 Stimuli

Each participant was shown a total of 24 images. Each image belonged to one of four conditions: Social – Face, Social-Cartoon, Non-Social and Non-Social of Interest. There were 6 images in each condition. Images in the Social-Face condition were sourced from an online database (Tarr, 2012) and depicted photographs of human faces with direct gaze. Images in the Social-Cartoon condition were sourced from previous research that had identified the emotion in the cartoon could be reliably recognised by those with ASD (Brosnan et al., 2013). The Non-Social and Non-Social of Interest images were freely available for use and sourced from the Google Images search engine (Google, Inc, n.d.). Images chosen for the Non-Social condition were items or objects that neither involved any human nor animal subject, and were not the subject of any participant’s interest. The images included: a bicycle; a paintbrush; a car; a paperclip; a train, and a telescope.

As well as investigating physiological responses to non-social compared with social stimuli and autistic traits in an NT sample, this study sought to investigate whether there was any relationship between autistic traits and responses to stimuli relevant to the individual’s own special interest. The online survey therefore included several questions about the participants’ own hobbies and interests, how much time and money they spent on their main hobby and the objects that they most associated

with it. Relevant images were then selected for presentation on the basis of this survey. Each image was converted to greyscale, sized to 100 pixels per inch, cropped and centred on a white background with a width of 20cm and a height of 10cm using Adobe Photoshop CS5 software (see Figure 4.1).



Figure 4.1. Examples of Social-Face, Non-Social and Social-Cartoon stimuli presented to participants.

The experiment was built and run using the E-Prime® 2.0 suite of applications. The order of stimulus presentation was initially randomised and each participant was shown images in that order. Individual Non-Social of Interest stimuli were changed for each participant according to images selected for them on the basis of their reported interest. Each stimulus was presented on screen for 5 seconds. The inter-stimulus interval (ISI) varied randomly between 8- 12 seconds, with a mean ISI of 10 seconds over the whole procedure in accordance with previous studies (Breska, et al., 2010). A fixation in the shape of a small cross appeared in the centre of the screen during each interval.

4.3.5 Skin Conductance Response

Skin conductance response (SCR) was chosen as the measure of arousal and orienting response to visual stimuli, in line with previous studies (Greenwald et al., 1989; Siddle, 1991). A Biopac GSR100C was used to measure skin conductance. An emotional or physiological response was deemed to have occurred when there was a rise in the amplitude of the skin conductance level of at least $0.01 \mu\text{S}$ within 1–4 seconds of a stimulus onset, as suggested by the literature (Dawson, et al., 2007; Venables & Christie, 1980). Acqknowledge™ 4.1 software was used to calculate SCRs from the recorded skin conductance level of each participant. SCRs were

measured by comparison to a localized baseline that was established by the software using median value smoothing. The calculation of skin conductance amplitude was determined by the change in the amplitude of the skin conductance level from the time of the SCR onset to the maximum amplitude attained during the SCR (Biopac, 2013).

4.3.6 Procedure

Participants were seated on an adjustable chair in an acoustically and electrically sealed booth, approximately 60 cm from a 20 inch Dell monitor, with a keyboard positioned in front of them on a small table. An isotonic gel was applied to the Biopac EDA finger transducer which was attached to the distal phalanx of both the fore and middle finger of the dominant hand in accordance with recommendations (Screbo et al., 1992). The on-screen instructions told the participant to passively view each image and to ensure they remembered each in preparation for a memory test at the end. This was included as an incentive for the participants to pay attention to stimuli in what was an otherwise passive task.

4.3.7 EDA Analysis

Electrodermal activity (EDA) was analysed for each participant from the recording using the Acqknowledge™ 4.1 software. The initial sampling rate was 1kHz, but due to high frequency noise obscuring the signal, the SCR waveform was downsampled to 30 samples/second to capture the true nature of the signal, and was 'cleaned up' by running a 1hz FIR low pass filter, as instructed by Biopac technical support (pers. comm). If a stimulus did not elicit a response according to the parameters described above, then this was recorded as a zero response. Log of (SCR +1) was calculated across all responses as recommended when including these zero responses. A mean SCR magnitude was calculated for each participant, for each condition (Dawson, et al., 2007). To correct for individual differences in skin conductance level between participants, the mean SCR magnitudes for each condition were transformed into z-scores and these were used for the statistical analysis.

4.3.8 Statistical Analysis

The data were explored using IBM SPSS Statistics 19 and the alpha was set at 0.05. A Shapiro-Wilk test revealed that all data for the transformed mean SCR magnitudes

for each of the four conditions were not normally distributed (for all conditions, $p < 0.05$), and it was not possible to transform the data to a normal distribution. Non-parametric tests were therefore employed for analysis. A one-tailed bivariate Spearman correlation was run to explore the relationship between AQ and mean SCR magnitude to each condition. To explore the average difference in arousal to non-social images compared with the response to social images, the transformed mean SCR magnitudes for the social condition were subtracted from those for the non-social condition.

The AQ and STAI scores were normally distributed so Pearson’s correlations were run to investigate the relationship between AQ and anxiety. To investigate the relationship between anxiety and physiological response to non-social stimuli of interest, a Spearman’s correlation was performed. Partial Pearson’s correlations were run to explore the relationship between AQ and mean SCR magnitudes to all conditions while controlling for anxiety.

4.4 Results

The mean age for the total sample was 27 (SD=10) and the mean AQ was 18 (SD=7). An independent-sample t-test revealed that there were no significant gender differences in AQ ($t(44) = -.59, p = .558$). The mean SCR magnitudes for each condition are shown in Table 4.1.

Table 4.1. Total mean SCR magnitude for each condition

Mean SCR Magnitude	Mean	SD
Non-Social	42	103
Non-Social: Of Interest	52	78
Social: Faces	24	56
Social: Cartoon	25	59

N=46

For the whole group, AQ was significantly positively correlated with mean SCR magnitude to non-social stimuli ($r = .407, p = 0.002$). There was also a significant negative correlation between AQ and social–cartoon stimuli ($r = -.312, p = 0.017$).

AQ was not significantly correlated with mean SCR magnitude to either the non-social stimuli of interest or social-faces conditions (both $p > .05$) (see Figure 4.2).

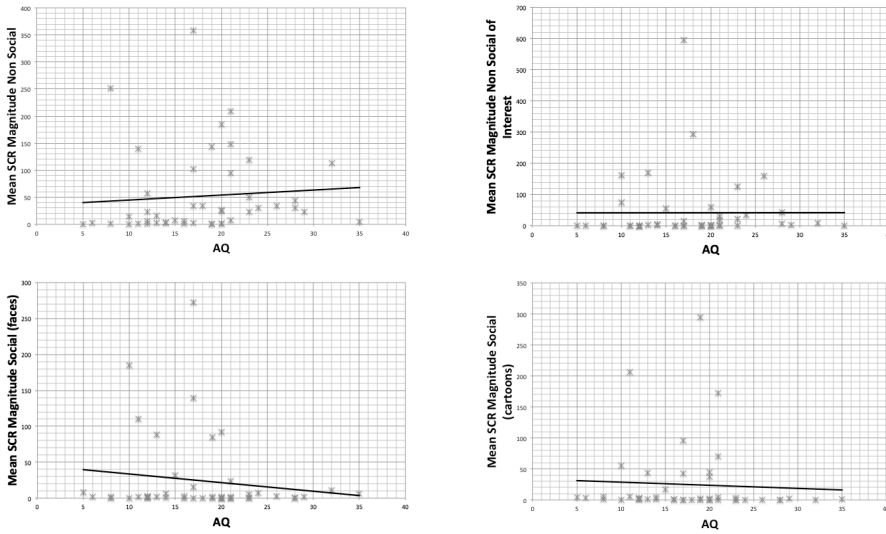


Figure 4.2 Mean SCR Magnitude for each condition plotted against AQ

In addition, there was a significant correlation between mean SCR magnitude to non-social of interest and social–faces conditions ($r=.317, p=0.016$) and between the mean SCR magnitude to social–faces and social–cartoon conditions ($r=.424, p=0.002$).

There was also a correlation between AQ and the average difference in mean SCR magnitude to all non-social images compared with that to all social images ($r=.267, p=0.036$), indicating that the greater the AQ, the larger the gap between the higher response to the non-social and the lower response to the social (see Figure 4.3).

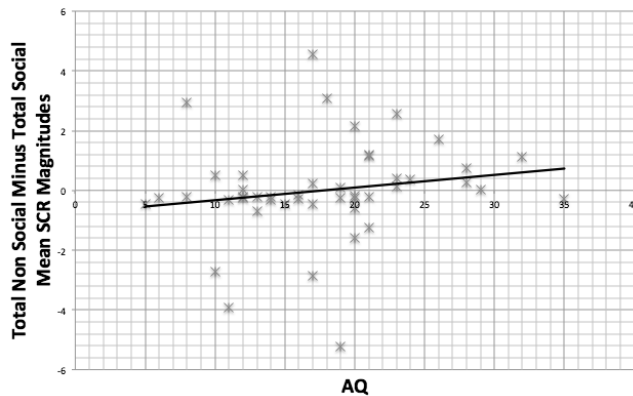


Figure 4.3 Difference in mean SCR magnitude between total non-social and total social conditions

Finally, as expected, AQ was significantly positively correlated with Trait Anxiety ($r=.451, p=.002$). However, AQ was not significantly correlated with State Anxiety ($r=.186, p=.216$). There was also a significant positive correlation between Trait Anxiety and mean SCR magnitude to the non-social of interest condition ($r=.353, p=.016$), but no relationship of significance between Trait Anxiety and mean SCR magnitude to any of the other conditions. When controlling for Trait Anxiety, the relationship between AQ and mean SCR magnitude to non-social stimuli remained significant ($r=.417, p=0.004$), as did the negative relationship between AQ and mean SCR magnitude to the social–cartoon condition ($r=-.314, p=.036$).

4.5 Discussion

The results of this study largely support the initial hypotheses, finding that those reporting a higher number of autistic traits have higher physiological arousal to non-social stimuli than those reporting fewer autistic traits. The correlations suggest that the higher the AQ, the greater the physiological response to non-social stimuli, and the higher the AQ, the greater the difference between physiological response to non-social compared with social stimuli. However, the results do not support the hypothesis that AQ would be negatively correlated with SCR to social stimuli, and it was also expected that there would be a correlation between AQ and arousal to the non-social items of interest, which was not found. The possible reasons for this are discussed below.

The finding that AQ is positively correlated with arousal to non-social stimuli demonstrates, for the first time, a connection between high self-reported autistic traits in an NT sample and a greater physiological response to the non-social. Although further research is needed to tease out the nature of this relationship, it suggests that physiological response may underlie the development of certain traits and behaviours seen in ASD, including poor or limited social functioning, and restricted and repetitive behaviours. This finding, along with the negative correlation found between AQ and mean SCR magnitude to the cartoon condition, supports the theory that physiological arousal to social and non-social stimuli differs across the subclinical range of the broader autism phenotype as it is defined by the E-S theory. Those self-reporting more ASD traits (higher Systemizing, lower Empathizing) display greater arousal to the non-social condition than those with a lower AQ, and

those with fewer ASD traits (i.e. higher Empathizing, lower Systemizing) display greater arousal to abstract social images (in the case of cartoons) than those with a higher AQ. If these results extend to an ASD population, physiological response to non-social stimuli could be part of the mechanism underlying both enhanced Systemizing and reduced Empathizing in ASD, for example by producing a stronger orienting response to non-social objects than to social information during a crucial stage for social learning.

That there was no correlation between AQ and the non-social of interest condition, contrary to the prediction, is possibly due to the participants' anticipation that this type of item would appear during the task eliciting a higher average response across all participants regardless of AQ (given that they had been asked in advance to provide details of their non-social interest). After having undertaken the task, several participants commented on seeing the images relating to their interest and sometimes mentioned that the wrong type or make of item had been used. Therefore, it would seem that these stimuli may have elicited a reaction across all participants that was not necessarily related to interest, but to anticipation, or the recognition that this image was 'for them' and in some cases that the image was not 'correct' in their view.

It had been hypothesised that those with a higher number of autistic traits would show larger responses to personal non-social items of interest, in line with evidence from the study by Grelotti, et al. (2005) that showed a 'social' response in the brain of an autistic child when viewing images of his special interest. It may be, however, that in NT individuals the kind of interest invested in non-social items or activities is not of the same quality or intensity as that of the autistic individual and their special restricted interests, which form a crucial part of an autism diagnosis. It may therefore be the case that while there exists a relationship between AQ and arousal to non-social items in general, this relationship breaks down in an NT sample for non-social items of interest when the responses of the whole group rise. As NT individuals, this increased arousal may be due either to heightened attention to an object of interest (in line with the somatic marker hypothesis), or due to other factors as mentioned above. To investigate the relationship between AQ and arousal to non-social stimuli of personal interest more comprehensively, future similar

studies looking at an NT population will need to find a way of minimizing the potential influence of such factors.

The significant relationship between arousal to non-social of interest stimuli and the response to human faces could be explained by the inherent interest of faces to a neurotypical population, and the personal interest in items relating to each participant's hobby. It would therefore make sense that in this sample of NT adults, those who are highly responsive to items that interest them are also highly responsive to faces. As noted above, it is possible that the arousal to the items of interest was in part due to anticipation or recognition of the personal nature of the images, in which case this correlation may be explained by individual differences in responsiveness to salient stimuli.

As previously mentioned, the fusiform face area is activated when typically developing subjects view social stimuli, but can also be activated in ASD subjects when viewing images related to their special interest (Grelotti, et al., 2005; Critchley, et al., 2000; Kanwisher, et al., 1997). The suggestion from this previous research is that areas of the brain involved in face processing may not actually be specialized for faces in particular, but for areas of expertise. The results from the current study suggest that physiological response could be related to what it is that we become experts in. Evidence suggests that having a physiological response to faces may result in increased attention to faces, thus resulting in having expertise in facial expressions and their emotional significance. For example, Dalton et al. (2005) demonstrated a link between arousal to faces and the time spent looking at them, and the study by Stagg, et al. (2013) suggested that the relationship they found between arousal to faces and language onset in ASD children could be due to the effect arousal to faces may have in directing attention towards them at an early age, facilitating language development. Conversely, having an increased physiological response to non-social stimuli such as geometric shapes, recurring patterns or rule-governed systems may result in increased attention to such stimuli, the consequence being an increased ability or drive towards such objects and systems. If arousal is related to attention towards a particular domain, such as people or systems, and thus related to cognitive ability in, or drive towards, that domain, then this could explain why the social and non-social traits of ASD have low genetic heritability in the general population, yet remain related to one another. If there is a primary cognitive

drive towards one particular domain (either social or non-social), it makes sense that the other is less likely to elicit as strong a response.

The positive correlation between AQ and trait anxiety supported the findings of previous research (Reed, et al., 2016; Romano et al., 2014) and was expected due to the high prevalence of comorbid anxiety disorders in ASD—if autistic traits are distributed along a spectrum then it would be expected that subclinical autistic traits would also be related to general disposition towards anxiety. It has been proposed that anxiety may play a role in the drive towards systemizing in ASD (Baron-Cohen et al., 1989; Spiker et al., 2012), in which case anxiety could potentially mediate the significant relationship between AQ and SCR mean magnitude to non-social stimuli found in this study. However, the results showed that the correlation between AQ and response to non-social stimuli was as strong, and still significant, when controlling for trait anxiety, indicating that anxiety does not play a role in the stronger orienting response towards general non-social stimuli for those with more autistic traits.

There was no significant relationship between trait or state anxiety and the non-social, social–faces or social–cartoon conditions, but there was a significant correlation between trait anxiety and the non-social of interest condition. This indicates the presence of a relationship between anxiety and special interests or hobbies in the NT population but the nature of that relationship is unclear. It is possible that hobbies and interests are used to cope with anxiety and so the heightened physiological response to objects of interest represents a positive association, or it could indicate that high anxiety in the NT population is related to a compulsion towards certain topics or activities as a way of dispelling negative emotion—this type of distinction has been made, in clinical terms, between ASD and Obsessive Compulsive Disorder (OCD), with the restricted interests and repetitive behaviours of ASD seen as being related to seeking positive affect and the compulsions and obsessions of OCD as related to reducing negative affect (Paula-Pérez, 2013). OCD is also a spectrum disorder that is strongly related to anxiety symptoms and disorders (Nestadt et al., 2001) and OCD traits are found in subclinical populations (Riskind, Abreu, Strauss, & Holt, 1997; Rosen & Tallis, 1995). So, it may be the case that in some NT individuals, personal interests and hobbies are related to feelings of compulsion or necessity to engage, leading to a

higher SCR mean magnitude when viewing images related to that interest in those who have higher trait anxiety.

The results of this study indicate that a stronger response to non-social stimuli, rather than simply a reduced response to social stimuli, may underlie the development of autistic traits in the NT population, and provided the basis for a later study to investigate whether these results would be replicated with an ASD sample (see Chapter 7).

Chapter 5

Study Two:

Attention-to-Detail and Attention to Social and Non-Social Stimuli: Change Blindness and the Embedded Figures Test

5.1 Overview

Abnormal attention is a core characteristic of ASD, including difficulty switching attention, hyperfocus on small and seemingly irrelevant details and lack of attention to social stimuli. This chapter details a study in an NT sample, the aim of which was to investigate the relationship between attention to social compared with non-social details, general attention to detail, and whether these relate to autistic traits in neurotypical adults. The intention was to establish whether attention to social and non-social aspects of a visual scene are related to each other and to degree of autistic traits, and therefore whether non-social and social behaviours such as those seen in ASD may in fact be explained together in terms of attentional biases. Methods for assessing attention to detail include the Embedded Figures Task (EFT), in which participants identify a shape within a complex visual array, and Change Blindness (CB) tasks, which measure how quickly it takes to identify changes in a flickering visual scene. Forty-six NT participants (25 female, 21 male) completed the Autism Quotient (AQ) questionnaire to measure ASD traits before completing an online version of the EFT and a Change Blindness task designed to include 52 scenes including both social and non-social features, with 26 images featuring social changes (e.g. changes to a person's face) and 26 featuring non-social changes (e.g. a change to a vehicle).

Analysis revealed a significant correlation between AQ and response time to social

changes and no significant correlation between AQ and time taken to spot the non-social changes. There was a significant correlation between response time to social and non-social changes. A paired-samples t-test revealed significant differences in response time for social and non-social changes, participants on the whole taking significantly longer to identify the non-social changes. The results indicate that AQ is related to greater difficulty identifying social changes, implying that those with more autistic traits pay less immediate attention to social details. Overall, people took longer to identify non-social changes, implying that in a neurotypical population social details are attended to more quickly. The strong correlation between response time to social and non-social changes indicates that, at an attentional level at least, these two cognitive features of ASD may not be wholly independent of one another. EFT scores were correlated with response times to spot both social and non-social changes, indicating that performance on both these measures of attention are related to one another.

5.2 Background

5.2.1 Attention to Detail

The previous study in Chapter 4 investigated physiological response to social and non-social stimuli in relation to autistic traits and anxiety. The aim of the present study was to further explore attention to social compared with non-social details and general attention to detail in relation to autistic traits and anxiety in a neurotypical sample. As discussed previously, atypical attention is thought to contribute to both the social deficits and restricted and repetitive behaviours (RRBs) seen in ASD. It has been proposed that ASD arises from impairments in social orienting (Dawson, Meltzoff, Osterling, Rinaldi, & Brown, 1998, and see Chapter 4), and that abnormal ascription of salience to social information may underlie the development of social difficulties in ASD (Dawson et al., 1998). Atypical attention has also been theorized to underlie the non-social aspects of ASD—for example the insistence on sameness, resistance to change, and distress due to even small changes in the environment or a routine, often seen in ASD, may be a result of enhanced attention to detail, meaning that even the slightest alteration disrupts the ability to meaningfully process information about the world. Attention to detail is also a feature of the high-level

RRBs in ASD (Turner, 1999; Leekam, 2011) and is thought to be a prerequisite for systemizing ability, allowing for quick identification of features that ‘break the rules’ and risk destabilising the system, such as a mistake in a piece of code (Baron-Cohen et al., 2009).

Attention to detail can also be conceptualized in terms of field-independence, that is, as a perceptual or cognitive style that involves the preferential processing of the local features of a given scene or stimulus rather than apprehending the whole scene globally and contextually. Typically, individuals attend to the properties of a larger figure faster than they do to its smaller components, indicating a global processing style (or field-dependence) whereby information is processed holistically and dependent upon context, before attention is paid to the details (Navon, 1977). A common method for assessing field-dependence and field-independence is the Embedded Figures Task, in which a simple shape must be identified from within a complex figure (Witkin, 1971). Those who are better able to distinguish the various shapes within the figure (i.e. those who have a field-independent cognitive style) will be faster and more accurate on this task than those who perceive the figure as a complex whole.

Much evidence has been accumulated to suggest that people with ASD have superior visuo-spatial skills to controls (Muth et al., 2014; Mitchell & Ropar, 2004) and several studies have found enhanced performance in ASD samples compared to controls on the Embedded Figures Task (Jolliffe & Baron-Cohen, 1997; Shah & Frith, 1983; de Jonge, Kemner & van Engeland, 2006; Schlooz et al., 2014), as well as on other measures of attention to detail such as the Block Design Task (Shah & Frith, 1993; Muth et al., 2014) and other visual search tasks (O’Riordan, Plaisted, Driver, & Baron-Cohen, 2001; Plaisted, O’Riordan, & Baron-Cohen, 1998). There have been various explanations put forward for this, including enhanced visual acuity (Brosnan, William & Walker, 2012), a bias towards local rather than global processing (Bölte et al., 2007; Happé, 1996) and an ‘overfunctioning’ of regions of the brain involved in core perceptual processes (Mottron et al., 2006). These findings of superior performance by ASD groups on measures of attention to detail have not been consistent, with several studies finding no such superiority (Dillen et al., 2015; Lee et al., 2007; Manjaly et al., 2007; White & Saldaña, 2011). However, no inferior performance of ASD groups on such tasks has been noted, and a more

recent meta-analysis of 59 studies found that ASD groups reliably exhibit superior performance compared with controls on the EFT and the Block Design Task (Muth et al., 2014).

Researchers have also investigated attention to detail in relation to autistic traits in neurotypical samples. Baron-Cohen et al. (2006) conducted an fMRI study on parents of children with ASD as they performed the EFT and found atypical patterns of brain activation. Similarly, Spencer et al. (2012) also found atypical activation in frontal and temporal regions of the brain during performance of the EFT in a group with ASD and their unaffected siblings, compared to controls, suggesting that atypical attention to detail is a feature of the broader autism phenotype and may be related to subclinical autistic traits. Several studies have explored attention to detail in relation to autistic traits as measured by the AQ, with some finding enhanced performance of those with a higher AQ on the EFT (Almeida et al., 2010, 2014; Grinter et al., 2009; Russell-Smith et al., 2012) and others finding no such differences between neurotypical high and low AQ scorers (Carroll & Chiew, 2006; Carton & Smith, 2014). A meta-analysis of research on AQ and EFT scores (along with other visual search tasks) concluded that superior attention to detail is a feature of the broader autism phenotype and that methodological differences across studies may account for inconsistent results (Cribb, Olathe, Lorenzo, Dunlop, & Maybery, 2016).

The current thesis seeks to elucidate the cognitive mechanisms underlying systemizing in ASD, and as attention to detail/field-independence has been posited as a prerequisite for systemizing, the EFT was chosen for this study as a well-established measure of local processing style, in order to assess its relationship with autistic traits as well as the relationship between field-independence as a cognitive style and attention to social and non-social stimuli.

5.2.2 Change Blindness

Attention can be generally defined as the mechanisms by which an organism selectively processes information or sensory inputs. There is too much information in the environment at any given moment for it all to be processed at once, so the selection of which stimuli to process or attend to is governed by an interplay of

endogenous (directed by the knowledge, mental state, goals and beliefs of the organism) and exogenous (directed by properties of a stimulus that capture the organism's attention regardless of its goals etc.) factors (Yantis, 1993). The SCR study detailed in Chapter 4 focused on single images in isolation—either socially-related or non-socially related—in order to understand which type of stimuli elicited larger responses in the absence of any specific or given goal or task. In order to identify any relationship between attention to social and non-social stimuli and autistic traits it is also important to investigate which features are attended to in a more complex scene in which both social and non-social details are present.

Change blindness is a phenomenon whereby people (NT and with normal or corrected vision) have difficulty spotting obvious changes in a given scene when a brief visual interruption (e.g. a momentary flicker of a blank screen) occurs between the original image and a modified image (Simons & Levin, 1997). Change blindness research has revealed that attention is needed for change detection and that, despite having the subjective experience of perceiving the full details of our visual field, we actually never form a complete visual representation of our environment and that we attend only to salient parts of a scene, making identification of changes in those areas faster (Rensink et al., 1997). This phenomenon is found not just in laboratory experiments but also in real-world naturalistic settings—for example, many people will fail to spot that a conversation partner has been replaced by someone else during an interaction (Simons & Levin, 1998; Levin, 2002). It has been shown that changes to semantically relevant items are spotted faster than semantically irrelevant ones, revealing that context is important for guiding attention—the background knowledge and expectations of the observer influence the direction of attention (Kelley, Chun & Chua, 2003).

Change blindness tasks have therefore been used to elucidate which areas of a scene attract initial attention—if a change happens in the area attended to first, it will be spotted more quickly (Rensink, 2002; Mazza et al., 2005). Change blindness tasks have also revealed that expertise in a particular subject will facilitate faster detection of changes relating to that subject more quickly than others, for example American football fans spot football-related changes quicker than non-fans (Werner & Thies, 2010), those with heavy alcohol and cannabis use detect substance-related changes faster than those with lighter or no use (Jones, Jones & Smith, 2003) and experts in

physics are faster to detect changes that affect the underlying principle of a physics problem than novices (Feil & Mestre, 2010). Given that most humans have expertise in faces (Kanwisher & Yovel, 2006), it is unsurprising therefore that studies using the flicker paradigm have shown that changes to faces are more readily spotted than changes to non-social features (Ro, Russell & Lavie, 2001) and changes to eyes are detected faster than changes to the mouth (Davies & Hoffman, 2001).

Change blindness studies have also been used to assess attention differences in ASD. Some evidence has shown that those with ASD have reduced change blindness compared with controls. One study found that an ASD group was faster to spot changes in the central interest of a scene, although they were slower than controls to spot semantically relevant changes (Fletcher-Watson, et al., 2006) and others have found that those with ASD exhibit reduced change blindness to changes in items of marginal (as opposed to central) interest (Ashwin, Wheelwright & Baron-Cohen, 2017) compared to controls and others finding reduced change blindness in ASD overall (Fletcher-Watson et al., 2012; Smith & Milne, 2009). However, other research has found no differences in change blindness between ASD groups and controls (Burack et al., 2009; Hochhauser, Aran, & Grynszpan, 2018; Loth et al., 2008) and some studies found even greater change blindness in ASD (Fletcher-Watson, Leekam, Findlay, & Stanton, 2008; Kikuchi, Senju, Tojo, Osanai, & Hasegawa, 2009).

Given the evidence for enhanced attention to detail and preferential local processing in ASD, it would be expected that those with ASD would outperform controls on change detection. A possible reason for these varying results may be that different experimental designs are used. Rensink (2002), in a review of change blindness, explains that the degree of change blindness will rise in a linear fashion as the complexity of the task, the setting and the demands of the paradigm rise. If the task presents a large number of objects, or more naturalistic scenes with various competing visual information, then the failure to detect changes will rise. The nature of the task and the change blindness paradigm used will also impact the rate of change detection. Some designs will only occlude part of the scene as the change takes place, for example with 'mud splashes,' whereas others completely obscure the image for a brief moment, which increases change blindness (Rensink, 2002). The semantic position of the change also has an effect on change blindness—changes are

detected much more quickly when they take place in an area of semantic significance or of salience to the observer (Kelley, Chun & Chua, 2003). Changes of greater semantic salience will even be spotted faster than changes of physical salience, suggesting that aspects of a scene that are preferentially attended to are more likely to be encoded and then compared within visual short-term memory (Simons & Rensink, 2005). This suggests that change blindness tasks are not really a measure of overall attention to detail, but, as mentioned above, assess which stimuli within a given scene have the most salience for an observer, so the use of different scenes and sites of change will produce different results—few, if any, people will be superior performers on change blindness tasks as a whole.

For example, the study by Kikuchi et al. (2009) found that children with ASD were slower to spot changes to faces than controls, but were not slower spotting changes to non-social objects. Within the ASD group, there were no differences in time taken to spot social and non-social changes, whereas the control group showed an attentional bias for faces, spotting social changes faster than non-social changes. There is evidence that people with ASD exhibit an attentional preference for items related to their own special interest (Grelotti et al., 2005; Sasson & Touchstone, 2013), and the results of the previous study in Chapter 4 reveal that higher AQ is related to a larger physiological or orienting response to non-social stimuli in an NT sample (Singleton et al., 2014). Together, this research suggests that those with ASD and with high levels of subclinical autistic traits may spontaneously attend to non-social items within a given scene before social items, or that what is usually seen as more salient in the environment (e.g. faces and social information) may not be perceived as such by those with ASD or a high degree of autistic traits.

Several studies have found attenuated change blindness among ASD participants for changes to areas of marginal interest, and it has been suggested that this is evidence for enhanced local processing (Vanmarcke et al., 2017; Ashwin, Wheelwright & Baron-Cohen, 2017; Fletcher-Watson et al., 2012). However, there is debate about the usefulness of ‘centre of interest’ (or marginal interest) methods of change blindness, as a priori categorization of marginal or central interest items, by assessing where in a given scene people typically attend to, does little to explain why such features should capture (or not capture) attention and may not be useful in studies with clinical populations, depending on what the study seeks to measure. As

Zelinsky (1998) argues, “calling something a centre-of-interest essentially just redefines an object of attention and adds little to the understanding of how this object becomes an attentional attractor.”

As discussed above, there is much evidence that change blindness tasks measure that which exogenously captures attention, i.e. which features of a scene prompt rapid encoding in short term memory. Given that this will be different across individuals and across various populations/clinical samples, these methodological differences with the change blindness paradigm may explain why there is variation in the results with ASD samples, i.e. change blindness tasks measure the exogenous attentional capture of features within a scene, rather than a general facility for attention to detail or overall local/global processing style (Scholl, 2000). In which case, it should not be surprising that while those with ASD may exhibit superior performance on measures of attention to detail and field-independence such as the EFT, they do not perform better than controls on all change blindness tasks across the board, given the differing methods and items of change reported on throughout the literature. The change blindness task for the present study therefore used only changes to social or non-social items, in order to investigate the salience of, and attentional biases to, social and non-social information in relation to autistic traits.

There has been little research into the relationship between change blindness and autistic traits in NT samples. One study used the AQ in an experiment with synaesthetes and an NT control group to assess whether autistic traits in synaesthesia relate to performance on both a change blindness task and the EFT (Ward et al., 2017). They found that synaesthetes outperformed NT controls on both tasks, and that the attention-to-detail subscale of the AQ was correlated with this performance, suggesting that synaesthetes have an autistic-like cognitive profile in terms of attention. However, this study investigated autistic traits in a specific population with a neurodevelopmental condition known to often co-occur with ASD (Baron-Cohen, et al., 2013; Neufeld et al., 2013). The current study is therefore the first to explore the relationship between subclinical autistic traits in the NT population and performance on a change blindness task and the EFT specifically to understand the non-social aspects of the broader autism phenotype.

5.2.3 Attention and Anxiety

There is evidence to suggest that the presence or absence of anxiety affects attention. For example, studies have found that induction of positive affect broadens attentional focus and increases distractibility, and that negative affect—including anger, anxiety and depression—increases local processing and reduces attentional flexibility (Basso et al., 1996; Dreisbach & Goschke, 2004; Fredrickson & Branigan, 2005; Gasper & Clore, 2002; de Fockert & Cooper, 2014). Studies have also found various results indicating that anxiety may affect attention in different ways, for example, that those with high trait anxiety lack an ability to maintain attentional focus (Fox, 1993), that high trait anxiety confers an advantage for attending to local information (Derryberry & Reed, 1998), that individuals with high trait anxiety exhibit worse selective attention (Bishop, 2009) and that trait anxiety improves spatial attention but does not affect postperceptual selection (Caparos & Linnell, 2012). Because anxiety often co-occurs with autism, it may be that anxiety levels affect the attentional differences found in the condition (Kim et al., 2000; Leyfer et al., 2006). Research has also found a relationship between higher levels of anxiety and self-reported autistic traits in non-clinical samples (Kanne et al., 2009; Scherff et al., 2014; Liew et al., 2015).

Burnette et al. (2005) investigated the relationship between anxiety and performance on various measures of weak central coherence (including the EFT) in HFA children and found no relationship between anxiety and local processing style, but the authors propose that this lack of association may be due to the use of self-report measures of anxiety, the reliability of which in children with ASDs is unclear.

Another study on children with ASDs by Hill et al. (2014) found that those with high anxiety levels and enhanced local processing possessed better social skills than children with low anxiety and enhanced local processing ability. The authors suggested that high anxiety combined with a local processing style may confer an advantage for social skills over those with low anxiety and enhanced local processing due to an amplification effect of the anxiety on local processing, leading them to fixate more closely on visual social details such as the mouth, leading to improved social understanding and interaction. However, this would seem to imply that there are other mechanisms in ASD, besides anxiety, that account for enhanced local

processing and suggests that high anxiety simply amplifies local processing ability in social contexts.

Studies exploring anxiety in relation to change detection have found that anxious individuals take significantly longer to identify changes than the non-anxious (Gregory & Lambert, 2012). Change blindness tasks have also been used to assess attentional biases towards threat/phobia related stimuli in people with anxiety disorders and specific phobias. For example, Mayer et al. (2006) used the Flicker change blindness paradigm to present arachnophobic and non-arachnophobic participants with spider-related and non-spider/threat irrelevant changes, finding that arachnophobic participants spotted more spider-related changes than the non-arachnophobic participants, and that overall more spider changes were spotted than threat-irrelevant changes. McGlynn et al. (2008) also used the change detection paradigm with respect to ophidiophobic participants, alternating scenes between those that contained a snake and those that did not. They found that ophidiophobes took longer to spot changes to scenes without a snake and suggest that this may be related to difficulty disengaging attention from the perceived snake-threat in the previously presented scene. Another study found that, using an adapted change blindness paradigm, arachnophobes were superior to controls at spotting when a spider had been replaced with another item, suggesting that those with a phobia or a specific stimulus-related anxiety have a working memory advantage for particular stimuli that facilitates threat monitoring (Reinecke, Becker & Rinck, 2010). Taken together, this research suggests that the presence of anxiety has an impact on directing and disengaging attention and on change detection.

As mentioned above, anxiety has been found to be one of the most common comorbid conditions experienced by people diagnosed with ASD (White, Oswald, Ollendick & Scahill, 2009; Davis, White & Ollendick, 2014; Vasa et al., 2013) and previous research has shown a positive correlation between anxiety and autistic traits (Romano et al., 2014; Reed et al., 2016), with the results of Study One in this thesis (Chapter 4) also finding a significant relationship between AQ score and Trait anxiety score. When investigating attention in relation to autistic traits, it is therefore useful to also measure anxiety in order to establish whether, and which, autistic traits may be related to attentional differences and whether anxiety mediates any relationships between autistic traits and performance on measures of attention to

detail and change detection. Self-report measures of anxiety (State and Trait) were therefore included in the analyses for this study in order to investigate the potential relationships between anxiety and attention and whether anxiety mediates relationships between performance on measures of attention and autistic traits.

5.2.4 Hypotheses

This study used the EFT to assess general attention to detail/field-independence, and a change blindness task to investigate attentional biases towards social or non-social stimuli, in relation to autistic traits in an NT sample. It was hypothesised that, in line with findings from previous research, performance on the EFT would be correlated with AQ score. It was also hypothesised that higher AQ score would be related to faster detection of non-social changes, and slower detection of social changes, and that better performance on the EFT would be correlated with better performance on the change blindness task. It was planned to divide AQ scores into a high and a low AQ group, using a median split (see Section 5.5.1 for more detail), and it was hypothesised that the high AQ group would take longer to spot social changes and would be faster at spotting the non-social changes. It was also predicted that the high AQ group would perform better on the EFT than the low AQ group.

5.3 Methods

5.3.1 Participants

An a priori power analysis in G*Power using a conservative estimate of a medium effect size (eta squared statistic of 0.4) determined that a sample size of at least 34 would be needed to achieve a power of 0.8 with an alpha level of 0.05, or 46 for an effect size of eta squared 0.35 (see Section 3.5.1). Forty-six neurotypical participants were recruited (as described in Chapter 3, Section 3.5.1) aged between 18 and 66 years ($M=26.7$ years), (25 female ($M=26$ years) and 21 male ($M=28$ years)). All participants reported having normal to corrected normal vision and no psychiatric diagnoses. Participants were provided information on the basic background of the study (without mention of ASD) and what was involved before giving their consent. Participants completed the Autism Spectrum Quotient online prior to coming to the

laboratory to undertake the change blindness and EFT tasks. Participants each received £5 on completion of the study.

5.3.2 Autism Quotient

Participants were first administered the full 50 item Autism Spectrum Quotient (AQ) questionnaire (Baron-Cohen et al., 2001) online, using Bristol Online Surveys (2012) as a self-report measure of autistic traits. AQ scores were calculated for each participant according to Baron-Cohen et al.'s (2001) specifications, resulting in an 'AQ score' for each participant out of a possible 50 (Mean AQ= 17.7, SD=6.7), with a minimum possible score was 0 and maximum possible score of 50, and scores (minimum score of 0 and maximum score of 10) for each of the theoretical subscales suggested by the original authors—social skill, communication, imagination, attention-to-detail and attention switching. The higher the score, the higher the number of autistic traits. Answering each question on the survey was mandatory, so there were no missing data for any participants completing it. For more detail on the AQ and the subscales, see Chapter 3 Section 3.3.

5.3.3 Change Blindness Task

The change blindness task used for the present study was based on Rensink et al.'s flicker paradigm (1997) and used images from a change blindness experiment by Ashwin et al. (2017). Participants were shown 54 scenes, each of which included both social and non-social details such as people and machinery or vehicles and the images each featured either one social change (e.g. to a person's face) or one non-social change (e.g. a change to a vehicle), totalling 27 social and 27 non-social changes (see Figure 5.1 for an example).

Participants were sat approximately 60 cm from a 20 inch Dell monitor, with a keyboard positioned in front of them on a small table. Each image was displayed for 240ms and was interrupted with a blank screen for 80ms, before displaying the changed image for a further 240ms, as detailed by Rensink et al. (1997). This cycle repeated for 30s (at which point it timed out) or until the participant pressed the keyboard to indicate they had spotted the change. After pressing the keyboard, participants then indicated to the experimenter what the change had been. Participants were each initially given two practice run-throughs (with different images from those used in the experiment) to ensure they understood the task

before the experiment began. The experimenter made a note of any errors, and misidentified changes and time-outs were recorded as a miss. The experiment was run on E-Prime software, and reaction times were recorded from the start of each image cycle to the press of the keyboard, in order to establish how long it took the participant to spot the change. An average response time for all correct change detections was calculated for each participant for both the social and non-social changes, and the number of misses was calculated for each participant for each condition.

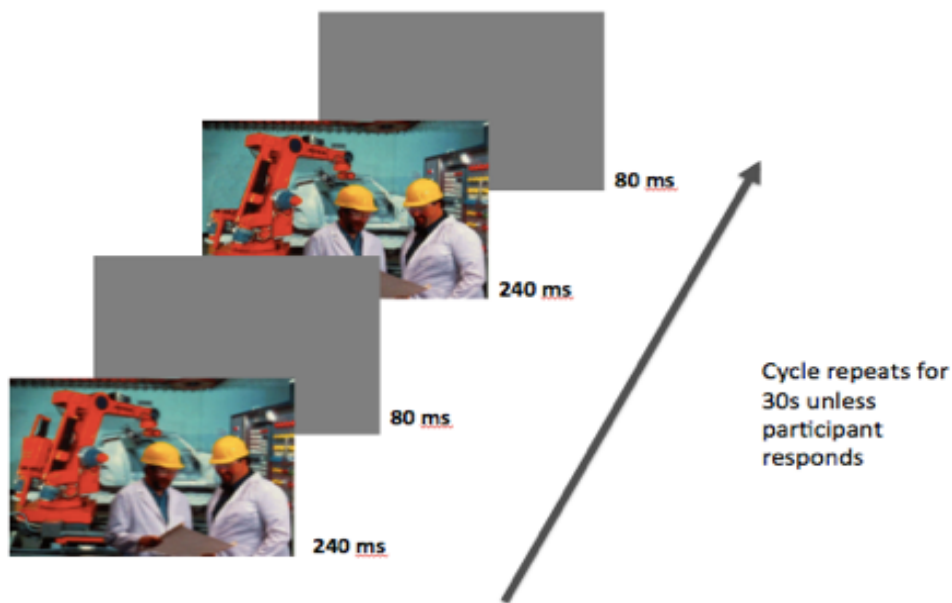


Figure 5.1 Example of the change blindness flicker paradigm. Participants must identify a change from image 1 to image 2, with a brief interruption of a blank

5.3.4 The Embedded Figures Task

A computerised version of the EFT was used for this study, which has been validated against the paper version and has previously been used in ASD research (Falter et al., 2008; Brosnan et al., 2012). Again, participants were seated approximately 60 cm from a 20-inch Dell monitor, with a keyboard positioned in front of them on a small table. Participants were asked to select, as quickly and as accurately as possible, which of two shapes—presented at the bottom left and right

of the screen respectively—appeared in a larger complex picture at the top of the screen. Pictures were all abstract, consisting of various configurations of lines and colours (see Figure 5.2). Participants selected the shape they had identified in the array by pressing either ‘F’ on the keyboard to indicate the shape presented on the left-hand side, or ‘J’ to indicate the shape on the right. Once the selection had been made, the outline of the correct shape appeared in the picture along with text-based feedback of either ‘correct’ or ‘incorrect’ before the next image appeared on the screen. There were two initial training tests with practice images, to ensure participants were familiarised with the task. The experiment itself consisted of 18 figures, half of which contained the shape on the left and half the shape on the right. Response times were automatically recorded by the program, along with the number of correct and incorrect responses. Mean response times for correct answers were calculated and this was divided by the number of correct responses to provide an inverse efficiency score for each participant—the lower the score the more efficient the performance (see Falter et al., 2008 and Brosnan et al., 2012).

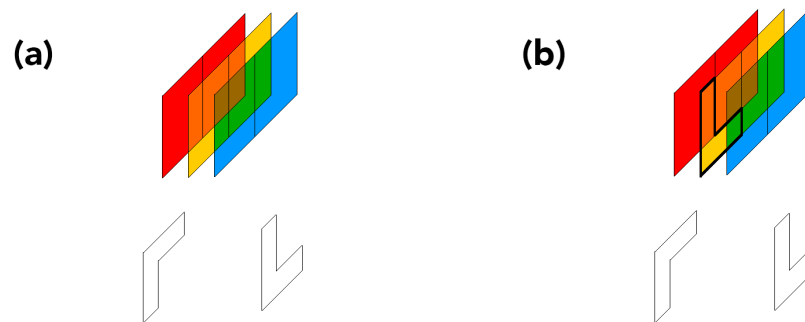


Figure 5.2 An example of the Embedded Figures Task. Participants are presented with image (a), and after selecting one of the two shapes at the bottom of the image, the correct shape is displayed as a black outline as seen in image (b).

5.3.5 State-Trait Anxiety Inventory

The State-Trait Anxiety Inventory (STAI Form Y; Spielberger et al., 1983) was used to measure anxiety levels in participants, both their general propensity to respond to

situations with anxiety (Trait anxiety questionnaire) and the level of anxiety they were experiencing as they took part in the change blindness and EFT tasks (State anxiety questionnaire). The trait anxiety questionnaire was completed online prior to coming to the laboratory for testing, and the State anxiety questionnaire was administered when the participant arrived for testing, prior to undertaking the EFT and change blindness tasks. Further detail on the STAI Form Y can be found in Chapter 4, Section 4.3.3.

5.4 Statistical Analysis

All data were explored using IBM SPSS Statistics 19 and the alpha was set at 0.05.

5.4.1 Change Blindness and AQ

A Shapiro-Wilk test revealed that the AQ scores, response times to the non-social change blindness condition and total mean response time to both social and non-social change blindness conditions were normally distributed ($p > 0.05$). The response time data for the social changes on the change blindness task and the number of errors/time-outs were not normally distributed and were positively skewed, so a square root transformation was applied to each variable to convert the data to a normal distribution so that parametric statistical tests could be employed.

Two-tailed Pearson bivariate correlations were run to investigate the relationships between: the mean change detection response time for each condition (social and non-social) and both total AQ score and AQ score for each of the five subscales; the overall mean change detection response time (social + non-social) and AQ scores (total AQ and for each AQ subscale); between AQ scores (total AQ and for each AQ subscale) and the number of errors and/or timeouts for each condition; and the relationship between mean change detection response times for the social and the non-social conditions. The difference scores between mean change detection response times for the social and non-social conditions were normally distributed as assessed with Shapiro-Wilk's test ($p = .726$), so a paired-samples t-test was employed to explore differences between response time to the social and non-social changes across the whole sample.

5.4.2 Embedded Figures Task and AQ

A Shapiro-Wilk test revealed that the final efficiency scores for the EFT and the average response time for correct answers were not normally distributed and were significantly positively skewed. A logarithmic transformation was therefore applied to these data to convert them to a normal distribution for parametric statistical analysis. Pearson bivariate correlations were run to explore the relationships between total AQ score and the scores for each of the five AQ subscales, and EFT efficiency score, number of correct responses and mean reaction time for correct answers. AQ scores were divided into a high AQ and a low AQ group to investigate differences between these groups on EFT performance using an independent samples t-test (see section 5.5.1 for further detail on the median split process).

5.4.3 Change Blindness and Embedded Figures Task

To investigate the relationship between attention to detail as measured by the EFT and attention to social and non-social changes, bivariate Pearson correlations were run between EFT final efficiency score, EFT number of correct answers and EFT mean response time for correct answers, and mean response time to each of the change blindness conditions, and number of errors/time-outs on the change blindness task.

5.4.4 Anxiety Analyses

Two-tailed Pearson bivariate correlations were run to explore relationships between Trait and State anxiety scores and EFT final efficiency score, EFT number of correct answers and EFT mean response time for correct answers, and mean response time to each of the change blindness conditions, and number of errors/time-outs on the change blindness task. Partial correlations between AQ and the various measures of attention (EFT scores and change blindness RTs and errors), controlling for Trait anxiety and controlling for State anxiety scores, were also carried out.

5.5 Results

5.5.1 Change Blindness and AQ

Analysis revealed a significant positive correlation between AQ and the mean change detection response time to social changes ($r=.406, p=0.005$) but no correlation between AQ and the mean change detection response time to the non-social changes ($r=.153, p=.310$). To further explore these relationships and to aid comparison with studies using ASD and control groups, participants were split into two groups of high and low AQ scores using a median split in order to perform independent t-tests to investigate differences in change blindness response times between groups. This involved grouping all participants scoring above the median AQ score ($Mdn=17.5$) as High AQ scorers and all those scoring below the median AQ score for the sample as Low AQ scorers, resulting in two equal groups containing 23 participants each. This approach has previously been used in research on autistic traits in neurotypical samples for statistical analysis (Brock, Xu, & Brooks, 2011; Chen & Yoon, 2011; Cox et al., 2015; Mayer, 2017; Stevenson & Hart, 2017; Vabalas & Freeth, 2016). The mean change detection response time data for both social and non-social changes were not normally distributed for the two AQ groups, as assessed by Shapiro Wilk's test, so a logarithmic transformation was applied to convert them to a normal distribution. There was homogeneity of variances for both conditions, as assessed by Levene's test ($p>0.05$). Independent t-tests revealed that there were no significant differences between high and low AQ scorers on the change detection response time for the non-social changes ($t(44)=-1.36, p=.18$) but there were significant differences in change detection response time to the social changes for the high ($M=3.73, SD=.11$) and low ($M=3.64, SD=.11$) AQ groups ($t(44)=2.72, p=.009$), those in the high AQ group taking significantly longer to spot changes to socially-related items than those in the low AQ group.

There was a significant positive relationship between the response time for the social changes and scores for the social skill and imagination subscales of the AQ ($r=.370, p=.011$ and $r=.380, p=.009$, respectively) but no significant correlation with the other three AQ subscales. Because overall AQ was not significantly correlated with the non-social condition, the alpha for correlations between this condition and the AQ subscales was adjusted to $p=0.01$ to reduce the risk of Type 1 error. The non-social change blindness condition was close to being significantly positively correlated with the imagination subscale of the AQ ($r=.343, p=0.02$) but not with the other subscales. The total combined average change detection response time for

both social and non-social conditions was very close to being significantly correlated with overall AQ score ($r=.287, p=.053$) and was significantly positively correlated with the social skill ($r=.328, p=.026$) and imagination ($r=.396, p=.006$) subscales of the AQ. There was no significant relationship between number of missed change detections for the social or non-social condition and overall AQ score or any of the AQ subscales. There was a significant correlation between mean change detection response times to the social and the non-social changes ($r=.583, p<0.005$).

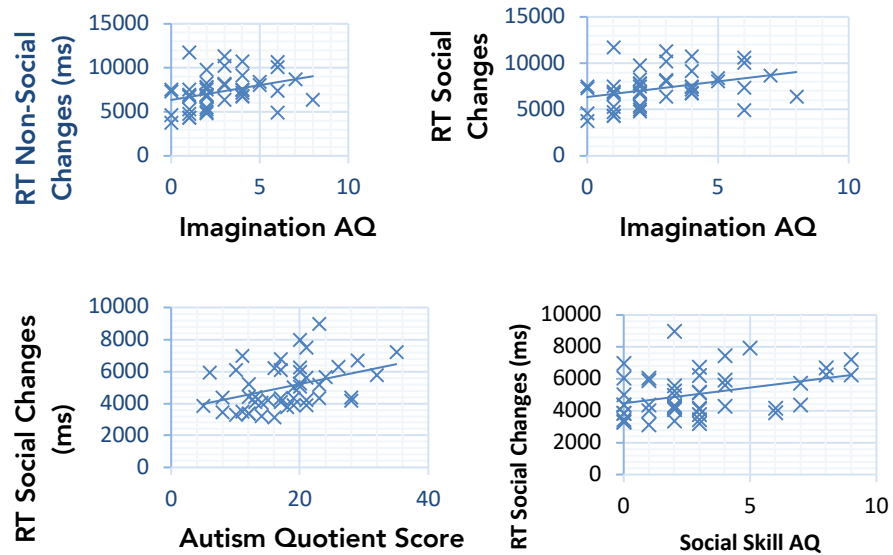


Figure 5.3 Plots representing significant correlations between mean change detection response times and the AQ/subscales of the AQ.

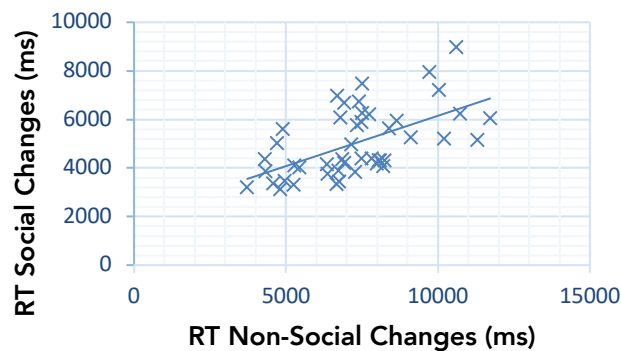


Figure 5.4 Plot representing the statistically significant relationship between mean change detection response times to social and non-social changes.

Table 5.1 Mean change detection response times for each condition

Condition	Mean Change Detection RT (ms)	Standard Deviation
Non-Social	7287	1934
Social	5026	4384
Combined Total	6156	1483

N=46

The paired-samples t-test revealed significant differences in response time for social ($M=5026$, $SD=1400$) and non-social ($M=7287$, $SD=1934$) changes, participants overall taking significantly longer to identify non-social changes; $t(45)=-9.51$, $p=0.000$.

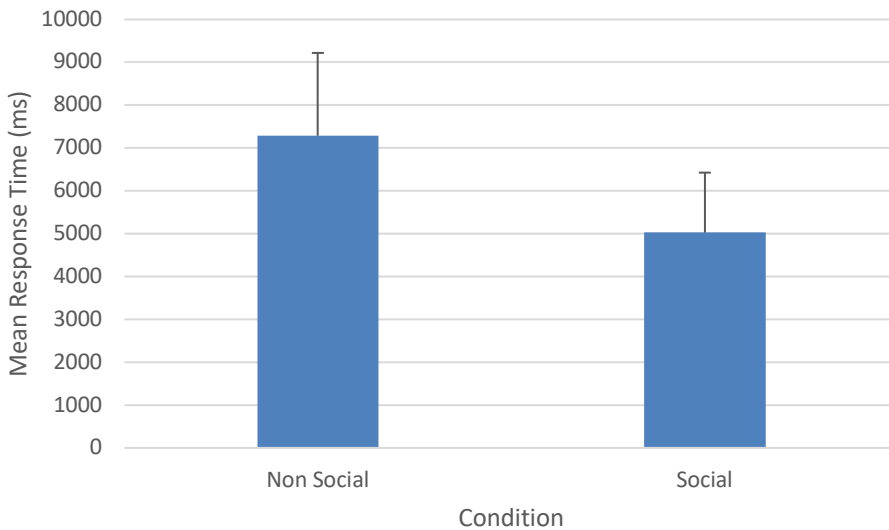


Figure 5.5 Mean change detection response times across participants for each condition. Standard deviations are represented by the error bars attached to each column.

5.5.2 Embedded Figures Task and AQ

The correlation between final EFT efficiency score and total AQ score ($r=.273$, $p=.067$) and mean response time for correct answers ($r=.262$, $p=.079$) and AQ both approached significance ($p<0.1$). There was no significant correlation between number of correct answers ($r=.009$, $p=.951$). Final EFT efficiency score was significantly correlated with the Imagination subscale of the AQ ($r=.372$, $p=.011$). There were no other significant correlations between EFT performance scores and AQ subscales. The independent t-test revealed no significant differences between the low and high AQ groups on EFT performance ($t(44)=-1.394$, $p=.170$).

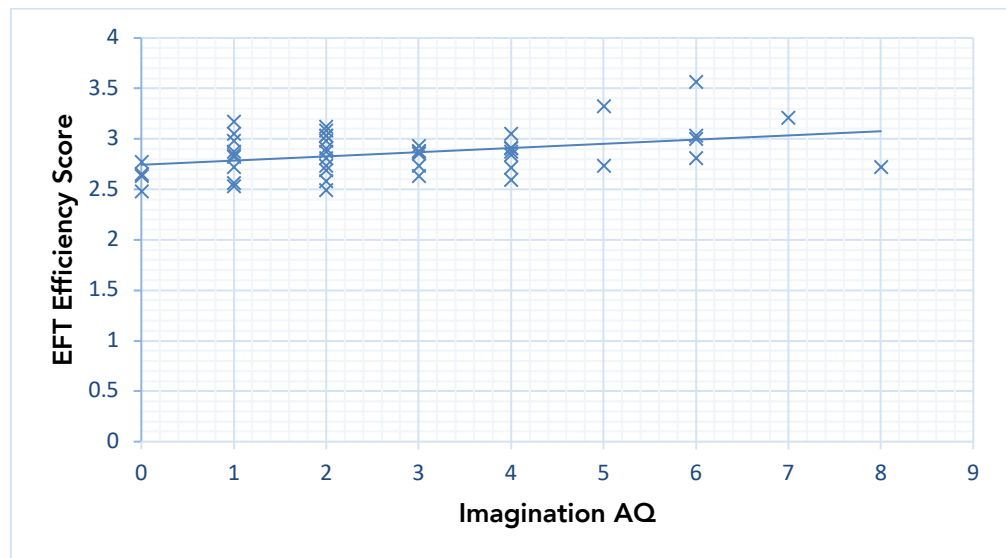


Figure 5.6 Plot of correlation between EFT efficiency score and Imagination AQ.

5.5.3 Change Blindness and Embedded Figures Task

EFT efficiency scores were significantly positively correlated with change detection response time to both non-social changes ($r=.293$, $p=.048$) and social changes ($r=.425$, $p=.003$) and with the number of errors/time-outs for the social change blindness condition ($r=.293$, $p=.048$). The mean response time for correct answers on the EFT was significantly positively correlated with the time it took to spot social changes ($r=.339$, $p=.021$) but not with the response time for detecting non-social changes ($r=.186$, $p=.484$) nor with the number of errors/time-outs for each

condition. The mean change detection response time for non-social changes was significantly negatively correlated with the number of correct answers on the EFT ($r=-.400, p=.006$), meaning that being quicker to spot non-social changes was related to accuracy on the EFT.

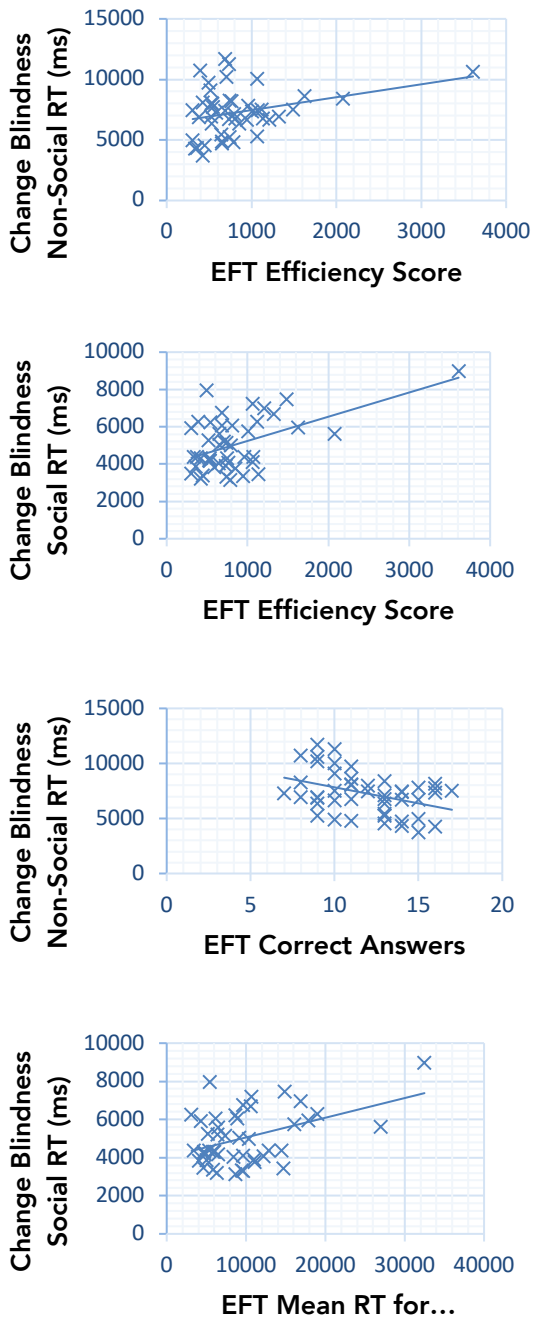


Figure 5.7 Plots of statistically significant relationships between EFT and Change Blindness scores.

5.5.4 Anxiety Analyses

AQ score was significantly correlated with Trait anxiety ($r=.451, p=.002$) but not with State anxiety score (see Chapter 4, Section 4.4). There was a statistically significant correlation between Trait anxiety and time taken to identify social changes ($r=.308, p=.038$), but with no other measures. State anxiety was not correlated with any of the EFT or change blindness results. When controlling for Trait anxiety, the relationship between AQ and reaction time to social changes was weaker but still statistically significant ($r_{\text{partial}}=.316, p=.035$). The correlation between EFT efficiency score and the response time to non-social changes became slightly weaker and approached significance ($r_{\text{partial}}=.285, p=.058$) and the relationship between EFT efficiency score and response time for social changes was minimally affected ($r_{\text{partial}}=.424, p=.004$). When controlling for State anxiety, however, the relationship between AQ and response time for social changes became much stronger and more significant ($r_{\text{partial}}=.406, p=.006$) and revealed a positive and significant correlation between AQ and EFT efficiency score ($r_{\text{partial}}=.334, p=.025$). The correlation between EFT efficiency score and response time for non-social changes approached significance when controlling for State anxiety ($r=.290, p=.053$) and remained similar for the social-change response times ($r_{\text{partial}}=.448, p=.002$). The relationship between response time to social and non-social changes was largely unaffected when controlling for Trait or State anxiety scores, as were the relationships between EFT efficiency score and the Imagination subscale of the AQ, and between social change response times and both the Social Skill and Imagination subscales of the AQ.

5.6 Discussion

The results of this study revealed that overall, participants took significantly longer to identify non-social changes, supporting the evidence from other research that in the NT population, there is an attentional bias to social information, allowing changes in the facial expressions, body language or behaviour of other individuals to be detected more quickly (Fletcher-Watson et al., 2006; Hershler & Hochstein, 2005; Palermo & Rhodes, 2003; Ro, Friggel, & Lavie, 2007). In support of one of the hypotheses of this study, AQ score was found to be significantly related to greater

difficulty identifying social changes, suggesting that even in the neurotypical population, the presence of more autistic-like characteristics may confer a disadvantage when it comes to paying attention to social details. This is consistent with results from previous studies that have found a relationship between reduced attention to social information and the presence of autistic traits in the NT population (Swanson et al., 2013) and across the broad autism phenotype, for example finding reduced attention to eyes compared to controls in the siblings of children with ASD (Dalton et al., 2007). This suggests that a higher level of autistic traits is related to social information being less salient than for those with fewer autistic traits, which would be consistent with the Social Motivation Theory of autism (i.e. social stimuli are less motivating the more autistic traits a person has).

The Extreme Male Brain theory of autism may suggest that the presence of autistic traits would result in attention being directed towards non-social stimuli instead, such as the vehicles and machinery present in the images in this change blindness task. It was hypothesised that higher AQ would be related to a faster performance when spotting the non-social changes, however, there was no significant correlation between AQ score and reaction time to the non-social changes, and while the results of the independent t-tests with the high and low AQ groups showed that those in the high AQ group took significantly longer to spot social changes than those in the low AQ group, there were no differences in time taken to detect changes to non-social items. These results were similar in nature to the results of Kikuchi et al.'s change blindness study with ASD children (2009), in which those with ASD took significantly longer to spot changes to a face than did typically developing children, but there were no differences between groups on response times for non-social changes. The authors of this study suggest that these results are due to the fact that faces capture special attention in NT individuals, leading to a faster performance with social changes, whereas for those with ASD, neither faces nor the non-social stimuli capture attention over the other, leading to a homogenous performance across both conditions for the autistic participants.

The results of the current study therefore suggest that this lack of attentional bias for social information extends to those with subclinical autistic traits in the neurotypical population but that non-social stimuli do not capture special attention either. However, results from Study One (Chapter 4) would suggest that the subjective

salience of non-social stimuli is related to autistic traits. The stimuli presented in that study consisted of single images on a white background, whereas for the change blindness study, images involved complex naturalistic scenes with many competing features, so it may be that in the NT population, even if non-social stimuli in isolation provoke a stronger physiological response among those with subclinical autistic traits, the ability to attend to social information at a certain level in high AQ neurotypical individuals mitigates the competing salience of non-social stimuli but still results in a slower reaction to social changes than those with a lower AQ.

There was a significant relationship between the time taken to detect social changes and the social skill subscale of the AQ. This finding is unsurprising given the hypothesis that social details would capture the attention of those with a higher AQ less readily than those with a lower AQ. This finding would be consistent with the results of research that suggests that atypical orienting to social information leads to poorer aptitude for social understanding (Bhat, Galloway & Landa, 2010; Keehn, Müller & Townsend, 2013). Response times on the change detection task, for both social and non-social changes, were significantly correlated with the imagination subscale of the AQ and the score for this subscale was also significantly correlated with the EFT efficiency score, indicating that autistic-like imagination traits are associated with poorer performance on these measures of attention. It had been predicted that AQ would be negatively correlated with EFT efficiency score (i.e., the higher the AQ, the better the performance on the EFT) but the results of this study did not support this hypothesis, with the correlation between them approaching significance, but in the opposite direction to that predicted. There was also no difference between the high and low AQ groups on EFT performance. The correlation between EFT and the Imagination subscale of the AQ went in the opposite direction to what had been hypothesised, and these results seem to contradict the idea that subclinical autistic traits are related to enhanced local processing. Findings of enhanced performance on the EFT in ASD have been inconsistent (Jolliffe & Baron-Cohen, 1997; Shah & Frith, 1983; Dillen et al., 2015; Manjaly et al., 2007; White & Saldaña, 2011) so it is not surprising that in this study, there was no significant positive correlation between EFT performance and overall AQ score. The fact that EFT score was related to one subscale of the AQ but not the others, and that anxiety impacted performance may suggest that certain symptoms, features or traits that are often, but not always, present in ASD are

responsible for the varying results of these assessments. As ASD is such a heterogeneous condition, it may be that the presence, absence, or severity of certain symptoms or common comorbid conditions may underlie performance on assessments of attention to detail and local processing, such as the EFT, Block Design Task and Navon Task etc.

The imagination subscale of the AQ reflects the fact that poor imagination is a core trait of ASD and forms part of the diagnostic criteria for the condition (American Psychological Association, 2013; Baron-Cohen et al., 2001). Imagining is the ability to form a mental representation of the world that is different from the world as it is actually perceived (Reuland, 2010) and several studies have found imagination lacking in those with ASD, with a focus in the literature particularly on socially-related imagination and pretend play in children (Rutherford & Rogers, 2003; Jarrold, 2003). The imagination subscale questions for the AQ mainly relate to ‘theory of mind’ and other socially-related types of imagination, such as imagining the intentions of others or following characters’ intentions in fictional stories, and the results of at least one study have suggested that imagination deficits in ASD are specific to social stimuli only (Eycke and Müller, 2015). The findings of the current study, that deficits in socially-related imagination in particular are related to poorer performance on measures of different attentional processes, both social (with regard to the social changes in the change blindness tasks) and non-social (with regard to non-social changes and the EFT), are curious. Exploring these relationships further, it seems that the common element is the response time for each task—poorer performance on the change blindness task is indicated by longer response times and, when controlling for the mean EFT response time for correct answers, the strength of the relationship between the final EFT efficiency score and the imagination subscale score reduces and its significance disappears ($r=.209$, $p=.169$). One possible explanation for this could be that, in the NT population, those with less self-reported ability to imagine another’s perspective are less likely to pay attention to the experimenter’s instructions (e.g. find the shape/change as quickly as possible) or to understand that the experimenter is looking for speed as well as accuracy, and instead spend more time attempting to ensure they have chosen the correct answer, rather than seeking a trade-off between speed and accuracy.

A higher EFT efficiency score was indicative of a poorer performance, so the finding of a significant positive relationship between EFT score and change detection response times for both social and non-social changes indicated that the worse a participant performed on the EFT, the longer it took them to spot both social and non-social changes. The relationship between poorer EFT performance and time taken to spot social changes was stronger than that with the non-social change blindness condition, and EFT score was also correlated with the number of errors on the social change blindness condition but not for the non-social detection errors, suggesting that overall poor EFT performance was more related to social deficits in attention than to non-social deficits. This would suggest that enhanced local processing ability, the type that is often reported as being enhanced in ASD, on its own is not related to social deficits. As with the study by Hill et al. (2014), it may be that anxiety mediates the relationship between global/local processing style, social attention and social skill. i.e. that higher anxiety levels improve social skills in those with enhanced local processing but not in those with a global processing style. However, when controlling for State and Trait anxiety, the relationship between poor EFT performance and poor social change blindness performance remains the same or increases in strength. Controlling for Trait anxiety reduced the strength and significance of the relationship between EFT efficiency score and reaction time to the non-social changes, suggesting that the presence of anxiety may impede performance on both these measures of non-social attention. It may be that in the NT population, the relationships between these measures are due to more general attentional capabilities, with anxiety having an influence on performance (as has been found by various other studies on the impacts of anxiety on different attentional processes, e.g., Caparos & Linnell, 2012; Fox, 1993; Bishop, 2009).

The strong correlation between response time to social and non-social changes indicates that, at an attentional level, these two cognitive domains may not be wholly independent of one another, reflecting the finding in Study One that physiological response to social and non-social stimuli were correlated with one another. This relationship between social and non-social attention would appear to contradict the proposition by Happé, Ronald and Plomin (2006) that the different cognitive features of ASD may be unrelated to one another. However, it is possible that the relationship between time taken to spot social and non-social changes may not be due to exogenous orienting responses, but could be due to strategies for deploying

endogenous attention to detect changes if the site of change was not at the area of the scene that initially exogenously captured attention. If the change is not spotted immediately, different individuals may employ different visual search strategies for locating the change, resulting in an overall relationship between response time to social and non-social changes (see Scholl, 2000).

Chapter 6

Studies Three and Four:

Understanding Components of Systemizing

6.1 Overview

There are two general cognitive theories that attempt to explain the presence of intact or enhanced non-social reasoning abilities that occur alongside deficits in social understanding in ASD and those with a high number of autistic traits in the NT population. Hyper-Systemizing accounts, which include the Empathizing-Systemizing theory, suggest that these abilities arise from a drive towards, and ability to, construct, understand and predict (i.e. reason about) rule-based systems (Baron-Cohen et al., 2003; 2009). This is contrasted with Empathizing, which, simply put, involves a drive towards understanding people. While a hyper-systemizing orientation has been found in certain professions in the NT population and in those with HFA (such as mathematicians, scientists, technologists etc. (Baron-Cohen et al., 2009; Svedholm-Häkkinen & Lindeman, 2016)), a high drive towards, or preference for, systems and repeating patterns in stimuli does not necessarily confer ability in these areas.

Hyper-systemizing accounts also explain the non-social biases in low functioning ASD, for example an obsession with calendars could be a case of numerical systemizing in someone with low functioning autism, where someone with high functioning autism may display the same drive through an ability to solve mathematical problems (Baron-Cohen et al., 2009). The Systemizing Quotient (SQ) is a self-report questionnaire commonly used to measure this drive to systemize, although it says little about systemizing ability (Baron-Cohen et al., 2002). Males tend to score higher on the SQ than females (Wakabayashi et al., 2007; Byrd-Craven et al., 2015). The Dual Process Theory of autism, on the other hand, proposes that autistic people and people high in autistic-like traits bias towards deliberative processing, which is characterised as slow, serial, and more laborious conscious processing that is heavily dependent on working memory and correlated with general cognitive ability. This is contrasted with a bias away from intuitive, social-emotional

processing, which is characterised as rapid, autonomous, effortless, parallel, and unconscious, that is independent of working memory and cognitive ability (Brosnan, et al., 2016; 2017). Sex differences have been reported inconsistently in these capabilities. Baron-Cohen and Lombardo (2017) have recently called for further research into the components of systemizing in terms of systemizing drive or motivation and systemizing ability, conceptualised as a capacity for understanding rules-based systems or logical input-output operations. The objectives of the current study were therefore to investigate the relationship between self-reported systemizing drive (measured using the SQ short version), systemizing ability (measured using an objective assessment of logical ability—the Test of Logical Thinking (TOLT; Tobin & Capie, 1981)) and self-reported deliberative and intuitive thinking styles (measured using the Rational Experiential Inventory (REI; Epstein et al., 1996)) and drive, as well as investigating sex differences in self-reported systemizing, deliberation and intuition and logical thinking ability in a general NT population sample and in a sample with a self-reported ASD group and NT control group.

6.2 Background

6.2.1 Systemizing

Systemizing has been posited as one of two cognitive mechanisms that are employed for understanding the world, empathizing being the other (Baron-Cohen, 2006; Baron-Cohen et al., 2009; see also Chapter 2). Baron-Cohen (2006) suggests that those with ASD are hyper-systemizers, that is, they can only process, or have a strong bias towards understanding, highly predictable rule-governed information that is incompatible with a drive towards, or capacity for, empathizing. The Empathizing-Systemizing (E–S) theory contrasts this bias towards systems-related cognition with a bias toward social-related cognition (i.e. empathizing or mentalizing), which is a drive towards understanding the affective states of others and an aptitude for responding appropriately to them (Baron-Cohen, 2003; 2009). A systemizing approach involves the interpretation of predictable and rule-based systems, where an empathizing approach involves the interpretation of intentions and social information. Distinguishing systemizing and empathizing as two distinct orientations used for understanding aspects of the world prompts the notion that there may be a specialised cognitive system for processing non-social information that is analogous

to the 'social brain' network that is used for understanding others and processing social information (Adolphs, 2009; Fields, 2011).

Measures of these two cognitive dimensions include the Systemizing Quotient (Baron-Cohen et al., 2003) and the Empathizing Quotient (Baron-Cohen & Wheelwright, 2004), both of which are self-report questionnaires that provide an assessment of a person's drive/bias towards each cognitive style, but do not in themselves indicate objective ability in either domain. There is significant evidence of sex differences in scores for both these measures, with females generally scoring higher on the EQ and males generally scoring higher on the SQ (Baron-Cohen & Wheelwright, 2004; Baron-Cohen, 2002; 2003; 2009; Wakabayashi et al., 2007; Nettle, 2007; Wright & Skagerberg, 2012). Behavioural assessments of both empathizing and systemizing ability have also revealed sex differences, for example females typically perform better on the Reading the Mind in the Eyes Test (RMET) than males (Baron-Cohen, Wheelwright, Hill, Raste & Plum, 2001) and males have been found to perform better than females on the Physical Prediction Questionnaire (Lawson, Baron-Cohen & Wheelwright, 2004) and a Mechanical Reasoning Test (Carroll & Chiew, 2004). There is, however, little research on whether a drive for systemizing type cognition as measured by the SQ is related to performance on measures of systems understanding. Carroll & Chiew investigated this relationship using the Mechanical Reasoning Test (Bennett, Seashore & Wesman, 1974), which presents multiple choice questions about the relative movements of various wheels and pulleys in a diagram, and they found no significant relationship between performance on this test and the SQ.

Strengths in systemizing may compensate for empathizing deficits by allowing for the formation of certain IF, THEN rules for social understanding, such as 'if mouth is upturned, then happy' (Rutherford & McIntosh, 2007; Walsh, Vida & Rutherford, 2014), and studies have shown that those with ASD (i.e. high in systemizing and low in empathizing drive) are unable to identify emotion from the expression of briefly presented faces compared to controls, when a reliance on such higher level cognitive skills is reduced (Clark, Winkielman & McIntosh, 2008). This suggests that in ASD, rules-based, higher level cognition is used for making social judgements, i.e. the social domain is navigated with a systemizing approach, whereas in the NT population, the social world is navigated by way of rapid emotional processing.

It has been suggested that there is a strong affective component to systemizing in ASD and in those with a high level of autistic traits in the NT population (Fields, 2011; Overskeid, 2016 and see Chapter 2). The current thesis seeks to understand whether there is a ‘non-social brain’ analogous to the ‘social brain’ network in neurotypical people whereby systemizing occurs in the same rapid and intuitive way that empathizing occurs in the NT population, or whether systemizing represents an entirely different cognitive method of information processing. The current study therefore investigates components of systemizing by exploring the relationship between drive to systemize, or preference for systems-based cognition, with ability to reason about systems using a behavioural assessment—the Test of Logical Thinking (TOLT; Tobin & Capie, 1981)—a multiple choice test that requires problem solving as well as giving the reasoning behind the chosen answer. This allows for a comparison of correct answers with correct reasoning—correct answers with faulty reasoning may indicate that a more rapid and intuitive method of discerning the answer is being utilized rather than a slower more deliberative one; so, as well as providing the opportunity to investigate the relationship between systemizing drive and systemizing ability, the TOLT also allows the study of how answers to logical problems are arrived at.

6.2.3 Dual Process Theories

Brosnan et al. (2014) posit that the concepts of empathizing and systemizing parallel dual process accounts of cognition, which propose two different reasoning and decision-making styles or systems, defined as Type 1 and Type 2 (Stanovich & West, 2000; Evans, 2008). Type 1 is characterized as a fast, low effort, automatic, intuitive and unconscious processing style that is independent of working memory and general intelligence, and has been linked to emotion and the rapid attribution of emotional/mental states and intention to others (Stanovich & West, 2000; Epstein, 1994; Hassin et al., 2004). It is also argued that as Type 1 processes do not require controlled attention, they can be involuntarily triggered by certain stimuli but can also be mediated by higher level reasoning processes (Stanovich, 2009; Evans & Stanovich, 2013). Type 2 is characterized as a slow, effortful, conscious and controlled deliberative processing style that is dependent on general intelligence and

working memory and is linked to the representation of rules and underlying principles (Stanovich & West, 2000). Brosnan, et al. (2014) suggest that Type 1 type processing is related to empathizing, due to the rapid, automatic and intuitive nature of emotion recognition that has been conjectured in the literature (Clark, Winkielman, & McIntosh, 2008; Kahneman & Egan, 2011; Tracy, et al., 2011; Oliva & Anikin, 2018). Type 2 type processing, they propose, is related to systemizing, which involves slower, more deliberative and higher-order cognitive processes. Their research on the relationships between self-reported systemizing and empathizing biases (using the Empathizing Quotient (EQ) and Systemizing Quotient (SQ)) and measures of intuitive and deliberative cognitive mechanisms (using the Rational Experiential Inventory (REI; Pacini & Epstein, 1999) and the Cognitive Reflection Task (CRT; Frederick, 2005) found correlations between empathizing and intuition/Type 1 type processes and systemizing and deliberation/Type 2 type processes (Brosnan, Hollinworth, Antoniadou & Lewton, 2014). These findings were explored by Brosnan et al. (2016; 2017) in the autism spectrum to establish whether the cognitive profile of ASD could be understood in terms of dual process accounts of cognition, and discovered that people with ASD produced fewer intuitive responses on the CRT and that a higher number of autistic traits in a pooled sample of NT and ASD participants was related to more deliberative responses and fewer intuitive responses.

While the CRT (Frederick, 2005) is a commonly used measure for assessing intuitive and reflective reasoning, it does so by asking questions for which there is an intuitive, but wrong, answer. For example, one of the three questions asks: “A bat and a ball cost \$1.10. The bat costs \$1.00 more than the ball. How much does the ball cost?” Many people respond intuitively and impulsively with the incorrect answer ‘10 cents,’ when contemplating the problem a little more reveals that if you take \$0.10 from \$1.00, you are left with 90 cents, not \$1.00. Therefore, the ball must cost \$0.05 and the bat \$1.05. However, many people will answer ‘intuitively’ and incorrectly, and studies have shown that those providing the incorrect and intuitive answer are generally more impatient and impulsive (Frederick, 2005; Nagin & Pogarsky, 2003). This test has therefore been used as a way of determining whether a person reflects on a question before answering or whether they prefer taking an intuitive approach to reasoning, and Brosnan et al. (2016; 2017) used this to establish whether those with ASD adopt a more deliberative cognitive style. The problem

with this is that if systemizing ability in ASD is not due to a bias towards Type 2, deliberative type thinking, but is due to having Type 1 type responses to systems (where in the NT population Type 1 type responses are more related to contextual and social information) then perhaps an intuitive response to the above question for them may in fact be the correct one, if ability to make accurate inferences about logical problems in hyper-systemizers is analogous to the ability to understand facial expressions in empathizers.

6.2.4 Sex Differences

Sex differences have been found in self-report measures of empathizing and systemizing drive and in behavioural assessments of empathizing and systemizing ability, as well as in Type 1 and Type 2 types of cognition. As mentioned above, there is much evidence of sex differences in scores on both the EQ and the SQ, with males typically reporting higher systemizing drive and females typically reporting higher drive to empathize (Baron-Cohen & Wheelwright, 2004; Baron-Cohen, 2002; 2003; 2009; Wakabayashi et al., 2007; Nettle, 2007; Wright & Skagerberg, 2012). More objective behavioural assessments of aptitude for empathizing and systemizing also reveal sex differences, with females usually performing better on the Reading the Mind in the Eyes Test (RMET) (Baron-Cohen, et al., 1997; Wheelwright, Hill, Raste & Plum, 2001), girls developing faster empathy skills than boys as measured by the faux pas test (Baron-Cohen et al., 1999) and males outperforming females on the Physical Prediction Questionnaire and the Mechanical Reasoning Test (Lawson, Baron-Cohen & Wheelwright, 2004; Carroll & Chiew, 2004) as well as on measures of attention to detail such as the Embedded Figures Test (Jolliffe & Baron-Cohen, 1997).

In terms of dual process theory, earlier research showed that women used empathic reasoning more than men when asked to resolve prosocial dilemmas (Mills & Grusec, 1989) and that males outperform females on tasks involving mathematical reasoning ability (Benbow & Stanley, 1983). Some studies have found that females report to prefer an experiential/intuitive and males a rational/deliberative reasoning style, as assessed by the REI (Sladek, Bond & Phillips, 2010; Epstein, 2003) while others have not found such sex differences (Epstein et al., 1996). However, assessments of performance on tasks measuring intuitive and deliberative styles, such as the CRT, have found that females tend to adopt an intuitive type process

where males are more likely to adopt the deliberative approach (Frederick, 2005; Brosnan et al., 2014).

6.2.5 Hypotheses

The current study sought to understand some of the cognitive mechanisms that may underlie systemizing by assessing: Type 1 and Type 2 biases and abilities using the REI to measure preferences for rational, “need for cognition” systems or experiential, “faith in intuition” systems (Pacini & Epstein, 1999); systemizing ability using the TOLT to measure logical ability and understanding; self-report measures of systemizing drive, the relationships between all these variables, any sex differences between them, and any differences between self-reported ASD and NT groups.

Neurotypical Sample

It was hypothesised that SQ (drive to systemize) would be correlated with TOLT correct solutions (ability to systemize). If hyper-systemizing involves an intuitive type process for systems cognition then it would be expected that SQ would not be correlated with TOLT correct reasoning score. It was further hypothesised that SQ scores would be correlated with self-reported “need for cognition” (NFC), as drive to systemize and NFC are similar concepts. It was predicted that TOLT correct solution scores would be positively correlated with the “need for cognition” subscales of the REI and it was thought that reasoning score on the TOLT may be negatively correlated with the “faith in intuition” (FI) subscale of the REI, indicating that answers on the TOLT would be intuited/impulsively guessed rather than reasoned through. Sex differences were expected, with males predicted to score higher than females on the SQ and the “need for cognition” subscales of the REI, and that females would score higher than males on the “faith in intuition” subscale. In line with E–S theory, it was anticipated that males would score higher than females on the TOLT, reflecting greater systemizing ability.

ASD vs Neurotypical Controls Sample

It was hypothesised that, as with the NT sample, high systemizing drive would be related to performance on the TOLT in terms of correct answers, but not with TOLT reasoning score; that SQ would be correlated with the NFC subscale of the REI; that TOLT solution scores would be correlated with the NFC subscales and that the TOLT reasoning score would be negatively correlated with the FI subscale

of the REI. Again, sex differences were expected as with the NT sample above. It was also predicted that the ASD group would score higher than the NT group on the SQ, the TOLT correct solution score and the NFC subscale of the REI.

6.3 Methods

6.3.1 Participants

Neurotypical Sample

A similar previous study examining self-report assessments of empathizing, systemizing and the rational-experiential inventory (Brosnan et al., 2013) used a sample size of 68, so a sample size equivalent to, or larger than this was planned for this study. The sample for this study was recruited from the University of Bath population by way of an online questionnaire, with 119 participants in total (60 male, 59 female) and with a range of ages from 18 to 66, and a mean age of 22 (SD=6). Participants were recruited by way of an online questionnaire, which was advertised on the University online noticeboard and emailed to students and staff.

ASD vs Neurotypical Controls Sample

As described in Chapter 3, Section 3.5.1, data were collected from an additional sample that included an ASD group and a control group. As the survey was distributed online, ASD diagnoses could not be confirmed for all participants reporting an ASD. The questionnaire was again advertised online on the University of Bath noticeboard and was emailed to participants who had taken part in Study 1 and had agreed to be contacted about any future studies. There was no payment or reward for participation. The total sample consisted of 64 participants, with an age range from 18-54, 30 reporting ASD and 34 NT controls. The ASD group consisted of 6 females and 24 males, with a mean age of 22.33 (SD=3.14) and the NT group was comprised of 21 males and 13 females, with a mean age of 22.45 (SD=8.52). Analysis revealed no significant differences between groups on age ($t(45) = -.55$, $p = .957$).

6.3.2 Systemizing Quotient

The Systemizing Quotient was developed as the first self-report measure of systemizing drive (Baron-Cohen et al., 2003). The original SQ has 60 items (40 systemizing-related and 20 control items), but a shorter version (the SQ–Short) was developed and validated by Wakabayashi et al. (2006) with 25 items—this is the version used for this study in order to maximize completion rates, as the online survey already contained several other questions and measures. As with the original version, the SQ–Short consists of statements to which the participant must either agree or disagree on a 4-point scale (i.e., Strongly Agree, Slightly Agree, Slightly Disagree, Strongly Disagree). Approximately half of the statements are worded so that an ‘agree’ answer indicates higher systemizing drive (e.g., “I am fascinated by how machines work”) with responses of ‘Strongly Agree’ and ‘Slightly Agree’ receiving 2 and 1 points, respectively, and disagree responses receiving 0 points; and half are worded so that a disagree answer indicates higher systemizing drive (e.g., “I find it difficult to read and understand maps”) with ‘Strongly Disagree’ receiving 2 points, ‘Slightly Disagree’ 1 point, and agree responses 0 points. There is therefore a maximum possible score of 50 and a minimum possible score of 0. In this study, the SQ–Short was found to have a high level of internal consistency with a Cronbach’s alpha of .81. Hereafter the SQ–Short will be referred to as SQ.

6.3.3 Rational Experiential Inventory

The REI (Epstein, Pacini & Heier, 1996) was developed to measure biases towards rational “need for cognition” (NFC) or experiential “faith in intuition” (FI) systems. It has been used in a wide variety of fields in psychology, including personality, depression and anxiety, intelligence, creativity and health psychology research. The reliability of the REI has been consistently reported, along with the validation of the distinct constructs of need for cognition and faith in intuition (Handley, Newstead & Wright, 2000; Epstein, 2003; Newstead, Handley, Harley, Wright & Farrelly, 2004). The REI is made up of 4 subscales, each of which measures either an individual’s engagement with or ability for rational or experiential styles of thinking. Each subscale consists of 10 questions/statements to which the participant must respond on a 5-point scale from Completely True to Completely False. There are 40 statements in total, and mean scores, with a minimum of 1 and a maximum of 5, are calculated for each subscale (Rational–Ability, Rational–Engagement, Intuition–Ability and Intuition–Engagement), with a higher score indicating a stronger

preference for that thinking style. In the present study, the REI had good internal reliability, with a Cronbach's alpha for the NFC subscale of .785 and for the FI subscale it was .804.

Examples of statements for each subscale include:

Rational/NFC–Ability: “I generally have no problems in thinking things through clearly.”

Rational/NFC–Engagement: “I prefer complex to simple problems.”

Intuition/FI–Ability: “I trust my initial feelings about people.”

Intuition/FI–Engagement: “I like to rely on my intuitive impressions.”

6.3.4 Test of Logical Thinking

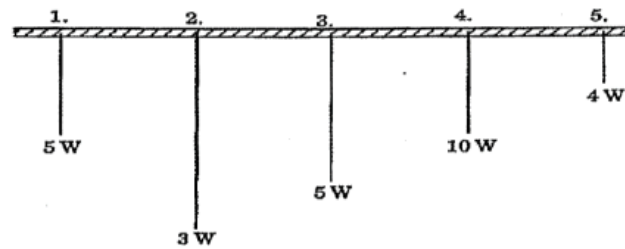
There are several behavioural assessments that can be used to evaluate facets of systemizing ability (as opposed to systemizing drive or a preference for thinking about systems). For example, the Physical Prediction Questionnaire (Lawson, Baron-Cohen & Wheelwright) or the Mechanical Reasoning Test (Bennett, Seashore & Wesman, 1974), both of which ask the participant to predict movements or outcomes on the basis of a diagram of some mechanical operation. Neither of these tests, however, measure reasoning style—participants simply answer either correctly or incorrectly and the method by which they arrive at their answer is unknown.

While this can provide an idea of how higher and lower systemizers perform when asked to understand and predict systems, for the purposes of the current study, a test was sought that not only assessed ability (i.e. correct answers) but also provided an idea of whether logical reasoning was being employed in arriving at the answer.

There are two tests that ask participants to provide justification for the answer given on a non-socially related aptitude assessment, one of which is the Test of Formal Reasoning (TOFR; Lawson, 1978) and the other the Test of Logical Thinking (TOLT; Tobin & Capie, 1981). A study that compared these two tests found that the TOLT had greater reliability and stability over time than the TOFR (Ahlawat & Billeh). The TOLT was therefore chosen for this study to evaluate systemizing ability and logical reasoning ability.

The TOLT was originally developed to measure formal reasoning ability (Tobin & Capie, 1981) and subsequent studies have confirmed its reliability (Ahlawat & Billeh, 1987; Jiang, Xu, Garcia & Lewis, 2010). The purpose of the test is to ask participants to solve problems and to then justify their answers, in order to assess whether

formal reasoning is being used for problem-solving, rather than some other process. The test consists of 10 questions with multiple choice answers/solutions, each with a sub question asking how the respondent arrived at their answer, offering them a choice of 5 possible statements of reasoning, only one of which is correct. For the purposes of the current study, scores on the TOLT were divided into a solution and a reasoning category, in order to compare accuracy at logical problem solving with reasoning ability. The Cronbach's alpha for the TOLT in the current study was .682.



The Pendulum's Length

5. Suppose you wanted to do an experiment to find out if changing the length of a pendulum changed the amount of time it takes to swing back and forth. Which pendulums, in the above figure, would you use for the experiment?
- a) 1 and 4 b) 2 and 4 c) 1 and 3 d) 2 and 5 e) all
6. What is the reason for your answer to question 5?
- a) The longest pendulum should be tested against the shortest pendulum.
 b) All pendulums need to be tested against one another.
 c) As the length is increased the number of washers should be decreased.
 d) The pendulums should be the same length but the number of washers should be different.
 e) The pendulums should be different lengths but the number of washers should be the same.

Figure 6.1 Example of one of the questions on the Test of Logical Thinking.

All measures were converted to an online survey format using the Limesurvey platform (Limesurvey GmbH).

6.3.5 Statistical Analysis

All data were exported from the Limesurvey platform into IBM SPSS version 24 for analysis. Data for all variables (SQ, TOLT Solution, TOLT Reasoning, Rational–Ability, Rational–Engagement, Intuition–Ability and Intuition–Engagement scores) were normally distributed for both the NT sample and ASD/Control sample, as assessed by inspection of Normal Q-Q Plots. Bivariate Pearson correlations were

performed to investigate possible relationships between the variables along with partial correlations controlling for sex. Scores for each variable were normally distributed for each level of the categorical sex variable (in both the NT only study and the ASD/NT groups study) and for each level of the ASD/NT variable, as assessed by inspection of Normal Q-Q Plots, however there were several outliers for one or both sexes for the majority of variables in the NT only sample, so a Mann-Whitney U test was chosen to investigate sex differences in the scores for each measure. Independent t-tests were used to investigate differences between the sexes and ASD and NT groups in the ASD/Control study.

6.5 Results

Neurotypical Sample

As hypothesised, scores on the SQ-Short were significantly positively correlated with TOLT Solution scores ($r=.444$, $p=.000$) but not with TOLT Reasoning scores ($r=.162$, $p=.078$), although this relationship approached statistical significance. SQ scores were significantly positively correlated with both the Rational-Ability ($r=.245$, $p=.007$) and Rational-Engagement ($r=.351$, $p=.000$) scores, but not with the Intuition-Ability or Intuition-Engagement, subscales of the REI. There was a significant relationship between TOLT Solution scores and both Rational-Ability ($r=.187$, $p=.042$) and Rational-Engagement ($r=.244$, $p=.008$) scores but not with the two Intuition subscales of the REI. TOLT Solution and TOLT Reasoning scores were significantly correlated with one another ($r=.545$, $p<.001$).

Due to running multiple independent t-tests across the same groups, a Bonferroni adjustment was applied, giving an alpha of 0.007. There was one significant sex difference for the SQ scores. A visual inspection revealed that distribution of SQ scores for males and females were similar, and males (Mdn=23) scored significantly higher than females (Mdn=15), $U=2621$, $z=4.53$, $p=.000$. For the Rational-Engagement measure, there was a similar distribution of scores for males and females, and males (Mdn=3.6) scored higher than females but this was not statistically significant (Mdn=3.4), $U=2189.5$, $z=2.23$, $p=.026$. Males also scored higher (Mdn=3.75) than females (Mdn=3.5) on the Rational-Ability self-report measure but this difference was also not statistically significant ($U=2123$, $z=1.88$, $p=.06$). There were no sex differences for the “faith in intuition” components of the

REI or for the TOLT Reasoning or TOLT Solution measures. These results are presented in Table 6.4.

When controlling for sex, the significant relationships between SQ and Rational–Ability and Rational–Engagement were still positive and statistically significant ($r_{\text{partial}}=.22$, $p=.016$ and $r_{\text{partial}}=.317$, $p=.000$), as was the correlation between SQ and TOLT Solution score ($r_{\text{partial}}=.423$, $p=.000$). After adjusting for sex, the relationship between TOLT Solution and Rational–Engagement scores remained positive and statistically significant ($r_{\text{partial}}=.225$, $p=.014$) and the correlation between TOLT Solution and Rational–Ability scores became less statistically significant, but still approached significance ($r_{\text{partial}}=.173$, $p=.06$).

Table 6.1 Correlations between SQ scores and REI and TOLT subscale scores for the NT sample.

Measure	Rational Ability	Rational Engagement	Intuition Ability	Intuition Engagement	TOLT Solution	TOLT Reasoning	n=119 *p<0.05 **p<0.01
r	.245*	.351**	-.042	.003	.444**	.162	
p	.007	<.001	.652	.972	<.001	.078	

Table 6.2 Correlations between TOLT scores and REI subscale scores for the NT sample.

	Rational Ability	Rational Engagement	Intuition Ability	Intuition Engagement
TOLT Solution	r=.187* p=.042	r=.244** p=.008	r=-.029 p=.752	r=.003 p=.977
TOLT Reasoning	r=-.033 p=.721	r=.032 p=.730	r=-.015 p=.874	r=-.006 p=.947

n=119 *p<0.05 **p<0.01

Table 6.3 Correlations between REI subscale scores for the NT sample.

	Rational Ability	Rational Engagement	Intuition Ability	Intuition Engagement
Rational Ability		$r=.749^{**}$ $p<.001$	$r=.228^*$ $p=.012$	$r=.187^{**}$ $p=.042$
Rational Engagement	$r=.749^{**}$ $p<.001$		$r=.107$ $p=.248$	$r=.272^{**}$ $p=.003$
Intuition Ability	$r=.228^{**}$ $p=.012$	$r=.107$ $p=.248$		$r=.690^{**}$ $p<.001$
Intuition Engagement	$r=.187^{**}$ $p=.042$	$r=.272^{**}$ $p=.003$	$r=.690^{**}$ $p<.001$	

n=119 * $p<0.05$ ** $p<0.01$

Table 6.4 Mean scores on all measures by sex for the NT sample (mean \pm SD)

	Male n=60	Female n=59	p value
SQ	22.58 \pm 9.52	15.34 \pm 6.87	<.001
Rational Ability	3.62 \pm 0.70	3.48 \pm 0.58	.06
Rational Engagement	3.52 \pm 0.81	3.29 \pm 0.61	.026
Intuition Ability	3.07 \pm 0.68	3.11 \pm 0.52	.802
Intuition Engagement	3.06 \pm 0.74	3.01 \pm 0.59	.693
TOLT Solution	8.48 \pm 3.25	7.51 \pm 3.20	.089
TOLT Reasoning	5.63 \pm 2.30	5.36 \pm 2.40	.552

ASD vs Neurotypical Controls Sample

As with the NT only sample, across the whole sample, SQ was positively correlated with TOLT solution score ($r=.386$, $p=.002$) but not with TOLT reasoning score ($r=.115$, $p=.364$). SQ was positively correlated with the Rational-Engagement subscale of the REI ($r=.285$, $p=.022$) but, unlike in the NT only sample, systemizing drive was not correlated with the Rational-Ability subscale ($r=.174$, $p=.169$). SQ was again not correlated with either component of the FI subscale of the REI. Neither TOLT solution score nor TOLT reasoning score for this sample were correlated

with either of the NFC subscales of the REI, unlike in the NT sample. Both TOLT subscales were also not correlated with the components of the FI subscale of the REI. Pearson's partial correlations were run controlling for sex, and found that the correlations between SQ and TOLT score still held ($r_{\text{partial}}=.379$, $p=.002$) as did the correlation with the Rational–Engagement subscale ($r_{\text{partial}}=.269$, $p=.033$). As with the NT sample, all scores for the subscales of the REI were positively correlated with one another other than Rational–Engagement and Intuition–Ability (see Table 6.5).

Table 6.5 Correlations between REI subscale scores for the ASD/NT sample.

	Rational Ability	Rational Engagement	Intuition Ability	Intuition Engagement
Rational Ability		$r=.798^{**}$ $p<.001$	$r=.322^{**}$ $p=.009$	$r=.357^{**}$ $p=.004$
Rational Engagement	$r=.798^{**}$ $p<.001$		$r=.188$ $p=.137$	$r=.377^{**}$ $p=.002$
Intuition Ability	$r=.322^{**}$ $p=.009$	$r=.188$ $p=.137$		$r=.770^{**}$ $p<.001$
Intuition Engagement	$r=.357^{**}$ $p=.004$	$r=.377^{**}$ $p=.002$	$r=.770^{**}$ $p<.001$	

$n=64$ * $p<0.05$ ** $p<0.01$

Independent t-tests revealed sex differences in SQ, with males scoring higher ($M=24.95$, $SD=9.28$) than females ($M=20.1$, $SD=7.56$), $t(62)=-2.011$, $p=.049$) but no differences between males and females on scores for any of the other measures (see Table 6.5 for means of all measures by sex). As the sample sizes for males and females were uneven, a Mann Whitney U test was also performed to investigate these differences because it is robust with unequal sample sizes (Mann & Whitney, 1947) and the results were the same, with only sex differences apparent for SQ scores ($U=570.5$, $z=2.104$, $p=.035$).

Table 6.6 Mean scores on all measures by sex for the ASD/NT sample (mean \pm SD)

	Male $n=45$	Female $n=19$	p value
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SQ	24.95 ± 9.28	20.1 ± 7.56	.049
Rational Ability	3.68 ± 0.73	3.65 ± 0.68	.887
Rational Engagement	3.61 ± 0.85	3.42 ± 0.73	.398
Intuition Ability	3.06 ± 0.75	3.10 ± 0.72	.842
Intuition Engagement	3.10 ± 0.80	3.03 ± 0.74	.725
TOLT Solution	8.98 ± 3.24	8.34 ± 3.20	.524
TOLT Reasoning	5.73 ± 2.37	5.58 ± 2.78	.822

Independent t-tests revealed that, as expected, the ASD group (M=30.67, SD=6.16) scored significantly higher on the SQ than the NT group (M=17.21, SD=5.89) ($t(62)=8.928, p<.001$). The ASD group (M=3.83, SD=.91) also scored significantly higher than the NT group (M=3.31, SD=0.64) on the Rational–Engagement subscale of the REI ($t(62)=2.69, p=.009$) but not on the Rational–Ability subscale. The ASD group (M=9.97, SD=3.62) also scored significantly higher than the NT group (M=7.76, SD=2.99) when it came to providing the correct solutions on the TOLT ($t(62)=2.664, p=.01$) but there were no significant group differences in the TOLT reasoning score ($t(62)=.440, p=.661$). The difference between TOLT solution score and TOLT reasoning score was calculated (TOLT Solution – TOLT Reasoning), and an independent t-test was run to investigate whether there were differences between groups on their logical reasoning in relation to their ability to

give a correct answer. It was found that the ASD group were significantly better at giving a correct answer without knowing the correct reasoning for reaching that answer, the mean difference between TOLT scores for the ASD group being almost twice that of the NT group (ASD mean=4.13, SD=4; NT mean=2.21, SD=2; $t(62)=2.496, p=.015$). There were no significant differences between ASD and NT groups on any of the other measures.

The TOLT difference score (TOLT Correct Solutions – TOLT Correct Reasoning score) was also found to be significantly positively correlated with SQ in the ASD/NT sample ($r=.327, p=.008$) and in the NT only sample ($r=.382, p<.001$), indicating that the higher the systemizing drive, the more correct answers were given on the TOLT along with an incorrect logical justification for those answers. In the NT only sample, the TOLT difference score was also significantly correlated with the Rational–Ability ($r=.246, p=.007$) and Rational–Engagement ($r=.258, p=.005$) subscales of the REI.

6.6 Discussion

Both studies found that self-reported systemizing drive was moderately and significantly correlated with correct responses on the test of logical thinking but its relationship with the ability to justify those responses using appropriate logical reasoning was much weaker and only approached statistical significance. In the ASD/NT study, those reporting an ASD diagnosis exhibited significantly greater performance on the TOLT in terms of getting the answer correct. However, this difference did not extend to the ability to justify their answers with the correct reasoning, and the ASD group were significantly more likely to get the correct answer along with the incorrect reasoning than were the NT group. This suggests that a drive to systemize may confer ability to solve logical problems, but does not necessarily confer a greater ability to consciously understand the logical reasoning that leads to the correct answer. This would seem to contradict the idea that hyper-systemizers prefer a slow, rational and deliberative method for solving problems, or at least that their self-reported preference for such a style actually translates into employing this reasoning approach to arrive at correct solutions to logical problems. It may be the case that high functioning hyper-systemizers use a Type 1 method for solving problems that are generally thought to require System2 type processes. Take

the phenomenon of subitization, for example. There is evidence that two processes are involved when determining a number of given elements—Type 1 type processes for determining small numbers of items (i.e. below four)—called subitizing—and Type 2 type processes for determining larger numbers of items—enumeration or counting (Trick & Pylyshyn, 1994; Wender & Rothkegel, 2000). There is evidence that in cases of savantism in ASD, certain tasks, such as factorization or counting very large numbers of items that usually require top-down higher level and more time-consuming conscious processes, seem to happen quickly and intuitively (Soulières et al., 2010; Sacks, 1985; Treffert, 2009). This suggests that it is at least possible for certain individuals to make calculations using cognitive approaches that are more akin to the Type 1, intuitive, rapid and unconscious style of problem solving, that for others require a more deliberative effort (e.g. counting or development and use of an algorithm).

If hyper-systemizers are able to accurately solve logical reasoning problems without understanding the reasoning procedure to arrive at the solution, i.e., if these problems are solved by some form of system/rules-related intuition, then it might be expected that those scoring higher on the SQ would also report higher intuition engagement and ability on the REI. However, in these studies, this was not found to be the case. SQ was significantly correlated with both subscales of the “need for cognition” construct of the REI in the NT sample, and with only the Rational-Engagement subscale in the ASD/NT sample but in both studies, there was no significant relationship between SQ and the “faith in intuition” subscales. This would suggest that those high in systemizing drive consider themselves to be Type 2 type thinkers, while the results for the TOLT Reasoning score seem to contradict that. It is possible, however, that the nature of the questions for the intuition subscale of the REI mean that it does not measure all types of intuition, especially in those with ASD, as the wording often relates to feelings, hunches, gut feelings and so on. Alexithymia is a condition whereby an individual finds it difficult to identify and describe their own feelings and emotions, and is thought to be highly comorbid with ASD, with estimates that the syndrome may co-occur in 40-50% of cases of ASD (Berthoz & Hill, 2005). So, the REI may not be a good way of assessing intuition about non-social rules-based systems especially in people with alexithymia and/or ASD, which may account for low self-reported intuition ability and

engagement in those who otherwise seem to exhibit a proficiency for intuitively solving logical problems without utilizing deliberative reasoning processes.

The results of these studies may suggest that findings by Brosnan et al. (2016) that people with ASD provided more accurate than intuitive/inaccurate responses on the CRT do not necessarily reflect a deliberative reasoning approach, but may instead reflect that people with ASD are more likely than controls to intuit the correct answer, rather than that they are using a specific slow, deliberative reasoning process to arrive at the correct answer. The results of the current study would suggest that if participants were asked how they arrived at their answer on the CRT, those with ASD would not be able to provide solid reasoning for their correct answers. Because these measures, such as the REI and the CRT, are developed with NT samples it may be that they are not appropriate for assessing deliberation and intuition in people with ASD or other clinical populations, if intuition works differently in some groups. However, the findings of these studies are not incompatible with a Dual Process account of autism—they simply suggest that instead of ASD involving a bias towards Type 2 type cognition with a lower reliance on Type 1 type thinking, it may be the case that Type 1 type cognition in ASD involves a bias towards systems, abstract relationships and rules-based, predictable mechanisms, where Type 2 type cognition is applied to social and emotional phenomena, and vice versa in the NT population.

It is interesting to note that in the ASD/NT study, the SQ was only correlated with the Rational–Engagement subscale, and that the ASD group scored significantly higher on this subscale than the NT group, but with no such correlation or group differences for the Rational–Ability subscale. This perhaps suggests that while feeling a drive to systemize or a need to engage in what are considered ‘rational’ processes might be high in ASD, it does not translate into self-reported ability in these areas. Yet, there does appear to be some relationship between these two measures in the NT sample and logic and rules-based ability as assessed by the TOLT, and with systemizing drive in the ASD/NT sample. The sex differences found in the NT sample in self-reported systemizing drive, Rational–Engagement and Rational–Ability, and in systemizing drive in the ASD/NT sample, but not in scores assessing systemizing and logical reasoning ability suggest that these self-

report measures do not accurately reflect ability, and that self-assessments of such capabilities may be vulnerable to response biases.

Chapter 7

Study Five: Physiological Responses to Social and Non-Social Stimuli in Autism Spectrum Disorder and Controls

7.1 Overview

The non-social biases and behaviours in ASD may be related to the employment of different mechanisms for processing and orienting towards non-social stimuli as compared with social stimuli. Study One, presented in Chapter 4, used skin conductance response to measure arousal to both social and non-social stimuli in an NT sample, and found that a higher number of subclinical autistic traits was related to a more pronounced physiological response to non-social stimuli, but not to non-social of interest or social stimuli. Findings included a correlation between SCRs to social and non-social stimuli, suggesting that, physiologically, these two domains may be related to one another in the NT population. Based on these findings, the study presented in the current chapter explored these relationships in an ASD sample and a group of matched controls, finding that those with ASD had a significantly larger physiological response to the images of non-social items that were related to their personal interests, than controls. Across the whole sample, social skill and imagination related autistic traits were both significantly correlated with arousal to the non-social of interest condition, suggesting that stronger orienting towards special interests is related to poor social skills and imaginative ability. The influence of anxiety on these relationships was also investigated, finding again that autistic traits were statistically significantly related to Trait anxiety, as well as to State anxiety, but there were no significant differences between ASD and NT groups on anxiety scores. It was found that when controlling for State anxiety, the correlation between autistic traits and the non-social of interest condition became stronger and more statistically significant, while controlling for Trait anxiety had the opposite result. These findings suggest a difference in the way people with ASD respond to non-social stimuli that comprise their own special interests and that anxiety may play a

role in these responses. Again, significant correlations were found between autonomic responses to the social and non-social conditions, suggesting that these two domains are related to one another at the physiological level.

7.2 Background

Study One, detailed in Chapter 4, found a significant relationship between autistic traits and physiological response to non-social stimuli, as well as a significant correlation between trait anxiety and autonomic arousal to non-social stimuli of particular interest to the individual participant in an NT sample. Because ASD is proposed to lie at the extreme end of a continuum, with many in the NT population possessing subclinical autistic traits to differing degrees, it made sense to explore whether these findings would be replicated in an ASD sample, or whether any difference would be found in physiological response to various categories of social and non-social stimuli between those with ASD and NT controls. See Chapter 4, Section 4.2 for information on the rationale for using physiological response as a measure of stimuli salience.

7.2.1 Physiological Response and Social Stimuli

Physiological response, including the measurement of electrodermal activity and other measures of autonomic arousal such as heart rate, has been utilised as a measure to investigate aspects of cognition in ASD, and primarily relating to social attention and perception. There are a large number of findings from this kind of research, and, as is often the case when studying such a heterogeneous condition, results are often conflicting. Physiological arousal has been employed in finding, for example, that children with ASD are hyporesponsive to threatening stimuli but respond typically to the distress of others (Blair, 1999); that autistic children do not habituate to repeatedly presented simple auditory and visual stimuli (James & Barry, 1984); that direct eye gaze elicits a stronger physiological response than averted gaze in children with ASD, when this difference was not found in controls (Kylliäinen & Hietanen, 2006); that despite looking at the eye region (as measured by eye tracking), a physiological orienting response is not elicited by direct gaze in children with ASD (Helminen et al., 2017) and, in contrast, that children with ASD exhibit larger skin conductance responses than controls to faces with both direct and averted gaze, which is related to impairments in face recognition (Joseph et al., 2008); and that

hypoarousal to faces in children with ASD is related to delayed language onset (Stagg, Davis & Heaton, 2013).

Such studies have also been performed on adults, for example, finding that emotional faces elicit lower skin conductance responses in adults with ASD than in matched NT controls, but that this lower orienting response does not hamper performance on emotional expression judgement tasks (Hubert et al., 2009). This suggests that SCR could be a way to measure individual differences in the kinds of processing elicited by different categories of stimuli. Adults with ASD have also been found to display attenuated physiological responses to threatening and stressful stimuli, compared with controls (Goodwin et al., 2006; Gaigg & Bowler, 2007).

7.2.2 Responses to Restricted Interests

The majority of research on autonomic responses in autism has focused on social attention, perception and stimuli, but there has historically been less research into physiological responses to non-social stimuli in ASD, despite the presence of the non-socially related aspects of the condition—such as repetitive behaviours and restricted interests—being essential for diagnosis. More recently, however, there has been an increase in research into mechanisms underlying the RRBs seen in ASD and there is evidence that there is a physiological and affective component underlying these interests and behaviours. The social motivation theory suggests that non-social circumscribed interests engage the reward system in people with ASD more than social stimuli (Chevallier et al., 2012). Much of the recent research in this area has involved EEG and fMRI studies to investigate neural responses to non-social and circumscribed interest-related stimuli.

Grelotti et al. (2005), in an fMRI study on a child with ASD, found activation of both the fusiform face area (FFA) and the amygdala—areas usually active in response to social stimuli (Schultz et al., 2003)—when he was shown images of his particular special interest, but no activation of these areas when viewing images of faces. An fMRI study by Dichter et al. (2012) found that participants with ASD showed intact ventral striatal responses to non-social objects typically associated with autistic special interests yet diminished response to monetary rewards, suggesting that the reward system in the brain in ASD is functional, but for non-social restricted interest related objects, and functions abnormally compared to

controls in relation to the anticipation of what is typically considered a rewarding stimulus (i.e. the acquisition of money). Both these studies suggest that networks in the brain thought to be dysfunctional in ASD may actually function properly, but only in relation to non-social stimuli of interest.

A similar study by Cascio et al. (2014) examined affective neural responses to the objects of restricted interest—personalizing the stimuli for each participant to reflect their own special interest—in a group with ASD and a group of matched controls. They found increased response in the insula and anterior cingulate cortex in the ASD group—areas of the brain known to be responsive to the salience of a stimulus (Seeley et al., 2007)—when viewing objects related to their special interest. They conclude that affective neural networks are involved in the development of RRBs in ASD. Another fMRI study involved showing participants with ASD and NT controls images related to their own personal restricted interest or hobby, and found a response in the fusiform face area to these stimuli in both groups, but that this response was stronger in the ASD group (Foss-Feig et al. 2016). An EEG study by Benning et al. (2016) found that children and adolescents with ASD exhibited larger late positive potential (LPP) amplitudes to non-social objects that are often the focus of circumscribed interests in autism than to social stimuli, compared with NT controls. A further EEG study by Rivard et al. (2018) also used stimuli relating to the individual interests of each participant and found no differences in LPP responses between those with ASD and controls, although they did not compare responses to circumscribed interests/non-social stimuli with responses to social stimuli. These studies have all found evidence for an affective neural component to the fixation on restricted interests in ASD, and while Benning et al. found group differences in LPP using typically autistic interest images, the use of personalized stimuli measures participant responses to restricted interests more accurately, as the types of interests can vary widely across individuals.

7.2.3 Anxiety, Emotion and Restricted Interests and Repetitive Behaviours

As discussed earlier (see Chapter 2 Section 2.3.3), anxiety is one of the most common comorbid conditions in ASD, with an occurrence rate as high as 84% in people with autism (White et al., 2009; Vasa et al., 2013). Anxiety symptoms have been found to be more strongly correlated with the non-social restricted interests and repetitive behaviours (RRBs) in ASD than the socially-related symptoms

(Guttman-Steinmetz et al., 2010). This relationship may be bidirectional, with evidence suggesting that the presence of anxiety increases RRBs as they are used as a type of coping mechanism (Mazefsky et al., 2013; Baron-Cohen, 1989) and suggestions that underlying features of RRBs, such as insistence on sameness/resistance to change, may increase anxiety levels due to difficulties adjusting to novel stimuli and inevitable changes in the environment (Muris & Ollendick, 2005). There is also evidence that being prevented from engaging in RRBs causes anxiety symptoms in those with a higher level of subclinical autistic traits (Liew et al., 2015).

Overskeid (2016) suggests that the drive to systemize is motivated by both positive and negative affect, proposing that those with ASD experience emotion more intensely than neurotypical individuals and that the enhanced drive to systemize in ASD is a reflection of more intense versions of the desire for the status quo and dislike of uncertainty that are seen in typically developing subjects (Samuelson & Zeckhauser, 1988; Anselme, 2010). The theory is that stronger than usual emotional responses in ASD lead to RRBs due to both the enhanced positive affect elicited when engaging in subjects of interest or behaviours that represent orderliness, control and predictability, and due to negative affect, whereby the experience of strong anxiety prompts self-soothing measures that include indulging in RRBs that increase positive affect in an attempt to achieve emotional equilibrium (Overskeid, 2016). This would suggest that systemizing drive and behaviours are related to general hyper-emotionality in ASD and if this hypothesis is correct, then those with ASD should exhibit stronger emotional/physiological responses to both social and non-social stimuli than NT controls, regardless of positive or negative affect. Measuring anxiety in conjunction with taking measures of physiological responses to stimuli related to special interests in ASD should provide the opportunity to investigate whether a) there is a heightened response to non-social stimuli of interest compared to controls in ASD subjects and b) whether responses to objects of interest are related to anxiety levels.

7.2.4 Hypotheses

The present thesis posits that it may not be a general hyper-emotionality that prompts systemizing drive, nor neural dysfunction per se, but that ASD may involve a kind of repurposing of systems used for social understanding in neurotypical

individuals, instead directing these systems towards understanding predictable rules-based systems. This could involve stronger orienting responses to non-social stimuli, similar to how social stimuli will often elicit a stronger orienting response in the NT population (Mares, Smith, Johnson, & Senju, 2016; Tomalski, Csibra, & Johnson, 2008). Because Study One had found a positive correlation between autistic traits and physiological response to the non-social condition, it was expected that the ASD group would exhibit stronger physiological responses to the non-social stimuli than the control group. No such relationship had been found between AQ scores and SCRs to the non-social of interest condition in the NT sample in Study One, and it was thought that this may be due to the responses to this condition being higher across the whole group, given that it was an NT sample and those with lower autistic traits may have also had stronger responses to items related to their personal interest. It was hypothesised that, due to the stronger drive to systemize and stronger investment in special interests seen in ASD, in this study, the ASD group would exhibit higher physiological responses to non-social stimuli related to their own interest than the control group. It was also expected that the ASD group would exhibit larger responses to the non-social stimuli condition (not of interest) than the NT group, and that conversely, the NT group would have stronger responses to the social stimuli than the ASD group. Consistent with these predictions, it was expected that AQ score would be positively correlated with mean SCR magnitude to both non-social conditions.

It was also predicted that, as with Study One, anxiety scores would be correlated with AQ score, and that the ASD group would have significantly higher levels of anxiety than the NT group. Anxiety has been implicated in the development of restricted interests and repetitive behaviours, with conflicting suggestions that negative affect may give rise to RRBs as a mitigating response, or that RRBs are independent from anxiety and only related in that they produce positive affect and so are used to mitigate anxiety when it arises (Lidstone et al., 2014; Sasson, Dichter & Bodfish, 2012; Jiujiias et al., 2017; Baron-Cohen, 1989). Given that the overall hypothesis is that the basis of the non-social features of ASD is related to preferential, innate, unconscious orienting towards non-social stimuli, it was predicted that while anxiety may be related to physiological response to non-social stimuli of interest, controlling for anxiety scores would reveal an intact, statistically

significant relationship between autistic traits and physiological response to non-social stimuli of interest.

7.3 Methods

7.3.1 Participants

The sample size for the ASD group was calculated on the basis of the results of the study with a neurotypical population detailed in Chapter 4 (and see Singleton, Ashwin, & Brosnan, 2014). The effect sizes for the correlations in this study were around 0.6, and using this effect size and the G*Power software, a sample size of 15 was calculated, given statistical power of 0.8. Participants were recruited from the University of Bath and University of Oxford populations, and from various Autism support groups and online through the Call for Participants website (Jisc, 2015). Participants with ASD provided evidence of diagnosis in the form of a report by their doctor or clinician. A final total of 17 participants were recruited for the ASD group (10 male, 7 female) and 16 for the NT control group (10 male, 6 female), matched by age, sex and education level. The age range for the ASD group was from 19-64 years, with a mean age of 35.71, and for the NT group, ages ranged from 19 to 67 with a mean age of 39.63. Age was not normally distributed for the NT group, so a Mann-Whitney U test was performed, which confirmed that the distribution of age was the same across both groups ($U=150$, $z=0.505$, $p=0.631$).

As with the first studies with the NT sample, participants initially completed an online survey before being invited to complete the rest of the study in the lab. Participants were each paid £10 on completion of the study. See Chapter 3 for further detail on participants and recruitment.

7.3.2 Measures

The measures used in this study were the same as those used in the study detailed in Chapter 4. Participants initially completed the online survey that established age, sex and education level, non-social objects of interest and included the full 50 item Autism Spectrum Quotient (AQ) questionnaire (Baron-Cohen, et al., 2001) as well as the STAI-Trait questionnaire (Spielberger et al., 1983).

The results of the AQ were scored according to Baron-Cohen et al.'s (2001) specifications, resulting in an 'AQ score' for each participant (minimum possible score was 0 and maximum possible score was 50), and scores (minimum score of 0 and maximum score of 10) for each of the theoretical subscales suggested by the original authors—social skill, communication, imagination, attention-to-detail and attention switching. For more detail on the AQ and the subscales, see Chapter 3 Section 3.3.

Participants completed the STAI-Trait questionnaire as part of the initial online survey, and then completed the STAI-State questionnaire on paper, when they arrived at the laboratory for testing. Each 20-item questionnaire includes both anxiety–present (e.g., I feel nervous) items and anxiety–absent (e.g., I feel calm) items. Participants mark how much each statement applies to them on a four-point Likert scale, with anxiety–absent items scored in the opposite manner to the anxiety–present items, a minimum–maximum score of 20–80 on each questionnaire, with a total maximum combined STAI score of 160. For more detail on the STAI, see Chapter 4, Section 4.3.3.

Each participant was shown a total of 24 images. Each image belonged to one of four conditions: Social – Face, Social-Cartoon, Non-Social and Non-Social of Interest. There were 6 images in each condition. Images in the Social-Face condition were sourced from an online database (Tarr, 2012) and depicted photographs of human faces with direct gaze. Images in the Social-Cartoon condition were sourced from previous research that had identified the emotion in the cartoon could be reliably recognised by those with ASD (Brosnan et al., 2013). The Non-Social and Non-Social of Interest images were freely available for use and sourced from the Google Images search engine (Google, Inc, n.d.). Images chosen for the Non-Social condition were items or objects that neither involved any human nor animal subject, and were not the subject of any participant's interest. Images were chosen for the Non-Social of Interest condition for each participant on the basis of their answers about their hobbies and interests on the online survey. More detail on the stimuli used in this study can be found in Chapter 4, Section 4.3.4. The design of this experiment was to measure skin conductance response while participants viewed each image to investigate whether there were differences in overall response to each of the four conditions and between ASD and NT groups. As SCR is an index of

orienting response and attention (Frith and Allen, 1983), higher average SCRs to one of the conditions (e.g. the non social images) compared with the other conditions would indicate stronger orienting to that class of stimuli in the sense that such stimuli prompt greater arousal/readiness to process incoming information.

The experiment was built and run using the E-Prime® 2.0 suite of applications. The order of stimulus presentation was initially randomised and each participant was shown images in that order. Each stimulus was presented on screen for 5 seconds. The inter-stimulus interval (ISI) varied randomly between 8- 12 seconds, with a mean ISI of 10 seconds over the whole procedure in accordance with previous studies (Breska, et al., 2010). A fixation in the shape of a small cross appeared in the centre of the screen during each interval.

Skin conductance response (SCR) was measured using a Biopac GSR100C, to assess arousal and orienting response to the visual stimuli. Physiological response was SCRs were determined when there was a rise in the amplitude of the skin conductance level of at least 0.01 μ S within 1–4 seconds of a stimulus onset (Dawson, et al., 2007; Venables & Christie, 1980). Acqknowledge™ 4.1 software was used to calculate SCRs from the recorded skin conductance level of each participant and were measured by comparison to a localized baseline that was established by the software using median value smoothing. The calculation of skin conductance amplitude was determined by the change in the amplitude of the skin conductance level from the time of the SCR onset to the maximum amplitude attained during the SCR (Biopac, 2013).

Procedure and EDA Analysis

Participants were seated on an adjustable chair approximately 60 cm from a 20 inch Dell monitor, with a keyboard positioned in front of them on a small table. An isotonic gel was applied to the Biopac EDA finger transducer which was attached to the distal phalanx of both the fore and middle finger of the dominant hand in accordance with recommendations (Screbo et al., 1992). The on-screen instructions told the participant to passively view each image and to ensure they remembered each in preparation for a memory test at the end. This was included as an incentive for the participants to pay attention to stimuli in what was an otherwise passive task.

Electrodermal activity (EDA) was analysed using the Acqknowledge™ 4.1 software and the same procedure as detailed in Chapter 4, Section 4.3.7. As in the initial study with the NT sample, individual differences in skin conductance level between participants were corrected for by transforming the mean SCR magnitudes for each condition into z-scores and these were used for the statistical analysis.

7.4 Statistical Analysis

The data were explored using IBM SPSS Statistics 24 and the alpha was set at 0.05.

7.4.1 AQ Analyses

For the ASD and NT groups, AQ score was not normally distributed for the ASD group so a Mann-Whitney U test was performed to assess differences in mean AQ score between ASD and NT groups. AQ score was normally distributed for each sex category (20 male and 13 female), there were no outliers and there was homogeneity of variances (assessed by Levene's test for equality of variances ($p=0.88$)), so an independent samples t-test was performed to investigate the differences in AQ score between the sexes. A two-way ANOVA was conducted to investigate possible interaction effects between sex and ASD/NT groups on AQ score. Bivariate Pearson's correlations were run to investigate relationships between AQ (and AQ subscales) and STAI-Trait and STAI-State scores, and between AQ (and AQ subscales) and SCRs to all four conditions (see SCR section below).

7.4.2 Skin Conductance Response Analyses

The distribution of SCR mean magnitudes for all conditions were non-normal and positively skewed so a logarithmic transformation was applied in order to use parametric statistical tests. A bivariate Pearson correlation was run to investigate the relationships between AQ (and AQ subscales) and SCR to each of the four stimulus conditions across the whole sample. Linear regressions were run to investigate whether AQ predicts SCR to each of the four stimuli conditions. The SCR data was not normally distributed for each of the ASD/NT groups or for either female/male category, as assessed by Shapiro Wilk's test ($p<0.05$), and were significantly positively skewed. It was not possible to transform these data to a normal distribution so Mann-Whitney U tests were used to determine differences between

ASD and NT groups and between the sexes in skin conductance response to each of the stimulus conditions.

7.4.3 State–Trait Anxiety Analyses

Both State and Trait anxiety scores were normally distributed, so Pearson's correlations were run to examine the relationship between these scores and AQ and SCRs to each of the four conditions. The two anxiety scores were also normally distributed for each of the ASD and NT groups and for each sex, so independent t-tests were performed to investigate any differences in anxiety between ASD and NT groups and between males and females. As anxiety often co-occurs with ASD and there was a correlation between trait anxiety and AQ in the initial study (Chapter 4; Singleton et al., 2014), partial correlations were planned between AQ and SCR to each stimulus condition, controlling for anxiety scores.

7.5 Results

7.5.1 Autism Spectrum Quotient

As expected, the ASD group (Mdn=37) had a significantly higher median AQ score than the NT group (Mdn=22.5) ($U=38.5$, $z=-3.52$, $p<0.01$). The independent samples t-test showed no significant differences between mean AQ score for male (mean=28.8, SD=9.89) and female (mean= 28.77, SD=10.25) participants ($t(31)=-0.009$, $p=0.993$). Although typically sex differences are found in AQ scores among the NT population, such sex differences are not found within ASD samples, so these results are consistent with previous findings given the numbers of female NT and ASD participants in the total sample (Ruzich et al., 2015). The two-way ANOVA found no statistically significant interaction between gender and autism diagnosis for AQ score ($F(1,29)=0.006$, $p=0.939$, partial $\eta^2=0.000$). There was, as expected, a statistically significant difference in AQ score between females in ASD and NT groups ($F(1,29)=7.078$, $p=0.013$, partial $\eta^2 =0.196$) and in AQ score between males in ASD and NT groups ($F(1,29)=11.789$, $p=0.002$, partial $\eta^2 =0.289$).

7.5.2 Skin Conductance Response

AQ was not significantly correlated with SCR to the non-social ($r=0.201$, $p=0.261$), social-faces ($r=0.252$, $p=0.158$) or social-cartoon ($r=0.116$, $p=0.520$) conditions, but the relationship between AQ and SCR to the non-social of interest stimuli was very

close to being significant ($r=0.343$, $p=0.051$). SCR to the non-social of interest condition was significantly and positively correlated with the social skill ($r=.350$, $p=.046$) and imagination ($r=.347$, $p=.048$) subscales of the AQ. Because the overall relationship between AQ score and the non-social of interest condition was so close to statistical significance, the alpha was not adjusted when considering the relationship between this condition and the AQ subscales. There were no significant relationships between any of the other conditions and AQ subscales. The total SCR mean magnitudes to the combined social (faces+cartoons) and combined non-social (non-social+non-social of interest) conditions were positively and significantly correlated with one another ($r=.436$, $p=.011$).

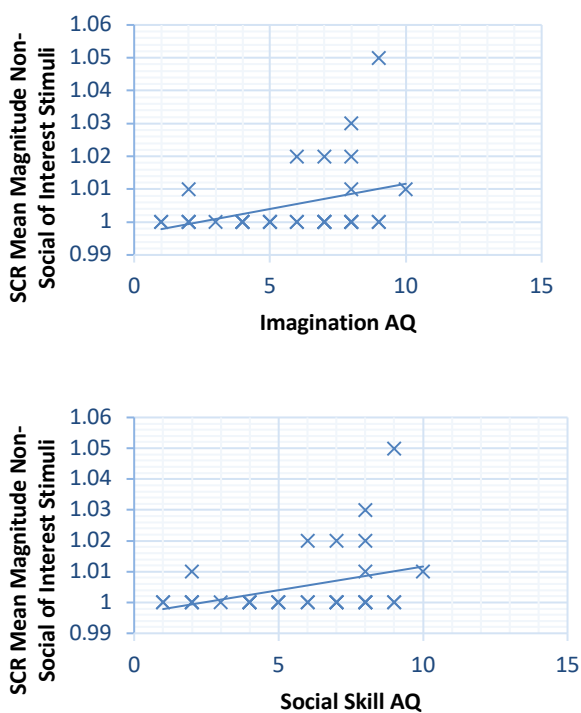


Figure 7.1 Correlations between AQ subscales and SCR to Non-Social of Interest stimuli.

The results of the Mann-Whitney U tests to determine any differences in skin conductance response to each of the stimulus conditions between ASD and NT groups showed that distributions of the SCR values were similar between the two groups for each condition, as assessed by a visual inspection. SCR to the social-faces ($U=117$, $z=1.691$, $p=.51$) social-cartoon ($U=104$, $z=-1.19$, $p=.26$) and non-social ($U=117$, $z=.689$, $p=.51$) conditions were not statistically different between the two

groups. However, there were significant differences between ASD (Mdn=48.42) and NT (Mdn=47.20) in SCR to the non-social of interest condition ($U=80$, $z=-2.023$, $p=0.043$), suggesting that people with ASD have a higher physiological response to non-social objects related to their own particular interest than do NT people. Mann Whitney U tests revealed that there were no significant differences between males and females in SCR to any of the stimulus conditions.

AQ did not predict SCR to the social-faces ($R^2=0.06$, $F(1,31)=1.99$, $p=0.168$), social-cartoon ($R^2=0.014$, $F(1,31)=0.426$, $p=0.519$) or non-social stimuli ($R^2=0.04$, $F(1,31)=1.297$, $p=0.263$). A linear regression found that AQ score accounted for 11.7% of the variance in SCRs to non-social of interest stimuli and this result was very close to being statistically significant ($R^2=0.117$, $F(1,31)=1.99$, $p=0.051$).

7.5.3 State-Trait Anxiety

AQ scores were significantly positively correlated with both Trait anxiety scores ($r=.570$, $p=.001$) and State anxiety scores ($r=.559$, $p=.001$). Those in the ASD group had higher mean Trait anxiety ($M=53.18$, $SD=13.93$) and State anxiety ($M=38.06$, $SD=10.15$) scores than those in the NT group ($M=46.25$, $SD=8.63$ and $M=31.88$, $SD=7.98$, respectively) and these differences approached statistical significance ($t(31)=1.704$, $p=.098$ and $t(31)=1.937$, $p=.062$, respectively). There were no significant differences in either Trait or State anxiety scores between males and females ($t(31)=.421$, $p=.677$ and $t(31)=.339$, $p=.737$, respectively).

Neither Trait nor State anxiety were significantly correlated with SCR mean magnitudes to any of the stimulus conditions. Partial correlations controlling for Trait anxiety revealed a significant relationship between SCR to the non-social condition and the Attention Switching subscale of the AQ ($r_{\text{partial}}=.374$, $p=.035$). The relationship between overall AQ score and the non-social of interest condition was slightly weaker and was less significant when adjusting for Trait anxiety score ($r_{\text{partial}}=.307$, $p=.087$). When controlling for State anxiety, however, the relationship between overall AQ score and SCR to the non-social of interest condition became stronger and statistically significant ($r_{\text{partial}}=.428$, $p=.015$). When controlling for State anxiety, the correlations between arousal to the non-social of interest condition and the Social Skill ($r_{\text{partial}}=.401$, $p=.023$) and Imagination ($r_{\text{partial}}=.370$, $p=.037$) subscales of the AQ became stronger and slightly more significant. There were no other

significant relationships between AQ or AQ subscales and SCR magnitudes for the four conditions when controlling for either state or trait anxiety.

7.6 Discussion

This study investigated physiological responses to categories of social and non-social stimuli, including images that were relevant to the participant's own special interest or hobby, along with a measure of anxiety to investigate the relationship between anxiety and strength of engagement in restricted interests in an ASD sample. It was found that the ASD group exhibited a significantly stronger physiological response to images related to their special interest than controls, and there were no differences between the two groups on responses to any of the other stimulus conditions. This finding is consistent with the hypothesis that there is an enhanced orienting response to restricted interests in ASD that is stronger than the response elicited in the NT population when viewing items relevant to a hobby. It is also consistent with findings of other research showing a bias towards non-social restricted interest type stimuli, for example in Unruh et al.'s (2016) study, autistic children took significantly longer to fixate on social images when a competing image of an object related to typical autistic interests was presented alongside it. In that study, the high autism interest stimuli influenced social attention more than non-social images that were of low autism interest.

Similarly, an eye tracking study by Sasson & Touchstone (2014) found children with ASD attended to faces significantly less than controls only when they were presented with a high autism interest image. The present study was different as stimuli were presented in sequence and differences in orienting responses analysed, rather than assessing attentional preference when given a choice of two types of stimuli to attend to at once. This design was intended to measure the extent to which each type of stimuli captured exogenous, unconscious attention, as this can add to the understanding of the results of the previous studies in which a bias was recorded. That the restricted interest condition provoked a stronger response in the ASD group compared to controls suggests that the bias or preference for restricted interest related images over social ones is due to the increased salience of the item of interest and its exogenous capture of the individual's attention. This would

contradict the Social Motivation Theory in that there is no reduced motivation towards social information as compared to controls, but instead there is an enhanced motivation towards particular kinds of non-social information.

Another study found no differences between children with ASD and controls in their attention to faces during an eye tracking task in which participants were presented with two social (one direct gaze, one averted gaze) and two non-social (one 'high autism interest' and one 'low autism interest') images (Parish-Morris et al., 2013). They also found that both the ASD group and the NT group preferentially attended to the non-social 'high autism interest' images. One possible reason for the conflicting findings in the above studies may be the types of images used for the high interest conditions. The current study used personalized images for the non-social of interest condition, instead of stimuli relating to what is typically considered to be an autistic-like interest (e.g., trains). Rivard et al. (2018) noted the use of general autistic interest images in studies on attention and restricted interests in ASD and suggests that tailor made stimuli may be more valuable. As these and other studies have shown, as well as being heterogeneous, attention in ASD appears to be highly context dependent, so it makes sense when exploring restricted interests with attention studies using presented stimuli to tailor the images to reflect each participant's individual manifestation of the symptom. Although it can be time consuming and may not be possible in all studies with ASD participants, testing in this personalized way may help to mitigate some of the heterogeneous presentation of autistic symptoms and help standardize results by ensuring all participants are being tested within the same context (i.e. presented with an image that does actually interest them).

The fact that the ASD group in this study did not exhibit a reduced orienting response to the social stimuli in comparison with the control group indicates intact social orienting, and the fact they did not produce a stronger response than controls for all conditions conflicts with the idea of hyper-emotionality proposed by Overskeid (2016). Although it was predicted for the present study that the ASD group would exhibit stronger responses for both non-social conditions—due to the findings of Study One—the absence of group differences in SCRs to the 'low interest' non-social stimuli and the social stimuli is consistent with results from the studies on attention and restricted interests mentioned above. Together, these results

suggest that it is particular types of non-social information that attract preferential attention or a stronger orienting response in ASD and that atypicalities found in social attention in ASD may be context dependent rather than evidence of general attentional dysfunction.

It had been predicted that across the whole sample, AQ score would be positively correlated with the skin conductance responses to both the non-social conditions but it was only close to being significantly correlated with the non-social of interest condition and no other condition. Partialling out the effect of State anxiety revealed a significant and stronger relationship between level of autistic traits and physiological response to the of interest condition, indicating that the presence of a strong orienting bias towards items related to restricted interests is related to autism symptomatology and not to the presence of anxiety. Controlling for State anxiety revealed that the SCRs to the non-social of interest condition were significantly positively correlated with both the Imagination and Social Skill subscales of the AQ. This indicates that a stronger orientation towards restricted interests is related to social deficits as measured by the AQ (although not the Communication construct), which would be expected if the usual mechanisms for social orienting are instead employed for or biased towards non-social stimuli in ASD.

Anxiety can interfere with the orienting response, and those with high state anxiety will often produce attenuated skin conductance responses to presented stimuli than those with low anxiety (Naveteur et al., 1987; 2005; Neary & Zuckerman, 1976). As the ASD group reported higher mean State and Trait anxiety than the control group (although it was not quite statistically significant) it may be that anxiety in the ASD group during the task hampered their perceptual alerting response. This is something to consider in future studies investigating electrodermal activity in ASD, due to the high rates of anxiety symptoms in the population and the possibility that engaging in an experimental study may increase state anxiety in this group to a greater extent than controls. Anxiety scores were not correlated with any of the stimulus conditions, which is a different result to studies that have found a relationship between anxiety and restricted interests (Lidstone et al., 2014). This, along with the strong correlation between AQ and SCRs to the non-social of interest condition when controlling for anxiety, and the strong correlations between AQ and both Trait and State anxiety, suggest that RRBs and anxiety are related to autistic traits but their

relationship to one another is not causal. Additionally, as found in Study One with the NT sample, there was a strong, significant relationship between physiological responses to the overall social and overall non-social conditions. This relationship indicates that orienting responses to both social and non-social domains are related to one another, and that explanations of attentional atypicalities in one domain may therefore have to account for attention in the other.

The results of this study do not support the Social Motivation Theory (Chevallier et al., 2012), as there was no evidence of reduced social orienting in the ASD group compared to controls, but instead point towards an enhanced orienting towards specific non-social stimuli. The theory of Enhanced Perceptual Functioning could perhaps explain the strong orientation towards objects of circumscribed interest, as it contends that ASD involves an overfunctioning and overconnectivity of areas of the brain involved in sensory perception leading to increased perceptual expertise, and so certain stimuli, particularly that which is interesting or the subject of expertise, may prompt heightened responses (Mottron and Burack, 2001; Mottron et al., 2006; Mottron et al., 2013). The results also support the Hypersystemizing Theory (Baron-Cohen et al., 2003), as the strong physiological response towards the non-social object of the individual's special interest may suggest an affective drive towards that system, reflecting a heightened drive to systemize in ASD.

Chapter 8

Attention-to-Detail and Attention to Social and Non-Social

Stimuli in Autism Spectrum Disorder and Controls

8.1 Overview

Study 2 (Chapter 5) compared attention to non-social and social stimuli presented together in a change blindness task and found that while social changes were spotted faster than non-social, as expected in an NT sample, a higher number of autistic traits was related to greater change blindness for social information. Because autistic traits are distributed across the general population on a continuum, ranging from very low to subclinical to those with a diagnosis of ASD, it was hypothesised that running the task with an ASD sample would result in a marked increase in change blindness for social changes compared to controls, and reduced change blindness for non-social changes. The results from the skin conductance studies detailed in Chapters 4 and 7 also supported this prediction, having found stronger orienting responses to non-social stimuli in those with ASD and those with a high level of subclinical autistic traits. As change blindness is reduced when the change is salient for the observer (Kelley et al., 2003), it was predicted that the ASD group would preferentially attend to non-social information in the task and therefore show attenuated change blindness for the non-social changes. The change blindness images and task procedure were kept the same to enable comparison of results with the initial study. See Chapter 5, Section 5.2.2 for further detail on the change blindness phenomenon.

Study Two contributed to findings on social attention and attention to detail in the NT population in relation to subclinical autistic traits. The results of the change blindness task in that study indicated that the lack of a bias for social stimuli found in clinical populations extends to the subclinical autism spectrum, and results on the Embedded Figures Task (EFT) suggested that poor performance on a measure of local processing and attention to detail was related to poor self-reported social skills. The findings also indicated that anxiety may play a role in performance on change

blindness and local processing tasks in neurotypical individuals. The present study sought to explore these findings further in a clinical sample, using the same change blindness task, the EFT and the STAI with an ASD sample and a matched group of neurotypical controls. The findings of this study did not support the results of Study Two, finding no differences between ASD/NT groups in response times to either the social or non-social changes and that across the whole sample, all participants took longer on average to spot the non-social changes than the social changes. The NT group also performed significantly better on the EFT than the ASD group, a surprising finding given that most research finds superior or equivalent performance on the EFT in ASD samples compared with controls. This chapter presents the study and discusses these results.

8.3 Methods

8.3.1 Participants

The sample size for the ASD group was calculated on the basis of the results of the change blindness study with a neurotypical population detailed in Chapter 5. The effect size of the paired samples t-test used in that study was large, with an eta squared statistic of 0.68. Using the G*Power software, a sample size of 15 was calculated using this effect size, for statistical power of 0.8 (See Chapter 3 Section 3.5.2). Participants were recruited from the University of Bath and University of Oxford populations, and from various Autism support groups and online through the Call for Participants website (Jisc, 2015). Participants with ASD provided evidence of diagnosis in the form of a report by their doctor or clinician (see Chapter 3 for further detail).

A total of 17 participants were recruited for the ASD group (10 male, 7 female) and 16 for the NT control group (10 male, 6 female), matched by age, sex and education level. The age range for the ASD group was from 19-64 years, with a mean age of 35.71, and for the NT group, ages ranged from 19 to 67 with a mean age of 39.63. Age was not normally distributed for the NT group, so a Mann-Whitney U test was performed, which confirmed that the distribution of age was the same across both groups ($U=150$, $z=0.505$, $p=0.631$). As with the first studies with the NT sample, participants initially completed an online survey before being invited to complete the

rest of the study in the lab. Participants were each paid £10 on completion of the study. See Chapter 3 for further detail on participants and recruitment.

8.3.2 Measures

As in the initial study with the NT sample, participants were administered the full 50 item Autism Spectrum Quotient (AQ) questionnaire (Baron-Cohen et al., 2001) online, using Bristol Online Surveys (2012) as a self-report measure of autistic traits. AQ scores were calculated for each participant, with a maximum possible score of 50 and a minimum possible score of 0. Mean AQ score of the whole sample was 17.7, SD=6.7. Scores were also calculated for each of the theoretical subscales suggested by the original authors—social skill, communication, imagination, attention-to-detail and attention switching (with a minimum score of 0 and a maximum score of 10 for each subscale). For more detail on the AQ and the subscales, see Chapter 3 Section 3.3.

The change blindness task used for the present study was the same as that used in Chapter 5, which was based on Rensink et al.'s flicker paradigm (1997) and it used the same images, which had been used previously in a change blindness study by Ashwin et al. (2017). Participants were shown 54 scenes, each of which included both social and non-social details such as people and machinery or vehicles and the images each featured either one social change (e.g. to a person's face) or one non-social change (e.g. a change to a vehicle), totalling 27 social and 27 non-social changes (see Chapter 5 Figure 5.1 for an example).

As with the initial study with the NT sample, participants were sat approximately 60 cm from a 20 inch Dell monitor, with a keyboard positioned in front of them on a small table. Each image was displayed for 240ms and was interrupted with a blank screen for 80ms, before displaying the changed image for a further 240ms, as detailed by Rensink et al. (1997). This cycle repeated for 30s (at which point it timed out) or until the participant pressed the keyboard to indicate they had spotted the change. The experiment was run on E-Prime software, and reaction times were recorded from the start of each image cycle to the press of the keyboard, in order to establish how long it took the participant to spot the change. An average response time for all correct change detections was calculated for each participant for both the social and non-social changes, and the number of misses was calculated for each

participant for each condition. See Chapter 5 Section 5.3.3. for further detail on how the Change Blindness experiment was run.

Again, participants were presented with a computerised version of the EFT (Falter et al., 2008; Brosnan et al., 2012 and see Chapter 5 Section 5.3.4). They were asked to select, as quickly and as accurately as possible, which of two shapes—presented at the bottom left and right of the screen respectively—appeared in a larger complex picture at the top of the screen (see Chapter 5, Figure 5.2 for an example). There were two initial training tests with practice images, to ensure participants were familiarised with the task, before they were presented with 18 trials, half of which contained the shape on the left and half the shape on the right. Response times were automatically recorded by the program, along with the number of correct and incorrect responses. Mean response times for correct answers were calculated and this was divided by the number of correct responses to provide an inverse efficiency score for each participant—the lower the score the more efficient the performance (see Falter et al., 2008 and Brosnan et al., 2012).

As before, the State-Trait Anxiety Inventory (STAI Form Y; Spielberger et al., 1983) was used to measure both trait anxiety and current anxiety levels in the participants. The trait anxiety questionnaire was completed online prior to coming to the laboratory for testing, and the State anxiety questionnaire was administered when the participant arrived for testing, prior to undertaking the EFT and change blindness tasks. Further detail on the STAI Form Y can be found in Chapter 4, Section 4.3.3.

8.4 Statistical Analysis

The data were explored using IBM SPSS Statistics 24 and the alpha was set at 0.05.

8.4.1 Change Blindness

Reaction time data for both conditions of the change blindness task were not normally distributed and were positively skewed, so a square root transformation was applied to achieve a normal distribution so that a bivariate Pearson correlation could be performed to investigate the relationship between AQ score, AQ subscale scores and mean response times for both social and non-social changes. Bivariate correlations were also run to explore the relationship between response times to

social and non-social changes. A linear regression analysis was planned, to explore whether change blindness response times could be predicted by AQ score. A one-way repeated measures analysis of variance was planned, to investigate whether there were any within-subjects differences in response times to the social and non-social changes. The change blindness mean reaction time data for ASD participants for both non-social and social conditions were not normally distributed and were positively skewed as assessed by the Shapiro-Wilk test ($p < 0.05$). A logarithmic transformation was applied to the data, which resulted in a normal distribution so that an independent t-test could be performed to explore differences in response times to the social and non-social changes between the NT and ASD groups and between the sexes.

.8.4.2 Embedded Figures Task

The AQ score data were normally distributed but the EFT final score data were not normally distributed and were positively skewed, so a square root transformation was applied to give a normal distribution. A bivariate Pearson correlation was then run to investigate whether there was a relationship between AQ score and EFT score. Independent t-tests were performed to investigate any differences between ASD and NT groups and between the sexes on the EFT score.

8.4.3 Change Blindness and EFT Performance

A bivariate Pearson correlation was run to investigate the relationship between EFT efficiency score and response times to spot the social and non-social changes on the change blindness task.

8.4.4 Anxiety Analyses

A bivariate Pearson correlation was run to explore the relationship between Trait and State anxiety scores and reaction times to social and non-social changes and between anxiety scores and EFT efficiency score. To investigate any influence of anxiety levels on the performance on the measures of attention, partial correlations, controlling for State and Trait anxiety, were run between AQ and EFT efficiency score, AQ and change blindness reaction times, and between EFT score and change blindness reaction times.

8.5 Results

8.5.1 Change Blindness

The bivariate Pearson correlation showed that AQ was not significantly correlated with reaction time to social ($r=-.178$, $p=0.321$) or non-social ($r=.142$, $p=0.431$) changes. An alpha of 0.01 was set for correlations with the AQ subscales due to the lack of significant relationship with the overall AQ score in order to avoid Type 1 error. There were no significant correlations between change blindness response times for either condition and any of the AQ subscales (all $r_s < .269$, all $p_s > .13$). The independent samples t-test found no significant differences between ASD and NT groups on mean reaction time to the non-social changes ($t(31)=1.093$, $p=0.283$), total non-social errors/time-outs ($t(31)=1.074$, $p=.291$) or to the social changes ($t(31)=1.236$, $p=0.226$) or social errors/time-outs ($t(31)=1.119$, $p=.272$). The linear regression showed that AQ did not predict reaction time to either non-social ($R^2=0.014$, $F(1,31)=0.45$, $p=0.51$) or social ($R^2=0.028$, $F(1,31)=0.88$, $p=0.356$) changes on the change blindness task. The two-way repeated measures ANOVA revealed that participants overall took longer to spot non-social changes ($M=73.23$, $SD=18.06$) than social ($M=67.27$, $SD=21.26$) changes ($F(1,32)=13.682$, $p=.001$, partial $\eta^2=.300$). Response times for spotting social and non-social changes were strongly and significantly correlated with one another ($r=.902$, $p<0.001$).

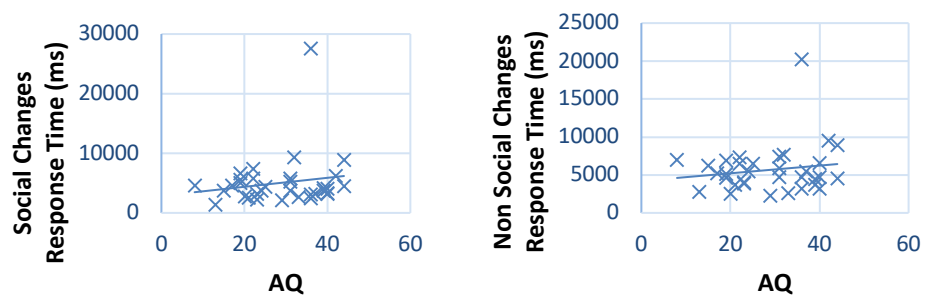


Figure 8.1 Correlations between AQ and response times to each Change Blindness condition

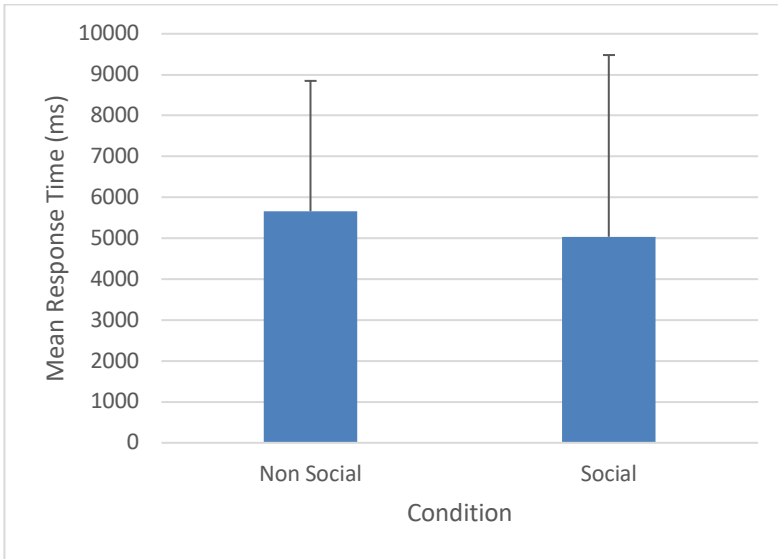


Figure 8.2 Mean change detection response times across participants for each condition. Standard deviations are represented by the error bars attached to each column.

8.5.2 Embedded Figures Task

On running the bivariate Pearson correlation, no statistically significant relationship between AQ score and EFT score was found ($r=0.266$, $p=0.134$). There was a statistically significant difference between groups on mean EFT score ($t(31)=2.1$, $p=0.044$, $d=0.73$), with the NT ($M=5813$, $SD=3181$) group outperforming the ASD ($M=9060$, $SD=5362$) group and no significant differences in EFT scores between males and females ($t(31)=.007$, $p=.995$).

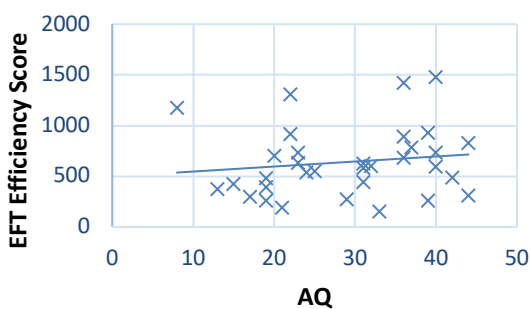


Figure 8.3 Relationship between AQ and EFT efficiency score

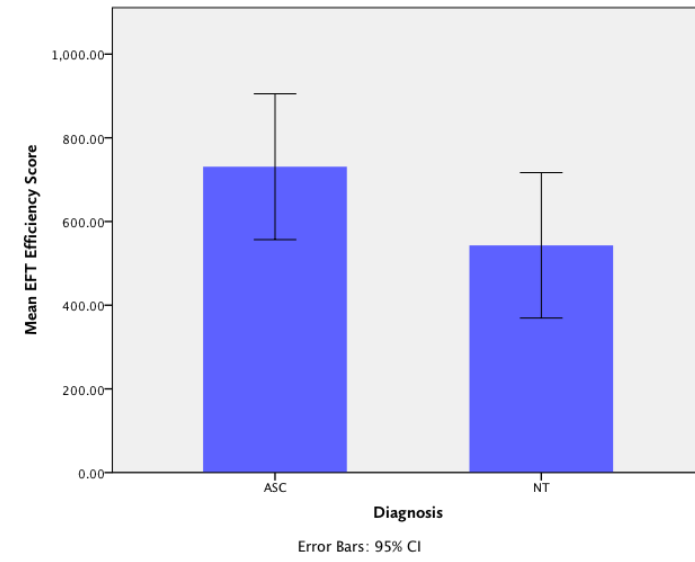


Figure 8.4 Mean EFT efficiency scores for ASD and NT groups

8.5.3 Change Blindness and EFT Performance

EFT efficiency score was significantly correlated with reaction time to both social ($r=0.427$, $p=0.013$) and non-social ($r=0.433$, $p=0.012$) changes on the change blindness task.

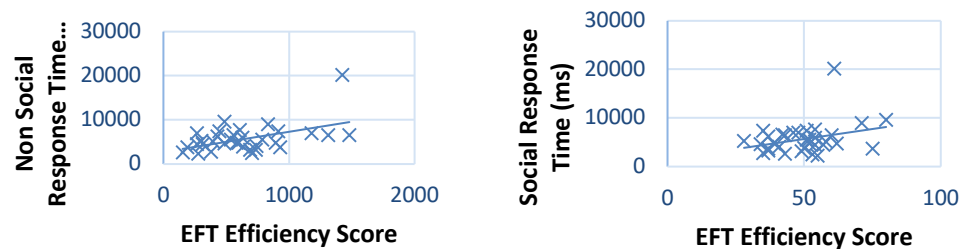


Figure 8.5 Correlations between EFT efficiency score and response times to each Change Blindness condition

8.5.4 State/Trait Anxiety

Trait anxiety was correlated with reaction time to social changes ($r=0.352$, $p=0.045$); the higher the trait anxiety score, the longer it took participants to spot social

changes. There was, however, no significant correlation between trait anxiety score and reaction time to the non-social changes ($r=0.249$, $p=0.163$). Controlling for Trait anxiety and for State anxiety did not affect the strength or significance of the relationships between EFT and change blindness performance.

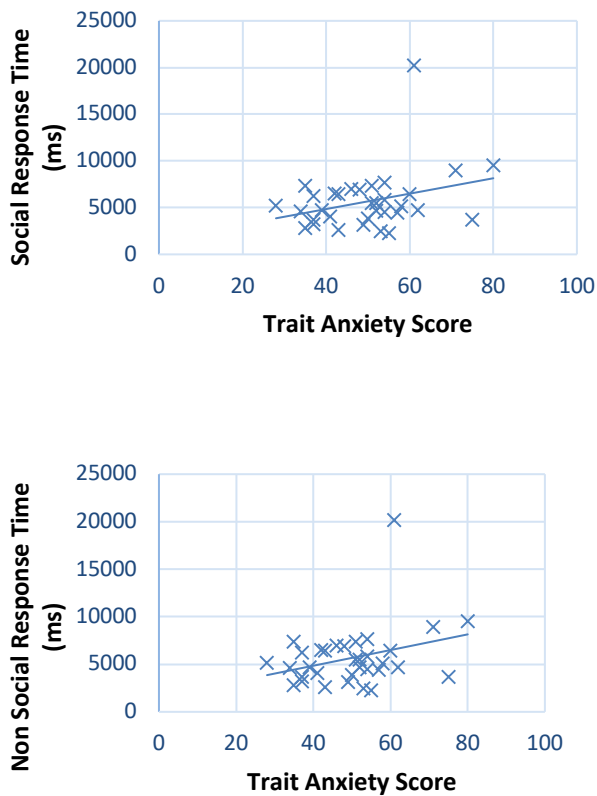


Figure 8.6 Relationship between Trait anxiety scores and mean response times to each Change Blindness condition

8.6 Discussion

The change blindness study presented in Chapter 5 found that autistic traits were related to enhanced change blindness for social changes. It would therefore be expected that in a group with ASD, this enhanced social change blindness would be even more pronounced. However, this study actually found not only no difference between ASD and NT groups on response times for detecting social and non-social changes, but that non-social changes took significantly longer to detect than social changes across the sample. This indicates that social attention is not impaired in

ASD, although it is curious that non-social attention is. However, results from Studies 1 and 5 (Chapters 4 and 7) would suggest that the salience of non-social stimuli is related to autistic traits, so it may be that the images used in these change blindness studies and the location of the changes in them are not suitable for making these comparisons. Both the present study and Kikuchi et al.'s study used images of naturalistic scenes in which there were multiple objects/vehicles etc. It is known that the more complex the scene in a change blindness task, the more enhanced the change blindness will be (Rensink, 2002). Given the heterogeneity in ASD with regards to non-social objects of interest, it may be that different aspects of the images capture initial attention and that slower, conscious visual search strategies then take over, enabling those in the ASD group (who were all high functioning adults) to consciously choose to attend to social aspects of the images. While many change blindness studies have found attenuated change blindness in children and adolescents with ASD, there have been very few to have replicated these results in adults (Ashwin et al., 2017), so the poor performance of the adults with ASD on this task is not inconsistent with findings from other change detection studies with ASD samples. As mentioned in Chapter 5, change detection is complex and depends on a variety of factors. The naturalistic scenes used in this study, while attempting to be ecologically valid, may make it difficult to understand what aspect of attention is being measured. Future studies on change blindness to social compared with non-social information should employ eye-tracking measures to better be able to understand what processes and strategies are being employed, and what is being attended to, when changes are missed or detected.

Chapter 9

General Discussion

9.1 Overview

This chapter summarises the findings of the six experimental studies presented in this thesis and explores what they contribute to the understanding of non-social cognition across the autism spectrum. The results from Studies 1 and 2 with the NT sample and Studies 4 and 5 with the ASD and matched controls are then consolidated and analysed as a larger sample that represents the spectrum of autistic traits. These findings are presented and discussed along with the limitations of the research and suggestions for potential future research.

9.2 Summary of the Research

The aim of this thesis was to explore aspects of non-social cognition across the autism spectrum in order to contribute to understanding of some of the cognitive processes and mechanisms that might underlie the systemizing drive and abilities seen in ASD. Experiments were designed that measured aspects of attention and affective response in relation to non-social and social stimuli alongside a test of aptitude for local processing and measures of anxiety, which is thought to be related to non-social behaviours and interests in ASD. Another study was designed in order to better understand the components of systemizing, which included separate measures of drive and ability to systemize along with measures of Type 1 (intuitive) and Type 2 (deliberative) cognitive processing styles in order to investigate whether dual process accounts of cognition could help explain the characteristics of systemizing. This design was administered separately to a NT sample and later an ASD/matched control sample (although confirmation of diagnosis was not possible for all participants).

This work makes several novel contributions to knowledge. Research into the non-social features of ASD that include special interests is a relatively new area, and the affective motivation towards non-social stimuli in ASD is only more recently being

explored. This research was the first to use electrophysiological measures to investigate orienting to non-social images of special interests in relation to autistic traits in the neurotypical population, and was the first to tailor stimuli to each participant's personal hobby or interest in a large NT sample in order to investigate special/circumscribed interests in the autism spectrum (Singleton et al., 2014). This work also sought to elucidate the relationship between anxiety and restricted interests in ASD, finding that preferential attention to RIs is related to autistic symptomatology and not to anxiety. The use of exactly the same methodology for a study with an NT sample, assessed for level of autistic traits, and a second study with a group of ASD participants and matched controls enables a very precise comparison of findings, to explore attention and orienting to non-social stimuli and restricted interests across the autism spectrum. Studies 3 and 4 (Chapter 6) contributed valuable findings on the drive and ability components of systemizing, which a recent paper by Baron-Cohen and Lombardo (2017) has called for, and contributes to the new area of dual process accounts of autism.

9.2.1 Summary of Results

Study 1 (Chapter 4) measured electrodermal activity in 46 NT participants as they view images of social and non-social objects, and objects that were directly related to their own professed hobby or interest. Autistic traits were measured with the Autism Quotient and the data revealed that a higher number of autistic traits was related to preferential orienting towards non-social stimuli and that the higher the score on the AQ, the greater the difference between physiological response to social and non-social stimuli. Fewer autistic traits was related to preferential orienting to cartoon faces, supporting the theory that physiological arousal to social and non-social stimuli differs across the subclinical range of the autism spectrum. The hypothesis that AQ would be correlated with arousal to the non-social stimuli of interest was not borne out. Response to the non-social of interest and social-faces conditions was significantly correlated, suggesting that in the NT population, items of interest prompt a stronger orienting response, with human faces being of inherent interest in neurotypical individuals. Consistent with previous research, Trait anxiety was significantly correlated with autistic traits—as there is a high prevalence of anxiety in ASD, it would be suspected that subclinical autistic traits would be related to a general disposition towards anxiety. When controlling for anxiety, the significant

positive relationship between AQ and response to the non-social of interest condition remained so, indicating that in the subclinical autism spectrum, anxiety does not play a role in the stronger orienting response towards non-social stimuli. A significant correlation between Trait anxiety and SCR to the non-social of interest condition suggested that anxiety may play a role in preferential orienting to special interests, a relationship that has been suggested in the literature on restricted interests and repetitive behaviours.

A change blindness flicker paradigm was used in Study 2 (Chapter 5) to explore attention to social and non-social information in naturalistic scenes that contained both people and mechanical type objects, with a sample of 46 NT participants having to detect changes that occurred at either social or non-social locations. Participants were also administered the AQ to measure autistic traits and the Embedded Figures Task, a test of local processing or field-independence that people with ASD usually perform well on. Participants overall took significantly longer to detect non-social changes, which is consistent with evidence from other research that neurotypical individuals exhibit an attentional bias to social information. AQ score was significantly related to enhanced change blindness for social changes, which is consistent with results from other research suggesting that autistic traits are related to reduced attention to social stimuli. Contrary to predictions, AQ was not related to reduced change blindness for non-social changes. Enhanced change blindness to social changes was associated with the Social Skill and Imagination subscales of the AQ. Enhanced change blindness to non-social changes was also correlated with the Imagination subscale of the AQ, as was the efficiency score for the EFT, indicating that worse performance on the EFT was related to poor ability to detect non-social changes. Poor performance on the EFT was also related to enhanced social change blindness, but the relationships between EFT and time taken to spot social and non-social changes became weaker and insignificant when controlling for Trait anxiety, suggesting that general predisposition towards anxiety interferes with attentional processes, as has been demonstrated in the field of attention research. EFT score was correlated with the Imagination subscale of the AQ, indicating that the poorer self-reported imagination ability was related to poorer performance on the EFT, which was unexpected. Performance on the EFT and autistic traits were otherwise unrelated to each other in this sample. Change

blindness to social and to non-social changes were significantly correlated, suggesting that the social and non-social attention are related to one another.

Chapter 6 reported two studies—Study 3 and Study 4—that both used the same methodology, one with an NT sample and one with an ASD group and NT controls matched for age and sex. These studies consisted of a battery of measures that were administered online so confirmation of ASD diagnosis could not be confirmed for all participants in the ASD group. Participants completed the Systemizing Quotient Short, the Test of Logical Thinking and the Rational Experiential Inventory. Both studies found that SQ was correlated with correct responses on the TOLT but was not correlated with the ability to justify those responses using appropriate logical reasoning. In the ASD/NT study, those reporting an ASD diagnosis exhibited significantly greater performance on the TOLT in terms of getting the answer correct but were significantly more likely to get the correct answer along with the incorrect reasoning than were the NT group. SQ was significantly correlated with both subscales of the “need for cognition” construct of the REI in the NT sample, and with only the Rational-Engagement subscale in the ASD/NT sample. There was no significant relationship between SQ and the “faith in intuition” subscales of the REI in either study. In the ASD/NT study, the SQ was only correlated with the Rational-Engagement subscale, and the ASD group scored significantly higher on this subscale than the NT group. Sex differences were found in the NT only study, with males scoring higher than females on the SQ and the Rational-Engagement and Rational-Ability subscales of the REI. In the ASD/NT sample, sex differences were found only in SQ score, with males scoring significantly higher than females.

Study 5 (Chapter 7) used the same methodology as Study one, including administering the AQ to measure autistic traits, but with a group of ASD participants and NT controls matched for age, sex and educational attainment level. It was found that the ASD group exhibited a significantly stronger physiological response to images related to their special interest than controls, and there were no differences between the two groups on responses to any of the other stimulus conditions. Overall AQ score was significantly correlated with SCR to the non-social of interest condition when State anxiety was controlled for. AQ was again correlated with Trait anxiety, as well as State anxiety.

Study 6 (Chapter 8) followed the same methodology as Study 2, but with a group of ASD participants and NT controls matched for age, sex and educational attainment level. There were no differences between the ASD and NT groups in change blindness response times to social or non-social changes and AQ was not related to performance on the change blindness task. Response times to the social and non-social changes were significantly related to one another. Overall, participants across both groups took longer to detect non-social changes. The NT group performed significantly better than the ASD group on the Embedded Figures Task, and EFT performance was related to performance on both conditions of the change blindness task. Higher trait anxiety was associated with enhanced change blindness for social changes.

9.3 Combined Analyses

9.3.1 Physiological Response to Social & Non-Social Stimuli

The data from Studies 1 and 5 were combined for an analysis of physiological responses to social and non-social stimuli in relation to autistic traits across the spectrum. This resulted in a sample of 77 in total with an age range from 18 to 67 (36 females (mean age=30.33, SD=11.64) and 41 males (mean age=31.93, SD=14.60)). The mean AQ score of the whole sample was 22 (SD=9.54; females mean AQ=20, SD=8.87; males mean AQ=23.46, SD=9.95) which would be fairly high in an NT sample but because the sample includes 17 people with a diagnosis of ASD, it represents the wider autism spectrum. As with the original analyses, bivariate correlations were run to investigate the relationship between AQ scores and orienting responses to the four stimulus conditions. AQ was significantly correlated with SCRs to both the non-social ($r=.330$, $p=.003$) and non-social of interest ($r=.305$, $p=.007$) conditions, was not significantly correlated with the Social-Faces condition ($r=.191$, $p=.097$) and was significantly negatively correlated with the Social-Cartoon condition ($r=-.306$, $p=.039$). AQ was also significantly positively correlated with both Trait ($r=.530$, $p<.001$) and State ($r=.291$, $p=.010$) anxiety. Independent samples t-tests revealed no significant sex differences on AQ, anxiety scores or any of the stimulus conditions. This suggests that, across the spectrum of autistic traits ranging from low AQ to a clinical diagnosis of ASD, there is a pattern of preferential orienting to non-social stimuli that is related to autistic symptomatology. The results of Study 1 found stronger orienting to the non-social

condition was related to higher autistic traits and in Study 2, a diagnosis of ASD was related to stronger orienting to images of restricted interests.

Put together, these relationships with autistic traits (non-social and non-social of interest) both emerge as significant, suggesting that fewer or less severe autistic traits relate to stronger autonomic arousal to general non-social items and clinically significant ASD traits relate to specific personal interests. This could imply a narrowing of focus with more severe ASD phenotypic expression, which would support the characterisation of the cognitive style of ASD as being narrow in focus, locally-oriented and preoccupied with an insistence on sameness. This could support both the EPF and E-S theories, as a general preferential orienting towards novel non-social stimuli (as opposed to social stimuli or the same non-social stimuli again and again) due to a certain level of enhanced perceptual functioning could underlie some milder social dysfunction associated with subclinical autistic traits, while a stronger bias towards the same, specific non-social perceptual features could manifest as an orientation away from social input and lead to much more severe socially-related deficits. This type of attentional bias could be characterized as a drive to systemize along with reduced empathizing. The negative correlation between AQ and the cartoon face condition also supports E-S theory, indicating that across the spectrum, those with few autistic traits exhibit a larger response to abstract face like pictures, most people along the middle of the subclinical spectrum orient to photographs of human faces (hence why there is no relationship between the faces condition and AQ) and those with the highest number of autistic traits and an ASD diagnosis orient strongly to items related to their restricted interest.

A bottom-up attentional bias for certain non-social stimuli (manifesting as a drive to systemize) is analogous to the apparent neural basis for being socially motivated that appears to be hardwired early in life in NT individuals. Evidence suggests that infants are born with visual biases that ensure they will fixate on faces (Johnson, 1991; 2005) and it is proposed that this initial exogenously controlled orienting towards others leads to eventual expertise in faces and social behaviour, facilitating social understanding. If the drive to systemize is analogous, then it is possible that the mechanisms by which NT infants innately and preferentially orient to faces or protoface stimuli may in others instead preferentially orient towards other types of shapes or patterns. Developmental accounts of face perception deficits in ASD had

suggested that innate social orienting may be impaired or absent, but studies revealed intact orienting to protoface stimuli in autistic individuals (Shah et al., 2013).

Conversely, there is intact orienting towards systems-related stimuli in the NT population in people who might generally be empathizers but have little real skill with systems-related thinking beyond simple arithmetic (Baron-Cohen & Lombardo, 2017).

These results would not support the Social Motivation Hypothesis (Chevallier, 2012), as they indicate that the socially relevant autistic symptoms arise from motivation towards the non-social domain in varying degrees, and not away from the social. These results together suggested a bottom-up attentional bias towards non-social stimuli across the autism spectrum from neurotypical to clinical populations, which could be consistent with both the Enhanced Perceptual Functioning (Mottron & Burack, 2001; Mottron et al., 2006) and Empathizing–Systemizing theories.

Further research therefore needs to establish whether increased physiological arousal increases attention or vice versa. The results of this current study provide a foundation for further exploration of physiological responses to non-social stimuli in an ASD population and across the autism spectrum; future studies are needed to investigate the relationship between attention to both social and non-social stimuli and physiological response in ASD and NT samples to determine whether autonomic arousal and motivation towards non-social stimuli does indeed play a role in the restricted interests and repetitive behaviours characteristic of autism.

9.3.2 Change Blindness & Embedded Figures

The data from Studies 2 and 6 were combined for analysis of performance on the EFT as a measure of attention to detail and the change blindness flicker paradigm with social and non-social changes, as a measure of attentional biases, in relation to autistic traits and anxiety across the autism spectrum. Results are similar to those in Study 6 with the ASD and control group sample. AQ score was not correlated with response times to either social or non-social changes, nor was it correlated with performance on the EFT. Again, response times to the social and non-social changes were significantly related ($r=.723, p<.001$). State and Trait anxiety scores were correlated with AQ but not the other measures. Partial correlations controlling for anxiety scores revealed no significant relationships between the other measures. These results (and those from Study 6) conflict with evidence that people with ASD

and a higher number of autistic traits have superior performance on measures of attention to detail and local processing.

The findings in Study One (Chapter 4) indicated that autistic traits were related to stronger physiological responses to non-social stimuli, and in Study Five (Chapter 7) it was found that those with ASD exhibited stronger autonomic responses for non-social stimuli related to their interests than did controls. This indicates that autistic traits are related to a stronger orienting response to non-social stimuli, and that this non-social orienting is more pronounced in ASD for items related to restricted interests. As the change detection paradigm used in these studies measures attentional preference, stronger orienting to non-social stimuli would be expected. However, as mentioned in Chapter 8, it may be that the change blindness paradigm used involved scenes that were too complex with too many competing and distracting features that make it difficult to really understand what the results mean. Naturalistic scenes were chosen in order to make the experiment as ecologically valid as possible, but given the nature of the task itself, change blindness paradigms do not really mimic visual search and change detection in real life settings. One way of using such complex scenes for change blindness studies, with multiple social and non-social features, would be to use eye tracking concurrently in order to evaluate which aspects are attended to first and in order to understand whether the changed non-social/social feature is being overlooked for some other background feature that may have salience for the individual observer, instead of concluding that longer detection times for social or non-social changes means that there is a deficit in attention to that domain. This is especially important when studying a heterogeneous disorder like autism, because the many idiosyncratic interests present across and within individuals with the disorder could mean some other detail in the background of a scene not considered as a factor, but which would fit into the category of stimuli under study, has salience for individual participants, meaning that the full picture is not grasped. Eye tracking has been used in conjunction with change blindness tasks to clarify areas of attention (Bayraktar & Bayram, 2013), and future research on understanding attention biases in ASD could benefit from adopting this method.

9.4 Interpretation & Conclusions

The results of this research provide some evidence for the role of exogenous orienting to non-social stimuli in the autism spectrum, including to general non-social images in NT participants with a high degree of autistic traits, and to images of personal restricted interests in those with ASD. Skin conductance responses, as used in these studies, have been associated with the emotional and motivational salience of a stimulus (Critchley, 2002; Sequeira et al., 2009). This suggests that there are perceptual features of certain non-social stimuli that exogenously engage the attention of the sympathetic system in ASD and its broader phenotype in a way that other, social stimuli do not. The perceptual and attentional systems of NT individuals will typically be engaged in this way in response to social stimuli (Mares et al., 2016; Driver et al., 1999). There exists a lot of research to suggest that reduced attention to social information in ASD is related to the preferential orienting towards, and enhanced motivation to engage with, non-social stimuli (Klin et al., 2009; Watson et al., 2015; Unruh et al., 2016) rather than reduced social motivation. The results of the current research, while finding enhanced responses to non-social stimuli in ASD and high AQ participants, did not find a corresponding reduction in social orienting and other studies have found intact social orienting in ASD (Johnson, 2014).

This evidence seems to point towards a great motivation towards non-social things in ASD (i.e. drive to systemize) that originates at a perceptual level with the particular sensory qualities of various objects, systems and the rule-governed relations between them prompting an autonomic response that stimulates motivation (Mottron et al., 2006). The fact that the ASD group in Study 5 responded more strongly to their restricted interest and the high AQ NT participants responded more strongly to unrelated non-social stimuli suggests that there might be degrees of intensity of non-social response throughout the autism spectrum, with those in the subclinical spectrum who respond affectively to non-social items and concepts simply maintaining an enhanced interest in these domains, responding to non-social novelty, but less strongly than those with ASD, who perhaps experience such intense motivational stimulation when perceiving particular non-social qualities early in life, that they become more fixated on the stimuli and so reinforce

their attachment and drive towards to it, akin to the more pronounced autonomic responses people typically experience towards loved ones. This would be consistent with the Enhanced Perceptual Functioning theory of autism which suggests that restricted interests and repetitive behaviours (and savant abilities) in autism are driven by low-level enhanced perceptual processes that involve stronger and more discriminatory sensory experiences (Mottron et al., 2013). In future research, the use of saliency maps in change blindness tasks could help to clarify whether (and which) non-social features are attend to exogenously in people with ASD and across the autistic spectrum.

The parallels between the NT individual's experience and understanding of, and behaviour towards, people (empathizing) and the ASD individual's experience and understanding of, and behaviour towards, the rules, things and patterns (systemizing) suggest that the non-social features of ASD might involve a kind of domain-swap synaesthesia, whereby the structures, networks, neurons and processes in the brain that usually guide social interaction and understanding of the social domain and its relationships, beginning with the innate protoface recognition system (Frank et al., 2009), are instead tuned to the non-social domain. As discussed in Chapter 1, there is evidence that areas of the 'social brain' thought to be dysfunctional in ASD are actually intact and will function in a non-socially directed way (e.g. Grelotti et al., 2005; Rosset et al., 2008).

The mirror neuron system has been implicated in ASD (Gallese & Goldman, 1998) and contributes to the mapping of one's own body and the states of the body while executing motor functions, as well as mapping the bodies of others (Murata et al., 2016). Alongside MNs are canonical neurons, which respond to the presentation of objects or the objects themselves (Rajmohan & Mohandas, 2007). Alexithymia is a condition characterized by an inability to identify one's own emotional states, it has a high co-occurrence rate in ASD (Shah, 2016) and a recent study found that alexithymia in people with ASD was associated with reduced awareness of their own physiological arousal as measured by skin conductance responses when viewing images with emotional salience (Gaigg, Cornell & Bird, 2018). Synaesthesia is more often found in ASD, along with cortical hyperconnectivity and difficulties with interoception, so it seems plausible that a kind of object-social synaesthesia occurs in ASD, whereby the system that in NT individuals is set up for mirroring others,

orienting to others and representing self-other relationships mediated by an awareness of one's own mental and physical states, somehow crosses wires with the canonical system used for representing and attending to non-social stimuli and patterns and rules in the environment—i.e. the canonical neurons activate for social stimuli and the mirror neurons for the non-social, which sounds like Mottron et al.'s (2013) concept of veridical mapping, which describes how low-level, enhanced perception allows for the bottom-up, rapid and unconscious cognitive mapping of various non-social phenomenological qualities of the world and the relations between them. This could explain the strong emotional drive towards the non-social and seemingly intuitive understanding of patterns in mathematics and music seen in some savants with ASD. It could also explain the wide heterogeneity seen in ASD, as there is a higher prevalence of synaesthesia among people with ASD (Johnson et al., 2011) the condition has been linked to savant syndrome (Baron-Cohen et al., 2007) and like autism, it is a heterogeneous and polygenetic condition (Brang & Ramachandran, 2011) that is also thought to constitute a continuum across the general population (Simner, 2012). Future research could investigate these ideas further.

Some of the findings of Study 3 and Study 4 in this thesis may support the notion that hyper-systemizing is perhaps more of a lower-level, affective, perceptual and spontaneous process than it would appear. The idea that systemizing drive and ability could arise from bottom-up, sensory and affective processes seems unintuitive, given that conceptions of systemizing involve rules, patterns, logical reasoning, mathematics and engineering etc., which are usually conceived of as requiring a higher-order, more rational and deliberative cognition. However, the studies outlined in Chapter 6 both found that while those who reported high drive to systemize also exhibited superior ability in answering correctly on the Test of Logical Thinking, they were also those who made the most errors on identifying the logical reasoning behind their right answers. So, while these studies established that systemizing drive and ability are indeed related, the comparative inability of both high SQ individuals and individuals with ASD to justify their answers with the correct reasoning suggests that there may be something other than slow, deliberative System 2 type cognitive processes mediating the relationship between being motivated towards rules and systems and the knowledge of how to successfully operate on or manipulate them.

High systemizing drive was, however, related to self-reported preference for deliberative type thinking and not for intuitive type thinking. It may be that if we define concepts such as mathematical and logical reasoning problems as being inherently related to, or solved by, Type 2 cognitive processes, then we may miss an intuitive, Type 1 type mechanism for solving such problems. The measures used in these studies (the TOLT and the REI) were developed with NT population and it has been suggested that self-report measures may not be reliable in people with autism (Berthoz & Hill, 2005). Future research could attempt to examine further whether high systemizers really cannot provide the reasoning for responses to the reasoning tasks they perform well on, and if not, to further investigate the mechanisms by which they formulate their answers. To explore further the cognitive dimensions of empathizing and systemizing in relation to deliberative and intuitive styles of thinking, it may be useful to develop a more thorough conception of 'intuitive systemizing' and some way of reliably measuring it.

References

- Adams, R. J. (1987). Visual acuity from birth to 5 months as measured by habituation: A comparison to forced-choice preferential looking. *Infant Behavior and Development*, *10*(3), 239–244. [https://doi.org/10.1016/0163-6383\(87\)90014-2](https://doi.org/10.1016/0163-6383(87)90014-2)
- Adolphs, R. (2009). The Social Brain: Neural Basis of Social Knowledge. *Annual Review of Psychology*, *60*(1), 693–716.
<https://doi.org/10.1146/annurev.psych.60.110707.163514>
- Adolphs, R., Russell, J. A., & Tranel, D. (1999). A Role for the Human Amygdala in Recognizing Emotional Arousal From Unpleasant Stimuli. *Psychological Science*, *10*(2), 167–171. <https://doi.org/10.1111/1467-9280.00126>
- Ahlawat, K. S., & Billeh, V. Y. (1987). Comparative investigation of the psychometric properties of three tests of logical thinking. *Journal of Research in Science Teaching*, *24*(2), 93–105. <https://doi.org/10.1002/tea.3660240202>
- Allan, J. (2018). *An analysis of Daniel Kahneman's Thinking, fast and slow*. London: Routledge.
Retrieved from
<http://search.ebscohost.com/login.aspx?direct=true&scope=site&db=nlebk&db=nlabk&AN=1723203>
- Allen, R., Davis, R., & Hill, E. (2013). The Effects of Autism and Alexithymia on Physiological and Verbal Responsiveness to Music. *Journal of Autism and Developmental Disorders*, *43*(2), 432–444. <https://doi.org/10.1007/s10803-012-1587-8>
- Almeida, R. A., Dickinson, E. J., Maybery, M. T., Badcock, J. C., & Badcock, D. R. (2010). A new step towards understanding Embedded Figures Test performance in the autism spectrum: The radial frequency search task. *Neuropsychologia*, *48*(2), 374–381. <https://doi.org/10.1016/j.neuropsychologia.2009.09.024>

- Almeida, R. A., Dickinson, J. E., Maybery, M. T., Badcock, J. C., & Badcock, D. R. (2014). Enhanced global integration of closed contours in individuals with high levels of autistic-like traits. *Vision Research*, *103*, 109–115. <https://doi.org/10.1016/j.visres.2014.08.015>
- Ames, C., & Fletcher-Watson, S. (2010). A review of methods in the study of attention in autism. *Developmental Review*, *30*(1), 52–73. <https://doi.org/10.1016/j.dr.2009.12.003>
- Anselme, P. (2010). The uncertainty processing theory of motivation. *Behavioural Brain Research*, *208*(2), 291–310. <https://doi.org/10.1016/j.bbr.2009.12.020>
- Ashwin, C., Wheelwright, S., & Baron-Cohen, S. (2006). Attention bias to faces in Asperger Syndrome: a pictorial emotion Stroop study. *Psychological Medicine*, *36*(6), 835–843. <https://doi.org/10.1017/s0033291706007203>
- Ashwin, C., Wheelwright, S., & Baron-Cohen, S. (2017). Differences in change blindness to real-life scenes in adults with autism spectrum conditions. *PLOS ONE*, *12*(10). <https://doi.org/10.1371/journal.pone.0185120>
- Austin, E. J. (2005). Personality correlates of the broader autism phenotype as assessed by the Autism Spectrum Quotient (AQ). *Personality and Individual Differences*, *38*(2), 451–460. <https://doi.org/10.1016/j.paid.2004.04.022>
- Auyeung, B., Baron-Cohen, S., Chapman, E., Knickmeyer, R., Taylor, K., & Hackett, G. (2006). Foetal testosterone and the child systemizing quotient. *European Journal of Endocrinology*, *155*(suppl 1). <https://doi.org/10.1530/eje.1.02260>
- Auyeung, B., Knickmeyer, R., Ashwin, E., Taylor, K., Hackett, G., & Baron-Cohen, S. (2012). Effects of Fetal Testosterone on Visuospatial Ability. *Archives of Sexual Behavior*, *41*(3), 571–581. <https://doi.org/10.1007/s10508-011-9864-8>
- Auyeung, B., Lombardo, M. V., & Baron-Cohen, S. (2013). Prenatal and postnatal hormone effects on the human brain and cognition. *Pflügers Archiv - European Journal of Physiology*, *465*(5), 557–571. <https://doi.org/10.1007/s00424-013-1268-2>

- Back, E., & Apperly, I. A. (2010). Two sources of evidence on the non-automaticity of true and false belief ascription. *Cognition*, *115*(1), 54–70.
<https://doi.org/10.1016/j.cognition.2009.11.008>
- Baio, J., Wiggins, L., Christensen, D. L., Maenner, M. J., Daniels, J., Warren, Z., ... White, T. (2018). Prevalence of autism spectrum disorder among children aged 8 years—Autism and Developmental Disabilities Monitoring Network, 11 Sites, United States, 2014. *MMWR Surveillance Summaries*, *67*. Retrieved from
http://scholar.google.com/scholar?q=Prevalence of autism spectrum disorder among children aged 8 years—Autism and Developmental Disabilities Monitoring Network, 11 Sites, United States, 2014&btnG=&hl=en&num=20&as_sdt=0%2C22
- Baird, G., Simonoff, E., Pickles, A., Chandler, S., Loucas, T., Meldrum, D., & Charman, T. (2006). Prevalence of disorders of the autism spectrum in a population cohort of children in South Thames: the Special Needs and Autism Project (SNAP). *The Lancet*, *368*(9531), 210–215. [https://doi.org/10.1016/s0140-6736\(06\)69041-7](https://doi.org/10.1016/s0140-6736(06)69041-7)
- Bakel, M. M. E. van, Delobel-Ayoub, M., Cans, C., Assouline, B., Jouk, P.-S., Raynaud, J.-P., & Arnaud, C. (2015). Low but Increasing Prevalence of Autism Spectrum Disorders in a French Area from Register-Based Data. *Journal of Autism and Developmental Disorders*, *45*(10), 3255–3261. <https://doi.org/10.1007/s10803-015-2486-6>
- Baker, S. M., Milivojevic, A., Kraycar, T., Holt, B., & Gade, S. (2014). Secular Trend of Sex Ratio and Symptom Patterns Among Children With Autism Spectrum Disorders. *Global Advances in Health and Medicine*, *3*(3), 92–101.
<https://doi.org/10.7453/gahmj.2014.028>
- Bargiela, S., Steward, R., & Mandy, W. (2016). The Experiences of Late-diagnosed Women with Autism Spectrum Conditions: An Investigation of the Female Autism

- Phenotype. *Journal of Autism and Developmental Disorders*, 46(10), 3281–3294.
<https://doi.org/10.1007/s10803-016-2872-8>
- Barnhill, G. P. (2007). Outcomes in Adults With Asperger Syndrome. *Focus on Autism and Other Developmental Disabilities*, 22(2), 116–126.
<https://doi.org/10.1177/10883576070220020301>
- Baron-Cohen, S. (1989). Do autistic children have obsessions and compulsions? *British Journal of Clinical Psychology*, 28(3), 193–200. <https://doi.org/10.1111/j.2044-8260.1989.tb01369.x>
- Baron-Cohen, S. (2005). Two new theories of autism: hyper-systemising and assortative mating. *Archives of Disease in Childhood*, 91(1), 2–5.
<https://doi.org/10.1136/adc.2005.075846>
- Baron-Cohen, S. (2009). Autism: The Empathizing–Systemizing (E-S) Theory. *Annals of the New York Academy of Sciences*, 1156(1), 68–80. <https://doi.org/10.1111/j.1749-6632.2009.04467.x>
- Baron-Cohen, S, Bor, D., & of ..., B.-J. (2007). Savant memory in a man with colour form-number synaesthesia and asperger. *Savant Memory in a Man with Colour Form-Number Synaesthesia and Asperger*. Retrieved from
<http://www.ingentaconnect.com/content/imp/jcs/2007/00000014/F0020009/art00011>
- Baron-Cohen, S., Jolliffe, T., Mortimore, C., & Robertson, M. (1997). Another Advanced Test of Theory of Mind: Evidence from Very High Functioning Adults with Autism or Asperger Syndrome. *Journal of Child Psychology and Psychiatry*, 38(7), 813–822.
<https://doi.org/10.1111/j.1469-7610.1997.tb01599.x>
- Baron-Cohen, S, O’Riordan, M., Stone, V., Jones, R., & Plaisted, K. (1999). Recognition of faux pas by normally developing children and children with Asperger syndrome

- or high-functioning autism. *Journal of Autism and Developmental Disorders*, 29(5), 407–418.
- Baron-Cohen, S., Ring, H. A., Bullmore, E. T., Wheelwright, S., Ashwin, C., & Williams, S. C. R. (2000). The amygdala theory of autism. *Neuroscience & Biobehavioral Reviews*, 24(3), 355–364. [https://doi.org/10.1016/s0149-7634\(00\)00011-7](https://doi.org/10.1016/s0149-7634(00)00011-7)
- Baron-Cohen, S, Wheelwright, S., & of autism and ..., S.-R. (2001). The autism-spectrum quotient (AQ): Evidence from asperger syndrome/high-functioning autism, males and females, scientists and mathematicians. *Journal of Autism and Developmental Disorders*. <https://doi.org/10.1023/A:1005653411471>
- Baron-Cohen, Simon. (2002). The extreme male brain theory of autism. *Trends in Cognitive Sciences*, 6(6), 248–254. [https://doi.org/10.1016/s1364-6613\(02\)01904-6](https://doi.org/10.1016/s1364-6613(02)01904-6)
- Baron-Cohen, Simon. (2006). The hyper-systemizing, assortative mating theory of autism. *Progress in Neuro-Psychopharmacology and Biological Psychiatry*, 30(5), 865–872. <https://doi.org/10.1016/j.pnpbp.2006.01.010>
- Baron-Cohen, Simon. (2008). Autism, hypersystemizing, and truth. *The Quarterly Journal of Experimental Psychology*, 61(1), 64–75. <https://doi.org/10.1080/17470210701508749>
- Baron-Cohen, Simon. (2010). Empathizing, systemizing, and the extreme male brain theory of autism. In *Progress in Brain Research* (Vol. 186, pp. 167–175). Elsevier. <https://doi.org/10.1016/B978-0-444-53630-3.00011-7>
- Baron-Cohen, Simon, Ashwin, E., Ashwin, C., Tavassoli, T., & Chakrabarti, B. (2009). Talent in autism: hyper-systemizing, hyper-attention to detail and sensory hypersensitivity. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 364(1522), 1377–1383. <https://doi.org/10.1098/rstb.2008.0337>
- Baron-Cohen, Simon, & Belmonte, M. K. (2005). AUTISM: A Window Onto the Development of the Social and the Analytic Brain. *Neuroscience*, 28(1), 109–126. <https://doi.org/10.1146/annurev.neuro.27.070203.144137>

- Baron-Cohen, Simon, Johnson, D., Asher, J., Wheelwright, S., Fisher, S. E., Gregersen, P. K., & Allison, C. (2013). Is synaesthesia more common in autism? *Molecular Autism*, 4(1), 40. <https://doi.org/10.1186/2040-2392-4-40>
- Baron-Cohen, Simon, Leslie, A. M., & Frith, U. (1985). Does the autistic child have a “theory of mind”? *Cognition*, 21(1), 37–46. [https://doi.org/10.1016/0010-0277\(85\)90022-8](https://doi.org/10.1016/0010-0277(85)90022-8)
- Baron-Cohen, Simon, & Lombardo, M. V. (2017). Autism and talent: the cognitive and neural basis of systemizing. *Dialogues in Clinical Neuroscience*, 19(4), 345–353.
- Baron-Cohen, Simon, Lombardo, M. V., Auyeung, B., Ashwin, E., Chakrabarti, B., & Knickmeyer, R. (2011). Why Are Autism Spectrum Conditions More Prevalent in Males? *PLoS Biology*, 9(6). <https://doi.org/10.1371/journal.pbio.1001081>
- Baron-Cohen, Simon, Murphy, L., Chakrabarti, B., Craig, I., Mallya, U., Lakatošová, S., ... Warrier, V. (2014). A Genome Wide Association Study of Mathematical Ability Reveals an Association at Chromosome 3q29, a Locus Associated with Autism and Learning Difficulties: A Preliminary Study. *PLoS ONE*, 9(5). <https://doi.org/10.1371/journal.pone.0096374>
- Baron-Cohen, Simon, Richler, J., Bisarya, D., Gurunathan, N., & Wheelwright, S. (2003). The systemizing quotient: an investigation of adults with Asperger syndrome or high-functioning autism, and normal sex differences. *Philosophical Transactions of the Royal Society of London B: Biological Sciences*, 358(1430), 361–374. <https://doi.org/10.1098/rstb.2002.1206>
- Baron-Cohen, Simon, Ring, H., Chitnis, X., Wheelwright, S., Gregory, L., Williams, S., ... Bullmore, E. (2006). fMRI of parents of children with Asperger Syndrome: A pilot study. *Brain and Cognition*, 61(1), 122–130. <https://doi.org/10.1016/j.bandc.2005.12.011>

- Baron-Cohen, Simon, Wheelwright, S., Hill, J., Raste, Y., & Plumb, I. (2001). The “Reading the Mind in the Eyes” Test Revised Version: A Study with Normal Adults, and Adults with Asperger Syndrome or High-functioning Autism. *Journal of Child Psychology and Psychiatry*, 42(2), 241–251.
<https://doi.org/10.1017/S0021963001006643>
- Barrera, M., & Maurer, D. (1981). Recognition of mother’s photographed face by the three-month-old infant. *Child Development*. <https://doi.org/10.2307/1129196>
- Barry, R. J., & Furedy, J. J. (1993). Stimulus intensity and novelty interact in elicitation of the phasic electrodermal orienting response. *International Journal of Psychophysiology*, 14(3), 249–254. [https://doi.org/10.1016/0167-8760\(93\)90039-r](https://doi.org/10.1016/0167-8760(93)90039-r)
- Basso, M. R., Schefft, B. K., Ris, M. D., & Dember, W. N. (1996). Mood and global-local visual processing. *Journal of the International Neuropsychological Society*, 2(3), 249–255.
<https://doi.org/10.1017/s1355617700001193>
- Bayley, N. (1936). The Development of Motor Abilities during the First Three Years: A Study of Sixty-One Infants Tested Repeatedly. *Monographs of the Society for Research in Child Development*, 1(1), 1. <https://doi.org/10.2307/1165480>
- Bayliss, A. P., & Tipper, S. P. (2005). Gaze and arrow cueing of attention reveals individual differences along the autism spectrum as a function of target context. *British Journal of Psychology*, 96(1), 95–114. <https://doi.org/10.1348/000712604x15626>
- Becker, K. R., Plessow, F., Coniglio, K. A., Tabri, N., Franko, D. L., Zayas, L. V., ... Eddy, K. T. (2017). Global/local processing style: Explaining the relationship between trait anxiety and binge eating. *International Journal of Eating Disorders*.
<https://doi.org/10.1002/eat.22772>
- Bedford, R., Pickles, A., Gliga, T., Elsabbagh, M., Charman, T., Johnson, M. H., & Team, B. (2014). Additive effects of social and non-social attention during infancy relate to

later autism spectrum disorder. *Developmental Science*, 17(4), 612–620.

<https://doi.org/10.1111/desc.12139>

- Belmonte, M. K., Gomot, M., & Baron-Cohen, S. (2010). Visual attention in autism families: 'unaffected' sibs share atypical frontal activation. *Journal of Child Psychology and Psychiatry*, 51(3), 259–276. <https://doi.org/10.1111/j.1469-7610.2009.02153.x>
- Benbow, C., & Stanley, J. (1983). Sex differences in mathematical reasoning ability: more facts. *Science*, 222(4627), 1029–1031. <https://doi.org/10.1126/science.6648516>
- Bennett, G., Seashore, H., & Wesman, A. (1974). DAT: Differential Aptitude Test. *New York, NY: The Psychological Corporation*. Retrieved from http://scholar.google.com/scholar?q=DAT: Differential Aptitude Test&btnG=&hl=en&num=20&as_sdt=0%2C22
- Benning, S. D., Kovac, M., Campbell, A., Miller, S., Hanna, E. K., Damiano, C. R., ... Dichter, G. S. (2016). Late Positive Potential ERP Responses to Social and Nonsocial Stimuli in Youth with Autism Spectrum Disorder. *Journal of Autism and Developmental Disorders*, 46(9), 3068–3077. <https://doi.org/10.1007/s10803-016-2845-y>
- Benson, V., Piper, J., & Fletcher-Watson, S. (2009). Atypical saccadic scanning in autistic spectrum disorder. *Neuropsychologia*, 47(4), 1178–1182. <https://doi.org/10.1016/j.neuropsychologia.2008.11.019>
- Berthoz, S., & Hill, E. L. (2005). The validity of using self-reports to assess emotion regulation abilities in adults with autism spectrum disorder. *European Psychiatry*, 20(3), 291–298. <https://doi.org/10.1016/j.eurpsy.2004.06.013>
- Bertone, A., Mottron, L., Jelenic, P., & Faubert, J. (2005). Enhanced and diminished visuo-spatial information processing in autism depends on stimulus complexity. *Brain*, 128(10), 2430–2441. <https://doi.org/10.1093/brain/awh561>

- Best, C., Arora, S., Porter, F., & Doherty, M. (2015). The Relationship Between Subthreshold Autistic Traits, Ambiguous Figure Perception and Divergent Thinking. *Journal of Autism and Developmental Disorders*, *45*(12), 4064–4073.
<https://doi.org/10.1007/s10803-015-2518-2>
- Bhat, A. N., Galloway, J. C., & Landa, R. J. (2010). Social and non-social visual attention patterns and associative learning in infants at risk for autism: Attention and learning in infants at risk for autism. *Journal of Child Psychology and Psychiatry*, *51*(9), 989–997.
<https://doi.org/10.1111/j.1469-7610.2010.02262.x>
- Billington, J., Baron-Cohen, S., & Bor, D. (2008). Systemizing influences attentional processes during the Navon task: An fMRI study. *Neuropsychologia*, *46*(2), 511–520.
<https://doi.org/10.1016/j.neuropsychologia.2007.09.003>
- Biopac. (2013). Acqknowledge 4 Software Guide. *Acqknowledge 4 Software Guide*. Retrieved from <https://www.biopac.com/wp-content/uploads/acqknowledge-4-software-guide.pdf>
- Birmingham, E., Cerf, M., & Adolphs, R. (2010). The role of the amygdala in orienting attention to eyes within complex social scenes. *Journal of Vision*, *9*(8), 497–497.
<https://doi.org/10.1167/9.8.497>
- Bishop, D. V. M., Maybery, M., Maley, A., Wong, D., Hill, W., & Hallmayer, J. (2004). Using self-report to identify the broad phenotype in parents of children with autistic spectrum disorders: a study using the Autism-Spectrum Quotient. *Journal of Child Psychology and Psychiatry*, *45*(8), 1431–1436. <https://doi.org/10.1111/j.1469-7610.2004.00325.x>
- Bishop, D. V. M., & Norbury, C. F. (2002). Exploring the borderlands of autistic disorder and specific language impairment: a study using standardised diagnostic instruments. *Journal of Child Psychology and Psychiatry*, *43*(7), 917–929.
<https://doi.org/10.1111/1469-7610.00114>

- Bishop, S. J. (2008). Trait anxiety and impoverished prefrontal control of attention. *Nature Neuroscience*, 12(1), 92–98. <https://doi.org/10.1038/nn.2242>
- Bishop, S. L., Hus, V., Duncan, A., Huerta, M., Gotham, K., Pickles, A., ... Lord, C. (2013). Subcategories of Restricted and Repetitive Behaviors in Children with Autism Spectrum Disorders. *Journal of Autism and Developmental Disorders*, 43(6), 1287–1297. <https://doi.org/10.1007/s10803-012-1671-0>
- Bishop, S. L., Richler, J., & Lord, C. (2006). Association Between Restricted and Repetitive Behaviors and Nonverbal IQ in Children with Autism Spectrum Disorders. *Child Neuropsychology*, 12(4–5), 247–267. <https://doi.org/10.1080/09297040600630288>
- Blair, R. J. . (1999). Psychophysiological responsiveness to the distress of others in children with autism. *Personality and Individual Differences*, 26(3), 477–485. [https://doi.org/10.1016/S0191-8869\(98\)00154-8](https://doi.org/10.1016/S0191-8869(98)00154-8)
- Bodfish, J. W., Symons, F. J., Parker, D. E., & Lewis, M. H. (2000). Varieties of Repetitive Behavior in Autism: Comparisons to Mental Retardation. *Journal of Autism and Developmental Disorders*, 30(3), 237–243. <https://doi.org/10.1023/a:1005596502855>
- Bölte, S., Feineis-Matthews, S., & Poustka, F. (2008). Brief Report: Emotional Processing in High-Functioning Autism—Physiological Reactivity and Affective Report. *Journal of Autism and Developmental Disorders*, 38(4), 776–781. <https://doi.org/10.1007/s10803-007-0443-8>
- Bölte, S., Holtmann, M., Poustka, F., Scheurich, A., & Schmidt, L. (2007). Gestalt Perception and Local-Global Processing in High-Functioning Autism. *Journal of Autism and Developmental Disorders*, 37(8), 1493–1504. <https://doi.org/10.1007/s10803-006-0231-x>
- Bölte, S., & Poustka, F. (2006). The broader cognitive phenotype of autism in parents: how specific is the tendency for local processing and executive dysfunction? *Journal*

of *Child Psychology and Psychiatry*, 47(6), 639–645. <https://doi.org/10.1111/j.1469-7610.2006.01603.x>

Bonda, E., Petrides, M., Ostry, D., & Evans, A. (1996). Specific Involvement of Human Parietal Systems and the Amygdala in the Perception of Biological Motion. *Journal of Neuroscience*, 16(11), 3737–3744. <https://doi.org/10.1523/jneurosci.16-11-03737.1996>

Bortolon, C., & Raffard, S. (2015). Self-reported psychotic-like experiences in individuals with obsessive-compulsive disorder versus schizophrenia patients: Characteristics and moderation role of trait anxiety. *Comprehensive Psychiatry*, 57, 97–105. <https://doi.org/10.1016/j.comppsy.2014.10.011>

Brang, D., & Ramachandran, V. S. (2011). Survival of the Synesthesia Gene: Why Do People Hear Colors and Taste Words? *PLoS Biology*, 9(11). <https://doi.org/10.1371/journal.pbio.1001205>

Breska, A., Maoz, K., & Ben-Shakhar, G. (2011). Interstimulus intervals for skin conductance response measurement. *Psychophysiology*, 48(4), 437–440. <https://doi.org/10.1111/j.1469-8986.2010.01084.x>

Brock, J., Xu, J. Y., & Brooks, K. R. (2011). Individual Differences in Visual Search: Relationship to Autistic Traits, Discrimination Thresholds, and Speed of Processing. *Perception*, 40(6), 739–742. <https://doi.org/10.1068/p6953>

Brosnan, M., Ashwin, C., & Lewton, M. (2017). Brief Report: Intuitive and Reflective Reasoning in Autism Spectrum Disorder. *Journal of Autism and Developmental Disorders*, 47(8), 2595–2601. <https://doi.org/10.1007/s10803-017-3131-3>

Brosnan, M., Chapman, E., & Ashwin, C. (2014). Adolescents with Autism Spectrum Disorder Show a Circumspect Reasoning Bias Rather than 'Jumping-to-Conclusions'. *Journal of Autism and Developmental Disorders*, 44(3), 513–520. <https://doi.org/10.1007/s10803-013-1897-5>

- Brosnan, M., Daggan, R., & Collomosse, J. (2010). The Relationship Between Systemising and Mental Rotation and the Implications for the Extreme Male Brain Theory of Autism. *Journal of Autism and Developmental Disorders*, *40*(1), 1–7.
<https://doi.org/10.1007/s10803-009-0815-3>
- Brosnan, M., Hollinworth, M., Antoniadou, K., & Lewton, M. (2014). Is Empathizing intuitive and Systemizing deliberative? *Personality and Individual Differences*, *66*, 39–43.
<https://doi.org/10.1016/j.paid.2014.03.006>
- Brosnan, M. J., Gwilliam, L. R., & Walker, I. (2012). Brief Report: The Relationship Between Visual Acuity, the Embedded Figures Test and Systemizing in Autism Spectrum Disorders. *Journal of Autism and Developmental Disorders*, *42*(11), 2491–2497.
<https://doi.org/10.1007/s10803-012-1505-0>
- Brosnan, M., Lewton, M., & Ashwin, C. (2016). Reasoning on the Autism Spectrum: A Dual Process Theory Account. *Journal of Autism and Developmental Disorders*, *46*(6), 2115–2125. <https://doi.org/10.1007/s10803-016-2742-4>
- Brosnan, M., Turner-Cobb, J., Munro-Naan, Z., & Jessop, D. (2009). Absence of a normal Cortisol Awakening Response (CAR) in adolescent males with Asperger Syndrome (AS). *Psychoneuroendocrinology*, *34*(7), 1095–1100.
<https://doi.org/10.1016/j.psyneuen.2009.02.011>
- Brosnan, M., & Walker, I. (2008). A preliminary investigation into the potential role of waist hip ratio (WHR) preference within the assortative mating hypothesis of autistic spectrum disorders. *Journal of Autism and Developmental Disorders*, *39*(1), 164–171.
<https://doi.org/10.1007/s10803-008-0615-1>
- Burack, J. A., Joseph, S., Russo, N., Shore, D. I., Porporino, M., & Enns, J. T. (2009). Change Detection in Naturalistic Pictures Among Children with Autism. *Journal of Autism and Developmental Disorders*, *39*(3), 471–479. <https://doi.org/10.1007/s10803-008-0647-6>

- Burnette, C. P., Mundy, P. C., Meyer, J. A., Sutton, S. K., Vaughan, A. E., & Charak, D. (2005). Weak central coherence and its relations to theory of mind and anxiety in autism. *Journal of Autism and Developmental Disorders*, *35*(1), 63–73.
<https://doi.org/10.1007/s10803-004-1035-5>
- Burnside, K., Wright, K., & Poulin-Dubois, D. (2017). Social motivation and implicit theory of mind in children with autism spectrum disorder. *Autism Research*, *10*(11), 1834–1844. <https://doi.org/10.1002/aur.1836>
- Butterfill, S. A., & Apperly, I. A. (2013). How to Construct a Minimal Theory of Mind. *Mind & Language*, *28*(5), 606–637. <https://doi.org/10.1111/mila.12036>
- Byrd-Craven, J., Massey, A. R., Calvi, J. L., & Geary, D. C. (2015). Is systemizing a feature of the extreme male brain from an evolutionary perspective? *Personality and Individual Differences*, *82*, 237–241. <https://doi.org/10.1016/j.paid.2015.03.026>
- Cadman, T., Spain, D., Johnston, P., Russell, A., Mataix-Cols, D., Craig, M., ... Murphy, D. (2015). Obsessive-Compulsive Disorder in Adults with High-Functioning Autism Spectrum Disorder: What Does Self-Report with the OCI-R Tell Us? *Autism Research*, *8*(5), 477–485. <https://doi.org/10.1002/aur.1461>
- Caparos, S., & Linnell, K. J. (2012). Trait anxiety focuses spatial attention. *Emotion*, *12*(1), 8. <https://doi.org/10.1037/a0026310>
- Carcani-Rathwell, I., Rabe-Hasketh, S., & Santosh, P. J. (2006). Repetitive and stereotyped behaviours in pervasive developmental disorders. *Journal of Child Psychology and Psychiatry*, *47*(6), 573–581. <https://doi.org/10.1111/j.1469-7610.2005.01565.x>
- Carey, D. P. (1996). Neurophysiology: ‘Monkey see, monkey do’ cells. *Current Biology*, *6*(9), 1087–1088. [https://doi.org/10.1016/s0960-9822\(02\)70673-8](https://doi.org/10.1016/s0960-9822(02)70673-8)
- Carlson, S. M., & White, R. E. (2013). *Executive Function, Pretend Play, and Imagination*. Oxford University Press.
<https://doi.org/10.1093/oxfordhb/9780195395761.013.0011>

- Carroll, J. M., & Chiew, K. Y. (2006). Sex and Discipline Differences in Empathising, Systemising and Autistic Symptomatology: Evidence from a Student Population. *Journal of Autism and Developmental Disorders*, 36(7), 949–957.
<https://doi.org/10.1007/s10803-006-0127-9>
- Carton, A. M., & Smith, A. D. (2014). Assessing the relationship between eating disorder psychopathology and autistic traits in a non-clinical adult population. *Eating and Weight Disorders - Studies on Anorexia, Bulimia and Obesity*, 19(3), 285–293.
<https://doi.org/10.1007/s40519-013-0086-z>
- Cascio, C. J., Foss-Feig, J. H., Heacock, J., Schauder, K. B., Loring, W. A., Rogers, B. P., ... Bolton, S. (2014). Affective neural response to restricted interests in autism spectrum disorders. *Journal of Child Psychology and Psychiatry*, 55(2), 162–171.
<https://doi.org/10.1111/jcpp.12147>
- Castelli, F., Happé, F., Frith, U., & Frith, C. (2000). Movement and mind: a functional imaging study of perception and interpretation of complex intentional movement patterns. *NeuroImage*, 12(3), 314–325. <https://doi.org/10.1006/nimg.2000.0612>
- Ceglie, D. D., Skagerberg, E., Baron-Cohen, S., & Auyeung, B. (2014). Empathising and Systemising in Adolescents with Gender Dysphoria. *Opticon* 1826, 0(16).
<https://doi.org/10.5334/opt.bo>
- Chamberlain, R., McManus, I. C., Riley, H., Rankin, Q., & Brunswick, N. (2013). Local processing enhancements associated with superior observational drawing are due to enhanced perceptual functioning, not weak central coherence. *The Quarterly Journal of Experimental Psychology*, 66(7), 1448–1466.
<https://doi.org/10.1080/17470218.2012.750678>
- Chen, F. S., & Yoon, J. M. D. (2011). Brief Report: Broader Autism Phenotype Predicts Spontaneous Reciprocity of Direct Gaze. *Journal of Autism and Developmental Disorders*, 41(8), 1131–1134. <https://doi.org/10.1007/s10803-010-1136-2>

- Chen, J. A., Peñagarikano, O., Belgard, T. G., Swarup, V., & Geschwind, D. H. (2015). The Emerging Picture of Autism Spectrum Disorder: Genetics and Pathology. *Annual Review of Pathology: Mechanisms of Disease*, *10*(1), 111–144. <https://doi.org/10.1146/annurev-pathol-012414-040405>
- Chevallier, C., Kohls, G., Troiani, V., Brodtkin, E. S., & Schultz, R. T. (2012). The social motivation theory of autism. *Trends in Cognitive Sciences*, *16*(4), 231–239. <https://doi.org/10.1016/j.tics.2012.02.007>
- Clark, T. F., Winkielman, P., & McIntosh, D. N. (2008). Autism and the extraction of emotion from briefly presented facial expressions: Stumbling at the first step of empathy. *Emotion*, *8*(6), 803. <https://doi.org/10.1037/a0014124>
- Clements, C. C., Zoltowski, A. R., Yankowitz, L. D., Yerys, B. E., Schultz, R. T., & Herrington, J. D. (2018). Evaluation of the Social Motivation Hypothesis of Autism. *JAMA Psychiatry*. <https://doi.org/10.1001/jamapsychiatry.2018.1100>
- Connellan, J., Baron-Cohen, S., Wheelwright, S., Batki, A., & Ahluwalia, J. (2000). Sex differences in human neonatal social perception. *Infant Behavior and Development*, *23*(1), 113–118. [https://doi.org/10.1016/S0163-6383\(00\)00032-1](https://doi.org/10.1016/S0163-6383(00)00032-1)
- Conner, C. M., Maddox, B. B., & White, S. W. (2013). Parents' State and Trait Anxiety: Relationships with Anxiety Severity and Treatment Response in Adolescents with Autism Spectrum Disorders. *Journal of Autism and Developmental Disorders*, *43*(8), 1811–1818. <https://doi.org/10.1007/s10803-012-1728-0>
- Constantino, J., & Gruber, C. (2012). Social responsiveness scale (SRS). *Social Responsiveness Scale (SRS)*. Retrieved from <https://www.kenniscentrum-kjp.nl/wp-content/uploads/2018/04/Social-Responsiveness-Scale-SRS.pdf>
- Constantino, J. N., & Todd, R. D. (2003). Autistic Traits in the General Population: A Twin Study. *Archives of General Psychiatry*, *60*(5), 524. <https://doi.org/10.1001/archpsyc.60.5.524>

- Constantino, J. N., & Todd, R. D. (2005). Intergenerational transmission of subthreshold autistic traits in the general population. *Biological Psychiatry*, *57*(6), 655–660.
<https://doi.org/10.1016/j.biopsych.2004.12.014>
- Cooper, R. A., Plaisted-Grant, K. C., Hannula, D. E., Ranganath, C., Baron-Cohen, S., & Simons, J. S. (2015). Impaired recollection of visual scene details in adults with autism spectrum conditions. *Journal of Abnormal Psychology*, *124*(3), 565–575.
<https://doi.org/10.1037/abn0000070>
- Corbett, B. A., Blain, S. D., Ioannou, S., & Balser, M. (2017). Changes in anxiety following a randomized control trial of a theatre-based intervention for youth with autism spectrum disorder. *Autism*, *21*(3), 333–343.
<https://doi.org/10.1177/1362361316643623>
- Couteur, A., Bailey, A., Goode, S., Pickles, A., Gottesman, I., Robertson, S., & Rutter, M. (1996). A Broader Phenotype of Autism: The Clinical Spectrum in Twins. *Journal of Child Psychology and Psychiatry*, *37*(7), 785–801. <https://doi.org/10.1111/j.1469-7610.1996.tb01475.x>
- Cox, A., Kohls, G., Naples, A. J., Mukerji, C. E., Coffman, M. C., Helena J. V. Rutherford, ... James C. McPartland. (2015). Diminished social reward anticipation in the broad autism phenotype as revealed by event-related brain potentials. *Social Cognitive and Affective Neuroscience*, *10*(10), 1357–1364.
<https://doi.org/10.1093/scan/nsv024>
- Cribb, S. J., Olathe, M., Lorenzo, R. D., Dunlop, P. D., & Maybery, M. T. (2016). Embedded Figures Test Performance in the Broader Autism Phenotype: A Meta-analysis. *Journal of Autism and Developmental Disorders*, *46*(9), 2924–2939.
<https://doi.org/10.1007/s10803-016-2832-3>
- Critchley, H. D., Daly, E. M., Bullmore, E. T., Williams, S. C., Amelsvoort, T., Dene M Robertson, ... Declan GM Murphy. (2000). The functional neuroanatomy of social

behaviour Changes in cerebral blood flow when people with autistic disorder process facial expressions. *Brain*, 123(11), 2203–2212.

<https://doi.org/10.1093/brain/123.11.2203>

Cuccaro, M. L., Shao, Y., Grubber, J., Slifer, M., Wolpert, C. M., Shannon L. Donnelly, ...

Margaret A. Pericak-Vance. (2003). Factor Analysis of Restricted and Repetitive Behaviors in Autism Using the Autism Diagnostic Interview-R. *Child Psychiatry and Human Development*, 34(1), 3–17. <https://doi.org/10.1023/A:1025321707947>

Dachez, J., & Ndobu, A. (2018). Coping Strategies of Adults with High-Functioning Autism: A Qualitative Analysis. *Journal of Adult Development*, 25(2), 86–95.

<https://doi.org/10.1007/s10804-017-9278-5>

Daffron, J. L., & Davis, G. (2016). Target templates specify visual, not semantic, features to guide search: A marked asymmetry between seeking and ignoring. *Attention, Perception, & Psychophysics*, 78(7), 2049–2065. <https://doi.org/10.3758/s13414-016-1094-7>

<https://doi.org/10.3758/s13414-016-1094-7>

Dalton, K. M., Nacewicz, B. M., Alexander, A. L., & Davidson, R. J. (2007). Gaze-Fixation, Brain Activation, and Amygdala Volume in Unaffected Siblings of Individuals with Autism. *Biological Psychiatry*, 61(4), 512–520.

<https://doi.org/10.1016/j.biopsych.2006.05.019>

Dalton, K. M., Nacewicz, B. M., Johnstone, T., Schaefer, H. S., Gernsbacher, M. A., H H Goldsmith, ... Richard J Davidson. (2005). Gaze fixation and the neural circuitry of face processing in autism. *Nature Neuroscience*, 8(4), 519–526.

<https://doi.org/10.1038/nn1421>

Damasio, A. R. (1996). The somatic marker hypothesis and the possible functions of the prefrontal cortex. *Philosophical Transactions of the Royal Society of London. Series B: Biological Sciences*, 351(1346), 1413–1420. <https://doi.org/10.1098/rstb.1996.0125>

<https://doi.org/10.1098/rstb.1996.0125>

- Davies, T. N., & Hoffman, D. D. (2001). Attention to Faces: A Change-Blindness Study. *Perception, 31*(9), 1123–1146. <https://doi.org/10.1068/p3391>
- Davis, G., & Holmes, A. (2005). What is enumerated by subitization mechanisms? *Perception & Psychophysics, 67*(7), 1229–1241. <https://doi.org/10.3758/bf03193555>
- Davis, G., & Plaisted-Grant, K. (2015). Low endogenous neural noise in autism. *Autism, 19*(3), 351–362. <https://doi.org/10.1177/1362361314552198>
- Davis III, T. E., White, S. W., & Ollendick, T. H. (Eds.). (2014). *Handbook of Autism and Anxiety*. Cham: Springer International Publishing. <https://doi.org/10.1007/978-3-319-06796-4>
- Dawson, G, Meltzoff, A., Osterling, J., Rinaldi, J., & Brown, E. (1998). Children with autism fail to orient to naturally occurring social stimuli. *Journal of Autism and Developmental Disorders, 28*(6), 479–485.
- Dawson, Geraldine. (2013). Dramatic Increase in Autism Prevalence Parallels Explosion of Research Into Its Biology and Causes. *JAMA Psychiatry, 70*(1), 9–10. <https://doi.org/10.1001/jamapsychiatry.2013.488>
- Dawson, Geraldine, Webb, S. J., & McPartland, J. (2005). Understanding the Nature of Face Processing Impairment in Autism: Insights From Behavioral and Electrophysiological Studies. *Developmental Neuropsychology, 27*(3), 403–424. https://doi.org/10.1207/s15326942dn2703_6
- Dawson, M. E., Schell, A. M., Filion, D. L., & Berntson, G. G. (2007). The Electrodermal System. In J. T. Cacioppo, L. G. Tassinary, & G. Berntson (Eds.), *Handbook of Psychophysiology* (3rd ed., pp. 157–181). Cambridge: Cambridge University Press. <https://doi.org/10.1017/CBO9780511546396.007>
- de Jonge, M., Kemner, C., & van der Gaag, E.-H. (2006). Superior disembedding performance of high-functioning individuals with autism spectrum disorders and

- their parents: The need for subtle measures. *Journal of Autism and Developmental Disorders*. <https://doi.org/10.1007/s10803-006-0113-2>
- Delmonte, S., Balsters, J. H., McGrath, J., Fitzgerald, J., Brennan, S., Fagan, A. J., & Gallagher, L. (2012). Social and monetary reward processing in autism spectrum disorders. *Molecular Autism*, 3(1), 1–13. <https://doi.org/10.1186/2040-2392-3-7>
- Derryberry, D., & and individual differences, R.-M. (1998). Anxiety and attentional focusing: Trait, state and hemispheric influences. *Personality and Individual Differences*. Retrieved from <https://www.sciencedirect.com/science/article/pii/S0191886998001172>
- Devlin, K. J. (2000). *The math gene: How mathematical thinking evolved and why numbers are like gossip*. Retrieved from [http://scholar.google.com/scholar?q=The math gene: How mathematical thinking evolved and why numbers are like gossip&btnG=&hl=en&num=20&as_sdt=0%2C22](http://scholar.google.com/scholar?q=The+math+gene:+How+mathematical+thinking+evolved+and+why+numbers+are+like+gossip&btnG=&hl=en&num=20&as_sdt=0%2C22)
- Dichter, G. S., Felder, J. N., Green, S. R., Rittenberg, A. M., Sasson, N. J., & Bodfish, J. W. (2012). Reward circuitry function in autism spectrum disorders. *Social Cognitive and Affective Neuroscience*, 7(2), 160–172. <https://doi.org/10.1093/scan/nsq095>
- Dickter, C. L., Burk, J. A., Fleckenstein, K., & Kozikowski, C. T. (2018). Autistic traits and social anxiety predict differential performance on social cognitive tasks in typically developing young adults. *PLoS ONE*, 13(3). <https://doi.org/10.1371/journal.pone.0195239>
- Dillen, C., Steyaert, J., Beeck, H. P. O. de, & Boets, B. (2015). Visual Processing in Adolescents with Autism Spectrum Disorder: Evidence from Embedded Figures and Configural Superiority Tests. *Journal of Autism and Developmental Disorders*, 45(5), 1281–1290. <https://doi.org/10.1007/s10803-014-2288-2>
- Dreisbach, G., & Goschke, T. (2004). How Positive Affect Modulates Cognitive Control: Reduced Perseveration at the Cost of Increased Distractibility. *Journal of Experimental*

Psychology: Learning, Memory, and Cognition, 30(2), 343. <https://doi.org/10.1037/0278-7393.30.2.343>

Driver, J., Davis, G., Ricciardelli, P., Kidd, P., Maxwell, E., & Baron-Cohen, S. (1999).

Gaze Perception Triggers Reflexive Visuospatial Orienting. *Visual Cognition*, 6(5), 509–540. <https://doi.org/10.1080/135062899394920>

DuBois, D., Ameis, S. H., Lai, M.-C., Casanova, M. F., & Desarkar, P. (2016).

Interoception in Autism Spectrum Disorder: A review. *International Journal of Developmental Neuroscience*, 52, 104–111.

<https://doi.org/10.1016/j.ijdevneu.2016.05.001>

Ehlers, S., & Gillberg, C. (1993). The Epidemiology of Asperger Syndrome. *Journal of*

Child Psychology and Psychiatry, 34(8), 1327–1350. <https://doi.org/10.1111/j.1469-7610.1993.tb02094.x>

Ellis, R. (2012). May I Have Your Attention Please? A Review of Change Blindness.

Organization Development Journal, 30(3). Retrieved from

<http://web.a.ebscohost.com.ezproxy1.bath.ac.uk/ehost/pdfviewer/pdfviewer?sid=068f8025-31c0-45e8-9661-6d5fc571551f%40sessionmgr4003&vid=3&hid=4201>

Elsabbagh, M., Fernandes, J., Webb, S. J., Dawson, G., Charman, T., & Johnson, M. H.

(2013). Disengagement of Visual Attention in Infancy is Associated with Emerging Autism in Toddlerhood. *Biological Psychiatry*, 74(3), 189–194.

<https://doi.org/10.1016/j.biopsych.2012.11.030>

Elsabbagh, M., Gliga, T., Pickles, A., Hudry, K., Charman, T., Johnson, M. H., & Team,

S. the. (2013). The development of face orienting mechanisms in infants at-risk for autism. *Behavioural Brain Research*, 251, 147–154.

<https://doi.org/10.1016/j.bbr.2012.07.030>

Elsabbagh, M., Volein, A., Csibra, G., Holmboe, K., Garwood, H., Leslie Tucker, ...

Mark H. Johnson. (2009). Neural Correlates of Eye Gaze Processing in the Infant

Broader Autism Phenotype. *Biological Psychiatry*, 65(1), 31–38.

<https://doi.org/10.1016/j.biopsych.2008.09.034>

Elsabbagh, M., Volein, A., Holmboe, K., Tucker, L., Csibra, G., Simon Baron-Cohen, ...

Mark H Johnson. (2009). Visual orienting in the early broader autism phenotype: disengagement and facilitation. *Journal of Child Psychology and Psychiatry*, 50(5), 637–642.

<https://doi.org/10.1111/j.1469-7610.2008.02051.x>

Emery, N. J., Capitano, J. P., Mason, W. A., Machado, C. J., Mendoza, S. P., & Amaral,

D. G. (2001). The effects of bilateral lesions of the amygdala on dyadic social interactions in rhesus monkeys (*Macaca mulatta*). *Behavioral Neuroscience*, 115(3), 515.

<https://doi.org/10.1037/0735-7044.115.3.515>

English, M. C. W., Maybery, M. T., & Visser, T. A. W. (2017). Threatening faces fail to

guide attention for adults with autistic-like traits. *Autism Research*, 10(2), 311–320.

<https://doi.org/10.1002/aur.1658>

Epstein, S. (1994). Integration of the cognitive and the psychodynamic unconscious.

American Psychologist, 49(8), 709. <https://doi.org/10.1037/0003-066x.49.8.709>

Epstein, S., Pacini, R., Denes-Raj, V., & Heier, H. (1996). Individual differences in

intuitive–experiential and analytical–rational thinking styles. *Journal of Personality and*

Social Psychology, 71(2), 390–405. <https://doi.org/10.1037/0022-3514.71.2.390>

Evans, J. B., & Stanovich, K. E. (2013). Dual-Process Theories of Higher Cognition.

Dual-Process Theories of Higher Cognition, 8(3), 223–241.

<https://doi.org/10.1177/1745691612460685>

Evans, J. S. B. T. (2008). Dual-Processing Accounts of Reasoning, Judgment, and Social

Cognition. *Annual Review of Psychology*, 59(1), 255–278.

<https://doi.org/10.1146/annurev.psych.59.103006.093629>

Eycke, K. D. T., & Müller, U. (2015). Brief Report: New Evidence for a Social-Specific

Imagination Deficit in Children with Autism Spectrum Disorder. *Journal of Autism*

and *Developmental Disorders*, 45(1), 213–220. <https://doi.org/10.1007/s10803-014-2206-7>

Eycke, K. D. T., & Müller, U. (2018). Drawing links between the autism cognitive profile and imagination: Executive function and processing bias in imaginative drawings by children with and without autism. *Autism*, 22(2), 149–160. <https://doi.org/10.1177/1362361316668293>

Falter, C. M., Grant, K. C. P., & Davis, G. (2010). Object-based attention benefits reveal selective abnormalities of visual integration in autism. *Autism Research*, 3(3), 128–136. <https://doi.org/10.1002/aur.134>

Falter, C. M., Plaisted, K. C., & Davis, G. (2008). Visuo-spatial Processing in Autism—Testing the Predictions of Extreme Male Brain Theory. *Journal of Autism and Developmental Disorders*, 38(3), 507–515. <https://doi.org/10.1007/s10803-007-0419-8>

Feil, A., & Mestre, J. P. (2010). Change Blindness as a Means of Studying Expertise in Physics. *Journal of the Learning Sciences*, 19(4), 480–505. <https://doi.org/10.1080/10508406.2010.505139>

Fields, C. (2012). Do autism spectrum disorders involve a generalized object categorization and identification dysfunction? *Medical Hypotheses*, 79(3), 344–351. <https://doi.org/10.1016/j.mehy.2012.05.032>

Filion, D., Dawson, M., Schell, A., & Hazlett, E. (1991). The relationship between skin conductance orienting and the allocation of processing resources. *Psychophysiology*, 28(4), 410–424.

Fitzgerald, M. (2017). The clinical utility of the ADI-R and ADOS in diagnosing autism. *The British Journal of Psychiatry*, 211(2), 117–117. <https://doi.org/10.1192/bjp.211.2.117>

Fletcher-Watson, S., Leekam, S. R., Benson, V., Frank, M. C., & Findlay, J. M. (2009). Eye-movements reveal attention to social information in autism spectrum disorder.

Neuropsychologia, 47(1), 248–257.

<https://doi.org/10.1016/j.neuropsychologia.2008.07.016>

Fletcher-Watson, S, Leekam, S., Turner, M., & Moxon, L. (2006). Do people with autistic spectrum disorder show normal selection for attention? Evidence from change blindness. *British Journal of Psychology*, 97(4).

<https://doi.org/10.1348/000712606x114057>

Fletcher-Watson, Sue, Findlay, J. M., Leekam, S. R., & Benson, V. (2006). Rapid Detection of Person Information in a Naturalistic Scene. *Perception*, 37(4), 571–583.

<https://doi.org/10.1068/p5705>

Fletcher-Watson, Sue, Leekam, S. R., Connolly, B., Collis, J. M., Findlay, J. M., McConachie, H., & Rodgers, J. (2012). Attenuation of change blindness in children with autism spectrum disorders. *British Journal of Developmental Psychology*, 30(3).

<https://doi.org/10.1111/j.2044-835x.2011.02054.x>

Fletcher-Watson, Sue, Leekam, S. R., & Findlay, J. M. (2013). Social Interest in High-Functioning Adults With Autism Spectrum Disorders. *Focus on Autism and Other Developmental Disabilities*, 28(4), 222–229.

<https://doi.org/10.1177/1088357613480829>

Fletcher-Watson, Sue, Leekam, S. R., Findlay, J. M., & Stanton, E. C. (2008). Brief Report: Young Adults with Autism Spectrum Disorder Show Normal Attention to Eye-Gaze Information—Evidence from a New Change Blindness Paradigm. *Journal of Autism and Developmental Disorders*, 38(9), 1785–1790.

<https://doi.org/10.1007/s10803-008-0548-8>

Fockert, J. W. de, & Cooper, A. (2013). Higher levels of depression are associated with reduced global bias in visual processing. *Cognition and Emotion*, 28(3), 541–549.

<https://doi.org/10.1080/02699931.2013.839939>

- Folstein, S., & Rutter, M. (1977). Infantile Autism: A Genetic Study of 21 twin pairs. *Journal of Child Psychology and Psychiatry*, 18(4), 297–321.
<https://doi.org/10.1111/j.1469-7610.1977.tb00443.x>
- Fombonne, E, Zakarian, R., Bennett, A., & Pediatrics, M.-L. (2006). Pervasive developmental disorders in Montreal, Quebec, Canada: prevalence and links with immunizations. *Pediatrics*. Retrieved from
<http://pediatrics.aappublications.org/content/118/1/e139.short>
- Fombonne, Eric. (2009). Epidemiology of Pervasive Developmental Disorders. *Pediatric Research*, 65(6), 591–598. <https://doi.org/10.1203/PDR.0b013e31819e7203>
- Fombonne, Eric. (2013). Epidemiological Studies of Pervasive Developmental Disorders. In F. R. Volkmar, R. Paul, A. Klin, & D. Cohen (Eds.), *Handbook of Autism and Pervasive Developmental Disorders* (pp. 42–69). Hoboken, NJ, USA: John Wiley & Sons, Inc. <https://doi.org/10.1002/9780470939345.ch2>
- Fonville, L., Lao-Kaim, N. P., Giampietro, V., Eynde, F. V. den, Davies, H., Naima Lounes, ... Kate Tchanturia. (2013). Evaluation of Enhanced Attention to Local Detail in Anorexia Nervosa Using the Embedded Figures Test; an fMRI Study. *PLoS ONE*, 8(5). <https://doi.org/10.1371/journal.pone.0063964>
- Foss-Feig, J. H., McGugin, R. W., Gauthier, I., Mash, L. E., Ventola, P., & Cascio, C. J. (2016). A functional neuroimaging study of fusiform response to restricted interests in children and adolescents with autism spectrum disorder. *Journal of Neurodevelopmental Disorders*, 8(1), 15. <https://doi.org/10.1186/s11689-016-9149-6>
- Fox, E. (1993). Attentional bias in anxiety: Selective or not? *Behaviour Research and Therapy*, 31(5), 487–493. [https://doi.org/10.1016/0005-7967\(93\)90129-i](https://doi.org/10.1016/0005-7967(93)90129-i)
- Frank, M. C., Vul, E., & Johnson, S. P. (2009). Development of infants' attention to faces during the first year. *Cognition*, 110(2), 160–170.
<https://doi.org/10.1016/j.cognition.2008.11.010>

- Frederick, S. (2005). Cognitive Reflection and Decision Making. *Journal of Economic Perspectives*, 19(4), 25–42. <https://doi.org/10.1257/089533005775196732>
- Fredrickson, B. L., & Branigan, C. (2005). Positive emotions broaden the scope of attention and thought-action repertoires. *Cognition and Emotion*, 19(3), 313–332. <https://doi.org/10.1080/02699930441000238>
- Freeth, M., Ropar, D., Chapman, P., & Mitchell, P. (2010). The eye gaze direction of an observed person can bias perception, memory, and attention in adolescents with and without autism spectrum disorder. *Journal of Experimental Child Psychology*, 105(1–2), 20–37. <https://doi.org/10.1016/j.jecp.2009.10.001>
- Freeth, Megan, & Bugembe, P. (2018). Social partner gaze direction and conversational phase; factors affecting social attention during face-to-face conversations in autistic adults? *Autism: The International Journal of Research and Practice*, 1987432882. <https://doi.org/10.1177/1362361318756786>
- Freeth, Megan, Bullock, T., & Milne, E. (2013). The distribution of and relationship between autistic traits and social anxiety in a UK student population. *Autism*, 17(5), 571–581. <https://doi.org/10.1177/1362361312445511>
- Freeth, Megan, Foulsham, T., & Kingstone, A. (2013). What Affects Social Attention? Social Presence, Eye Contact and Autistic Traits. *PLoS ONE*, 8(1). <https://doi.org/10.1371/journal.pone.0053286>
- Frith, C. D., & Allen, H. A. (1983). The skin conductance orienting response as an index of attention. *Biological Psychology*, 17(1), 27–39.
- Frith, U., & Frith, C. (2010). The social brain: allowing humans to boldly go where no other species has been. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 365(1537), 165–176. <https://doi.org/10.1098/rstb.2009.0160>
- Frith, U., & Happé, F. (1994). Autism: beyond “theory of mind”. *Cognition*, 50(1–3), 115–132. [https://doi.org/10.1016/0010-0277\(94\)90024-8](https://doi.org/10.1016/0010-0277(94)90024-8)

- Gaigg, S. B., & Bowler, D. M. (2007). Differential fear conditioning in Asperger's syndrome: Implications for an amygdala theory of autism. *Neuropsychologia*, *45*(9), 2125–2134. <https://doi.org/10.1016/j.neuropsychologia.2007.01.012>
- Gaigg, S. B., Cornell, A. S., & Bird, G. (2018). The psychophysiological mechanisms of alexithymia in autism spectrum disorder. *Autism*, *22*(2). <https://doi.org/10.1177/1362361316667062>
- Gallese, V., & Goldman, A. (1998). Mirror neurons and the simulation theory of mind-reading. *Trends in Cognitive Sciences*, *2*(12), 493–501. [https://doi.org/10.1016/s1364-6613\(98\)01262-5](https://doi.org/10.1016/s1364-6613(98)01262-5)
- Gasper, K., & Clore, G. L. (2002). Attending to the big picture: mood and global versus local processing of visual information. *Psychological Science*, *13*(1), 34–40. <https://doi.org/10.1111/1467-9280.00406>
- Gauthier, I., Skudlarski, P., Gore, J. C., & Anderson, A. W. (2000). Expertise for cars and birds recruits brain areas involved in face recognition. *Nature Neuroscience*, *3*(2). <https://doi.org/10.1038/72140>
- Geschwind, D. H. (2011). Genetics of autism spectrum disorders. *Trends in Cognitive Sciences*, *15*(9), 409–416. <https://doi.org/10.1016/j.tics.2011.07.003>
- Ghaziuddin, M., & Mountain-Kimchi, K. (2004). Defining the Intellectual Profile of Asperger Syndrome: Comparison with High-Functioning Autism. *Journal of Autism and Developmental Disorders*, *34*(3), 279–284. <https://doi.org/10.1023/B:JADD.0000029550.19098.77>
- Giarelli, E., Wiggins, L. D., Rice, C. E., Levy, S. E., Kirby, R. S., Pinto-Martin, J., & Mandell, D. (2010). Sex differences in the evaluation and diagnosis of autism spectrum disorders among children. *Disability and Health Journal*, *3*(2), 107–116. <https://doi.org/10.1016/j.dhjo.2009.07.001>

- Goodwin, M. S., Groden, J., Velicer, W. F., Lipsitt, L. P., Baron, M. G., Hofmann, S. G., & Groden, G. (2006). Cardiovascular Arousal in Individuals With Autism. *Focus on Autism and Other Developmental Disabilities*, 21(2), 100–123.
<https://doi.org/10.1177/10883576060210020101>
- Gotham, K., Risi, S., Pickles, A., & Lord, C. (2007). The Autism Diagnostic Observation Schedule: Revised Algorithms for Improved Diagnostic Validity. *Journal of Autism and Developmental Disorders*, 37(4), 613–627. <https://doi.org/10.1007/s10803-006-0280-1>
- Greenwald, M., Cook, E., & Land, P. (1989). Affective judgment and psychophysiological response: Dimensional covariation in the evaluation of pictorial stimuli. *Journal of Psychophysiology*. Retrieved from
https://www.researchgate.net/profile/Mark_Greenwald/publication/232459835_Affective_judgment_and_psychophysiological_response_Dimensional_covariation_in_the_evaluation_of_pictorial_stimuli/links/09e415086ed718f18b000000.pdf
- Gregersen, P. K., Kowalsky, E., Lee, A., Baron-Cohen, S., Fisher, S. E., Asher, J. E., ... Li, W. (2013). Absolute pitch exhibits phenotypic and genetic overlap with synesthesia. *Human Molecular Genetics*, 22(10), 2097–2104.
<https://doi.org/10.1093/hmg/ddt059>
- Gregory, S. M., & Lambert, A. (2012). Anxiety, conscious awareness and change detection. *Consciousness and Cognition*, 21(1), 69–79.
<https://doi.org/10.1016/j.concog.2011.09.009>
- Grelotti, D. J., Klin, A. J., Gauthier, I., Skudlarski, P., Cohen, D. J., Gore, J. C., ... Schultz, R. T. (2005). fMRI activation of the fusiform gyrus and amygdala to cartoon characters but not to faces in a boy with autism. *Neuropsychologia*, 43(3), 373–385.
<https://doi.org/10.1016/j.neuropsychologia.2004.06.015>

- Grill-Spector, K., Knouf, N., & Kanwisher, N. (2004). The fusiform face area subserves face perception, not generic within-category identification. *Nature Neuroscience*, 7(5), 555–562. <https://doi.org/10.1038/nn1224>
- Grinter, E. J., Maybery, M. T., Beek, P. L. V., Pellicano, E., Badcock, J. C., & Badcock, D. R. (2009). Global Visual Processing and Self-Rated Autistic-like Traits. *Journal of Autism and Developmental Disorders*, 39(9), 1278–1290. <https://doi.org/10.1007/s10803-009-0740-5>
- Groom, M. J., Kochhar, P., Hamilton, A., Liddle, E. B., Simeou, M., & Hollis, C. (2017). Atypical Processing of Gaze Cues and Faces Explains Comorbidity between Autism Spectrum Disorder (ASD) and Attention Deficit/Hyperactivity Disorder (ADHD). *Journal of Autism and Developmental Disorders*, 47(5), 1496–1509. <https://doi.org/10.1007/s10803-017-3078-4>
- Grove, R., Baillie, A., Allison, C., Baron-Cohen, S., & Hoekstra, R. A. (2015). Exploring the quantitative nature of empathy, systemising and autistic traits using factor mixture modelling. *The British Journal of Psychiatry*, 207(5), 400–406. <https://doi.org/10.1192/bjp.bp.114.155101>
- Grove, Rachel, Baillie, A., Allison, C., Baron-Cohen, S., & Hoekstra, R. A. (2013). Empathizing, systemizing, and autistic traits: Latent structure in individuals with autism, their parents, and general population controls. *Journal of Abnormal Psychology*, 122(2), 600. <https://doi.org/10.1037/a0031919>
- Grove, Rachel, Roth, I., & Hoekstra, R. A. (2016). The motivation for special interests in individuals with autism and controls: Development and validation of the special interest motivation scale. *Autism Research*, 9(6), 677–688. <https://doi.org/10.1002/aur.1560>

- Guillon, Q., Hadjikhani, N., Baduel, S., & Rogé, B. (2014). Visual social attention in autism spectrum disorder: Insights from eye tracking studies. *Neuroscience & Biobehavioral Reviews*, 42, 279–297. <https://doi.org/10.1016/j.neubiorev.2014.03.013>
- Guilmatre, A., Dubourg, C., Mosca, A.-L., Legalic, S., Goldenberg, A., Valérie Drouin-Garraud, ... Dominique Campion. (2009). Recurrent Rearrangements in Synaptic and Neurodevelopmental Genes and Shared Biologic Pathways in Schizophrenia, Autism, and Mental Retardation. *Archives of General Psychiatry*, 66(9), 947–956. <https://doi.org/10.1001/archgenpsychiatry.2009.80>
- Guttmann-Steinmetz, S., Gadow, K. D., DeVincent, C. J., & Crowell, J. (2010). Anxiety Symptoms in Boys with Autism Spectrum Disorder, Attention-Deficit Hyperactivity Disorder, or Chronic Multiple Tic Disorder and Community Controls. *Journal of Autism and Developmental Disorders*, 40(8), 1006–1016. <https://doi.org/10.1007/s10803-010-0950-x>
- Handley, S., Newstead, S., & Wright, H. (2000). Rational and experiential thinking: A study of the REI. In R. Riding & S. Rayner (Eds.), *International Perspectives on Individual Differences* (Vol. 1). Greenwood Publishing Group. Retrieved from <http://books.google.com/books?hl=en&lr=&id=QAYIra8zB34C&oi=fnd&pg=PA97&dq=Rational+and+experiential+thinking:+A+study+of+the+REI+International+Perspectives+on+Individual+Differences&ots=uWQZ2ys2El&sig=3UUuERWTgoXUkGxxan0vZbk5WBs>
- Happé, F. (1996). Studying Weak Central Coherence at Low Levels: Children with Autism do not Succumb to Visual Illusions. A Research Note. *Journal of Child Psychology and Psychiatry*, 37(7), 873–877. <https://doi.org/10.1111/j.1469-7610.1996.tb01483.x>
- Happé, F., Cook, J. L., & Bird, G. (2016). The Structure of Social Cognition: In(ter)dependence of Sociocognitive Processes. *Annual Review of Psychology*, 68(1). <https://doi.org/10.1146/annurev-psych-010416-044046>

- Happé, F., & Frith, U. (2006). The Weak Coherence Account: Detail-focused Cognitive Style in Autism Spectrum Disorders. *Journal of Autism and Developmental Disorders*, 36(1), 5–25. <https://doi.org/10.1007/s10803-005-0039-0>
- Happé, F. G. (1994). Annotation: Current Psychological Theories of Autism: The “Theory of Mind” Account and Rival Theories. *Journal of Autism and Developmental Disorders*, 35(2), 215–229. <https://doi.org/10.1111/j.1469-7610.1994.tb01159.x>
- Happé, F., Ronald, A., & Plomin, R. (2006). Time to give up on a single explanation for autism. *Nature Neuroscience*, 9(10), 1218–1220. <https://doi.org/10.1038/nn1770>
- Hassin, R. R., Uleman, J. S., & Bargh, J. A. (Eds.). (2005). *The new unconscious*. Oxford ; New York: Oxford University Press.
- Helminen, T. M., Leppänen, J. M., Eriksson, K., Luoma, A., Hietanen, J. K., & Kylliäinen, A. (2017). Atypical physiological orienting to direct gaze in low-functioning children with autism spectrum disorder. *Autism*, 10(5), 810–820. <https://doi.org/10.1002/aur.1738>
- Helt, M. S., Eigsti, I.-M. M., Snyder, P. J., & Fein, D. A. (2010). Contagious yawning in autistic and typical development. *Child Development*, 81(5), 1620–1631. <https://doi.org/10.1111/j.1467-8624.2010.01495.x>
- Hershler, O., & Hochstein, S. (2005). At first sight: A high-level pop out effect for faces. *Vision Research*, 45(13), 1707–1724. <https://doi.org/10.1016/j.visres.2004.12.021>
- Hill, T. L., Varela, R. E., Kamps, J. L., & Niditch, L. A. (2014). Local processing and social skills in children with Autism Spectrum Disorders: The role of anxiety and cognitive functioning. *Research in Autism Spectrum Disorders*, 8(9), 1243–1251. <https://doi.org/10.1016/j.rasd.2014.06.005>
- Hishinuma, E. S., Miyamoto, R. H., Nishimura, S. T., Goebert, D. A., Yuen, N. Y. ., Makini, G. K., ... Carlton, B. S. (2001). Prediction of anxiety disorders using the

- State–Trait Anxiety Inventory for multiethnic adolescents. *Journal of Anxiety Disorders*, 15(6), 511–533. [https://doi.org/10.1016/S0887-6185\(01\)00079-2](https://doi.org/10.1016/S0887-6185(01)00079-2)
- Hochhauser, M., Aran, A., & Grynspan, O. (2018). How Adolescents with Autism Spectrum Disorder (ASD) Spontaneously Attend to Real-World Scenes: Use of a Change Blindness Paradigm. *Journal of Autism and Developmental Disorders*, 48(2), 502–510. <https://doi.org/10.1007/s10803-017-3343-6>
- Hoekstra, R. A., Bartels, M., Cath, D. C., & Boomsma, D. I. (2008). Factor Structure, Reliability and Criterion Validity of the Autism-Spectrum Quotient (AQ): A Study in Dutch Population and Patient Groups. *Journal of Autism and Developmental Disorders*, 38(8), 1555–1566. <https://doi.org/10.1007/s10803-008-0538-x>
- Hoekstra, R. A., Bartels, M., Verweij, C. J. H., & Boomsma, D. I. (2007). Heritability of Autistic Traits in the General Population. *Archives of Pediatrics & Adolescent Medicine*, 161(4), 372. <https://doi.org/10.1001/archpedi.161.4.372>
- Holder, J., Wilson, C. E., Mendez, M. A., & Murphy, D. G. (2014). Autistic Traits and Abnormal Sensory Experiences in Adults. *Journal of Autism and Developmental Disorders*, 44(6), 1461–1469. <https://doi.org/10.1007/s10803-013-2012-7>
- Howlin, P., Goode, S., Hutton, J., & Rutter, M. (2009). Savant skills in autism: psychometric approaches and parental reports. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 364(1522), 1359–1367. <https://doi.org/10.1098/rstb.2008.0328>
- Howlin, Patricia, Goode, S., Hutton, J., & Rutter, M. (2004). Adult outcome for children with autism. *Journal of Child Psychology and Psychiatry*, 45(2), 212–229. <https://doi.org/10.1111/j.1469-7610.2004.00215.x>
- Hubert, B. E., Wicker, B., Monfardini, E., & Deruelle, C. (2009). Electrodermal reactivity to emotion processing in adults with autistic spectrum disorders. *Autism*, 13(1), 9–19. <https://doi.org/10.1177/1362361308091649>

- Hubert, B., Wicker, B., Moore, D. G., Monfardini, E., Duverger, H., Fonséca, D. D., & Deruelle, C. (2007). Brief Report: Recognition of Emotional and Non-emotional Biological Motion in Individuals with Autistic Spectrum Disorders. *Journal of Autism and Developmental Disorders*, *37*(7), 1386–1392. <https://doi.org/10.1007/s10803-006-0275-y>
- Hughes, J. E. A., Simner, J., Baron-Cohen, S., Treffert, D. A., & Ward, J. (2017). Is Synaesthesia More Prevalent in Autism Spectrum Conditions? Only Where There Is Prodigious Talent. *Multisensory Research*, *30*(3–5), 391–408. <https://doi.org/10.1163/22134808-00002558>
- Hughes, R. N. (1981). Sex differences in Group Embedded Figures Test performance in relation to sex-role, state and trait anxiety. *Current Psychology*, *1*(3–4), 227–234. <https://doi.org/10.1007/BF03186733>
- Hurley, R. S. E., Losh, M., Parlier, M., Reznick, J. S., & Piven, J. (2007). The Broad Autism Phenotype Questionnaire. *Journal of Autism and Developmental Disorders*, *37*(9), 1679–1690. <https://doi.org/10.1007/s10803-006-0299-3>
- Hurst, R. M., Mitchell, J. T., Kimbrel, N. A., Kwapil, T. K., & Nelson-Gray, R. O. (2007). Examination of the reliability and factor structure of the Autism Spectrum Quotient (AQ) in a non-clinical sample. *Personality and Individual Differences*, *43*(7), 1938–1949. <https://doi.org/10.1016/j.paid.2007.06.012>
- Ingersoll, B., Hopwood, C. J., Wainer, A., & Brent Donnellan, M. (2011). A Comparison of Three Self-Report Measures of the Broader Autism Phenotype in a Non-Clinical Sample. *Journal of Autism and Developmental Disorders*, *41*(12), 1646–1657. <https://doi.org/10.1007/s10803-011-1192-2>
- Jacquemont, S., Coe, B. P., Hersch, M., Duyzend, M. H., Krumm, N., Bergmann, S., ... Eichler, E. E. (2014). A Higher Mutational Burden in Females Supports a “Female

- Protective Model” in Neurodevelopmental Disorders. *The American Journal of Human Genetics*, 94(3), 415–425. <https://doi.org/10.1016/j.ajhg.2014.02.001>
- James, A. L., & Barry, R. J. (1984). Cardiovascular and electrodermal responses to simple stimuli in autistic, retarded and normal children. *International Journal of Psychophysiology*, 1(2), 179–193. [https://doi.org/10.1016/0167-8760\(84\)90037-0](https://doi.org/10.1016/0167-8760(84)90037-0)
- Jarrold, C., & Russell, J. (1997). Counting abilities in autism: possible implications for central coherence theory. *Journal of Autism and Developmental Disorders*, 27(1), 25–37.
- Jarrold, Christopher. (2003). A Review of Research into Pretend Play in Autism. *Autism*, 7(4), 379–390. <https://doi.org/10.1177/1362361303007004004>
- Jiang, B., Xu, X., Garcia, A., & Lewis, J. E. (2010). Comparing two tests of formal reasoning in a college chemistry context. *Comparing Two Tests of Formal Reasoning in a College Chemistry Context*, 87(12), 1430–1437. <https://doi.org/10.1021/ed100222v>
- Jiujiyas, M., Kelley, E., & Hall, L. (2017). Restricted, Repetitive Behaviors in Autism Spectrum Disorder and Obsessive–Compulsive Disorder: A Comparative Review. *Child Psychiatry & Human Development*, 48(6), 944–959. <https://doi.org/10.1007/s10578-017-0717-0>
- Johnson, M. H. (2005). Subcortical face processing. *Nature Reviews Neuroscience*, 6(10), 766–774. <https://doi.org/10.1038/nrn1766>
- Johnson, M. H. (2014). Autism: Demise of the Innate Social Orienting Hypothesis. *Current Biology*, 24(1), R30–R31. <https://doi.org/10.1016/j.cub.2013.11.021>
- Johnson, M. H., Dziurawiec, S., Ellis, H., & Morton, J. (1991). Newborns’ preferential tracking of face-like stimuli and its subsequent decline. *Cognition*, 40(1–2), 1–19. [https://doi.org/10.1016/0010-0277\(91\)90045-6](https://doi.org/10.1016/0010-0277(91)90045-6)
- Jolliffe, T., & Baron-Cohen, S. (1997). Are People with Autism and Asperger Syndrome Faster Than Normal on the Embedded Figures Test? *Journal of Child Psychology and Psychiatry*, 38(5), 527–534. <https://doi.org/10.1111/j.1469-7610.1997.tb01539.x>

- Jones, B. T., Jones, B. C., Smith, H., & Copley, N. (2003). A flicker paradigm for inducing change blindness reveals alcohol and cannabis information processing biases in social users. *Addiction*, *98*(2), 235–244. <https://doi.org/10.1046/j.1360-0443.2003.00270.x>
- Jones, C. R. G., Happé, F., Golden, H., Marsden, A. J. S., Tregay, J., Simonoff, E., ... Charman, T. (2009). Reading and arithmetic in adolescents with autism spectrum disorders: Peaks and dips in attainment. *Neuropsychology*, *23*(6), 718–728. <https://doi.org/10.1037/a0016360>
- Jones, R. M., & Lord, C. (2013). Diagnosing autism in neurobiological research studies. *Behavioural Brain Research*, *251*, 113–124. <https://doi.org/10.1016/j.bbr.2012.10.037>
- Jones, W., Carr, K., & Klin, A. (2008). Absence of Preferential Looking to the Eyes of Approaching Adults Predicts Level of Social Disability in 2-Year-Old Toddlers With Autism Spectrum Disorder. *Archives of General Psychiatry*, *65*(8), 946. <https://doi.org/10.1001/archpsyc.65.8.946>
- Jones, W., & Klin, A. (2013). Attention to eyes is present but in decline in 2–6-month-old infants later diagnosed with autism. *Nature*, *504*(7480), 427–431. <https://doi.org/10.1038/nature12715>
- Jordan, C. J., & Caldwell-Harris, C. L. (2012). Understanding Differences in Neurotypical and Autism Spectrum Special Interests Through Internet Forums. *Intellectual and Developmental Disabilities*, *50*(5), 391–402. <https://doi.org/10.1352/1934-9556-50.5.391>
- Joseph, R. M., Ehrman, K., McNally, R., & Keehn, B. (2008). Affective response to eye contact and face recognition ability in children with ASD. *Journal of the International Neuropsychological Society*, *14*(06), 947. <https://doi.org/10.1017/S1355617708081344>
- Kahneman, D. (2012). *Thinking, fast and slow*. London: Penguin Books.

- Kahneman, D., & Frederick, S. (2002). Representativeness Revisited: Attribute Substitution in Intuitive Judgment. In T. Gilovich, D. Griffin, & D. Kahneman (Eds.), *Heuristics and Biases* (1st ed., pp. 49–81). Cambridge University Press.
<https://doi.org/10.1017/CBO9780511808098.004>
- Kanne, S. M., Christ, S. E., & Reiersen, A. M. (2009). Psychiatric Symptoms and Psychosocial Difficulties in Young Adults with Autistic Traits. *Journal of Autism and Developmental Disorders*, *39*(6), 827–833. <https://doi.org/10.1007/s10803-008-0688-x>
- Kanne, S. M., Wang, J., & Christ, S. E. (2012). The Subthreshold Autism Trait Questionnaire (SATQ): Development of a Brief Self-Report Measure of Subthreshold Autism Traits. *Journal of Autism and Developmental Disorders*, *42*(5), 769–780. <https://doi.org/10.1007/s10803-011-1308-8>
- Kanner, L. (1968). Autistic disturbances of affective contact. *Acta Paedopsychiatrica*, *35*(4), 100–136.
- Kanwisher, N. (2000). Domain specificity in face perception. *Nature Neuroscience*, *3*(8), 759–763. <https://doi.org/10.1038/77664>
- Kanwisher, N., McDermott, J., & Chun, M. M. (1997). The Fusiform Face Area: A Module in Human Extrastriate Cortex Specialized for Face Perception. *The Journal of Neuroscience*, *17*(11), 4302–4311. <https://doi.org/10.1523/JNEUROSCI.17-11-04302.1997>
- Kanwisher, N., & Yovel, G. (2006). The fusiform face area: a cortical region specialized for the perception of faces. *The Fusiform Face Area: A Cortical Region Specialized for the Perception of Faces*, *361*(1476), 2109–2128. <https://doi.org/10.1098/rstb.2006.1934>
- Keehn, B., Müller, R.-A., & Townsend, J. (2013). Atypical attentional networks and the emergence of autism. *Neuroscience & Biobehavioral Reviews*, *37*(2), 164–183.
<https://doi.org/10.1016/j.neubiorev.2012.11.014>

- Kelley, T. A., Chun, M. M., & Chua, K.-P. (2003). Effects of scene inversion on change detection of targets matched for visual salience. *Journal of Vision*, *3*(1), 1.
<https://doi.org/10.1167/3.1.1>
- Kikuchi, Y., Senju, A., Akechi, H., Tojo, Y., Osanai, H., & Hasegawa, T. (2011). Atypical Disengagement from Faces and Its Modulation by the Control of Eye Fixation in Children with Autism Spectrum Disorder. *Journal of Autism and Developmental Disorders*, *41*(5), 629–645. <https://doi.org/10.1007/s10803-010-1082-z>
- Kikuchi, Y., Senju, A., Tojo, Y., Osanai, H., & Hasegawa, T. (2009). Faces Do Not Capture Special Attention in Children With Autism Spectrum Disorder: A Change Blindness Study. *Child Development*, *80*(5), 1421–1433.
<https://doi.org/10.1111/j.1467-8624.2009.01342.x>
- Kim, J. A., Szatmari, P., Bryson, S. E., Streiner, D. L., & Wilson, F. J. (2000). The Prevalence of Anxiety and Mood Problems among Children with Autism and Asperger Syndrome. *Autism*, *4*(2), 117–132.
<https://doi.org/10.1177/1362361300004002002>
- Kim, S. H., & Lord, C. (2012). Combining information from multiple sources for the diagnosis of autism spectrum disorders for toddlers and young preschoolers from 12 to 47 months of age: Combining information for the diagnosis of ASD for toddlers and young preschoolers. *Journal of Child Psychology and Psychiatry*, *53*(2), 143–151.
<https://doi.org/10.1111/j.1469-7610.2011.02458.x>
- King, M., & Bearman, P. (2009). Diagnostic change and the increased prevalence of autism. *International Journal of Epidemiology*, *38*(5), 1224–1234.
<https://doi.org/10.1093/ije/dyp261>
- Kjellmer, L., Hedvall, Å., Fernell, E., Gillberg, C., & Norrelgen, F. (2012). Language and communication skills in preschool children with autism spectrum disorders: Contribution of cognition, severity of autism symptoms, and adaptive functioning to

the variability. *Research in Developmental Disabilities*, 33(1), 172–180.

<https://doi.org/10.1016/j.ridd.2011.09.003>

Kliemann, D., Dziobek, I., Hatri, A., Baudewig, J., & Heekeren, H. R. (2012). The Role of the Amygdala in Atypical Gaze on Emotional Faces in Autism Spectrum Disorders.

Journal of Neuroscience, 32(28), 9469–9476.

<https://doi.org/10.1523/JNEUROSCI.5294-11.2012>

Klin, A., Danovitch, J. H., Merz, A. B., & Volkmar, F. R. (2007). Circumscribed Interests in Higher Functioning Individuals With Autism Spectrum Disorders: An

Exploratory Study. *Research and Practice for Persons with Severe Disabilities*, 32(2), 89–100.

<https://doi.org/10.2511/rpsd.32.2.89>

Klin, A., Jones, W., Schultz, R., Volkmar, F., & Cohen, D. (2002). Visual Fixation

Patterns During Viewing of Naturalistic Social Situations as Predictors of Social

Competence in Individuals With Autism. *Archives of General Psychiatry*, 59(9), 809.

<https://doi.org/10.1001/archpsyc.59.9.809>

Klin, A., Lin, D. J., Gorrindo, P., Ramsay, G., & Jones, W. (2009). Two-year-olds with autism orient to non-social contingencies rather than biological motion. *Nature*,

459(7244), 257–261. <https://doi.org/10.1038/nature07868>

Kling, A. S. (1986). Neurological correlates of social behavior. *Ethology and Sociobiology*,

7(3–4), 175–186. [https://doi.org/10.1016/0162-3095\(86\)90046-4](https://doi.org/10.1016/0162-3095(86)90046-4)

Kloosterman, P. H., Keefer, K. V., Kelley, E. A., Summerfeldt, L. J., & Parker, J. D. A.

(2011). Evaluation of the factor structure of the Autism-Spectrum Quotient.

Personality and Individual Differences, 50(2), 310–314.

<https://doi.org/10.1016/j.paid.2010.10.015>

Knickmeyer, R., Baron-Cohen, S., Raggatt, P., & Taylor, K. (2005). Foetal testosterone, social relationships, and restricted interests in children. *Journal of Child Psychology and*

Psychiatry, 46(2), 198–210. <https://doi.org/10.1111/j.1469-7610.2004.00349.x>

- Kogan, M. D., Blumberg, S. J., Schieve, L. A., Boyle, C. A., Perrin, J. M., Ghandour, R. M., ... van Dyck, P. C. (2009). Prevalence of Parent-Reported Diagnosis of Autism Spectrum Disorder Among Children in the US, 2007. *PEDIATRICS*, *124*(5), 1395–1403. <https://doi.org/10.1542/peds.2009-1522>
- Kohls, G., Antezana, L., Mosner, M. G., Schultz, R. T., & Yerys, B. E. (2018). Altered reward system reactivity for personalized circumscribed interests in autism. *Molecular Autism*, *9*(1). <https://doi.org/10.1186/s13229-018-0195-7>
- Kohls, G., Chevallier, C., Troiani, V., & Schultz, R. T. (2012). Social ‘wanting’ dysfunction in autism: neurobiological underpinnings and treatment implications. *Journal of Neurodevelopmental Disorders*, *4*(1). <https://doi.org/10.1186/1866-1955-4-10>
- Kovacs, A. M., Teglas, E., & Endress, A. D. (2010). The Social Sense: Susceptibility to Others’ Beliefs in Human Infants and Adults. *Science*, *330*(6012), 1830–1834. <https://doi.org/10.1126/science.1190792>
- Kuhl, P. K., Coffey-Corina, S., Padden, D., & Dawson, G. (2005). Links between social and linguistic processing of speech in preschool children with autism: behavioral and electrophysiological measures. *Developmental Science*, *8*(1), F1–F12. <https://doi.org/10.1111/j.1467-7687.2004.00384.x>
- Kvaal, K., Ulstein, I., Nordhus, I. H., & Engedal, K. (2005). The Spielberger State-Trait Anxiety Inventory (STAI): the state scale in detecting mental disorders in geriatric patients. *International Journal of Geriatric Psychiatry*, *20*(7), 629–634. <https://doi.org/10.1002/gps.1330>
- Kylliäinen, A., & Hietanen, J. K. (2006). Skin Conductance Responses to Another Person’s Gaze in Children with Autism. *Journal of Autism and Developmental Disorders*, *36*(4), 517–525. <https://doi.org/10.1007/s10803-006-0091-4>

- Lai, M.-C., Lombardo, M. V., Suckling, J., Ruigrok, A. N. V., Chakrabarti, B., Ecker, C., ... Baron-Cohen, S. (2013). Biological sex affects the neurobiology of autism. *Brain*, 136(9), 2799–2815. <https://doi.org/10.1093/brain/awt216>
- Lai, Meng-Chuan, Lombardo, M. V., Auyeung, B., Chakrabarti, B., & Baron-Cohen, S. (2015). Sex/Gender Differences and Autism: Setting the Scene for Future Research. *Journal of the American Academy of Child & Adolescent Psychiatry*, 54(1), 11–24. <https://doi.org/10.1016/j.jaac.2014.10.003>
- Lai, Meng-Chuan, Lombardo, M. V., Pasco, G., Ruigrok, A. N. V., Wheelwright, S. J., Sadek, S. A., ... Baron-Cohen, S. (2011). A Behavioral Comparison of Male and Female Adults with High Functioning Autism Spectrum Conditions. *PLoS ONE*, 6(6), e20835. <https://doi.org/10.1371/journal.pone.0020835>
- Lai, Meng-Chuan, Lombardo, M. V., Ruigrok, A. N. V., Chakrabarti, B., Wheelwright, S. J., Auyeung, B., ... Baron-Cohen, S. (2012). Cognition in Males and Females with Autism: Similarities and Differences. *PLoS ONE*, 7(10), e47198. <https://doi.org/10.1371/journal.pone.0047198>
- Lam, K. S. L., Bodfish, J. W., & Piven, J. (2008). Evidence for three subtypes of repetitive behavior in autism that differ in familiarity and association with other symptoms: Evidence for three subtypes of repetitive behavior in autism. *Journal of Child Psychology and Psychiatry*, 49(11), 1193–1200. <https://doi.org/10.1111/j.1469-7610.2008.01944.x>
- Lawson, A. E. (1978). The development and validation of a classroom test of formal reasoning. *Journal of Research in Science Teaching*, 15(1), 11–24. <https://doi.org/10.1002/tea.3660150103>
- Lawson, J., Baron-Cohen, S., & Wheelwright, S. (2004). Empathising and Systemising in Adults with and without Asperger Syndrome. *Journal of Autism and Developmental Disorders*, 34(3), 301–310. <https://doi.org/10.1023/B:JADD.0000029552.42724.1b>

- Lee, P. S., Foss-Feig, J., Henderson, J. G., Kenworthy, L. E., Gilotty, L., Gaillard, W. D., & Vaidya, C. J. (2007). Atypical neural substrates of Embedded Figures Task performance in children with Autism Spectrum Disorder. *NeuroImage*, *38*(1), 184–193. <https://doi.org/10.1016/j.neuroimage.2007.07.013>
- Leekam, S. R., Prior, M. R., & Uljarevic, M. (2011). Restricted and repetitive behaviors in autism spectrum disorders: A review of research in the last decade. *Psychological Bulletin*, *137*(4), 562–593. <https://doi.org/10.1037/a0023341>
- Lehnhardt, F.-G., Falter, C. M., Gawronski, A., Pfeiffer, K., Tepest, R., Franklin, J., & Vogeley, K. (2016). Sex-Related Cognitive Profile in Autism Spectrum Disorders Diagnosed Late in Life: Implications for the Female Autistic Phenotype. *Journal of Autism and Developmental Disorders*, *46*(1), 139–154. <https://doi.org/10.1007/s10803-015-2558-7>
- Levy, A., & Perry, A. (2011). Outcomes in adolescents and adults with autism: A review of the literature. *Research in Autism Spectrum Disorders*, *5*(4), 1271–1282. <https://doi.org/10.1016/j.rasd.2011.01.023>
- Leyfer, O. T., Folstein, S. E., Bacalman, S., Davis, N. O., Dinh, E., Morgan, J., ... Lainhart, J. E. (2006). Comorbid Psychiatric Disorders in Children with Autism: Interview Development and Rates of Disorders. *Journal of Autism and Developmental Disorders*, *36*(7), 849–861. <https://doi.org/10.1007/s10803-006-0123-0>
- Lidstone, J., Uljarević, M., Sullivan, J., Rodgers, J., McConachie, H., Freston, M., ... Leekam, S. (2014). Relations among restricted and repetitive behaviors, anxiety and sensory features in children with autism spectrum disorders. *Research in Autism Spectrum Disorders*, *8*(2), 82–92. <https://doi.org/10.1016/j.rasd.2013.10.001>
- Liew, S. M., Thevaraja, N., Hong, R. Y., & Magiati, I. (2015). The Relationship Between Autistic Traits and Social Anxiety, Worry, Obsessive–Compulsive, and Depressive Symptoms: Specific and Non-specific Mediators in a Student Sample. *Journal of*

Autism and Developmental Disorders, 45(3), 858–872. <https://doi.org/10.1007/s10803-014-2238-z>

Lin, A., Rangel, A., & Adolphs, R. (2012). Impaired Learning of Social Compared to Monetary Rewards in Autism. *Frontiers in Neuroscience*, 6.

<https://doi.org/10.3389/fnins.2012.00143>

Lockwood, K. A., Alexopoulos, G. S., & van Gorp, W. G. (2002). Executive Dysfunction in Geriatric Depression. *American Journal of Psychiatry*, 159(7), 1119–1126.

<https://doi.org/10.1176/appi.ajp.159.7.1119>

Loomes, R., Hull, L., & Mandy, W. P. L. (2017). What Is the Male-to-Female Ratio in Autism Spectrum Disorder? A Systematic Review and Meta-Analysis. *Journal of the American Academy of Child & Adolescent Psychiatry*, 56(6), 466–474.

<https://doi.org/10.1016/j.jaac.2017.03.013>

Lord, C., Risi, S., Lambrecht, L., Cook, E. H., Leventhal, B. L., DiLavore, P. C., ... Rutter, M. (2000). The autism diagnostic observation schedule-generic: a standard measure of social and communication deficits associated with the spectrum of autism. *Journal of Autism and Developmental Disorders*, 30(3), 205–223.

Lord, Catherine, & Jones, R. M. (2012). Annual Research Review: Re-thinking the classification of autism spectrum disorders: Re-thinking autism. *Journal of Child Psychology and Psychiatry*, 53(5), 490–509. [https://doi.org/10.1111/j.1469-](https://doi.org/10.1111/j.1469-7610.2012.02547.x)

[7610.2012.02547.x](https://doi.org/10.1111/j.1469-7610.2012.02547.x)

Lord, Catherine, Rutter, M., & Le Couteur, A. (1994). Autism Diagnostic Interview-Revised: A revised version of a diagnostic interview for caregivers of individuals with possible pervasive developmental disorders. *Journal of Autism and Developmental Disorders*, 24(5), 659–685. <https://doi.org/10.1007/BF02172145>

Losh, M., Childress, D., Lam, K., & Piven, J. (2008). Defining key features of the broad autism phenotype: A comparison across parents of multiple- and single-incidence

- autism families. *American Journal of Medical Genetics Part B: Neuropsychiatric Genetics*, 147B(4), 424–433. <https://doi.org/10.1002/ajmg.b.30612>
- Loth, E., Carlos Gómez, J., & Happé, F. (2008). Detecting changes in naturalistic scenes: contextual inconsistency does not influence spontaneous attention in high-functioning people with autism spectrum disorder. *Autism Research*, 1(3), 179–188. <https://doi.org/10.1002/aur.19>
- Maccari, L., Casagrande, M., Martella, D., Anolfo, M., Rosa, C., Fuentes, L. J., & Pasini, A. (2013). Change Blindness in Children With ADHD: A Selective Impairment in Visual Search? *Journal of Attention Disorders*, 17(7), 620–627. <https://doi.org/10.1177/1087054711433294>
- Machado, C. J., Bliss-Moreau, E., Platt, M. L., & Amaral, D. G. (2011). Social and Nonsocial Content Differentially Modulates Visual Attention and Autonomic Arousal in Rhesus Macaques. *PLoS ONE*, 6(10), e26598. <https://doi.org/10.1371/journal.pone.0026598>
- Magrelli, S., Jermann, P., Noris, B., Ansermet, F., Hentsch, F., Nadel, J., & Billard, A. (2013). Social orienting of children with autism to facial expressions and speech: a study with a wearable eye-tracker in naturalistic settings. *Frontiers in Psychology*, 4. <https://doi.org/10.3389/fpsyg.2013.00840>
- Mandy, W., Chilvers, R., Chowdhury, U., Salter, G., Seigal, A., & Skuse, D. (2012). Sex Differences in Autism Spectrum Disorder: Evidence from a Large Sample of Children and Adolescents. *Journal of Autism and Developmental Disorders*, 42(7), 1304–1313. <https://doi.org/10.1007/s10803-011-1356-0>
- Mandy, W. P. L., & Skuse, D. H. (2008). Research Review: What is the association between the social-communication element of autism and repetitive interests, behaviours and activities? *Journal of Child Psychology and Psychiatry*, 49(8), 795–808. <https://doi.org/10.1111/j.1469-7610.2008.01911.x>

Manjaly, Z. M., Bruning, N., Neufang, S., Stephan, K. E., Brieber, S., Marshall, J. C., ...

Fink, G. R. (2007). Neurophysiological correlates of relatively enhanced local visual search in autistic adolescents. *NeuroImage*, *35*(1), 283–291.

<https://doi.org/10.1016/j.neuroimage.2006.11.036>

Manson, C., & Winterbottom, M. (2012). Examining the association between

empathising, systemising, degree subject and gender. *Educational Studies*, *38*(1), 73–88.

<https://doi.org/10.1080/03055698.2011.567032>

Mares, I., Smith, M. L., Johnson, M. H., & Senju, A. (2016). Direct gaze facilitates rapid

orienting to faces: Evidence from express saccades and saccadic potentials. *Biological*

Psychology, *121*, 84–90. <https://doi.org/10.1016/j.biopsycho.2016.10.003>

Martínez-Velázquez, E. S., Honoré, J., de Zorzi, L., Ramos-Loyo, J., & Sequeira, H.

(2017). Autonomic Reactivity to Arousing Stimuli with Social and Non-social

Relevance in Alexithymia. *Frontiers in Psychology*, *8*.

<https://doi.org/10.3389/fpsyg.2017.00361>

Matson, J. L., & Kozlowski, A. M. (2011). The increasing prevalence of autism spectrum

disorders. *Research in Autism Spectrum Disorders*, *5*(1), 418–425.

<https://doi.org/10.1016/j.rasd.2010.06.004>

Mathersul, D., McDonald, S., & Rushby, J. A. (2013). Psychophysiological correlates of

social judgement in high-functioning adults with autism spectrum disorder.

International Journal of Psychophysiology, *87*(1), 88–94.

<https://doi.org/10.1016/j.ijpsycho.2012.11.005>

Mayer, B., Muris, P., Vogel, L., Nojoredjo, I., & Merckelbach, H. (2006). Fear-relevant

change detection in spider-fearful and non-fearful participants. *Journal of Anxiety*

Disorders, *20*(4), 510–519. <https://doi.org/10.1016/j.janxdis.2005.05.001>

Mayer, J. L. (2017). The Relationship Between Autistic Traits and Atypical Sensory

Functioning in Neurotypical and ASD Adults: A Spectrum Approach. *Journal of*

Autism and Developmental Disorders, 47(2), 316–327. <https://doi.org/10.1007/s10803-016-2948-5>

Mazefsky, C. A., Herrington, J., Siegel, M., Scarpa, A., Maddox, B. B., Scahill, L., & White, S. W. (2013). The Role of Emotion Regulation in Autism Spectrum Disorder. *Journal of the American Academy of Child & Adolescent Psychiatry*, 52(7), 679–688. <https://doi.org/10.1016/j.jaac.2013.05.006>

Mazza, V., Turatto, M., & Umiltà, C. (2005). Foreground-background segmentation and attention: A change blindness study. *Psychological Research Psychologische Forschung*, 69(3), 201–210. <https://doi.org/10.1007/s00426-004-0174-9>

McGlynn, F. D., Wheeler, S. A., Wilamowska, Z. A., & Katz, J. S. (2008). Detection of change in threat-related and innocuous scenes among snake-fearful and snake-tolerant participants: Data from the flicker task. *Journal of Anxiety Disorders*, 22(3), 515–523. <https://doi.org/10.1016/j.janxdis.2007.05.002>

McGugin, R. W., McKeeff, T. J., Tong, F., & Gauthier, I. (2011). Irrelevant objects of expertise compete with faces during visual search. *Attention, Perception, & Psychophysics*, 73(2), 309–317. <https://doi.org/10.3758/s13414-010-0006-5>

Mercier, C., Mottron, L., & Belleville, S. (2000). A Psychosocial Study on Restricted Interests in High Functioning Persons with Pervasive Developmental Disorders. *Autism*, 4(4), 406–425. <https://doi.org/10.1177/1362361300004004006>

Mills, R. S. L., Pedersen, J., & Grusec, J. E. (1989). Sex differences in reasoning and emotion about altruism. *Sex Roles*, 20(11–12), 603–621. <https://doi.org/10.1007/BF00288074>

Milne, E., & Szczerbinski, M. (2009). Global and local perceptual style, field-independence, and central coherence: An attempt at concept validation. *Advances in Cognitive Psychology*, 5(1), 1–26. <https://doi.org/10.2478/v10053-008-0062-8>

- Milne, E., White, S., Campbell, R., Swettenham, J., Hansen, P., & Ramus, F. (2006). Motion and Form Coherence Detection in Autistic Spectrum Disorder: Relationship to Motor Control and 2:4 Digit Ratio. *Journal of Autism and Developmental Disorders*, *36*(2), 225–237. <https://doi.org/10.1007/s10803-005-0052-3>
- Mitchell, P., & Ropar, D. (2004). Visuo-spatial abilities in autism: A review. *Infant and Child Development*, *13*(3), 185–198. <https://doi.org/10.1002/icd.348>
- Mito, H., Matsuura, N., Mukai, K., Yanagisawa, Y., Nakajima, A., Motoyama, M., ... Matsunaga, H. (2014). The impacts of elevated autism spectrum disorder traits on clinical and psychosocial features and long-term treatment outcome in adult patients with obsessive-compulsive disorder. *Comprehensive Psychiatry*, *55*(7), 1526–1533. <https://doi.org/10.1016/j.comppsy.2014.05.005>
- Mosconi, M. W., Mack, P. B., McCarthy, G., & Pelphrey, K. A. (2005). Taking an “intentional stance” on eye-gaze shifts: A functional neuroimaging study of social perception in children. *NeuroImage*, *27*(1), 247–252. <https://doi.org/10.1016/j.neuroimage.2005.03.027>
- Moseley, R. L., Shtyrov, Y., Mohr, B., Lombardo, M. V., Baron-Cohen, S., & Pulvermüller, F. (2015). Lost for emotion words: What motor and limbic brain activity reveals about autism and semantic theory. *NeuroImage*, *104*, 413–422. <https://doi.org/10.1016/j.neuroimage.2014.09.046>
- Mottron, L., & Burack, J. A. (2001). Enhanced perceptual functioning in the development of autism. In J. A. Burack (Ed.), *The development of autism: perspectives from theory and research* (pp. 131–148). Mahwah, N.J: L. Erlbaum.
- Mottron, L., Dawson, M., Soulières, I., Hubert, B., & Burack, J. (2006). Enhanced Perceptual Functioning in Autism: An Update, and Eight Principles of Autistic Perception. *Journal of Autism and Developmental Disorders*, *36*(1), 27–43. <https://doi.org/10.1007/s10803-005-0040-7>

- Mul, C., Stagg, S. D., Herbelin, B., & Aspell, J. E. (2018). The Feeling of Me Feeling for You: Interoception, Alexithymia and Empathy in Autism. *Journal of Autism and Developmental Disorders*, 48(9), 2953–2967. <https://doi.org/10.1007/s10803-018-3564-3>
- Murata, A., Wen, W., & Asama, H. (2016). The body and objects represented in the ventral stream of the parieto-premotor network. *Neuroscience Research*, 104, 4–15. <https://doi.org/10.1016/j.neures.2015.10.010>
- Muris, P., & Ollendick, T. H. (2005). The Role of Temperament in the Etiology of Child Psychopathology. *Clinical Child and Family Psychology Review*, 8(4), 271–289. <https://doi.org/10.1007/s10567-005-8809-y>
- Muschalla, B., Linden, M., & Olbrich, D. (2010). The relationship between job-anxiety and trait-anxiety—A differential diagnostic investigation with the Job-Anxiety-Scale and the State-Trait-Anxiety-Inventory. *Journal of Anxiety Disorders*, 24(3), 366–371. <https://doi.org/10.1016/j.janxdis.2010.02.001>
- Muth, A., Hönekopp, J., & Falter, C. M. (2014). Visuo-Spatial Performance in Autism: A Meta-analysis. *Journal of Autism and Developmental Disorders*, 44(12), 3245–3263. <https://doi.org/10.1007/s10803-014-2188-5>
- Nagin, D. S., & Pogarsky, G. (2003). An experimental investigation of deterrence: cheating, self-serving bias, and impulsivity. *Criminology*, 41(1), 167–194. <https://doi.org/10.1111/j.1745-9125.2003.tb00985.x>
- Naveteur, J., Buisine, S., & Gruzelier, J. H. (2005). The influence of anxiety on electrodermal responses to distractors. *International Journal of Psychophysiology*, 56(3), 261–269. <https://doi.org/10.1016/j.ijpsycho.2004.12.006>
- Naveteur, J., & Freixa I Baque, E. (1987). Individual differences in electrodermal activity as a function of subjects' anxiety. *Personality and Individual Differences*, 8(5), 615–626. [https://doi.org/10.1016/0191-8869\(87\)90059-6](https://doi.org/10.1016/0191-8869(87)90059-6)

- Navon, D. (1977). Forest before trees: The precedence of global features in visual perception. *Cognitive Psychology*, 9(3), 353–383. [https://doi.org/10.1016/0010-0285\(77\)90012-3](https://doi.org/10.1016/0010-0285(77)90012-3)
- Nestadt, G., Samuels, J., Riddle, M. A., Liang, K.-Y., Bienvenu, O. J., Hoehn-Saric, R., ... Cullen, B. (2001). The relationship between obsessive–compulsive disorder and anxiety and affective disorders: results from the Johns Hopkins OCD Family Study. *Psychological Medicine*, 31(03). <https://doi.org/10.1017/S0033291701003579>
- Nettle, D. (2007). Empathizing and systemizing: What are they, and what do they contribute to our understanding of psychological sex differences? *British Journal of Psychology*, 98(2), 237–255. <https://doi.org/10.1348/000712606X117612>
- Neufeld, J., Roy, M., Zapf, A., Sinke, C., Emrich, H. M., Prox-Vagedes, V., ... Zedler, M. (2013). Is synesthesia more common in patients with Asperger syndrome? *Frontiers in Human Neuroscience*, 7. <https://doi.org/10.3389/fnhum.2013.00847>
- New, J. J., Schultz, R. T., Wolf, J., Niehaus, J. L., Klin, A., German, T. C., & Scholl, B. J. (2010). The scope of social attention deficits in autism: Prioritized orienting to people and animals in static natural scenes. *Neuropsychologia*, 48(1), 51–59. <https://doi.org/10.1016/j.neuropsychologia.2009.08.008>
- Newstead, S. E., Handley, S. J., Harley, C., Wright, H., & Farrelly, D. (2004). Individual Differences in Deductive Reasoning. *The Quarterly Journal of Experimental Psychology Section A*, 57(1), 33–60. <https://doi.org/10.1080/02724980343000116>
- Nummenmaa, L., Engell, A. D., von dem Hagen, E., Henson, R. N. A., & Calder, A. J. (2012). Autism spectrum traits predict the neural response to eye gaze in typical individuals. *NeuroImage*, 59(4), 3356–3363. <https://doi.org/10.1016/j.neuroimage.2011.10.075>

- Oliva, M., & Anikin, A. (2018). Pupil dilation reflects the time course of emotion recognition in human vocalizations. *Scientific Reports*, 8(1).
<https://doi.org/10.1038/s41598-018-23265-x>
- Onishi, K. H. (2005). Do 15-Month-Old Infants Understand False Beliefs? *Science*, 308(5719), 255–258. <https://doi.org/10.1126/science.1107621>
- O’Riordan, M. (2000). Superior modulation of activation levels of stimulus representations does not underlie superior discrimination in autism. *Cognition*, 77(2), 81–96. [https://doi.org/10.1016/S0010-0277\(00\)00089-5](https://doi.org/10.1016/S0010-0277(00)00089-5)
- O’Riordan, M. A. (2004). Superior Visual Search in Adults with Autism. *Autism*, 8(3), 229–248. <https://doi.org/10.1177/1362361304045219>
- O’Riordan, M. A., Plaisted, K. C., Driver, J., & Baron-Cohen, S. (2001). Superior visual search in autism. *Journal of Experimental Psychology: Human Perception and Performance*, 27(3), 719–730. <https://doi.org/10.1037/0096-1523.27.3.719>
- Overskeid, G. (2016). Systemizing in autism: The case for an emotional mechanism. *New Ideas in Psychology*, 41, 18–22. <https://doi.org/10.1016/j.newideapsych.2016.01.001>
- Ozonoff, S., Pennington, B. F., & Rogers, S. J. (1991). Executive Function Deficits in High-Functioning Autistic Individuals: Relationship to Theory of Mind. *Journal of Child Psychology and Psychiatry*, 32(7), 1081–1105. <https://doi.org/10.1111/j.1469-7610.1991.tb00351.x>
- Pacini, R., & Epstein, S. (1999). The relation of rational and experiential information processing styles to personality, basic beliefs, and the ratio-bias phenomenon. *Journal of Personality and Social Psychology*, 76(6), 972–987.
- Palermo, R., & Rhodes, G. (2003). Change detection in the flicker paradigm: Do faces have an advantage? *Visual Cognition*, 10(6), 683–713.
<https://doi.org/10.1080/13506280344000059>

- Parsons, O. E., Bayliss, A. P., & Remington, A. (2017). A few of my favorite things: circumscribed interests in autism are not accompanied by increased attentional salience on a personalized selective attention task. *Molecular Autism*, 8(1).
<https://doi.org/10.1186/s13229-017-0132-1>
- Pascalis, O., de Schonen, S., Morton, J., Deruelle, C., & Fabre-Grenet, M. (1995). Mother's face recognition by neonates: A replication and an extension. *Infant Behavior and Development*, 18(1), 79–85. [https://doi.org/10.1016/0163-6383\(95\)90009-8](https://doi.org/10.1016/0163-6383(95)90009-8)
- Paul, L. K., Corsello, C., Tranel, D., & Adolphs, R. (2010). Does bilateral damage to the human amygdala produce autistic symptoms? *Journal of Neurodevelopmental Disorders*, 2(3), 165–173. <https://doi.org/10.1007/s11689-010-9056-1>
- Paula-Pérez, I. (2013). Differential diagnosis between obsessive compulsive disorder and restrictive and repetitive behavioural patterns, activities and interests in autism spectrum disorders. *Revista de Psiquiatría y Salud Mental (English Edition)*, 6(4), 178–186. <https://doi.org/10.1016/j.rpsmen.2012.07.006>
- Pellicano, E., Dinsmore, A., & Charman, T. (2014). What should autism research focus upon? Community views and priorities from the United Kingdom. *Autism*, 18(7), 756–770. <https://doi.org/10.1177/1362361314529627>
- Piven, J. (1997). Broader autism phenotype: evidence from a family history study of multiple-incidence autism families. *American Journal of Psychiatry*, 154(2), 185–190.
<https://doi.org/10.1176/ajp.154.2.185>
- Piven, Joseph, & Sasson, N. J. (2014). On the Misapplication of the Broad Autism Phenotype Questionnaire in a Study of Autism. *Journal of Autism and Developmental Disorders*, 44(8), 2077–2078. <https://doi.org/10.1007/s10803-014-2076-z>
- Plaisted, K., O'Riordan, M., & Baron-Cohen, S. (1998). Enhanced Visual Search for a Conjunctive Target in Autism: A Research Note. *Journal of Child Psychology and Psychiatry*, 39(5), 777–783. <https://doi.org/10.1111/1469-7610.00376>

- Posserud, M.-B., Lundervold, A. J., & Gillberg, C. (2006). Autistic features in a total population of 7-9-year-old children assessed by the ASSQ (Autism Spectrum Screening Questionnaire). *Journal of Child Psychology and Psychiatry*, 47(2), 167–175. <https://doi.org/10.1111/j.1469-7610.2005.01462.x>
- Proverbio, A. M., Adorni, R., Zani, A., & Trestianu, L. (2009). Sex differences in the brain response to affective scenes with or without humans. *Neuropsychologia*, 47(12), 2374–2388. <https://doi.org/10.1016/j.neuropsychologia.2008.10.030>
- Quiroga, R. Q., Mukamel, R., Isham, E. A., Malach, R., & Fried, I. (2008). Human single-neuron responses at the threshold of conscious recognition. *Proceedings of the National Academy of Sciences*, 105(9), 3599–3604. <https://doi.org/10.1073/pnas.0707043105>
- Quiroga, R. Quian, Reddy, L., Kreiman, G., Koch, C., & Fried, I. (2005). Invariant visual representation by single neurons in the human brain. *Nature*, 435(7045), 1102–1107. <https://doi.org/10.1038/nature03687>
- Qureshi, A. W., Apperly, I. A., & Samson, D. (2010). Executive function is necessary for perspective selection, not Level-1 visual perspective calculation: Evidence from a dual-task study of adults. *Cognition*, 117(2), 230–236. <https://doi.org/10.1016/j.cognition.2010.08.003>
- Rajmohan, V., & Mohandas, E. (2007). Mirror neuron system. *Indian Journal of Psychiatry*, 49(1), 66. <https://doi.org/10.4103/0019-5545.31522>
- Ravizza, S. M., Solomon, M., Ivry, R. B., & Carter, C. S. (2013). Restricted and repetitive behaviors in autism spectrum disorders: The relationship of attention and motor deficits. *Development and Psychopathology*, 25(03), 773–784. <https://doi.org/10.1017/S0954579413000163>
- Reed, P., Giles, A., Gavin, M., Carter, N., & Osborne, L. A. (2016). Loneliness and Social Anxiety Mediate the Relationship between Autism Quotient and Quality of Life in

- University Students. *Journal of Developmental and Physical Disabilities*, 28(5), 723–733.
<https://doi.org/10.1007/s10882-016-9504-2>
- Reinecke, A., Becker, E. S., & Rinck, M. (2010). Visual working memory and threat monitoring: Spider fearfuls show disorder-specific change detection. *Behaviour Research and Therapy*, 48(8), 770–778. <https://doi.org/10.1016/j.brat.2010.05.003>
- Rensink, R. (1995). Image flicker is as good as saccades in making large scene changes invisible. *Perception*, 24, 26–27.
- Rensink, R. A., O'Regan, J. K., & Clark, J. J. (1997). To See or not to See: The Need for Attention to Perceive Changes in Scenes. *Psychological Science*, 8(5), 368–373.
<https://doi.org/10.1111/j.1467-9280.1997.tb00427.x>
- Reuland, E. (2010). Imagination, Planning, and Working Memory: The Emergence of Language. *Current Anthropology*, 51(S1), S99–S110. <https://doi.org/10.1086/651260>
- Riby, D. M., & Hancock, P. J. B. (2009). Do Faces Capture the Attention of Individuals with Williams Syndrome or Autism? Evidence from Tracking Eye Movements. *Journal of Autism and Developmental Disorders*, 39(3), 421–431.
<https://doi.org/10.1007/s10803-008-0641-z>
- Ring, H. A., Baron-Cohen, S., Wheelwright, S., Williams, S. C. R., Brammer, M., Andrew, C., & Bullmore, E. T. (1999). Cerebral correlates of preserved cognitive skills in autism. *Brain*, 122(7), 1305–1315. <https://doi.org/10.1093/brain/122.7.1305>
- Risi, S., Lord, C., Gotham, K., Corsello, C., Chrysler, C., Szatmari, P., ... Pickles, A. (2006). Combining Information From Multiple Sources in the Diagnosis of Autism Spectrum Disorders. *Journal of the American Academy of Child & Adolescent Psychiatry*, 45(9), 1094–1103. <https://doi.org/10.1097/01.chi.0000227880.42780.0e>
- Riskind, J. H., Abreu, K., Strauss, M., & Holt, R. (1997). Looming vulnerability to spreading contamination in subclinical OCD. *Behaviour Research and Therapy*, 35(5), 405–414. [https://doi.org/10.1016/S0005-7967\(96\)00113-1](https://doi.org/10.1016/S0005-7967(96)00113-1)

- Rivard, K., Protzner, A. B., Burles, F., Schuetze, M., Cho, I., Ten Eycke, K., ... Bray, S. (2018). Largely Typical Electrophysiological Affective Responses to Special Interest Stimuli in Adolescents with Autism Spectrum Disorder. *Journal of Autism and Developmental Disorders*, 48(9), 3133–3143. <https://doi.org/10.1007/s10803-018-3587-9>
- Rivet, T. T., & Matson, J. L. (2011). Review of gender differences in core symptomatology in autism spectrum disorders. *Research in Autism Spectrum Disorders*, 5(3), 957–976. <https://doi.org/10.1016/j.rasd.2010.12.003>
- Rizzolatti, G., Fadiga, L., Matelli, M., Bettinardi, V., Paulesu, E., Perani, D., & Fazio, F. (1996). Localization of grasp representations in humans by PET: 1. Observation versus execution. *Experimental Brain Research*, 111(2). <https://doi.org/10.1007/BF00227301>
- Ro, T., Friggel, A., & Lavie, N. (2007). Attentional biases for faces and body parts. *Visual Cognition*, 15(3), 322–348. <https://doi.org/10.1080/13506280600590434>
- Robertson, C. E., Kravitz, D. J., Freyberg, J., Baron-Cohen, S., & Baker, C. I. (2013). Tunnel Vision: Sharper Gradient of Spatial Attention in Autism. *Journal of Neuroscience*, 33(16), 6776–6781. <https://doi.org/10.1523/JNEUROSCI.5120-12.2013>
- Rodgers, J., Glod, M., Connolly, B., & McConachie, H. (2012). The Relationship Between Anxiety and Repetitive Behaviours in Autism Spectrum Disorder. *Journal of Autism and Developmental Disorders*, 42(11), 2404–2409. <https://doi.org/10.1007/s10803-012-1531-y>
- Romano, M., Truzoli, R., Osborne, L. A., & Reed, P. (2014). The relationship between autism quotient, anxiety, and internet addiction. *Research in Autism Spectrum Disorders*, 8(11), 1521–1526. <https://doi.org/10.1016/j.rasd.2014.08.002>

Ronald, A., Happé, F., Bolton, P., Butcher, L. M., Price, T. S., Wheelwright, S., ...

Plomin, R. (2006). Genetic Heterogeneity Between the Three Components of the Autism Spectrum: A Twin Study. *Journal of the American Academy of Child & Adolescent Psychiatry*, 45(6), 691–699. <https://doi.org/10.1097/01.chi.0000215325.13058.9d>

Ronald, A., & Hoekstra, R. A. (2011). Autism spectrum disorders and autistic traits: A decade of new twin studies. *American Journal of Medical Genetics Part B: Neuropsychiatric Genetics*, 156(3), 255–274. <https://doi.org/10.1002/ajmg.b.31159>

Rosen, K. V., & Tallis, F. (1995). Investigation into the relationship between personality traits and OCD. *Behaviour Research and Therapy*, 33(4), 445–450. [https://doi.org/10.1016/0005-7967\(94\)00073-S](https://doi.org/10.1016/0005-7967(94)00073-S)

Russell-Smith, S. N., Maybery, M. T., & Bayliss, D. M. (2010). Are the Autism and Positive Schizotypy Spectra Diametrically Opposed in Local Versus Global Processing? *Journal of Autism and Developmental Disorders*, 40(8), 968–977. <https://doi.org/10.1007/s10803-010-0945-7>

Russell-Smith, S. N., Maybery, M. T., Bayliss, D. M., & Sng, A. A. H. (2012). Support for a Link Between the Local Processing Bias and Social Deficits in Autism: An Investigation of Embedded Figures Test Performance in Non-Clinical Individuals. *Journal of Autism and Developmental Disorders*, 42(11), 2420–2430. <https://doi.org/10.1007/s10803-012-1506-z>

Ruta, L., Mazzone, D., Mazzone, L., Wheelwright, S., & Baron-Cohen, S. (2012). The Autism-Spectrum Quotient—Italian Version: A Cross-Cultural Confirmation of the Broader Autism Phenotype. *Journal of Autism and Developmental Disorders*, 42(4), 625–633. <https://doi.org/10.1007/s10803-011-1290-1>

Rutherford, M. D., & McIntosh, D. N. (2007). Rules versus Prototype Matching: Strategies of Perception of Emotional Facial Expressions in the Autism Spectrum.

Journal of Autism and Developmental Disorders, 37(2), 187–196.

<https://doi.org/10.1007/s10803-006-0151-9>

- Rutherford, M. D., & Rogers, S. J. (2003). Cognitive underpinnings of pretend play in autism. *Journal of Autism and Developmental Disorders*, 33(3), 289–302.
- Ruzich, E., Allison, C., Chakrabarti, B., Smith, P., Musto, H., Ring, H., & Baron-Cohen, S. (2015). Sex and STEM Occupation Predict Autism-Spectrum Quotient (AQ) Scores in Half a Million People. *PLOS ONE*, 10(10), e0141229.
<https://doi.org/10.1371/journal.pone.0141229>
- Ruzich, E., Allison, C., Smith, P., Watson, P., Auyeung, B., Ring, H., & Baron-Cohen, S. (2015). Measuring autistic traits in the general population: a systematic review of the Autism-Spectrum Quotient (AQ) in a nonclinical population sample of 6,900 typical adult males and females. *Molecular Autism*, 6(1), 2. <https://doi.org/10.1186/2040-2392-6-2>
- Ruzich, E., Allison, C., Smith, P., Watson, P., Auyeung, B., Ring, H., & Baron-Cohen, S. (2016). Subgrouping siblings of people with autism: Identifying the broader autism phenotype: Subgrouping Siblings of People with Autism. *Autism Research*, 9(6), 658–665. <https://doi.org/10.1002/aur.1544>
- Sacks, O. (2011). *The man who mistook his wife for a hat*. London: Picador.
- Saitovitch, A., Bargiacchi, A., Chabane, N., Brunelle, F., Samson, Y., Boddaert, N., & Zilbovicius, M. (2012). Social cognition and the superior temporal sulcus: Implications in autism. *Revue Neurologique*, 168(10), 762–770.
<https://doi.org/10.1016/j.neurol.2012.07.017>
- Samson, D., Apperly, I. A., Braithwaite, J. J., Andrews, B. J., & Bodley Scott, S. E. (2010). Seeing it their way: Evidence for rapid and involuntary computation of what other people see. *Journal of Experimental Psychology: Human Perception and Performance*, 36(5), 1255–1266. <https://doi.org/10.1037/a0018729>

- Samuelson, W., & Zeckhauser, R. (1988). Status quo bias in decision making. *Journal of Risk and Uncertainty*, 1(1), 7–59. <https://doi.org/10.1007/BF00055564>
- Sasson, N. J., Dichter, G. S., & Bodfish, J. W. (2012). Affective Responses by Adults with Autism Are Reduced to Social Images but Elevated to Images Related to Circumscribed Interests. *PLoS ONE*, 7(8), e42457. <https://doi.org/10.1371/journal.pone.0042457>
- Sasson, N. J., & Touchstone, E. W. (2014). Visual Attention to Competing Social and Object Images by Preschool Children with Autism Spectrum Disorder. *Journal of Autism and Developmental Disorders*, 44(3), 584–592. <https://doi.org/10.1007/s10803-013-1910-z>
- Scerbo, A. S., Freedman, L. W., Raine, A., Dawson, M. E., & Venables, P. H. (1992). A Major Effect of Recording Site on Measurement of Electrodermal Activity. *Psychophysiology*, 29(2), 241–246. <https://doi.org/10.1111/j.1469-8986.1992.tb01693.x>
- Scherff, A., Taylor, M., Eley, T. C., Happé, F., Charman, T., & Ronald, A. (2014). What Causes Internalising Traits and Autistic Traits to Co-occur in Adolescence? A Community-Based Twin Study. *Journal of Abnormal Child Psychology*, 42(4), 601–610. <https://doi.org/10.1007/s10802-013-9796-y>
- Schlooz, W. A. J. M., & Hulstijn, W. (2014). Boys with autism spectrum disorders show superior performance on the adult Embedded Figures Test. *Research in Autism Spectrum Disorders*, 8(1), 1–7. <https://doi.org/10.1016/j.rasd.2013.10.004>
- Schneirla, T. C. (1965). Aspects of Stimulation and Organization in Approach/Withdrawal Processes Underlying Vertebrate Behavioral Development. In *Advances in the Study of Behavior* (Vol. 1, pp. 1–74). Elsevier. [https://doi.org/10.1016/S0065-3454\(08\)60055-8](https://doi.org/10.1016/S0065-3454(08)60055-8)

- Scholl, B. J. (2000). Attenuated Change Blindness for Exogenously Attended Items in a Flicker Paradigm. *Visual Cognition*, 7(1–3), 377–396.
<https://doi.org/10.1080/135062800394856>
- Schultz, R. T., Grelotti, D. J., Klin, A., Kleinman, J., Van der Gaag, C., Marois, R., & Skudlarski, P. (2003). The role of the fusiform face area in social cognition: implications for the pathobiology of autism. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 358(1430), 415–427. <https://doi.org/10.1098/rstb.2002.1208>
- Seeley, W. W., Menon, V., Schatzberg, A. F., Keller, J., Glover, G. H., Kenna, H., ... Greicius, M. D. (2007). Dissociable Intrinsic Connectivity Networks for Salience Processing and Executive Control. *Journal of Neuroscience*, 27(9), 2349–2356.
<https://doi.org/10.1523/JNEUROSCI.5587-06.2007>
- Seltzer, M. M., Shattuck, P., Abbeduto, L., & Greenberg, J. S. (2004). Trajectory of development in adolescents and adults with autism. *Mental Retardation and Developmental Disabilities Research Reviews*, 10(4), 234–247.
<https://doi.org/10.1002/mrdd.20038>
- Senju, A., Southgate, V., White, S., & Frith, U. (2009). Mindblind Eyes: An Absence of Spontaneous Theory of Mind in Asperger Syndrome. *Science*, 325(5942), 883–885.
<https://doi.org/10.1126/science.1176170>
- Shah, A., & Frith, U. (1983). An Islet of Ability in Autistic Children: A Research Note. *Journal of Child Psychology and Psychiatry*, 24(4), 613–620.
<https://doi.org/10.1111/j.1469-7610.1983.tb00137.x>
- Shah, A., & Frith, U. (1993). Why Do Autistic Individuals Show Superior Performance on the Block Design Task? *Journal of Child Psychology and Psychiatry*, 34(8), 1351–1364.
<https://doi.org/10.1111/j.1469-7610.1993.tb02095.x>

- Shah, P., Gaule, A., Bird, G., & Cook, R. (2013). Robust orienting to protofacial stimuli in autism. *Current Biology*, 23(24), R1087–R1088.
<https://doi.org/10.1016/j.cub.2013.10.034>
- Shang, C. Y., Wu, Y. H., Gau, S. S., & Tseng, W. Y. (2013). Disturbed microstructural integrity of the frontostriatal fiber pathways and executive dysfunction in children with attention deficit hyperactivity disorder. *Psychological Medicine*, 43(05), 1093–1107.
<https://doi.org/10.1017/S0033291712001869>
- Shefcyk, A. (2015). Count us in: Addressing gender disparities in autism research. *Autism*, 19(2), 131–132. <https://doi.org/10.1177/1362361314566585>
- Siddle, D. A. T. (1991). Orienting, Habituation, and Resource Allocation: An Associative Analysis. *Psychophysiology*, 28(3), 245–259. <https://doi.org/10.1111/j.1469-8986.1991.tb02190.x>
- Simner, J. (2012). Defining synaesthesia. *British Journal of Psychology*, 103(1), 1–15.
<https://doi.org/10.1348/000712610X528305>
- Simon, A., & Thomas, A. (1983). Test data for the state-trait anxiety inventory for British further Education, certificate of education and B.Ed. students. *Personality and Individual Differences*, 4(2), 199–200. [https://doi.org/10.1016/0191-8869\(83\)90020-X](https://doi.org/10.1016/0191-8869(83)90020-X)
- Simons, D. J. (2000). Current Approaches to Change Blindness. *Visual Cognition*, 7(1–3), 1–15. <https://doi.org/10.1080/135062800394658>
- Simons, D. J., & Levin, D. T. (1997). Change blindness. *Trends in Cognitive Sciences*, 1(7), 261–267. [https://doi.org/10.1016/S1364-6613\(97\)01080-2](https://doi.org/10.1016/S1364-6613(97)01080-2)
- Simons, D. J., & Levin, D. T. (1998). Failure to detect changes to people during a real-world interaction. *Psychonomic Bulletin & Review*, 5(4), 644–649.
<https://doi.org/10.3758/BF03208840>
- Simons, D. J., & Rensink, R. A. (2005). Change blindness: past, present, and future. *Trends in Cognitive Sciences*, 9(1), 16–20. <https://doi.org/10.1016/j.tics.2004.11.006>

- Singleton, C. J., Ashwin, C., & Brosnan, M. (2014). Physiological Responses to Social and Nonsocial Stimuli in Neurotypical Adults With High and Low Levels of Autistic Traits: Implications for Understanding Nonsocial Drive in Autism Spectrum Disorders: Physiological response and the nonsocial in ASD. *Autism Research*, 7(6), 695–703. <https://doi.org/10.1002/aur.1422>
- Skorich, D. P., Gash, T. B., Stalker, K. L., Zheng, L., & Haslam, S. A. (2017). Exploring the Cognitive Foundations of the Shared Attention Mechanism: Evidence for a Relationship Between Self-Categorization and Shared Attention Across the Autism Spectrum. *Journal of Autism and Developmental Disorders*, 47(5), 1341–1353. <https://doi.org/10.1007/s10803-017-3049-9>
- Sladek, R. M., Bond, M. J., & Phillips, P. A. (2010). Age and gender differences in preferences for rational and experiential thinking. *Personality and Individual Differences*, 49(8), 907–911. <https://doi.org/10.1016/j.paid.2010.07.028>
- Smith, C. J., Lang, C. M., Kryzak, L., Reichenberg, A., Hollander, E., & Silverman, J. M. (2009). Familial associations of intense preoccupations, an empirical factor of the restricted, repetitive behaviors and interests domain of autism. *Journal of Child Psychology and Psychiatry*, 50(8), 982–990. <https://doi.org/10.1111/j.1469-7610.2009.02060.x>
- Smith, H., & Milne, E. (2009). Reduced change blindness suggests enhanced attention to detail in individuals with autism. *Journal of Child Psychology and Psychiatry*, 50(3), 300–306. <https://doi.org/10.1111/j.1469-7610.2008.01957.x>
- Sonié, S., Kassai, B., Pirat, E., Bain, P., Robinson, J., Gomot, M., ... Manificat, S. (2013). The French Version of the Autism-Spectrum Quotient in Adolescents: A Cross-Cultural Validation Study. *Journal of Autism and Developmental Disorders*, 43(5), 1178–1183. <https://doi.org/10.1007/s10803-012-1663-0>

- Soulières, I., Hubert, B., Rouleau, N., Gagnon, L., Tremblay, P., Seron, X., & Mottron, L. (2010). Superior estimation abilities in two autistic spectrum children. *Cognitive Neuropsychology*, 27(3), 261–276. <https://doi.org/10.1080/02643294.2010.519228>
- South, M., Ozonoff, S., & McMahon, W. M. (2005). Repetitive Behavior Profiles in Asperger Syndrome and High-Functioning Autism. *Journal of Autism and Developmental Disorders*, 35(2), 145–158. <https://doi.org/10.1007/s10803-004-1992-8>
- South, M., Taylor, K. M., Newton, T., Christensen, M., Jamison, N. K., Chamberlain, P., ... Higley, J. D. (2017). Psychophysiological and Behavioral Responses to a Novel Intruder Threat Task for Children on the Autism Spectrum. *Journal of Autism and Developmental Disorders*, 47(12), 3704–3713. <https://doi.org/10.1007/s10803-017-3195-0>
- Spek, A. A., & Wouters, S. G. M. (2010). Autism and schizophrenia in high functioning adults: Behavioral differences and overlap. *Research in Autism Spectrum Disorders*, 4(4), 709–717. <https://doi.org/10.1016/j.rasd.2010.01.009>
- Spencer, M. D., Holt, R. J., Chura, L. R., Calder, A. J., Suckling, J., Bullmore, E. T., & Baron-Cohen, S. (2012). Atypical activation during the Embedded Figures Task as a functional magnetic resonance imaging endophenotype of autism. *Brain*, 135(11), 3469–3480. <https://doi.org/10.1093/brain/aws229>
- Spielberger, C. D. (1983). *Manual for the State-Trait Anxiety Inventory STAI (form Y) ('self-evaluation questionnaire')*. Palo Alto, CA: Consulting Psychologists Press, Inc. Retrieved from [http://scholar.google.com/scholar?q=Manual for the State-Trait Anxiety Inventory STAI \(form Y\) \('self-evaluation questionnaire'\)&btnG=&hl=en&num=20&as_sdt=0%2C22](http://scholar.google.com/scholar?q=Manual+for+the+State-Trait+Anxiety+Inventory+STAI+(form+Y)+('self-evaluation+questionnaire')&btnG=&hl=en&num=20&as_sdt=0%2C22)
- Spiker, M. A., Lin, C. E., Van Dyke, M., & Wood, J. J. (2012). Restricted interests and anxiety in children with autism. *Autism*, 16(3), 306–320. <https://doi.org/10.1177/1362361311401763>

- Stagg, S. D., Davis, R., & Heaton, P. (2013). Associations Between Language Development and Skin Conductance Responses to Faces and Eye Gaze in Children with Autism Spectrum Disorder. *Journal of Autism and Developmental Disorders*, 43(10), 2303–2311. <https://doi.org/10.1007/s10803-013-1780-4>
- Stanovich, K. E., & West, R. F. (2000). Individual differences in reasoning: implications for the rationality debate? *The Behavioral and Brain Sciences*, 23(5), 645–665; discussion 665-726.
- Stanovich, Keith E. (2009). Distinguishing the reflective, algorithmic, and autonomous minds: Is it time for a tri-process theory? In J. Evans & K. Frankish (Eds.), *In two minds: Dual processes and beyond* (pp. 55–88). Oxford University Press. <https://doi.org/10.1093/acprof:oso/9780199230167.003.0003>
- Stevenson, J. L., & Hart, K. R. (2017). Psychometric Properties of the Autism-Spectrum Quotient for Assessing Low and High Levels of Autistic Traits in College Students. *Journal of Autism and Developmental Disorders*, 47(6), 1838–1853. <https://doi.org/10.1007/s10803-017-3109-1>
- Stewart, M. E., & Austin, E. J. (2009). The structure of the Autism-Spectrum Quotient (AQ): Evidence from a student sample in Scotland. *Personality and Individual Differences*, 47(3), 224–228. <https://doi.org/10.1016/j.paid.2009.03.004>
- Svedholm-Häkkinen, A. M., Halme, S., & Lindeman, M. (2018). Empathizing and systemizing are differentially related to dimensions of autistic traits in the general population. *International Journal of Clinical and Health Psychology*, 18(1), 35–42. <https://doi.org/10.1016/j.ijchp.2017.11.001>
- Svedholm-Häkkinen, A. M., & Lindeman, M. (2016). Testing the Empathizing-Systemizing theory in the general population: Occupations, vocational interests, grades, hobbies, friendship quality, social intelligence, and sex role identity. *Personality and Individual Differences*, 90, 365–370. <https://doi.org/10.1016/j.paid.2015.11.044>

- Svedholm-Häkkinen, A. M., & Lindeman, M. (2017). Intuitive and Deliberative Empathizers and Systemizers: Dual-Process Theory and E-S Theory. *Journal of Personality, 85*(5), 593–602. <https://doi.org/10.1111/jopy.12263>
- Swanson, M. R., Serlin, G. C., & Siller, M. (2013). Broad Autism Phenotype in Typically Developing Children Predicts Performance on an Eye-Tracking Measure of Joint Attention. *Journal of Autism and Developmental Disorders, 43*(3), 707–718. <https://doi.org/10.1007/s10803-012-1616-7>
- Tammet, D., Vance, S., & Tantor Media. (2009). *Born on a blue day: inside the extraordinary mind of an autistic savant : a memoir*. Old Saybrook, Conn.: Tantor Media. Retrieved from <http://search.ebscohost.com/login.aspx?direct=true&scope=site&db=nlebk&db=nlabk&AN=273999>
- Tavassoli, T., Miller, L. J., Schoen, S. A., Nielsen, D. M., & Baron-Cohen, S. (2014). Sensory over-responsivity in adults with autism spectrum conditions. *Autism, 18*(4), 428–432. <https://doi.org/10.1177/1362361313477246>
- Tinbergen, N. (1989). *The study of instinct*. Oxford [England] : New York: Clarendon Press ; Oxford University Press.
- Tobin, K. G., & Capie, W. (1981). The Development and Validation of a Group Test of Logical Thinking. *Educational and Psychological Measurement, 41*(2), 413–423. <https://doi.org/10.1177/001316448104100220>
- Tomalski, P., Csibra, G., & Johnson, M. H. (2009). Rapid Orienting toward Face-like Stimuli with Gaze-Relevant Contrast Information. *Perception, 38*(4), 569–578. <https://doi.org/10.1068/p6137>
- Tracy, J. L., Robins, R. W., Schriber, R. A., & Solomon, M. (2011). Is Emotion Recognition Impaired in Individuals with Autism Spectrum Disorders? *Journal of*

Autism and Developmental Disorders, 41(1), 102–109. <https://doi.org/10.1007/s10803-010-1030-y>

- Treffert, D. A. (2009). The savant syndrome: an extraordinary condition. A synopsis: past, present, future. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 364(1522), 1351–1357. <https://doi.org/10.1098/rstb.2008.0326>
- Trick, L. M., & Pylyshyn, Z. W. (1994). Why are small and large numbers enumerated differently? A limited-capacity preattentive stage in vision. *Psychological Review*, 101(1), 80–102.
- Trick, Lana M., & Enns, J. T. (1997). Measuring Preattentive Processes: When is Pop-out Not Enough? *Visual Cognition*, 4(2), 163–198. <https://doi.org/10.1080/713756754>
- Truett, A., Puce, A., & McCarthy, G. (2000). Social perception from visual cues: role of the STS region. *Trends in Cognitive Sciences*, 4(7), 267–278. [https://doi.org/10.1016/S1364-6613\(00\)01501-1](https://doi.org/10.1016/S1364-6613(00)01501-1)
- Truzzi, A., Setoh, P., Shinohara, K., & Esposito, G. (2016). Physiological responses to dyadic interactions are influenced by neurotypical adults' levels of autistic and empathy traits. *Physiology & Behavior*, 165, 7–14. <https://doi.org/10.1016/j.physbeh.2016.06.034>
- Turner, M. (1999). Annotation: Repetitive Behaviour in Autism: A Review of Psychological Research. *Journal of Child Psychology and Psychiatry*, 40(6), 839–849. <https://doi.org/10.1111/1469-7610.00502>
- Turner-Brown, L. M., Lam, K. S. L., Holtzclaw, T. N., Dichter, G. S., & Bodfish, J. W. (2011). Phenomenology and measurement of circumscribed interests in autism spectrum disorders. *Autism*, 15(4), 437–456. <https://doi.org/10.1177/1362361310386507>
- Unruh, K. E., Sasson, N. J., Shafer, R. L., Whitten, A., Miller, S. J., Turner-Brown, L., & Bodfish, J. W. (2016). Social Orienting and Attention Is Influenced by the Presence

of Competing Nonsocial Information in Adolescents with Autism. *Frontiers in Neuroscience*, 10. <https://doi.org/10.3389/fnins.2016.00586>

Vabalas, A., & Freeth, M. (2016). Brief Report: Patterns of Eye Movements in Face to Face Conversation are Associated with Autistic Traits: Evidence from a Student Sample. *Journal of Autism and Developmental Disorders*, 46(1), 305–314. <https://doi.org/10.1007/s10803-015-2546-y>

Van Wijngaarden-Cremers, P. J. M., van Eeten, E., Groen, W. B., Van Deurzen, P. A., Oosterling, I. J., & Van der Gaag, R. J. (2014a). Gender and Age Differences in the Core Triad of Impairments in Autism Spectrum Disorders: A Systematic Review and Meta-analysis. *Journal of Autism and Developmental Disorders*, 44(3), 627–635. <https://doi.org/10.1007/s10803-013-1913-9>

Van Wijngaarden-Cremers, P. J. M., van Eeten, E., Groen, W. B., Van Deurzen, P. A., Oosterling, I. J., & Van der Gaag, R. J. (2014b). Gender and Age Differences in the Core Triad of Impairments in Autism Spectrum Disorders: A Systematic Review and Meta-analysis. *Journal of Autism and Developmental Disorders*, 44(3), 627–635. <https://doi.org/10.1007/s10803-013-1913-9>

Van Wijngaarden-Cremers, P. J. M., van Eeten, E., Groen, W. B., Van Deurzen, P. A., Oosterling, I. J., & Van der Gaag, R. J. (2014c). Gender and Age Differences in the Core Triad of Impairments in Autism Spectrum Disorders: A Systematic Review and Meta-analysis. *Journal of Autism and Developmental Disorders*, 44(3), 627–635. <https://doi.org/10.1007/s10803-013-1913-9>

Vanmarcke, S., Mullin, C., Van der Hallen, R., Evers, K., Noens, I., Steyaert, J., & Wagemans, J. (2016). In the Eye of the Beholder: Rapid Visual Perception of Real-Life Scenes by Young Adults with and Without ASD. *Journal of Autism and Developmental Disorders*, 46(8), 2635–2652. [https://doi.org/10.1007/s10803-016-2802-](https://doi.org/10.1007/s10803-016-2802-9)

- Vanmarcke, S., Noens, I., Steyaert, J., & Wagemans, J. (2018). Change detection of meaningful objects in real-world scenes in adolescents with and without autism spectrum disorder. *Autism*, 22(6), 728–739.
<https://doi.org/10.1177/1362361317702559>
- Vasa, R. A., Kalb, L., Mazurek, M., Kanne, S., Freedman, B., Keefer, A., ... Murray, D. (2013). Age-related differences in the prevalence and correlates of anxiety in youth with autism spectrum disorders. *Research in Autism Spectrum Disorders*, 7(11), 1358–1369. <https://doi.org/10.1016/j.rasd.2013.07.005>
- Veenstra-VanderWeele, J., Christian, S. L., & Cook, Jr., E. H. (2004). Autism as a Paradigmatic Complex Genetic Disorder. *Annual Review of Genomics and Human Genetics*, 5(1), 379–405. <https://doi.org/10.1146/annurev.genom.5.061903.180050>
- Volk, H. E., Lurmann, F., Penfold, B., Hertz-Picciotto, I., & McConnell, R. (2013). Traffic-related air pollution, particulate matter, and autism. *JAMA Psychiatry*, 70(1), 71–77. <https://doi.org/10.1001/jamapsychiatry.2013.266>
- Volkmar, F. R. (Ed.). (2005). *Handbook of autism and pervasive developmental disorders* (3rd ed). Hoboken, NJ: John Wiley & Sons.
- Wakabayashi, A., Baron-Cohen, S., Uchiyama, T., Yoshida, Y., Kuroda, M., & Wheelwright, S. (2007). Empathizing and Systemizing in Adults with and without Autism Spectrum Conditions: Cross-Cultural Stability. *Journal of Autism and Developmental Disorders*, 37(10), 1823–1832. <https://doi.org/10.1007/s10803-006-0316-6>
- Wakabayashi, A., Baron-Cohen, S., Wheelwright, S., Goldenfeld, N., Delaney, J., Fine, D., ... Weil, L. (2006). Development of short forms of the Empathy Quotient (EQ-Short) and the Systemizing Quotient (SQ-Short). *Personality and Individual Differences*, 41(5), 929–940. <https://doi.org/10.1016/j.paid.2006.03.017>

- Wakabayashi, A., Baron-Cohen, S., Wheelwright, S., & Tojo, Y. (2006). The Autism-Spectrum Quotient (AQ) in Japan: A Cross-Cultural Comparison. *Journal of Autism and Developmental Disorders*, 36(2), 263–270. <https://doi.org/10.1007/s10803-005-0061-2>
- Walsh, J. A., Vida, M. D., & Rutherford, M. D. (2014). Strategies for Perceiving Facial Expressions in Adults with Autism Spectrum Disorder. *Journal of Autism and Developmental Disorders*, 44(5), 1018–1026. <https://doi.org/10.1007/s10803-013-1953-1>
- Ward, J., Brown, P., Sherwood, J., & Simner, J. (2018). An autistic-like profile of attention and perception in synaesthesia. *Cortex*, 107, 121–130. <https://doi.org/10.1016/j.cortex.2017.10.008>
- Ward, J., Hoadley, C., Hughes, J. E. A., Smith, P., Allison, C., Baron-Cohen, S., & Simner, J. (2017). Atypical sensory sensitivity as a shared feature between synaesthesia and autism. *Scientific Reports*, 7(1). <https://doi.org/10.1038/srep41155>
- Waterhouse, L. (2008). Autism Overflows: Increasing Prevalence and Proliferating Theories. *Neuropsychology Review*, 18(4), 273–286. <https://doi.org/10.1007/s11065-008-9074-x>
- Watson, K. K., Miller, S., Hannah, E., Kovac, M., Damiano, C. R., Sabatino-DiCrisco, A., ... Dichter, G. S. (2015). Increased reward value of non-social stimuli in children and adolescents with autism. *Frontiers in Psychology*, 6. <https://doi.org/10.3389/fpsyg.2015.01026>
- Weiner, H. (1992). *Perturbing the organism: The biology of stressful experience*. University of Chicago Press. Retrieved from [http://scholar.google.com/scholar?q=Perturbing the organism: The biology of stressful experience&btnG=&hl=en&num=20&as_sdt=0%2C22](http://scholar.google.com/scholar?q=Perturbing+the+organism:+The+biology+of+stressful+experience&btnG=&hl=en&num=20&as_sdt=0%2C22)

- Weiss, J. A., & Fardella, M. A. (2018). Victimization and Perpetration Experiences of Adults With Autism. *Frontiers in Psychiatry, 9*.
<https://doi.org/10.3389/fpsy.2018.00203>
- Wender, K. F., & Rothkegel, R. (2000). Subitizing and its subprocesses. *Psychological Research, 64*(2), 81–92. <https://doi.org/10.1007/s004260000021>
- Werling, D. M., & Geschwind, D. H. (2013). Sex differences in autism spectrum disorders: *Current Opinion in Neurology, 26*(2), 146–153.
<https://doi.org/10.1097/WCO.0b013e32835ee548>
- Werner, S., & Thies, B. (2000). Is ‘Change Blindness’ Attenuated by Domain-specific Expertise? An Expert-Novices Comparison of Change Detection in Football Images. *Visual Cognition, 7*(1–3), 163–173.
<https://doi.org/10.1080/135062800394748>
- Westwood, H., Eisler, I., Mandy, W., Leppanen, J., Treasure, J., & Tchanturia, K. (2016). Using the Autism-Spectrum Quotient to Measure Autistic Traits in Anorexia Nervosa: A Systematic Review and Meta-Analysis. *Journal of Autism and Developmental Disorders, 46*(3), 964–977. <https://doi.org/10.1007/s10803-015-2641-0>
- Wheelwright, S., Baron-Cohen, S., Goldenfeld, N., Delaney, J., Fine, D., Smith, R., ... Wakabayashi, A. (2006). Predicting Autism Spectrum Quotient (AQ) from the Systemizing Quotient-Revised (SQ-R) and Empathy Quotient (EQ). *Brain Research, 1079*(1), 47–56. <https://doi.org/10.1016/j.brainres.2006.01.012>
- Wheelwright, Sally, Auyeung, B., Allison, C., & Baron-Cohen, S. (2010). Defining the broader, medium and narrow autism phenotype among parents using the Autism Spectrum Quotient (AQ). *Molecular Autism, 1*(1), 10. <https://doi.org/10.1186/2040-2392-1-10>
- White, S. J., & Saldaña, D. (2011). Performance of Children with Autism on the Embedded Figures Test: A Closer Look at a Popular Task. *Journal of Autism and*

Developmental Disorders, 41(11), 1565–1572. <https://doi.org/10.1007/s10803-011-1182-4>

White, S. W., Oswald, D., Ollendick, T., & Scahill, L. (2009). Anxiety in children and adolescents with autism spectrum disorders. *Clinical Psychology Review*, 29(3), 216–229.

<https://doi.org/10.1016/j.cpr.2009.01.003>

Whitehouse, A. J. O., Maybery, M. T., Hart, R., Sloboda, D. M., Stanley, F. J., Newnham, J. P., & Hickey, M. (2010). Free testosterone levels in umbilical-cord blood predict infant head circumference in females: Fetal Androgens and Head Circumference.

Developmental Medicine & Child Neurology, 52(3), e73–e77.

<https://doi.org/10.1111/j.1469-8749.2009.03546.x>

Williams, D., & Happé, F. (2010). Recognising ‘social’ and ‘non-social’ emotions in self and others: A study of autism. *Autism*, 14(4), 285–304.

<https://doi.org/10.1177/1362361309344849>

Williams, J. H. G., Whiten, A., Suddendorf, T., & Perrett, D. I. (2001). Imitation, mirror neurons and autism. *Neuroscience & Biobehavioral Reviews*, 25(4), 287–295.

[https://doi.org/10.1016/S0149-7634\(01\)00014-8](https://doi.org/10.1016/S0149-7634(01)00014-8)

Wilson, C. E., Murphy, C. M., McAlonan, G., Robertson, D. M., Spain, D., Hayward, H., ... Murphy, D. G. (2016). Does sex influence the diagnostic evaluation of autism spectrum disorder in adults? *Autism*, 20(7), 808–819.

<https://doi.org/10.1177/1362361315611381>

Wing, L. (1981). Sex ratios in early childhood autism and related conditions. *Psychiatry Research*, 5(2), 129–137. [https://doi.org/10.1016/0165-1781\(81\)90043-3](https://doi.org/10.1016/0165-1781(81)90043-3)

Wing, L., & Gould, J. (1979). Severe impairments of social interaction and associated abnormalities in children: Epidemiology and classification. *Journal of Autism and Developmental Disorders*, 9(1), 11–29. <https://doi.org/10.1007/BF01531288>

- Witkin, H. A., Oltman, P. K., Raskin, E., & Karp, S. A. (1971). *Manual for embedded figures test, children's embedded figures test, and group embedded figures test*. Palo Alto, CA: Consulting Psychologists Press, Inc. Retrieved from [http://scholar.google.com/scholar?q=Manual for embedded figures test, children's embedded figures test, and group embedded figures test&btnG=&hl=en&num=20&as_sdt=0%2C22](http://scholar.google.com/scholar?q=Manual+for+embedded+figures+test,+children's+embedded+figures+test,+and+group+embedded+figures+test&btnG=&hl=en&num=20&as_sdt=0%2C22)
- Woodbury-Smith, M. R., Robinson, J., Wheelwright, S., & Baron-Cohen, S. (2005). Screening Adults for Asperger Syndrome Using the AQ: A Preliminary Study of its Diagnostic Validity in Clinical Practice. *Journal of Autism and Developmental Disorders*, 35(3), 331–335. <https://doi.org/10.1007/s10803-005-3300-7>
- Wright, D. B., & Skagerberg, E. M. (2012). Measuring Empathizing and Systemizing with a Large US Sample. *PLoS ONE*, 7(2), e31661. <https://doi.org/10.1371/journal.pone.0031661>
- Yagi, T. (2013). Genetic Basis of Neuronal Individuality in the Mammalian Brain. *Journal of Neurogenetics*, 27(3), 97–105. <https://doi.org/10.3109/01677063.2013.801969>
- Yantis, S. (1993). Stimulus-driven attentional capture and attentional control settings. *Journal of Experimental Psychology: Human Perception and Performance*, 19(3), 676–681. <https://doi.org/10.1037/0096-1523.19.3.676>
- Yu, A. C. L. (2010). Perceptual Compensation Is Correlated with Individuals' "Autistic" Traits: Implications for Models of Sound Change. *PLoS ONE*, 5(8), e11950. <https://doi.org/10.1371/journal.pone.0011950>
- Zahorodny, W., Shenouda, J., Howell, S., Rosato, N. S., Peng, B., & Mehta, U. (2014). Increasing autism prevalence in metropolitan New Jersey. *Autism*, 18(2), 117–126. <https://doi.org/10.1177/1362361312463977>
- Zelinsky, G. (1998). *Detecting changes between scenes: A similaritybased theory using iconic representations* (CNS Technical Report No. CNS-98-01). Beckman Institute for

Advanced Science and Technology. Retrieved from

[http://scholar.google.com/scholar?q=Detecting changes between scenes: A similaritybased theory using iconic representations&btnG=&hl=en&num=20&as_sdt=0%2C22](http://scholar.google.com/scholar?q=Detecting+changes+between+scenes:+A+similaritybased+theory+using+iconic+representations&btnG=&hl=en&num=20&as_sdt=0%2C22)

Zhang, L., Sun, Y., Chen, F., Wu, D., Tang, J., Han, X., ... Wang, K. (2016).

Psychometric properties of the Autism-Spectrum Quotient in both clinical and non-clinical samples: Chinese version for mainland China. *BMC Psychiatry*, 16(1).

<https://doi.org/10.1186/s12888-016-0915-5>

Zilbovicius, M., Meresse, I., Chabane, N., Brunelle, F., Samson, Y., & Boddaert, N.

(2006). Autism, the superior temporal sulcus and social perception. *Trends in*

Neurosciences, 29(7), 359–366. <https://doi.org/10.1016/j.tins.2006.06.004>