The social cognition and attentional preferences of autistic adults

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Candidate's Statement

This is to certify that the research presented in this thesis is solely my own work.

Signed: ____________________________ David Moore

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Abstract

Attentional bias to faces can be seen from 9 minutes old in typical development (TD; Goren Sarty & Wu, 1975) and this is thought to underlie face processing expertise observed in adults (Johnson & Morton, 1991). In contrast people with Autistic Spectrum Disorders (ASDs) have deficits in orienting towards social information (e.g. Dawson et al., 2004). Novel methods, the Visual Dot Probe (VDP; Mathews, MacLeod & Tata, 1986) to measure automatic bias (at both sub and supra threshold presentation times) and Face-in-the-Crowd (FITC) to measure conscious bias (Hansen & Hansen, 1988), will be used to examine attentional bias for face stimuli in ASD and control participants.

Experiments 1 and 3 examined attentional bias for faces (including emotional faces; Study Three) compared to non-face stimuli using the VDP task. In Study One neither group showed a sub-threshold bias. However at supra threshold durations the TD group had a bias for faces that was absent in the ASD group. In Study Three the TD group had a sub-threshold bias for neutral faces compared to non-face stimuli. However the ASD group showed no bias. Neither group had a supra-threshold bias.

Experiments 2 and 4 used the FITC task to examine participants' attentional bias for faces (including emotional faces; Study Four) compared to non-face stimuli. In Study Two both groups showed an attentional bias for faces compared to non-face stimuli. However in Study Four neither group showed a bias for faces.

Previous research has shown the social presentation of ASD to be heterogeneous (Wing & Attwood, 1987) and in the normative literature findings using the VDP and FITC tasks relate to personality variables (e.g. Mogg & Bradley, 1999a; b). In Chapter 7 the consistency of bias across tasks was relatively poor. In the ASD group bias for faces was found to relate to increased anxiety, reduced ASD severity, and increased intelligence. Psychometric variables did not to predict bias for faces in controls.

In conclusion the control group show a bias for faces and there are some indications that the ASD group shows a face bias when under conscious control however this does not appear to be an automatic process. This suggests a potential cognitive model of ASD reliant on automatic social inattention as a key variable in ASD.

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Chapter 1

Literature Review

Chapter summary

This chapter provides a theoretical framework for the current research by first examining the social deficit in autistic spectrum disorders (ASD). As a comparison, the face processing expertise of the general population will be considered as an example of the social expertise seen in typical development (TD). The attentional processes that are thought to underlie the development of these face processing abilities will then be examined. The role that attentional dysfunction may play in autistic development will then be considered followed by a examination of the specific role that social inattention might play in this relationship. The chapter ends by examining the evidence that supports the role that social inattention plays in the development of autistic spectrum disorders and the theoretical perspectives adopted to explain this hypothesis.

Defining autistic spectrum disorders (1.1)

Autism belongs to a collection of disorders referred to as Pervasive Developmental Disorders (APA, 2000). The Diagnostic and Statistical Manual (DSM IV-TR; APA, 2000) bases a diagnosis of autism on deficits in social skills (i.e. lack of social or emotional reciprocity), repetitive or stereotyped behavioural routines (i.e. persistent preoccupation with parts of objects) and communication ability (i.e. stereotyped and repetitive use of language or idiosyncratic language). The diagnostic criteria according to DSM IV-TR (APA, 2000) require the child to satisfy at least two of the social criteria and at least one of each of the communication and imagination criteria (with a total of six or more items in total; the diagnostic criteria for autism can be found in Appendix 1).

A diagnosis of Asperger's syndrome (AS) is based on two of the same criteria as autism; those of 'severe and sustained impairment in social interaction.... and the development of restricted, repetitive patterns of behaviour, interests and activities' (APA, 2000, pp80). The difference from a diagnosis of autism is that there should be no clinically significant delay in the development of language (single words by two years, spontaneous phrases by three). There should also be no clinically significant delays in learning age appropriate behaviours, cognitions and normal interest and curiosity as long as these relate to non-social situations. Additionally these symptoms should cause a clinically significant impairment in social, occupational or other important areas of functioning.

There has been some debate over whether autism and Asperger's syndrome can be reliably differentiated from each other based on DSM IV criteria. A number of independent studies have suggested that most if not all individuals with AS diagnoses actually meet the criteria for autism not AS (e.g. Eisenmajer et al., 1996; Howlin, 2003), and this can be said to include Asperger's original cases (Miller & Ozonoff, 1997). This has raised a more fundamental question about whether autism and AS should be considered as separate disorders. Howlin suggests that although there may be some slight differences in the very early presentation of autism and AS when IQ is equivalent the later manifestation of these conditions does not differ.

Reflecting on the debate about whether autism and Asperger's syndrome are separate disorders it seems that even if two separate disorders exist they are not presently being diagnosed reliably (e.g. Howlin, 2003). It is due to the lack of clarity regarding the diagnosis of these disorders that for the purposes of this review of the literature as well as the subsequent research High Functioning Autism (HFA) and AS will be used synonymously and will be referred to by the broader title of Autistic Spectrum Disorder (ASD).

The symptoms of ASDs are not considered to be a result of a single deficit and do not appear to reflect a single co-occurring factor. Based on data from a number of diagnostic and screening measures evidence has consistently been found for between three and six independent factors within the diagnostic criteria for ASD (e.g. Miranda-Linne & Melin 2002; Lecavalier, 2005; van Lang et al., 2006). This suggests that participants can independently vary along a number of the criteria for ASD. It is therefore possible that this independent variance will result in a number of unique subtype presentations within the ASD population.

Hypothesised causes of autism (1.1.1)

Genetics (1.1.1.1)

It is now widely accepted that autism is a genetically based disorder. Epidemiological studies have indicated an increased prevalence of ASD associated with a number of single gene disorders. Tuberous sclerosis has been shown to be 100 times more prevalent in ASD and Fragile X syndrome 120 times greater than in the general population (Fombonne, 2003) as well as higher prevalence of Smith-Lemli-Opiz syndrome (Sikora et al., 2006) and epilepsy (Fombonne, 2003). Further evidence for a genetic basis to ASD comes from elevated concordance rates of autism in monozygotic compared to dizygotic twins (e.g. MZ 69% DZ 0%; Bailey et al., 1995) and increased autistic symptomology in relatives of individuals with ASD (Bolton et al., 1994; Piven et al., 1990). Estimates based on these findings are that over 90% of the etiological factors are genetic (Bailey et al., 1995) and may involve up to 10 genetic loci (Pickles et al., 1995). Given the consistency of findings that genetics appear to underlie the development of ASD, others have taken this research further examining for candidate genes and have started to focus on linkage of genetic sites to specific symptoms of ASD. A number of candidate genes have been implicated in ASD and specific symptoms of ASD. A comprehensive genome screen performed by the International

Molecular Genetic Study of Autism Consortium (IMGSAC, 2001) indicated that the 2q21-33 region appeared to result in the most likely candidates for ASD from a sample of 153 sib-pairs. Further linkage studies have been conducted to examine the relationship between specific gene sites and individual autistic symptoms. The most interesting findings for the current research are variations in the WNT2 gene have been noted in ASD (Wassink et al., 2001). Mice lacking the proteins associated with the WNT2 gene have shown reduced social interaction (Lijam et al., 1997) indicating an interesting potential explanation for the social deficit in ASD. Severe social deficits have also recently been linked to a shortened version of the 5-HTTLPR serotonin transported promoter gene in ASD (Brune et al. 2006). Additionally the engrailed 2 gene on chromosome 7q36 has also been implicated in cerebella (e.g. Gharani et al., 2005) and brain stem development that are similar to post-mortem findings in ASD (e.g. Bauman, 1996). The findings that multiple genetic sites appear related to different presentations of ASD are suggestive of sub-types of ASD which may have differing biological causes manifesting potentially different cognitive profiles but all meeting the same behavioural criteria. It is therefore important that research considers the variability in individual presentation of ASD.

Neurobiology (1.1.1.2)

In addition to the genetic explanations, others have examined the potential neurobiological markers of ASD. Kanner (1943) noted that the children on which his original descriptions were made had enlarged heads. This has been shown to translate into an increased brain volume using MRI (e.g. Sparks et al., 2002) and post-mortem (Bailey et al., 1998) studies. This increase in brain volume appears to be across the entire of the brain and is not localised to specific regions (Aylward et al., 2002). These findings indicate that the brain volume increased by up to 10% compared to TD individuals (Sparks et al., 2002). There have also been suggestions that specific neurological systems operate differently in ASD compared to typical development. The limbic system (particularly the amygdala and hypothalamus) have been implicated in causal models of ASD (e.g. Baron-Cohen et al., 2000) and post-mortem studies have found irregularities in these regions (Bauman and Kemper, 1995). In addition the best animal model of autism has been provided by lesioning the amygdala (Bachevalier, 1994). This is of importance given the role the amygdala plays in the detection of salient information, through dense reciprocal anatomical connections to the ventral temporal cortex (Aggleton, 1993). This places the amygdala in the ideal position to channel the acquisition of face expertise. This is supported in studies showing that the amygdala is implicated in emotional learning (e.g. Gaffen, Gaffen & Harrison, 1988), signalling the emotional salience of events (e.g. Aggleton, 1993), social behaviour (Brothers and Ring, 1993), social cognition (Castelli, Happe, Frith & Frith, 2000), and the perception of facial expressions (Adolphs, Tranel, & Damasio, 1998). In addition to the amygdala other regions of the 'social brain' have also been considered. Hypoactivation of the right Fusiform Gyrus has been shown to occur in ASD when performing face processing tasks (e.g. Schultz et al., 2000). In addition to the Right Fusiform Gyrus and amygdala the superior temporal sulcus has also been implicated in understanding facial expressions and eye gaze and has been shown to be hypoactive in ASD when performing these tasks (e.g. Schultz et al., 2003). More recently several research groups have proposed that the social brain dysfunction in ASD might be best considered in terms of a defective mirror neuron (e.g. Martineau et al., 2008). Mirror neurons are unique in that they respond both to an individual making an action and to the observation of the action (e.g. Di Pellegrino et al, 1992). Individuals with ASD have been shown to have reduced suppression of the mu rhythm when observing another's actions, which indicates an impaired mirror neuron system (e.g. Oberman et al, 2005). More general neural regions of dysfunction have included the cerebellum which been shown to have a reduced number of purkinje cells in post-mortem studies (e.g. Bauman, 1996) and although studies have shown enlarged cerebella size in ASD this appears to be in proportion to the rest of the brain (Herbert et al., 2003). This is important for the understanding of ASD and in particular for this thesis as cerebella function has been implicated in attentional functioning (e.g. Allen, Buxton, Wong & Courchesne, 1997). In addition to regional differences, others have looked for neurochemical differences between controls and ASD participants. Best candidates include reduced dopaminergic activity in the medial prefrontal cortex (Ernst et al., 1997), and the existence of high peripheral serotonin levels in approximately one third of ASD children (Anderson & Hoshiono, 1997).

Behavioural and cognitive links (1.1.2)

The biological cause of autism is not yet fully understood and at present there are no biological tests for autism, therefore clinicians must diagnose ASD based on behavioural patterns. In an attempt to bridge the gap between the presumed biological causes and behavioural manifestations in autism, Morton and Frith (1995) emphasised the importance of examining cognitive pathways. Morton and Frith suggested that these would provide important information about effective ways of educating, interacting with and assisting individuals with ASDs as well as helping to find the potential sites of interest for those looking for the biological causes.

Morton and Frith (1995) suggest that a number of potential causal pathways are possible when trying to understand this relationship, including a single biological impairment working through multiple cognitive pathways to produce different behavioural symptoms (which would explain the different manifestations of autism). Alternatively several biological causes may converge through a single cognitive mediator to cause several behavioural patterns. Finally in the case of a syndrome, which can only be diagnosed based on behavioural symptoms, many biological causes may operate through different cognitive mechanisms to cause a single pattern of behavioural dysfunction. Given that there is this gap in understanding between the biological causes and the behavioural diagnoses/manifestation of these syndromes, it is important to attempt to understand the cognitive bridge between behaviour and biology to allow for more effective diagnosis and more productive understanding of potential biological markers for ASD. Again with the variety of pathways that might result in ASD it appears that different presentations on ASD might exist which converge on similar behavioural outcomes but from different cognitive pathways. This thesis will not only consider the performance of an ASD group but also examine individuals' performance to examine for subgroups in attentional bias.

Psychological Theories of ASD (1.1.3)

Weak Central Coherence (1.1.3.1)

Three main psychological explanations have been offered for the clinical features of autism; one such explanation is that of Weak Central Coherence (WCC). The concept of central coherence was developed by Frith (1989). Frith used this term to explain the tendency that people have for processing information in context and for global meaning, as opposed to attending to every little detail. Frith suggested that autistic people have weak central coherence and that instead of focusing on global factors they focus on local features. People with autism have been shown to be less susceptible to optical illusions (Happé, 1996), to read the more common rather that the most appropriate pronunciation of homographs when reading (Happé, 1997), show superior performance on tasks which involve focus on local rather than global meaning such as the Wechsler block design task and embedded figures task (Shah & Frith, 1993), to have superior visual search abilities (Plaisted, O'Riordan, & Baron-Cohen, 1998 a, b; O'Riordan, 2004), greater ability to identify perfect pitch (Heaton, Hermelin & Pring, 1998) and enhanced processing of local components of music (Heaton, 2003).

In a recent review Happé and Frith (2006) concluded that the original suggestion of a deficit in global processing should be replaced by a cognitive style favouring local processing based on findings that when a task called explicitly for global processing ASD participants' performance was not impaired (e.g. Heaton, Hermelin & Pring, 1998; Mottron et al., 2000). The finding that local processing is enhanced in ASD without necessarily a deficit in global processing lead Mottron and Burack (2001) to propose the alternative Enhanced Perceptual Functioning (EPF) account of autism. The EPF account essentially proposes that the primary indicator of ASD is an enhanced local perceptual functioning without the necessity for an impairment of global processing (Mottron et al. 2006).

Executive dysfunction (1.1.3.2)

The second theoretical approach suggested to underlie ASD is that of executive dysfunction. Executive functions are usually seen as those cognitions involved in guiding meaningful actions within the environment and include planning, mental flexibility, working memory, impulse control and monitoring of self (Rabbitt, 1997; Hill, 2004a, b). A review of the executive dysfunction account of ASD reveals that although deficits are shown on a range of executive function tasks there are also studies reporting normal functioning on each of these components (e.g. Minshew et al., 1992; Hughes, Russell, & Robbins, 1994). Hill (2004a, b) also highlight a number of problems with the executive dysfunction account of ASD, including that there is little consensus about which element or pattern of executive dysfunction underlies ASD and that executive difficulties are seen in other conditions (e.g. ADHD). It also seems problematic that executive functioning deficits do not seem to be universal in ASD and that in particular, executive functioning appears relatively normal in individuals with IQ's in the normal range (e.g. Russell & Hill, 2001; Hill & Russell, 2002).

Theory of Mind (1.1.3.3)

One of the most widely discussed deficits in social functioning in ASDs is that of a mentalising or metarepresentational deficit (Leslie, 1988), which has been extended in to the Theory of Mind (ToM) hypothesis. This concept was originally proposed by Premack and Woodruff (1978), who defined this as the ability to attribute mental states to oneself and others and the ability to make suppositions about other's beliefs in specific situations and therefore predict their behaviour. Baron-Cohen, Leslie and Frith (1985) proposed the hypothesis that those with autism lack a ToM and as such cannot understand the beliefs of others.

Support for the ToM hypothesis has traditionally come from false belief tasks where the child is asked to indicate what a third party will believe about a situation even though the child knows something else to be true (e.g. the Sally-Ann task; Baron-Cohen, Leslie & Frith, 1985). Although these studies have indicated a ToM deficit in ASD 20% of children pass these tasks and it is possible to pass these tasks based on an intellectual process as opposed to a ToM skill meaning that older individuals with higher IQ's can easily pass these tasks (e.g. Bowler, 1992). Subsequent studies in this area have developed more advanced and sensitive methods to explore the ToM deficit in autism, (e.g. awkward moments task; Heavey et al., 2000) which indicate that ToM deficits continue into adulthood and with individuals with IQ in the normal range in those with ASD when measured in more complex and ecologically valid tasks.

It is still the case however, that some autistic individuals perform reasonably well on even the most advanced measures of ToM, however these same individuals will show similar real life social problems to the rest of the autistic population. It is because of the lack of sensitivity in these tasks and findings that the deficits on ToM do not seem to be universal in autism that new and improved measures of social functioning need to be developed. One of the largest problems with the ToM hypothesis is that many of the social pragmatic problems in autism have been shown to be present before the child reaches the mental or chronological age at which ToM normally develops (e.g. Klin et al. 1992; Roeyers et al., 1998). Although there are recognised precursors of ToM such as joint attention (e.g. Leekam & Ramsden, 2006) which will be discussed later.

Combining the classical theories (1.1.3.4)

Each of the above theories can explain certain characteristics of ASD but all are unable to explain some of the others sufficiently. As Pellicano et al. (2006) point out Weak Central Coherence accounts best for the visuo-spatial abnormalities seen in ASD with Executive Dysfunction relating to repetitive behavioural routines and ToM relating to social functioning. Although originally it was suggested that these theories should be viewed as entirely separate and distinct (e.g. Frith & Happé, 1994), Bailey et al. (1996) stated that integration is a goal because it is required for a full understanding of autism at all its levels. As such researchers have started to explore the ways in which these theoretical approaches may be linked. Baron-Cohen and Hammer (1997) indicate that people who were poor at telling a persons emotions from their eyes (poor Theory of Mind) tended to be good at the embedded figures task (weak central coherence). However, Baron-Cohen, Jolliffe, Mortimore and Robinson (1997) acknowledged that the eye task has a central coherence element as it can be argued to rely in part on subtle local cues such as direction of eyebrows, and as such this finding might relate to the WCC component of this task rather than a link between WCC and ToM. Others have found no relationship between central coherence tasks (the embedded figures task) and social skills tasks, which have been shown to be precursors to ToM (e.g. joint attention; Morgan, Maybery & Durkin, 2003).

Tests of Weak Central Coherence have also been shown to relate to Executive tasks. Pellicano et al. (2005; 2006) found a relationship between planning and measures of WCC however Booth et al. (2003) found no relationship between these variables and indicated that only WCC differentiated children with ASD from controls additionally Teunisse et al. (2001) reported that set shifting and WCC were not highly related.

Jarrold, Butler, Cottington and Jimenez (2000) warned against over generalising these findings saying *'suggesting that the two tasks are linked is a long way from suggesting that Theory of Mind and weak central coherence are linked.'* (pp. 129). This has led a number of researchers to attempt to specify how the theories might be linked and how one may cause another. Happé (1999) suggested that weak central coherence might influence Theory of Mind because processing information in a piecemeal way (e.g. faces) could impact upon the ability to sense another person's emotions.

Opposing views have arisen about which of Executive Functioning (EF) or ToM should be considered the primary deficit and which should be thought of as secondary. Perner (1998, 2000) suggested that the development of ToM is a necessary precursor to EF. Perner reasoned that to perform a series of actions one must create a mental representation of the intended goal. Russell (1996, 1997) conversely proposed that the capacity to monitor action and act with intent is vital to developing a theory of others minds. This combined with a difficulty shifting set would reduce the capacity to move between states of mind, impairing the ability to mentalise (Russell, 2002; Hill & Russell, 2002).

Additionally there are a number of studies, which suggest that the deficits seen in each of the theories are clearly dissociable. Ozenoff et al. (1991) indicated that children who passed ToM measures still failed a number of EF tasks, and Happé (1994, 1997) has indicated that improved performance on block design and impaired word integration (indicative of Weak Central Coherence) are independent from performance of ToM tasks. In addition the main neural substrates related to these three cognitive accounts are different. Assigning mental states relates to the prefrontal cortex, temporo-parietal junction and amygdala complex (e.g. Amodio & Frith, 2006). Executive functions require activation of a wide range of higher order neural function including the fronto-striatal network and fronto-pariatal-thalamic network (e.g. Wagner et al., 2006). Whereas tasks measuring Central Coherence have been linked to early visual areas (i.e. Inferior Parietal Sulcus, and the left ventral premotor cortex; Manjaly et al, 2007). This suggests that if these three accounts of ASD have the ability to independently underlie various aspects of ASD then the presentation of ASD may be greatly different depending on which deficits are primary in an individual case. For this reason combined with the varying genetic explanations above and findings of multi-factor structures on diagnostic measures for ASD (e.g. van Lang et al., 2006) it is important to examine individual presentation of ASD within research as well as any group differences.

It is clear from these accounts that there are a number of theoretical positions relating to which deficit in ASD is primary and how the development of these cognitive differences should be considered. No one explanation can truly be considered to be satisfactory at present. To address this, this thesis will examine the role of the attention of ASD adults to face stimuli (to represent social stimuli) as a potential measure of social learning and possibly social dysfunction in this population.

Attentional processing in ASD (1.1.4)

In addition to the above theories that propose specific accounts of the symptoms of ASD others have proposed more general explanations. Attention is a particularly appropriate mechanism to consider when attempting to understand the development of individuals with ASD as a variety of differences in performance have been suggested on tests of attentional functioning (e.g. Dawson & Lewy, 1989). It seems logical therefore to explore attentional functioning before exploring higher executive (e.g. Ozonoff et al., 1991) or Theory of Mind functions (Baron-Cohen, Leslie & Frith, 1985).

High functioning adults and adolescents with ASD show no significant difference in sustained attention (the ability to maintain attention on an unstimulating and continuous task lasting for a set period of time (Williamson et al. 1996) compared to TD participants (e.g. Pascualvaca, Fantie, Papageorgiou & Mirsky, 1998). This establishes that the deficits in ASD cannot be attributed to a lack of motivation (Hermlin & O'Connor, 1970), and that people with ASD are as able as controls to maintain their attention on a task in order to perform it. In terms of selective attention, participants with ASD have been argued to have over focused attention, attending to a target to the detriment of other tasks (Pierce, Glad, & Schriebman, 1997). Burack et al. (1997) however have questioned this conclusion suggesting that this may reflect the low intellectual functioning of many of the participants. In contrast to Pierce et al. (1997) Burack (1994) suggested that an inefficient 'attentional lens' (impairment in filtering out distracting information) underlies the attentional deficit in ASD and not a tendency to over select. In an attempt to resolve these apparent inconsistencies in the focus of visual attention in ASD, Mann and Walker (2003) suggested from this that individuals with ASD have a deficit in broadening attention and presumably in switching attentional mode. Goldstein, Johnson and Minshew (2001) have concluded that on reflection there is no conclusive evidence for deficits in the arousal, sustained attention, selectivity or filtering of attention in individuals with ASD when these do not include some high level component of executive functioning.

General orienting ability (1.1.4.1)

One of the most important functions of an intact attentional system, and the one under consideration in this thesis, is to orient to potentially important spatial locations. Wainwright-Sharp and Bryson (1993) examined endogenous (consciously controlled) attentional shifts in individuals with ASDs. They asked autistic adolescents and adults with a broad range of intellectual capacities to respond to a target that was on the left or right side of a fixation point at the centre of the screen. The target was preceded by an orientation cue (an arrow), which could be either valid (66%; oriented attention towards the target), invalid (17%; orienting attention away from the target) or neutral (17%; a line at fixation which did not orient attention). When the cues were displayed 100 ms before the target TD controls showed faster reactions to valid cues, however autistic participants did not show the same cue validity effect. However autistic participants did show an even larger cue validity effect than controls when the cue was presented 800ms before the target. A criticism of these findings is that the ASD group were matched to a TD control group on chronological age and verbal ability. This is not the most appropriate matching technique because this task is primarily a visuo-spatial task and thus matching on verbal mental age seems inappropriate. Reports of Raven's progressive matrices (RPM, Raven, 1947) revealed that the controls were in the 90-99th percentile (mean 94.9) compared to the ASD group who's scores were in the 5-95th percentile (mean 48.4), which may have contributed to the lack of a validity effect in the ASD group in the 100ms condition. Based on these findings the precise nature of non-social orienting cannot be determined, however it seems that ASD individuals have some tendency to orient attention to cues as these individuals showed an orienting effect when the cues were presented for 800ms.

Iarocci and Burack (2004) also explored the effects of orientation cues in children with ASDs; however this study engaged exogenous (automatic) cueing. Participants focused on a central point before a flash of light oriented attention to either the right or left of the screen. Iarocci and Burack found that in both groups valid cues elicited quicker responses than invalid ones suggesting these cues orient attention effectively in autistic individuals. There were however similar problems with the matching used in Iarocci and Burack's study as in Wainwright-Sharp and Bryson's above. ASD participants with a mean age of 11.6 years and developmental delay were matched with young children (mean age 5.7 years) based on their mental age. This does not account for differences in other developmental milestones and the additional affects of intellectual delay; as such participants should be matched on both age and intellectual ability. Given that poor matching techniques were used by both of the above studies conclusions have to be tentative. This however does highlight the importance of accurate group matching to allow for conclusions to be drawn. This will be addressed in this thesis by using a systematic matching procedure on age, and both verbal and spatial IQ.

If the above findings reflect the true nature of attentional orienting in an ASD population then a number of inferences can be made. First, Iarocci and Burack's findings suggest that the automatic allocation of attention is intact in ASD and that sudden changes in the periphery of vision will result in the capture of attention to that location. This is important as one of the major themes of this thesis will be to examine the spontaneous and preconscious capture of attention. Secondly, there are questions raised by the study of Wainwright-Sharp and Bryson about the speed at which conscious attention is shifted in individuals with ASDs and it is possible that the response to external cues may be delayed, although not absent in this group. It is possible however, that this delay relates more to the intellectual functioning of the ASD participants in Wainwright-Sharp and Bryson's study and not their ASD.

Focusing on the social deficit (1.1.5)

In addition to general cognitive hypotheses of ASD the social deficit has frequently been posited to be the central deficit underlying autism (e.g. Baron-Cohen et al., 2000; Bushwick, 2001). Although ASD is diagnosed based on criteria in three domains this thesis focuses on the deficit in social reciprocity. The social deficit of ASD has attracted particular attention within the past 20 years and a considerable body of literature has been generated in an attempt to characterise the nature of this deficit. This has been reflected by the change in the diagnostic focus of ASDs. While DSM III (APA, 1980) regarded the impairments in social processing, behavioural stereotypy and communication as equally important DSM IV (APA, 1994) suggests a weighting of the symptomology of ASD (a minimum of two social criteria compared to only one from the communication and behavioural criteria). This indicates that the social deficit is considered clinically to be the most critical in defining ASD. Schultz (2005) has also suggested that concentrating on the social deficit when attempting to understand autism is advised, as relative to the other criteria for autism, the social pattern of behavioural deficits is the most specific to autism. For example Schultz points out that communicative delays are present in a number of other disorders, and Bodfish et al. (2000) have noted that repetitive/restricted behaviours and interests are not specific to autism, being shared by a number of syndromes of mental retardation.

It is important to note that even with the highest functioning and most able people with ASD, atypical social behaviour is apparent at least in certain unfamiliar or stressful surroundings (Tantum, 2000; Frith, 2004). These social deficits have also been shown to be extremely pervasive. Howlin, et al. (2004) have examined the outcomes in adulthood of a number of children diagnosed with autism, and explored which factors predict a better or worse prognosis. At follow up only 15 of the sample were considered to have a good social outcome with 39 having a poor outcome. Better outcomes were observed in those individuals with higher cognitive, language and fewer ritualised behaviours, however even amongst these individuals a number still had fair or poor outcomes. These results were supported by Szatmari, Bryson, Boyle, Streiner and Duku (2003) with a high functioning (IQ>70 at diagnosis) population of individuals with autism and Asperger syndrome. Consistent with Howlin et al.'s findings the population showed a great deal of social and communicative delays, while the major predictor of social outcome in autism was verbal IQ and in AS it was performance IQ.

Although all individuals with ASD show a deficit in social skills it has been suggested that the presentation of this varies between individuals. Wing and Attwood (1987) suggested that the social deficit in autism should be understood as consisting of three distinctive subtypes. Wing and Attwood's subtypes comprised the 'aloof child' (avoids contact with others), the passive child (accepts the social advances of others with indifference) and the active but odd child (actively seeks social engagement but lacking the skills to make these exchanges 'normal'). Additionally some children with ASD are able to pass social cognitive tasks. Baron-Cohen, Leslie and Frith's (1985) found that 20% of their ASD participants were able to pass the Sally-Ann false belief task and additionally only 85% of controls passed this test. It is therefore important to consider whether social subgroups exist within the ASD population and research conducted with these individuals. Examining subgroups within the autistic population has now begun to be considered within the broader research literature on autism (e.g. Heaton, Williams, Cummins & Happé, 2008).

Social processing and attention in TD individuals (1.2)

Before consideration is given to the atypical social development observed in ASDs it is necessary to consider how social skills develop in the typical population to allow for a comparison to be made. Johnson (2001, pp478) has suggested that the processing of social information is of particular importance to both the child and adult. Johnson points out that for babies *'perceiving and acting on information from caregiver adults is clearly critical for the survival and development of babies'.* Illustrating the importance of early social development Bowlby (1969) indicated that from an evolutionary perspective the human infant is clearly at great danger of attack from predators and the capacity to elicit protection from stronger adults would be vital to survival. Feldman et al. (1999) argued that the formation of attachment is dependent upon an initial period of complete parental involvement in infant's unique signals.

This social predisposition can be seen in the synchronous relationships which children adopt with caregivers (e.g. Jaffee et al., 2001). The development of a synchronous relationship between an infant and caregiver has been shown to be an important predictor of later social development (e.g. Jaffee et al., 2001). This process involves the infant and caregiver entering into a natural exchange of engagement and disengagement (Tronick, 1989). This process appears to develop at approximately three months of age with initial face-to-face interactions including mutual gaze and emotional facial exchanges (Stern, 1985). Parent-Infant synchrony has been shown to be an important precursor to attachment formation (Feldman, Weller, Leckman, Kvint & Eidelman, 1999), attachment security (Jaffee et al., 2001), self-regulation capacities

(Feldman, Greenbaum, & Yirmiya, 1999), symbolic competence (Feldman & Greenbaum, 1997), and cognitive skills (Feldman, Greenbaum, Yirmiya, & Mayes, 1996). One aspect of social ability that has received a great deal of attention is that of face processing. This aspect of social interaction has been examined throughout development and will be the focus of this thesis.

Face processing of typically developing individuals (1.2.1)

It has been noted that faces are a unique class of object that hold specific biological and social significance (Carey, 1992; Grüsser & Landis, 1991). Although there is still debate about whether people are innately experts in face processing, or that this expertise is a learned process, it is clear when reviewing the literature that in typical development most people perform the processing of faces as experts. The superior processing of information from faces when compared to other objects is especially outstanding given that they are one of the most complex visual stimuli we are exposed to (Jemel, Mottron & Dawson, 2006). This complexity in differentiating faces can be seen to originate from the striking homogeneity of the structure and composition of faces (eyes above nose, which is above a mouth; Diamond & Carey, 1986).

Some of the earliest research supporting the unique processing of faces in typical development comes from the face inversion effect. Goldstein and Chance (1980) reasoned that if faces were stored only as patterns of visual information then the orientation of the face should have no impact on recognition. Given that a number of studies previously had found that orienting a face through 180 degrees hinders recognition (e.g. Yin, 1969; 1970) to a greater extent than with other complex stimuli, it has been proposed that faces must be processed in a unique manner.

This has caused some to propose that faces are processed through the use of a holistic approach not used for other objects. Young, Hellawell and Hay (1987) presented adults with celebrity faces that had been cut in half, the top half of the face was then paired with a different persons' bottom half. Adults found it significantly harder to identify the top half of the face when it was aligned with the bottom half than when the bottom half was displaced to the side. Hole (1994) also showed that this was the case for making same/different judgements about unfamiliar faces. Tanaka and Farah (1993) have also indicated that participants recognise individual facial features better when they are presented in the context of the face than when presented in isolation.

Although children may not have developed the same face processing expertise as adults they still appear to process faces in a more sophisticated way than other objects. Previous research has shown that by the age of 4 children begin to show the whole/part advantage (that faces are processed better when viewed as complete objects rather than in separate parts; Tanaka, Kay, Grinnell, Stansfield & Szechter, 1998) similar to that reported in adults (Tanaka & Farah, 1993). By the age of 6 years children have been suggested to have developed a composite face effect as seen in adulthood (Carey & Diamond, 1994). This indicates that holistic face processing is present in children from very early in development.

The special role that faces have in human processing has received support from neurological studies. These studies have implicated the Fusiform gyrus as central in face processing so consistently that Kanwisher et al. (1997) coined this area as the Fusiform Face Area (FFA). In Kanwisher et al.'s study the right Fusiform gyrus was significantly more active in 12 of 15 participants when viewing faces compared to other highly familiar objects, the findings of hyper-activation of the FFA have been replicated in a number of studies (McCarthy et al., 1997; Puce et al., 1995, 1996).

The assumption that people are innately superior at processing faces than other objects was challenged by Diamond and Carey (1986), who claimed that the face inversion effect was more an effect of practice and expertise than an innate superiority of face processing. This was supported by the finding that dog judges experienced an inversion effect for dogs similar to the face inversion effect. This was supported by Gauthier et al. (2000) who found using fMRI that the right FFA (Fusiform face area) and OFA (occipital face area) of car experts activates significantly more for cars than birds, while the opposite is true for bird experts. The implications of these findings are that the inversion effect seems to be more a product of stimulus familiarity than one of a special class of an object.

Social orienting and attention to faces in typical development (1.2.2)

Given the findings of Diamond and Carey (1986) and Gauthier et al. (2000) that the superior ability at processing faces in typical development may be at least partially learned it is important to examine why this learning might happen; one proposal is that this information is given more attention. From a developmental perspective, visual interest in social information is of great importance to parents, who respond to this by providing stimulation by changing facial expressions, rocking and vocalisations for example (Dawson & Lewy, 1989). This is evidenced by Stern (1971), who noted parents reduce stimulation when the child looks away. Brazelton (1982) also suggested that as a consequence of this, gaze behaviour could act as a regulatory function in early social interaction, which allows the child to moderate the amount of social arousal. Jennings (1975) also discussed the implications of attentional orientation in social development, showing that amount of time engaging in social and non-social activities predicted children's social competence at age four.

Early research examining the development of a preference for attending to faces typically involved the presentation of two images (a schematic face and varying degrees of scrambled faces) to the child in an otherwise unstimulating environment and examining how much time was spent looking at each image. Consistently it was found that a preference for examining the faces more than the scrambled image did not emerge until approximately four months of age (e.g. Haaf & Bell, 1967; Haaf 1974; Haaf & Brown 1976). Goren, Sarty and Wu (1975) attempted to show that some perceptual 'knowledge' of faces was present from birth in the human infant and examined social orienting in a group of neonates with an average age of 9 minutes. The extent to which babies tracked the movement of a schematic face shape, scrambled face shapes, and a blank display was taken to reflect their 'innate' preference. An image was displayed to the infant and this was then moved at a constant speed in an arc to the left or right of the visual field. Goren Sarty and Wu found that neonates oriented both their heads and eyes further to the 'face' than any other stimulus. From this they concluded that some perceptual information must be organised within the visual system from birth, and that faces represent a vital pattern that the infant is born with at least some visual information about.

Further research has examined the capacity of faces to capture attention in an adult population. Shelley-Tremblay and Mack (1999) found faces were able to capture attention when under metacontrast masking (presenting a stimuli for a short time, outside of conscious awareness, briefly followed by a meaningless stimuli designed to 'mark' the area of the display that the stimuli appeared on). The key finding of this study was that the detection of the happy face icon was significantly greater than the other two icons (inverted face and scrambled face) which did not differ from each other, across all durations. This indicates that in an adult population face stimuli have a superior capacity to capture attention even under conditions when this information is presented below conscious threshold.

Support for the idea that face stimuli is resistant to inattentional blindness has come from a study by Mack, Pappas, Silverman and Gay (2002) utilising the concept of the attentional blink. Inattentional blindness is a cognitive effect where there is a failure to see a stimuli due to the attentional system failing to capture this stimulus rather than not looking in the correct location (i.e. when another stimulus is being processed the individual fails to see a target as there are no attentional resources remaining). The attentional blink is observed when a stimulus of interest is presented followed by a second stimulus a short duration afterwards. In cases of the attentional blink the second stimulus is not reported, it is presumed because of the processing time required to identify the first stimuli. Happy faces were detected more often than other non-face stimuli in this study regardless of position after the target; this alone suggests that faces have a special place in the attentional systems of TD adults. Further, evidence of face stimuli overcoming inattentional blindness is provided by the finding that a picture of a tree was detected more often in positions 1 and 2 after the target than positions 3-5 (the conventional attentional blink). The face and the inverted face however were detected equally frequently in all five positions, showing a resistance to the attentional blink. This study suggests that face stimuli are processed preferentially and that processing faces requires fewer attentional resources and can be conducted during cases of reduced attentional capacity.

Further research has examined the extent to which faces capture attention when in direct competition with other non-face stimuli using the flicker paradigm (Ro, Russel & Lavie, 2001). Photographs from six different categories were simultaneously presented to participants for 533ms, followed by an 83ms interval in which the screen was blank. On half of the trials the same six original images were presented whereas on the other half one of the images changed to a different example of the same class. Participants were asked to indicate if any of the images had changed. Ro, Russel and Lavie found that faces were detected quicker and more often than any other category of stimuli. This finding could not be explained by the changes in faces being more obvious as in a second experiment when only a single stimulus was presented at a time, all stimuli changes were detected with equal speed and accuracy. This suggests that when in competition for attention with other stimuli faces have an advantage in capturing attentional resources.

Further evidence for faces having a greater capacity to capture attention when in competition with other stimuli comes from the inhibition of return effect. Inhibition of return is observed when people delay attending to a location that has previously been attended to (Klein, 2000). An important observation about inhibition of return is that it only occurs when the original shift in attention was reflexive but not when the shift was a result of a conscious shift (Posner and Cohen, 1984). In Theeuwes, Stefan and Strigchel's (2006) study participants were presented for 200ms with a stimuli pair (female faces and household appliances) left and right of a central fixation point, after a duration of between 600 and 800ms a central arrow was presented pointing left or right, participants were required to direct their eyes to the direction of the arrow. Making saccades to the location previously occupied by faces in this study was found to take significantly longer than saccades to object locations; this suggests that attention had previously been reflexively oriented to the location of the faces. Not only does this study suggest that faces call for attention preferentially to non-face objects but also suggests that this process is out of the conscious control of individuals, and may therefore be automatic.

Possibly the most direct study of social attention in adults at present is that of Bindemann et al. (2007). Bindemann et al.'s participants were presented with a face and an object either side of a central fixation point. Once these disappeared, participants were presented with a probe directly behind one of the two images. Participants were asked to indicate whether the probe appeared on the left or right of the screen. When the probe appeared with equal frequency behind faces and objects participants responded significantly faster to probes that replaced faces than probes that replaced objects in all conditions. In contrast with Theeuwes, Stefan and Strigchel, (2006) Bindemann et al. found that if the probes appeared behind the objects 75% of the time then this pattern was reversed. This suggests that although attentional preference is given to faces, it is possible to override this in instances where this attentional pattern will not be beneficial to task performance. This raises questions about whether this preference can be considered automatic.

This review of the literature on social attention in typical development presents a clear pattern of a lifelong attentional bias for face and other social stimuli. It is clear from this review that a social bias has had a key evolutionary advantage for the species. This seems to be a good indicator of why such a level of expertise for processing social stimuli would be seen in adult humans.

CONSPEC and CONLERN: A theory of face learning (1.2.3)

In 1991 Mark Johnson and John Morton developed an influential theory about the interactions between biology and the environment in terms of the acquisition of face processing expertise. The basis for the theory was apparently contradictory evidence that infants appear to track face shapes to a greater extent than non face configurations at a median age of 9 minutes old (Goren, Sarty & Wu, 1976; Johnson, Dziurawiec, Ellis & Morton, 1991). However, children show no preference for looking at face shapes compared to non-face shapes at one month old, with this cognitive preference appearing to re-emerge at about two months of age (Maurer & Barrera, 1981).

Johnson and Morton claimed that the findings of Goren, Sarty and Wu (1976) and Maurer and Barrera (1981) appear to suggest a U shaped developmental curve, best explained not by a single developmental mechanism but by two mechanisms interacting with one another. This is supported by evidence that the visual cortex moves from a subcortical to cortical system early in the child's development (Johnson, 1990a, b). Therefore, the infants' subcortical visual pathways will include basic mechanisms that cause them to orient attention to simple and easily differentiable visual information. This will later give way to more organised and 'top-down' controlled cortical orientation of attention.

Johnson and Morton suggested that the human infant (as well as other species) is born with information about certain key stimuli that affects behaviour and development. In terms of the development of face processing, Johnson and Morton proposed a cognitive mechanism they term CONSPEC. This is responsible for infants' early attentional interest in faces. This mechanism in the neonate brain would have to contain structural information about conspecifics (i.e. relative location of items, in the case of faces 3 blobs in the correct spatial arrangement to be considered a face) this need only be enough to allow for identification of parents from the typical environment encountered by members of the species. Additionally the mechanism would have to be available to the organism without having to be exposed to the stimuli.

It is not enough to have a preference for orienting towards faces for the infant to grow up with social competence they will need to learn to distinguish a great number of individuals and a number of emotional and other social cues from the face. The mechanism proposed by Johnson and Morton to operate in the learning of face stimuli was termed CONLERN. CONLERN is defined as '*a device that acquires and retains specific information about the visual characteristics of individual conspecifics*' Johnson and Morton (1991, pp90). Johnson and Morton argue that once the subcortical CONSPEC mechanism has caused an early attentional bias towards faces that the cortical pathways in CONLERN configure to process faces and the detail about them in a superior manner.

Social processing and attention in individuals with ASD (1.3)

The above section (1.2) deals with the salience of faces and how these draw attention for TD individuals as well as the subsequent expertise in processing these stimuli. Klin (1989) and Dawson et al. (1998) however have suggested that social information may not be judged as salient by autistic individuals and therefore not preferentially attended to. This difficulty in processing social information can be seen in a number of domains. The following sections will consider two important social processing impairments that have been suggested; those of processing speech and processing information from faces.

Processing voices in ASD (1.3.1)

As indicated above, in typical development the human voice is one of the earliest stimuli that children attend to (Vouloumanos & Werker, 2004). In ASD however, voices may not be imbibed with the same importance, and often the first referral that ASD children receive is for deafness (Lowell, 1972) as their parents are concerned that they seem to be ignored by their child. Research has been conducted by Pamela Heaton and colleagues to examine the relative processing of voices and music in ASD individuals.

Järvinen-Pasley and Heaton (2007) tested the ability of nineteen children with ASD and 19 matched controls to match the pitch sequence of four-syllable nouns and pieces of music. Participants were asked to indicate if the pitch sequences were the same or different for two stimuli played one second apart. Findings indicated that although pitch matching is equivalent in ASD and typical development in a non-social context (music), providing a social (speech) context significantly interferes with the performance of controls but not with that of children with ASD. It seems therefore that speech does not take on a special role in the processing systems of individuals with ASD and can be objectively processed as another sound. These findings have been shown to be reliable and have been replicated by Heaton, Hudry, Ludlow and Hill (2008).

One reason that voices may not be processed in a perceptually distinct manner by individuals with ASD is that preference is not given to the social meaning of speech when processing sound. Järvinen-Pasley, Pasley and Heaton (2008) examined processing preference in 28 children with ASD and IQ matched controls. Children listened to a number of sentences and were asked to indicate which of four graphical stimuli best represented the sentence. Although both groups were more likely to select a semantic representation as the best match to the sentence, the ASD group made a significantly greater number of perceptual pitch selections than the control group. This suggests that although children with ASD still show a preference for the semantic content of a sentence, this bias is not as strong as in typical development.

The above studies appear to indicate that for individuals with ASD voices are not processed in the same unique way as observed in typical development and are treated as another sound to be processed instead of a source of social significance. This gives an example of the difficulties with social processing seen in individuals with ASD. A second area in which social processing difficulties in ASD have frequently been reported is that of face processing.

Face processing in autism (1.3.2)

It has been noted that faces are a unique class of object that hold specific biological and social significance (Carey, 1992; Grüsser & Landis, 1991). As such in any examination of the social cognition and understanding of ASD individuals an exploration of these socially unique stimuli is necessary. Research suggests that face processing is less developed in individuals with ASD than in TD individuals. This is consistent with the idea that ASD individuals have not learned to be experts in face processing. Additionally the neurological findings that ASD individuals do not process faces in the right FFA as in typical development, is consistent with the proposal that the neurological mechanism responsible for face processing expertise has not developed in this population (Schultz et al., 2000).

A variety of selective cognitive deficits have been observed in the processing of face stimuli for those with ASD. Hauck, Fein, Maltby, Waterhouse and Feinstein (1998) examined memory abilities in children with ASD. Participants were shown a number of pictures some of which had been seen in a previous task and asked to indicate if they had seen them before. The ASD and control children showed equivalent performance on recalling the objects. However the control group showed a greater recall for the faces, which was not displayed by the ASD children. This study suggests that faces are not processed and encoded as a special and distinct stimuli compared to other objects in children with ASD, therefore a selective deficit is seen in the recall of this information. Williams, Goldstein and Minshew (2005) also found a selective impairment for faces in high functioning adults with autism on both immediate and delayed recall on the Wechsler Memory Scale III (Wechsler, 1997b)

The above findings of differences in the processing of faces between ASD and non-ASD individuals suggests that faces are processed using a different cognitive style by these two groups. In his early examination of face processing in children with autism Langdell (1978) tested the ability of separate groups of chronological and mental age matched children with and without autism to recognise their classmates based on photographs of either the whole or parts of their face. Photographs which had been taken of the children's classmates were revealed to the participant one feature at a time until the whole face was shown. While the control participants showed greater recognition of their peers when presented with the eyes compared to the mouth, this was not the case for the autistic children. Langdell concluded that for the autistic child the face does not represent a social stimulus and is merely another visual pattern and therefore the eyes which are typically considered more socially informative are not given greater focus. This was supported by the findings that autistic individuals are less susceptible to the face inversion effect than non-ASD controls (Langdell; 1978; Hobson, Ouston, & Lee 1988).

Evidence for autistic individuals' atypical attentiveness to social information comes from a number of sources, one of which is research on face scanning. In typical populations when a picture of a face is scanned the more social facial features, which reveal more about the meaning of any communication, are prioritised in scanning (eyes, nose, and mouth; e.g. Luria & Strauss, 1978; Manor et al., 1999). Walker-Smith et al. (1977) found that almost all fixations were directed towards this area, with 70% of fixations on the eyes. Pelphrey et al. (2002) examined the visual scan paths of autistic and non-autistic individuals during a face recognition task. While TD individuals' scan paths can be categorised as following the triangle of eyes, nose and mouth, autistic children's fixations were not focused in this area, they tended to fix on an ear, or the lower face.

The above findings that individuals with autism do not look towards the eyes when processing faces are not wholly surprising, given that one of the original diagnostic criteria of autism was avoidance of eye contact (Kanner, 1943). However, a strict avoidance of eye gaze is now assumed to be a myth, it has been observed that with maturation autistic individuals begin to show eye contact, nevertheless this eye gaze is still abnormal in nature. The tendency in those with autism is to look too closely and for too long at the eyes of others on some occasions and not enough or at all on others, seemingly unable to synchronise and maintain the mutual making and breaking of eye contact (Mirenda, Donnellan, & Yoder, 1983). This suggests that individuals with ASD show a learned approach to eye contact which lacks the automatic skills needed for normal eye contact and reflect instead a learned process.

Further evidence for the atypical processing of faces in ASD comes from a number of fMRI studies. Schultz et al. (2000) conducted a study of 14 individuals with ASD who were asked to make same/different judgments for faces and objects. During the face trials TD individuals showed the expected activation of the FFA; however ASD individuals showed no such activations. Instead, ASD individuals showed activation in the inferior temporal gyrus, an area associated with the processing of objects in TD individuals, suggesting that they show no specialisation for the processing of faces. This has subsequently been confirmed by other studies (e.g. Critchley et al., 2000; Dierks, Bolte, Hubl, Lanfermann, & Poustka, 2001). Based on the above research it seems that some face learning is achieved by higher functioning individuals with ASD however this may happen later and to a lesser extent than in typical individuals and therefore will not reach the same level as the typical population.

Emotional processing in autism (1.3.3)

Although people with autism have been argued by some to be face novices (e.g. Grelottie, Gauther, & Schultz, 2002), when compared to TD individuals, their face processing deficit is not universal. People with autism have been shown to be able to discriminate between faces (Boucher & Lewis, 1992; Ozenoff, Pennington, & Rodgers, 1990), be able to identify familiar individuals (e.g. Langdell, 1978), match the identity of people from different photographs (Celani, Battacchi, & Arcidiacono, 1999) and higher functioning adolescents with ASD have even been shown to be susceptible to the inversion effect (Teunisse & de Gelder, 2003). However when the task demands are increased or elements of emotional processing are introduced, the impaired performance of individuals with ASD becomes more evident (Davies, Bishop, Manstead, & Tantum, 1994; Tantum, Nicholson, Monaghan, & Stirling, 1989).

Palermo and Rhodes (2007) conducted a comprehensive review of the automatic processing of emotional expressions in TD individuals. They argued that that *'regardless of its expression a face is a salient emotional stimulus, allowing us to distinguish friend from foe and conveying crucial information for social interaction'* (Palermo & Rhodes,200, p 76). To be considered automatic Palermo and Rhodes reasoned that the processing of faces and emotional expressions should be: rapid, non-conscious, mandatory and capacity free. Calvo and Esteves (2005) indicated that emotional faces (angry, happy and sad) were able to prime a later emotional face at shorter presentation durations than neutral and atypical emotional (scheming) faces. This suggests that the processing of emotions is rapid and can occur without conscious awareness, which is supported by EEG findings that the amygdala reacts differently to emotional and neutral faces at about 100ms after presentation (e.g. Streit et al. 2003). Although when face stimuli are cues as a cue they can result in an inhibition of return effect (Theeuwes, Stephan & Strigchel, 2006) suggesting that these stimuli are processed automatically. This runs contrary to the findings of Bindemann et al. (2007) that when the location of a face does not predict the subsequent location of a probe stimulus then participants are not faster to detect these probes. The findings of Bindemann et al. suggest that face processing is not mandatory. A similar contradiction exists in the emotional processing research. In studies when participants have to perform a central discrimination task at the centre of the screen fearful faces presented at the periphery have been shown to result in the same amount of amygdala activation when the attentional load was low (Vuilleumeir et al. 2001), but not when the task was made more difficult (Pessoa et al. 2002). The major method which has been used to examine if the processing of faces is capacity free has been through visual search tasks. Hansen and Hansen (1988) indicated that the increase in search times for angry faces among neutral faces was not significantly greater when 8 distracters where used than when 3 distracters where used. Purcell, Stewart and Skov (1996) have however argued that this was a result of a low level artefact and that search time does increase with number of distracters (this is reviewed in more detail in Chapter 2). Upon reflection it would appear that if the processing of emotions is not automatic that it is a very rapid and preferential process for TD individuals.

With regard to ASD since Kanner (1943, p 250) stated that the autistic child has an 'inborn disturbance of affect contact' emotional processing in individuals with ASD has been a key area of study. Braverman, Fein, Lucci, and Waterhouse (1989) conducted an experiment to examine the ability of a group of children with Pervasive Developmental Disorders (PDD; including a subgroup of HFA children), to match test photographs to the most appropriate of four target photographs. PDD individuals performed at the same level as TD controls when matching both objects and the identity of faces, however they were significantly impaired compared to controls on matching and comprehending affect. Hobson (1986a, 1986b) extended this research by examining the ability of individuals with ASD to match across sensory modalities. He found that autistic children were impaired, compared to TD controls, in their ability to match facial expressions of emotion to corresponding videotaped gestures, voices or contexts (e.g. matching a sad face to the sound of crying).

The impaired emotional processing in individuals with ASD indicated above, has been supported by Hobson, Ousted and Lee (1988) who examined the effect of inversion upon the processing of emotional facial expressions. As explained previously (section 1.2.1) the recognition of faces is impaired by presenting them upside-down to a greater extent than for other stimuli (e.g. Yin, 1969, 1970). Hobson et al. asked participants to select which of two test images showed the same emotional expression as a probe image presented above. The participants with ASD in this study showed a far smaller effect of inverting the images than for those without ASD. This is indicative of a less expert approach to the processing of emotional expressions.

There have however been some criticisms about the findings of these studies. Ozonoff, Pennington and Rodgers (1990) attempted to replicate the findings of Braverman, Fein, Lucci, and Waterhouse (1989) and Hobson (1986) using a verbal IQ matched group as opposed to a non-verbal ability matched group. Ozonoff et al. found that when matched on verbal IQ there were no significant differences between autistic and control children. This indicates that the simple emotional processing deficit observed in these early studies might relate to the verbal abilities of the participants rather than specifically the participants' autistic diagnosis.

Instead of examining the ability of participants to pass or fail a task Jennings (1973) examined the preference of autistic children and adolescents for the spontaneous sorting of information based on emotional or non emotional criteria using Izard's (1971) facial effect photographs. Jennings asked autistic and non-autistic intellectually impaired children to sort cards of people's faces that varied in terms of age, sex, facial expression of emotion, and the type of hat they were wearing. Non-autistic children categorized the cards most often based on the facial expression of emotion; however autistic children were most likely to organize the cards based on type of hat. In an extended replication of Jennings study Weeks and Hobson (1987), showed that of 15 autistic children 6 spontaneously sorted by facial expression of emotion and that 4 more were able to do this when they were informed that this was the dimension of interest. This suggests that this preference may not be as clear cut as originally thought, and that autistic children are not only able to organise information based on social cues but that a significant minority (40% in Weeks & Hobson's study) may do so spontaneously and preferentially, with another 27% able to do so when prompted. This furthers the suggestion that some individuals with ASD might be a part of a subgroup that either prefers to or can when prompted engage with some basic social cues.

The above research indicates that high functioning ASD individuals appear to be able to perform tasks classifying emotions when these are clear and explicit. Therefore when examining emotional abilities in adults with ASD measures need to be more subtle. Hall, West and Szatmari (2007) examined whether emotional stimuli presented outside of conscious awareness are able to influence the decisions of adolescents with ASD and typical high functioning controls. Hall et al. presented participants with a series of photographs of faces on the left and right of the screen that usually displayed neutral emotional expressions. However, on one side of the display, a fearful expression was presented for 33ms two images before the test display. The display then returned to the presentation of neutral expressions. Participants were then asked to indicate which of two faces presented on either side of the screen was friendly. Although both ASD and control participants were more likely to respond that the face preceded by the neutral face was friendlier, control participants were significantly more likely than the ASD participants to indicate that the face preceded by a neutral face was friendlier. This could not be explained as being because the ASD group were less likely to detect the sub-threshold prime as both groups were equally sensitive to a sub-threshold Stroop task. This indicates that adolescents with ASD are not as sensitive to fear related stimuli presented to them for sub-threshold durations as control participants. The findings that ASD adults are less responsive to emotional stimuli when presented outside of conscious awareness is important for this thesis as the current research will involve examining whether emotional faces presented for a sub-threshold duration capture attention.

Grossman, Klin, Carter and Volkmar (2000) have suggested that the emotional knowledge of individuals with ASDs may be more complex than outlined above. In Grossman et al.'s study a group of high functioning adolescents with ASD and verbal IQ matched TD controls were asked to identify emotional expressions paired with congruent or incongruent emotional words and irrelevant fruit words. Consistent with Ozonoff, Pennington and Rodgers (1990), when participants were matched on verbal IQ individuals with ASD were as accurate as controls in identifying emotional expressions when they were paired with congruent or irrelevant words. However, when incongruent emotional words were used, the accuracy of the ASD group was significantly poorer than that of controls. Grossman et al. suggested that these findings combined with some of the out loud verbal strategies used by the ASD participants in this study suggested a 'rehearsed' and intellectualised approach to this task, and that emotional processing can be learned but not automatised by these individuals.

Boraston, Corden, Miles, Skuse and Blakemore (2007) also distinguished between more and less sophisticated approaches to emotional identification as a potential way to explain the differences between the contradictory findings of the above studies. Boraston et al. examined the ability of high functioning adults with ASD to detect differences between real and 'false' smiles. The distinction between real and false smiles can only be detected by looking for the 'crow's feet' around the eyes (Boraston et al., 2007). Although there were no differences between the groups in distinguishing smiles from neutral expressions, the ASD group were significantly worse at telling which smiles were real and which were false. One explanation for this is that the ASD group spent less time looking at the eye region when completing this study and this is supported by eye tracking data; however the relationship seems more complex than this as there was no correlation between time looking at eyes and task performance. Another explanation for this is that individuals with ASD have a less sophisticated approach to emotional identification and have tried to learn just the gross indicators of happiness.

The above research indicates that the processing of faces and faces depicting emotional expressions in ASD is impaired compared to TD individuals. Individuals with ASD have been shown to have poorer memories for faces than TD individuals (Williams, Goldstein & Minshew, 2005) process faces differently (Pelphrey et al., 2002) and use different neurological regions when processing faces compared to TD individuals (Schultz et al., 2000). Additionally individuals with ASD are poorer than TD controls at matching emotional faces to other signs of emotion (Hobson 1986a; b) and process emotions in a less sophisticated way (Boraston et al., 2007).

Social orientation in autism (1.3.4)

Following the theory of CONSPEC and CONLERN put forward by Johnson and Morton (1991) an explanation for a lack of face processing expertise in ASD may be an absence of the mechanisms which cause an infant to engage with (and presumably learn about) these stimuli. As compared to typical development an examination of research on the social processing and orienting of attention to social cues within an ASD population reveals a different idea of preference and priority.

Joint attention skills typically emerge between 9 and 15 months of age (Dunham & Moore, 1995) and are key to the social development of the child, as these relate to the learning of socially and culturally appropriate behaviours (Bruner, 1983). Joint attention skills however appear to either be delayed or absent in the development of individuals with ASD (Leekam, Hunnisett & Moore, 1998). Joint attention is usually considered to be a 'triadic' relationship between self, other and object (e.g. Bakeman & Adamson, 1984) however this can be seen to be built upon an earlier dyadic relationship between the child and other (e.g. Bruner, 1975; Vygotsky, 1978). Leekam and Ramsden (2006) examined if the child's response to a bid for dyadic attention (e.g. calling the child's name) could be seen to be a precursor to triadic joint attention. They found that for all children dyadic orienting was significantly correlated with triadic joint attention and that this was particularly strong in the case of children with autism. This study supports the proposition that joint attention is impaired in individuals with ASD and that a precursor to this might be attention to others in general.

The findings of Leekam and Ramsden support the model of social development created by Baron-Cohen (1995) which could explain the social deficit seen in ASD. At the most basic level he proposed two systems; one designed for identifying basic intentionality and the other for detecting eye direction. These fed into a shared attention mechanism, which finally resulted in the capacity for Theory of Mind. Baron-Cohen suggests that the 'Intentionality Detector' operates initially by assuming a goal to be present in the direction of an agent's movement before developing more complex, desire based intentional inferences later in childhood. The 'Eye Direction Detector' (EDD) has three functions, ascertaining whether eyes are directed at one's self or something else, inferring that if an agent's eyes are directed towards something then the agent can see that item, and attributing a perceptual state to an agent (e.g. identifying their mother can see a particular item). The concept of the EDD can be seen to be reflected in the normative literature in studies, which indicate early infant attentional bias for faces (e.g. Goran, Sarty and Wu, 1975). According to Baron-Cohen the next stage in the model involves the 'Shared Attention Mechanism' that allows the child to realise that an agent looking at them can see that they see a third object (this is a version of triadic joint attention as discussed above). Finally full Theory of Mind capacity is reached and the child is able to attribute intention, desires and mental states to others.

It can be seen from the suggestions of Leekam and Ramsden (2006) and the model of Baron-Cohen (1995) that triadic joint attention, Theory of Mind and other social competencies are built upon early social attention. What is not clear from this is what these key initial capacities are. Leekam and Ramsden argue that the process of engaging attention with another is the root of this deficit. However, Baron-Cohen suggests that knowledge of the function of the eyes is the core of ASD. Given Baron-Cohen's claim it is important to observe the development of ability with gaze cues.

The ability of older individuals with ASD to use social cues in the environment has also been examined. Kylliäinen and Hietanen (2004) used an adapted version of the Posner (Posner, Nissen & Ogden, 1978) pre-cueing task that included a social element. As opposed to arrows or light flashes being used to orient attention, they used a face at the centre of the screen with eyes directing attention to either the right or left for 200 or 800ms (eye direction did not predicted target location). It was found that autistic children showed shorter response latencies to probes pre-cued by the direction of the eyes. Based on this it appears children with autism are able to orient their attention to the eye movement of another individual. This indicates that under certain highly structured circumstances social orienting is intact. This also suggests that autistic individuals can appropriately respond to subtle social cues and do not require the gross cues, such as overt head turning (e.g. Leekam et al., 1997). Senju, Tojo, Dairoku and Hasegawa (2004) have reported similar findings.

The findings of Kylliäinen and Hietanen (2004) and Senju et al. (2004) were further explored by Ristic et al. (2005). Ristic et al. pointed out that there are two interpretations of the above findings; the first is that the individual understands that eye gaze conveys social information, including status and attentional engagement, this they called the *social engagement hypothesis*. The second explanation is that people are sensitive to basic changes in the environment including gaze direction as indicating an important event, this they called the *feature correspondence hypothesis*. Ristic broke down the social variant of Posner's orientation task to allow these two hypotheses to be separately tested. Participants were either in a non-predictive gaze condition where the target was in the cued direction 50% of the time, or in a predictive gaze condition were the target was congruently presented 80% of the time. They reasoned that if participants showed a congruency effect in the predictive condition only then this would be best explained by the *feature correspondence hypothesis* however if a congruency effect was found in both conditions this would show that participants were using social reading. Ristic et al. found that TD participants oriented their attention to the eye direction in both the predictive and non-predictive conditions, however autistic participants did not orient their attention in the non-predictive condition, indicating that only TD individuals use social reading. This appears to suggest that autistic individuals do not consider the eyes to hold socially relevant information. This suggests that although individuals with ASD are able to use social cues from eye direction when it is beneficial to performance this is not an automatic mechanism and may be a result of an alternative learned response.

It is important to note that social attention is much broader than the ability to appropriately use eye gaze, and can be considered to include the general tendency of people to orient their attention towards other people. Early accounts of social disinterest have come from clinical observations of the behaviour of young autistic individuals, who may not seek physical comfort from parents and may be difficult to hold (DeMyer, 1979). This is supported by retrospective reports by parents of autistic children that social interest was reduced or absent in their child's early years. In one study Ornitz et al. (1978) reported that 85% of the young autistic children in their sample were described by parents as having ignored people, 90% seemed 'hard to reach' and that 76% avoided eye contact. Findings based on retrospective reports especially those of parents need to be considered with caution as they are open to response bias of the parent who will report information that is congruent with their current knowledge (Dawson et al., 1998). This may make them more likely to recall their child's social isolation as they are aware that this is symptomatic of autism.

As well as the visual stimuli of the face the other obvious social stimulation prevalent in day to day life is that of speech, it has been shown the human voice is given preferential attentional processing in TD neonates (when compared to white noise; Butterfield & Siperstein, 1972). Conversely it has been noted in clinical (Clancy & McBride, 1969; Kanner, 1943; Prior & Gajzago, 1974; Rutter, 1968), anecdotal (e.g. Rowlands, 1972), and retrospective accounts (Ornitz, Guthrie & Farley, 1977) that autistic children are less responsive to and may appear oblivious to speech sounds.

This was experimentally examined by Klin (1991) using a preferential listening task with a group of young autistic children. This task involved the presentation of each child's mother's voice and alternative noise designated as babble. Five of the autistic children showed a preference for babble and seven showed no preference either way (preference was defined as being over a 60% cut off towards either babble or speech). This is compared to all TD and intellectually delayed control children who showed a bias towards the speech. A potential confound in this study was that no standardised measure of receptive language ability was collected. As such these findings may reflect an inability of autistic childrens to understand the speech used. Klin (1992) also showed that this technique could differentiate between two children with ASD and two who had been misreferred for evaluation for autism and had been diagnosed with non-autistic global intellectual delay, and developmental receptive language disorder.

Dawson et al. (1998; 2004) conducted more naturalistic examinations of social (and non-social) orienting in young children with ASD. Children were taken into a room where their behaviour was videotaped from behind a one-way mirror while engaging in free play. During this a number of sounds were played through speakers placed around the room. Sounds could be social (e.g. the call of the child's name) or non-social (e.g. shaking a rattle) and the child was said to have oriented to stimuli if they turned their head and/or eyes towards the auditory stimuli. Dawson et al.'s findings in both cases suggested that autistic individuals had a general impairment in orienting, and that this effect was more severe for social stimuli.

In an attempt to explore the early development of social interest in infants later diagnosed with ASD, Osterling and Dawson (1994) examined whether it was possible to identify autistic individuals before diagnosis by their first birthday using retrospective techniques. To control for some of the problems with any retrospective study (e.g. people tend to report information that is congruent with their later knowledge), Osterling and Dawson examined videotapes of children's behaviour that were coded by observers who were blind to the child's diagnosis. While this has been done by a number of other researchers (Losche, 1990; Adrien et al., 1991; 1993) Osterling and Dawson also controlled for the developmental level that the child was at, and the context that the video was taken in by only including tapes of the child's first birthday. They found it was possible to retrospectively differentiate between autistic and TD children by their first birthdays and that how often the child looked at others was the single best predictor of later diagnosis. When this was combined with showing, pointing, and failure to orient to own name, 91% of the cases could be correctly identified. A problem with this study was that the control group were TD and were not affected by mental retardation whereas 40% of the ASD children had an IQ lower than 75, thus the findings in this study may also be partially explained by the children's developmental delay not the child's autism. Controlling for mental age Baranek (1999) found that attention to people and orienting to social cues were the main contributors to discriminating between those who later developed ASD and those who did not. Osterling, Dawson and Munson (2002) also found these effects in a group of individuals with ASD who had intellectual functioning in the normal range.

Maestro et al. (2002) also used retrospective video and found reduced social attention at 6 months of age in children later diagnosed with ASD. As well as confirming the findings of Osterling and Dawson (1994), this study provides further evidence that a deficit in processing, and attending to social information is present from a very young age (if not birth) for those with autism and is not a process of maturation as suggested by other researchers (e.g. Baranek, 1999). These studies appear to indicate that a reduction in social orienting is a deficit present very early in the lives of individuals with ASDs and that this possibly acts a precursor to a number of impairments which present later in life. It is therefore important that this deficit be examined in greater detail and with stricter controls than are available using a retrospective analysis of video.

The above studies suggest that orienting to social cues is a problem associated with ASD early in development. If these findings can be shown to relate directly to the individuals' ASD and not to any co-morbid intellectual deficit then it is possible to see this as evidence for a deficit in the CONSPEC mechanism proposed by Johnson and Morton. This needs to be considered tentatively as the evidence for CONSPEC in typical development came from participants of a mean age of 9 minutes (Goren, Sarty & Wu, 1978). These findings could be a result of a learned process even at the early age of 6 months.

Others have examined how older children and adults with ASD allocate their attention to social and non-social information. van der Geest, Kemner, Camfferman, Verbaten, & Engeland (2002) used eye-tracking to examine the time spent looking at depictions of people and 7-9 non-human objects within a number of cartoon like scenes, in 16 autistic and 14 TD children. van der Geest et al. found no differences between autistic and TD children in total time spent looking at the target figures within the scene. They also found that there was no difference between the groups in attention to social stimuli, measured by total time spent looking at, and number of fixations for social stimuli (i.e. the person), as well as the time taken to make the first fixation for the person.

In contrast in Klin et al.'s (2002a) study they examined the visual path of one cognitively able, male, adult with autism (full scale IQ = 119) as well as an age, gender and IQ matched TD individual while watching dynamic digitized clips from the socially and emotionally rich film version of Edward Albee's (1967) 'Who's afraid of Virginia Woolf'. In this study the autistic viewer showed a stark lack of attention to the eyes of the protagonists focusing instead on the mouths consistent with previous findings (e.g. Pelphrey et al., 2002). The autistic viewer also failed to monitor listeners' reactions in ironic exchanges where these were far more revealing than the speakers words, in contrast to the control viewer. These findings did not appear to be a result of failure to identify visual cues in general as physical cues were monitored in the same way as by the controls. Although interesting and in line with the above findings suggesting impaired social orienting in ASD (e.g. Dawson et al., 1998; 2004) these findings are based on a single case and a single film and should be considered cautiously.

To counteract some of these problems (such as a sample size of one) Klin et al. (2002b) examined 15 cognitively able individuals compared to 15 matched TD controls. Although autistic participants were cognitively able they were also highly socially impaired (based on standardised scores on Vineland Adaptive Behaviour Scale, VABS;

Sparrow, Balla, & Cicchetti, 1984 and the Autism Diagnostic Observation Schedule, ADOS, Lord, Rutter, DiLavore, & Risi, 1999). Klin et al. (2002b) used many of the same clips as used by Klin et al. (2002a). In this study Klin et al. (2002b) measured the amount of time spent looking at 'key regions' of the scene (defined as the eyes, the mouth, the body and objects). Klin et al. (2002b) found that there were differences in fixation times for all the classes of information with autistic participants spending significantly less time looking at the eyes (24.6-65.4%) and significantly more time looking at mouths (41.2-21.2%), bodies (24.6-9.7%) and objects (9.6-3.7%). The best predictor of group membership was found to be fixation time on the eye regions, with the control group spending more than twice as much time fixating on these regions. Additionally there was no overlap between the groups in the distribution of time spent looking at the characters' eyes, indicating that even the most attentive autistic individual (to the eyes) still did not spend as much time looking at this region as the least attentive control participant.

In addition to examining where in the scenes individuals attended to Klin et al. also sought to examine the relationship between visual fixation time and social competence (based on scores on the VABS and ADOS). No relationship was found between time spent fixating on eyes and social competence, however fixation times to mouths and objects were found to be good predictors of social competence, though in different directions. Fixation time for the mouth region was found to be positively related to social capacity, whereas fixation for objects was found to be negatively related to social competence. The finding that it is a greater number of fixations on the mouth regions and not the eye regions which is predictive of greater social outcome is a fascinating one. While it is known from a number of previous studies that autistic individuals tend to attend more to mouths than eyes during face processing tasks (Pelphrey et al, 2002), the finding that this may relate to greater social adaptability raises the possibility that by focusing on the mouth of an individual during a social exchange, additional social understanding may be provided (possibly because of more attention to speech).

In contrast a lack of the ability to read information from the eyes (Baron-Cohen, Wheelwright & Jolliffe, 1997) may mean that no extra information can be gained from this region. The final matter of interest from this study comes in the form of the negative relationship between social competence and fixation time to objects. This would suggest that social inattention is a good predictor of higher level social competence and that attentional bias for faces might be predicted by this and other individual differences variables. This will be examined in further detail in this thesis.

Although eye tracking has provided some fascinating findings about potential differences between those with and without ASDs in terms of social interest this method is not without its problems. While it may seem logical that the direction of a persons' eyes are a direct measure of where they are attending it has been established on a number of occasions that attention can be directed to peripheral locations within the visual field without moving the eyes from the centre of the display (e.g. Posner, 1980). Therefore eye tracking cannot categorically tell us where in the visual field an individual is attending only where their eyes are directed. In addition to this eye tracking techniques can give us an idea of how people engage with visual information but reaction time studies can tell us more about the early time course of this behaviour. It is important when considering automatic social orienting as a potential cause of the social deficits observed in ASD to bear in mind where attention is allocated first between social and non-social stimuli.

Reaction time measures of attentional bias to emotional expressions in adults with ASD have been explored by Ashwin, Wheelwright and Baron-Cohen (2006a) using a pictorial version of the modified Stroop task. Ashwin et al. used this to examine the capacity of faces with different emotional expressions as well as non-social objects to capture the attention of high functioning ASD adults and IQ matched controls. Angry and neutral faces as well as non-social stimuli (chairs) were modified with a colour filter, and participants' were asked to name the colour of the filter. Ashwin et al. found that the control participants showed longer latencies for angry faces than neutral faces and chairs, which did not differ. The ASD group however showed longer latencies for all face stimuli, regardless of expression, compared to chairs. The findings of this study appear to indicate that individuals have an attentional bias for faces in general, irrespective of expression. There are however problems with this study. Firstly, this study can be seen to have the same problems associated with the Stroop task generally, as it is not clear if these findings truly reflect an attentional capture by this information, or possibly a difficulty in disengaging from these stimuli (e.g. MacLeod, Mathews and Tata, 1986). This study also failed to examine the influence of positive emotional expressions in these groups as it is possible that the ASD group with their known difficulties in processing emotion misinterpreted the 'neutral' faces as a threat. Finally, the anger bias effect with the emotional Stroop task has been shown to be mediated by the underlying level of anxiety felt by the individual (e.g. Mathews and Macleod, 1985). Given that it is known that affective disorders are more prevalent in ASD (e.g. Gillott and Standen, 2007; Tantum, 2000; which will be discussed in more detail in the following chapter) this is a potentially important consideration for studies such as this, as attentional biases observed may be a result of anxiety levels rather than participants' ASD. During this thesis the role of anxiety in these effects will be examined.

Ashwin, Wheelwright and Baron-Cohen, (2006b) utilised a version of the Face-in-the-Crowd task to explore attentional search for faces depicting emotional expressions. Ashwin et al. asked groups of ASD and IQ matched TD controls to identify the odd-one-out from various displays of line drawings depicting angry, happy and neutral faces. Ashwin et al. found that angry faces were found faster than happy faces amongst neutral distracters when presented for either one or two seconds, and that both groups were slower to search through emotional distracters than neutral ones. Although this study suggests that ASD and typical adults do not differ in their attentional bias for angry facial expressions, the findings need to be considered with caution due to the use of schematic stimuli resulting in reduced ecological validity.

The above research suggests a mixed pattern of findings relating to social attention in ASD. Research by Kylliäinen and Hietanen (2004) suggests that ASD individuals can orient their attention to the direction of another's eye under controlled circumstances and van der Geest et al. (2002) found that children with ASD spent more time looking at cartoon pictures of people compared to other stimuli in the scene. Ashwin et al. (2006a; b) have also indicated that individuals with ASD show similar attention to faces and faces of emotion as in TD individuals. In contrast however Klin et al. (2002a; b) have suggested that high functioning adults with ASD show a deficit in looking at people while watching dynamic film clips and Osterling and Dawson (1994) have suggested that this may be one of the earliest observable deficits in ASD. This suggests that under some, possibly more simplistic, circumstances ASD adults show a bias for faces, however when tasks involve greater demands these biases are no longer observed.

The implications of social inattention: an explanation for ASD? (1.4)

In summary the research presented suggests that a reduction in social salience may prevent the autistic individual from being 'geared-up' to become an expert in social, and face, processing. Thus a failure to orient to social information could be reasonably hypothesised to be the root cause of the later deficits in social understanding, and processing. Due to the fact that ASDs are rarely diagnosed until after the age of 2 years old (e.g. Sivberg, 2003) it is hard to directly measure attentional allocation in this group at birth and during infancy. Therefore it is important to try to look for tasks that can measure underlying cognitions later in life but still reflect the original abnormality.

There has been support for the proposition that the reason that neurologically specific regions of expertise (i.e. the FFA) are activated less during social processing (and specifically face processing) in those with autism is a result of a lack of social attention and not a general dysfunction in this area of the brain. This comes from a study examining neuronal activation when processing information about which an autistic boy was an expert. Grelotti et al. (2005) compared one TD child and one autistic adolescent to an 11-year-old autistic boy, who watched the Digimon television show daily for two years, knew most of the characters and wished to become one of the children in the show. Grelotti asked participants to make a true false response to images (of familiar faces, familiar objects, and Digimon characters) with different labels (e.g. the label of mum with a picture of the participant's mother would be a true response). While participants were completing this task, Grelotti et al. were also using fMRI to assess neurological activation. On the response task the TD child was overall faster than the child with an interest in Digimon, however this is likely a result of higher cognitive ability. The TD child was faster at identifying faces than objects or Digimon characters, which were identified at the same speed. In contrast to this the Digimon child identified Digimon characters quicker than both face and objects (again identified at the same speed). As expected, when analysing the neuroimaging data, the TD child showed a greater FFA response to the faces than to objects, unlike both autistic participants who showed more response to the objects. In addition the TD participant showed no more activation for Digimon characters than for objects. In contrast the Digimon child showed greater activation of the FFA for Digimon characters than both faces and objects. In addition this activation was similar to the pattern observed when TD individuals view faces. Furthermore when exploring activation of the amygdala the TD child had greater activation for faces than Digimon characters and vice versa for the autistic child obsessed with Digimon.

These results provide preliminary evidence that the FFA is functional in autistic individuals and that it is possible for people with autism to develop processing expertise for preferred classes of information. This raises the question of why faces, and other social stimuli, are not identified as salient by autistic children from a young age. This preliminary evidence from Grelotti et al. (2005) seems to indicate that this is not a result of a total dysfunction of the amygdala (which has been implicated in detection of salient information, Aggleton, 1993), as the Digimon obsessed child in their study showed amygdala activation for Digimon characters. Therefore this child was able to identify important information to him as being salient. This seems to indicate that the problem in autism is specifically identifying the salience of social information, and therefore orienting attention to and engaging with this information. One reason that social stimuli might not be judged as salient by an ASD population could be that a CONSPEC mechanism for faces might be absent or altered in this population, and thus these stimuli might not hold special significance for these individuals.

The implications of early inattention to faces have been highlighted by Le Grand, Mondloch, Maurer and Brent (2003) who showed that infants with congenital cataracts which blocked visual input to the right hemisphere were significantly impaired in the holistic processing of faces years after these visual impairments had been removed. Johnson (2005) suggested that with particular reference to autism a lack of a broader social saliency might underlie many of the deficits in this group. In light of what is known about the neural plasticity and the development of expertise for processing social information in the Fusiform gyrus in TD infants (Kanwisher, McDermott & Chun, 1997) and that people who are highly familiar with a particular stimuli will also use the FFA to process these stimuli (Grelotti et al., 2005), it seems reasonable to propose that if people with autism do not expose themselves to social stimulation at a young age (manifested by a lack of attention to social cues in infancy) then normal social abilities will not be available to them (Mundy, 1995; Schultz, 2005).

Although reduced early social orientation and approach appears to be a consistent finding in ASD the availability of facial information to the neural system is impaired in a number of other groups (e.g. infants with congenital cataracts) who do not go on to develop such a broad range of social deficits as those seen in ASD. It is possible that while other groups may develop later preference for faces or may show a preference for social stimuli in other sensory modalities that this is not the case in ASD. However little is known about the development of automatic social attention in ASD. Although adults with ASD may develop an interest in social relationships (e.g. Baron-Cohen, 2004) and show the capacity to use social cues (Kylliäinen & Hietanen, 2004; Senju et al., 2004) this process may not become automatic.

Aims of the thesis (1.5)

The overall aim of the thesis is to systematically examine if faces, in comparison to non-social stimuli, capture the attention of high-functioning adults with ASD. Their performance will be compared to a group of TD control participants, who are expected, based on previous research to show a bias for face stimuli (e.g. Bindemann et al., 2007). This will allow for both the within participants bias to be examined (e.g. whether either group show an attentional bias for faces or non-face stimuli) as well as to examine whether the extent of any bias (or pattern of any bias) differs between the ASD and control groups. Research presented above has indicated a contradictory pattern of attentional biases in individuals with ASD in the visual domain with some studies suggesting individuals with ASD show no differences from typical controls in social attention (e.g. van der Geest et al., 2002; Kylliäinen & Hietanen, 2004) compared to others who have found a clear deficit in social attention in children and adults with ASD compared to TD controls (e.g. Dawson et al., 1998; 2004; Klin et al., 2002a, b). This thesis also aims to examine these effects at three attentional levels; when participants have full conscious control over attention, when participants are consciously aware of the stimuli presented to them but are not under conscious control of attention (i.e. when participants can see the stimulus but do not have time to make an overt decision about it) and when stimuli are presented outside of conscious awareness. To present stimuli under conscious control they will be presented for an unlimited time using the Face-in-the-Crowd task (discussed in Chapter 2), and participants will have control over their allocation of attention. To present stimuli which will capture attention outside of conscious awareness the Visual Dot Probe task will be used (also discussed in Chapter 2). Presentation times used in this study will be kept very short (<200ms) as it can be argued that these presentation duration do not allow for the participants to consciously allocate their attention and record only attentional capture as a result of bottom up processing. By examining attentional bias at the three levels of attentional control it will be possible to examine whether some of the inconsistencies in previous research can be explained by the level of control the participants had over their allocation of attention.

To achieve this aim, novel and innovative methods of assessing attentional bias will be employed. These will allow for the attentional bias of adults with ASD to face and non-face stimuli to be examined in a highly controlled way. At present attention to faces compared to non-face stimuli has not been explored in ASD using the Visual Dot Probe (Mathews, McLeod & Tata, 1986) or the Face-in-the-Crowd tasks (Hansen & Hansen, 1988). These techniques have been used to examine the allocation of attention to stimuli presented for both sub and supra threshold durations in a number of clinical groups (most commonly bias for threat stimuli in anxious participants; e.g. Mathews, McLeod & Tata, 1986). These techniques have a number of advantages compared to previous methods, as they can be used with high functioning adult populations and can be varied to examine a number of attentional functions (reviews of these techniques appear in the next chapter).

This thesis will add to previous research in a number of ways. Firstly, a series of studies will be conducted with a single population. It will therefore be possible to examine the pattern of consistency in attentional bias in both the ASD and control groups. Additionally previous studies examining social attention in ASD, especially in adults, have overlooked a number of potentially important moderating variables in understanding these biases. With the exception of a small number of studies (e.g. Klin et al., 2002 a; b; Ashwin et al, 2006a, b) little consideration has been given to the role of emotional stimuli in bias for social stimuli. Given that Palermo and Rhodes (2007) have suggested that knowledge of a persons' emotional valence is important in identifying a person as a potential friend or person to be avoided, this can be considered a potentially important factor in attentional allocation.

Additionally previous research has tended to consider attention in ASD in simple terms of whether a group of participants with ASD differ from those without ASD in attentional bias. In this thesis a number of psychometric and demographic variables will also be collected from participants. This will allow for the role of these variables to be considered in relation to individuals' attentional profiles. Given that Wing and Attwood (1987) indicated that children with ASD can be said to be a member of one of three social subtypes; aloof, passive and active but odd, it will be examined if subgroups might exist within the ASD population with regard to their attentional bias. In addition to this, previous research has indicated that diagnostic measures of ASD might reveal many independent subtypes of ASD (e.g. Lecavalier, 2005) rather than a single diagnostic presentation and this has been supported by research indicating that a number of independent genetic sites underlie ASD (Freitag, 2007) and that ASD individuals appear to vary in cognitive profile (e.g. Ozenoff et al. 1991; Happé, 1994, 1997).

To summarise, in this thesis attention to face stimuli, compared to non-face stimuli, will be examined in a high functioning ASD population. This attentional bias will be examined at varying levels of attentional control to allow for the automaticity of these effects to be considered. These effects will be considered using a variety of emotional expressions to examine how these contribute to any bias in attention. Finally, attentional bias will be examined both on a group level and an individual level. This will allow for the presence of sub-groups to be examined with respect to social attentional bias in ASD and the role that individual differences may play in these biases.

Chapter 2:

Methodological review (2)

Before reporting the experimental procedures and findings of the research conducted within this thesis, it is important to review the methodological techniques that will be used, and the assumptions and theories that underlie them. This review will address theories of visual attention, and specifically selective attention, drawing upon the work of Posner and colleagues to highlight potential sub-components of selective visual attention. A review of the Visual Dot Probe task will follow addressing the key methodological variations in this design, namely; the type of stimuli presented, the orientation of the stimuli pairs, presentation time and response method. This has been used to design the most appropriate variation of the test for the current research. The second technique for measuring attentional bias which will be reviewed is that of the Face-in-the-Crowd task, which is a visual search measure. This technique has been used to measure attentional bias for meaningful stimuli in a number of ways and the variations in this design will be considered. Methods for calculating visual detection threshold will then be reviewed. Finally a review of the psychometric measures and techniques will be presented and a rationale provided for the use of these measures during this thesis.

Selective attention (2.1)

Mesulam (1985, p125) wrote that 'If the brain had infinite capacity for information processing, there would be little need for an attentional mechanism' and Broadbent (1971) suggested that selection of attention must occur to protect a mechanism of limited capacity. It is because of this that it is necessary to attend selectively to meaningful sources of information while ignoring irrelevant ones (Lane & Pearson, 1982). Given the limits on human processing abilities it is important that what is 'selected' gives the individual the best ability to learn about their environment and identify important and salient information.

Most researchers have moved away from the idea that attentional selection is a singular process and have begun to assume that a number of subsystems and subcomponents exist in the process of attending to a particular stimuli. This is reflected within Kinchla's (1992, pp726) review on attentional research that '*there doesn't appear to be an abrupt all-or-nothing switching but instead a gradual build up of 'attention' at the cue location'* and based on research by Eriksen (1990) this process seems to begin after about 50ms and reaches a peak at about 200ms.

Others such as Posner and colleagues (e.g. Posner, 1980; Posner & Petersen, 1990; Posner, Walker, Frances, & Rafel, 1984) and Allport (1989) have attempted to identify evidence for what sub-processes may go into attending to a stimulus. The prevalent account of the fragmentation of attention is that of Posner, Walker, Frances, and Rafel (1984) which broadly proposes that the process of selectively attending to a new stimulus can be broken down into three subcomponents. Attending to a new location involves first disengaging from the current location of attention, followed by switching attention to the new location, and finally the re-engagement of attention at the new location.

Orienting of attention and Posner's Attentional task (2.2)

The effect of pre-cueing the potential location of a target stimulus has frequently been used in tasks examining various components of selective attention. In their seminal work Posner, Nissen and Ogden (1978) presented participants with centrally located arrows pointing either left or right for one second. These predicted with 80% validity the location of a change in luminance which it was the participants' task to detect (on some trials a '+' sign was presented, indicating that the target was equally likely to appear on either side). Two response methods were used in this study to record reaction times; participants were either instructed to use a single key press to indicate the detection of a luminance change, or a two forced choice decision about the location of the luminance change. Posner, Nissen and Ogden found that both response methods resulted in roughly equal benefits in speeding up response times for the valid cues and costs in terms of slowed responses to invalid cues when compared to the neutral ('+') non-predictive trials. This study established that reaction times can be used as a method of recording the allocation of spatial attention. Hommel, Pratt, Colzato and Godijn (2001) found that semantic (directional word) cues can also be successfully used to elicit these effects and that even when the pre-cues are not predictive valid cues result in shorter reaction times.

Others have also suggested that attention may be oriented by peripheral cues, such as flashes of light, using similar mechanisms (e.g. Remington, 1978). Jonides (1981) examined the differences between the attentional mechanisms operating when people are presented with either centrally located or peripherally located cues. Participants could be cued to the probable location of the target (70% valid cues) by the presentation of either an arrowhead at the edge of the location where the letters appeared or a centrally located arrowhead at the centre of the imaginary circle. Jonides reasoned that the orienting to peripherally presented cues was an automatic exogenous process out of the control of the individual and as a bottom up feature of the stimuli. Whereas orienting to centrally presented cues was an endogenous process consistent with a planned allocation of attention using a top down approach. This was tested by asking participants to perform a concurrent serial recall of 3, 5, or 7 items that had been presented prior to the attentional task. The benefit of valid cues on reaction times remained constant across the memory load task for the peripheral cues, however got significantly smaller as memory load was increased for the central cues presentation. This is consistent with the idea that the allocation of attention to peripheral cues is an automatic process not affected by concurrent task demands. Jonides sought to support these findings by examining the ability participants had to suppress the orientation effects. In a second experiment participants were told that the cues did not predict the location of the target and to try to ignore them. Participants were able to do this for the central cues (i.e. no cue validity effect) however they were still quicker to respond to peripherally located targets at a pre-cued location. This again supports the proposition that the orienting associated with peripheral cues is exogenous and outside of the conscious control of the individual. These findings are important as they indicate that orienting to meaningful central cues is within the conscious control of the participant (endogenous) while peripheral stimuli capture attention outside of conscious control (exogenous).

In addition to peripheral or symbolic cues some researchers have examined the capacity of socially meaningful stimuli to effect attentional allocation. Langton and Bruce (1999) examined the effect of centrally located face stimuli to orient attention. Although these seem on the surface to be more like the arrowhead stimuli and would therefore be expected to engage endogenous orienting Langton and Bruce proposed that due to the highly evolved social orienting system the orienting observed for these stimuli would more closely resemble the automatic exogenous allocation seen with peripheral stimuli. Participants showed faster reaction times to face cued locations when cues were predictive or non-predictive. This was however only the case where faces were presented for 100ms and not for 500 or 1000ms. The findings that even non-predictive cues result in an advantage and that this is only present on fast presentations is consistent with the proposal that the orientation observed is as a result of exogenous orienting outside of conscious control. This suggests that the direction of the face and eyes have a special place in the orientation of human beings. The findings that the direction of another's eyes result in reflexive orientation of attention has been replicated in a number of studies (Langdon & Smith, 2005; Driver et al., 1999).

The Visual Dot Probe Task (2.3)

While research in the tradition of the orientation tasks developed by Posner et al. have examined the effects of peripherally presented 'covert' cues and centrally presented meaningful orientation cues an examination of a different area is needed to more completely understand the effects that semantically meaningful information may have on attentional bias. In the 'real world' our attention is captured by information which is meaningful and/or important to us (our friend walking down the road, a car coming when we turn to cross the road) and not by information which has no relevance to us (a lamppost outside your window). Knowing what information captures people's attention can tell us a lot about the particular importance of stimuli to processing.

Theories of cognitive bias in anxiety (2.3.1)

The examination of attentional bias to different stimuli classes is commonplace, within anxiety and phobia research, and a number of experimental designs have been used to examine for these attentional biases. These studies are based on the theories of Bower (1981) and Beck (1976), who suggested semantic network, and schema theories relating to attentional and processing biases (respectively). Both of Beck and Bower's theories propose that due to the development of excessive and unproductive cognitions related to negative affective states (particularly anxiety) which will result in attention being allocated to threat to a greater extent than in the general population.

Development of the Visual Dot Probe technique: research with words (2.3.2)

Early research testing this hypothesis was conducted using an emotional variant on the colour naming Stroop task (Stroop, 1935). However instead of colour words interfering with participants ability to name the colour of the ink, emotional words were presented to participants. Ray (1979) found that students in the weeks before their final exams were slower to name the ink colours of exam words than body part words. Mathews and Macleod (1985) also indicated that individuals with diagnoses of general anxiety disorder were slower to name the colour of threat words than healthy controls.

The above studies have indicated that the emotional variant on the Stroop task is successful in supporting the proposition that threat stimuli would draw a greater amount of attention that other emotional words however, there are a number of major problems with the emotional Stroop task. Firstly given that attention is already allocated to the location in which the stimuli are presented it is not a pure measure of attentional orienting and reflects instead the global or local nature of attention. MacLeod, Mathews and Tata (1986) also point out that different attentional allocation because of the emotional content is not the only explanation for the findings of longer latencies for threat stimuli. It is also possible that the presence of the threat stimuli heightens the anxious individuals' level of distress and thus impairs performance, therefore the Stroop effect may be caused by delayed responding when presented threat rather than attentional capture (i.e. people are 'frozen by fear'). Additionally the Stroop task usually requires the stimuli to remain present on the screen until the participant makes and response thus making it harder to look at the time course of these proposed biases occur (e.g. early in the process or at a later more conscious level).

Due to the criticisms of the emotional Stroop task as a measure of attentional bias in anxiety disorders Macleod, Mathews and Tata (1986) developed an improved technique to investigate this phenomenon using groups of socially anxious, physically anxious (i.e. those who are anxious about physical or medical harm) and non anxious controls. The technique they designed was the Visual Dot Probe; this involves the simultaneous presentation of two words on a computer screen (one in the upper half and one in the lower half). One threat word (e.g. fatal or lonely) and one neutral word (e.g. shirt). After the offset of the stimuli (500ms in Macleod Mathews & Tata's study), a dot appears at the location either of the threat stimuli (congruent presentation) or of the control stimuli (incongruent presentation). Probes were presented on 96 of the 288 total stimuli pair presentations, and participants were asked to indicate when they detected a probe. Attentional allocation is measured by the time needed to respond to the dot, the rationale being that the response time will be shorter if attention is already allocated to the location of the dot. Macleod, Mathews and Tata found that their anxious participants showed a significant bias towards anxiety congruent words (indicated by shorter response latencies to probes presented in the location previously occupied by threat words, than non-threat words) thus supporting their hypothesis as well as the theories of Beck and Bower.

Visual Dot Probe and the use of pictures (2.3.3)

A problem with using word stimuli in the Visual Dot Probe task is that although these have been shown to capture attention, words only provide an indirect representation of a stimulus whereas photographs provide a more direct depiction of the stimuli of interest. Ekman (1992) suggested that, especially within the field of social phobia, the faces represent a more ecologically valid stimulus and relate better to social evaluations. Mogg and Bradley (1999a) also suggested that although the word frequency is usually controlled for to ensure that the words in threat and control lists have similar occurrence in the general population, if one presumes that those with anxiety spend more time focusing on threat information then these threat words may have a higher frequency in their lives thus adding a confound to the results.

This led researchers such as Bradley et al. (1998) to re-examine the anxiety bias effects observed using the standard word based Visual Dot Probe task using a modified pictorial version. Bradley et al. presented high and low anxious participants with happy-neutral and angry-neutral face pairs presented on the left and right of a central fixation point for either 500 or 1250 ms, before asking them to indicate which of two potential visual probes had been presented. The findings of this study indicate that those in the high anxiety group showed a significant bias towards the angry faces and away from the happy ones, no bias was seen in the low anxious group. This study established that pictorial stimuli can be successfully used to provide, possibly more ecologically valid, evidence of attentional biases for threat in anxious members of the general population.

Visual Dot Probe and response methods (2.3.4)

In a variation of Bradley et al.'s (1998) study, Mogg and Bradley (1999a) tested whether the threat bias effect was preserved if the response task participants were asked to perform was changed. Participants were given a forced choice as to whether the probe appeared on the left or right of the screen, rather than the probe classification task (indicating which of two probes has been presented) used by Bradley et al. (1998). High anxiety participants in Mogg and Bradley's study showed the predicted attentional bias toward threat faces. Mogg and Bradley's study establishes that attentional bias measured using the Visual Dot Probe task is robust to changes in the participants' instructions about the probe response. One observable difference between the classification and location tasks was that reaction times were slower (approximately 200ms) on the classification task, indicating that this task may consume a greater amount of cognitive resources and therefore require longer processing time, and that although still reliably revealing bias effects, may introduce an element of conscious control, providing some confound to results using this response technique. However, a comparison of effect sizes reveals equal effects on both tasks suggesting that the classification task is as sensitive at the location task when exploring these effects.

Visual Dot Probe and the time course of attentional bias (2.3.5)

As stated above, one of the advantages of the Visual Dot Probe task compared to the emotional Stroop task is that the experimenter has much greater control over such factors as participants' exposure time to the stimuli. This allows for a fuller understanding of the time course of any bias effects observed (e.g. an early 'automatic' bias followed by later avoidance, or no early bias and a later conscious attentional allocation). The time course of attentional allocation of anxious individuals when presented with threatening stimuli was systematically explored by Mogg, Bradley, De Bono and Painter (1997); in this study high and low anxious members of the general population were presented with threat-neutral word pairs (e.g. stupid-shirt, or illness-tree) in a vertical presentation for 100, 500 and 1500 ms. Participants were required to respond to the location of the subsequent probe. The findings of this study were that the threat bias effect in the high anxiety group was only significant in the 100ms presentation duration with strong trends in the 500 and 1500ms conditions. This appears to be consistent with the idea that the anxiety bias observed in those with high or clinical anxiety is reflective of an initial vigilance in attention for threat, and although not significant there appears to be a subsequent disengagement from these stimuli. This study also shows that the Visual Dot Probe task can be successfully utilised to explore the different biases that may exist at different stimulus durations, and although an overall bias was observed and a trend towards a threat bias was observed at all presentation times this was only significant at the fastest presentation time.

Cooper and Langton (2006) have also performed a study examining the time course of attentional bias; however in their study they were interested in testing weather a threat bias could be observed in a non-anxious population. This tests the theory that an anxiety bias is reflective of an evolutionary response that allows people to identify potentially dangerous situations and protect themselves from potential harm (e.g. Öhman, 1993). Cooper and Langton presented participants with angry, happy, neutral and gaze averted neutral faces for 100 and 500ms in a vertical presentation, while participants completed a probe classification task. Cooper and Langton's findings support those of Mogg, Bradley, De Bono and Painter as they indicate that the attentional bias operates early in the time course of allocation. Cooper and Langton found that their participants showed a significant bias away from happy faces and a non-significant bias towards the angry faces when they were presented for 100ms. However, in the longer 500ms presentation duration attention was biased towards happy faces and away from angry ones. In addition to providing support to the idea that different emotional biases will exist at different stages of the time course of attentional allocation, this study also established that these effects can be observed in the general population without having to focus on those with particular levels of anxiety.

Sub-threshold presentations and the Visual Dot Probe (2.3.6)

Although the above literature has suggested that threatening information captures the attention of anxious individuals when they are consciously aware of it, if the schema's (Beck, 1976) or semantic networks (Bower, 1981) are sufficiently strong and not under the control of the individual then threat stimuli may also capture attention when they are presented outside of conscious awareness (i.e. when they are presented too quickly to be consciously perceived).

The presentation of visual stimuli outside of conscious awareness is usually achieved through presenting information for very short durations so that the participant is unaware of the stimulus that has been presented. In their study Mogg, Bradley and Williams (1995) presented individuals diagnosed with depression, general anxiety disorder, and non-effected controls depression relevant-neutral word pairs, anxiety relevant-neutral word pairs and positive-neutral word pairs in the top and bottom halves of a computer screen. Half the word pairs were presented to participants for a supra-threshold duration (500ms) with the other half being presented for a sub-threshold duration of 14ms followed by a backwards pattern mask of randomly generated letters for 14ms. Participants were then required to perform a probe location task. In this study both clinical groups showed a significant bias for the negative words, this was found at both the sub and supra-threshold presentation durations. This study established that negative visual stimuli presented below the conscious threshold can capture attention in individuals with affective disorders.

Mogg and Bradley (1999b) further examined the preconscious attentional capture of threat information, however in this study angry faces were used. High and low anxious members of the general population were presented, on the left and right of the screen, with angry-neutral and happy-neutral face pairs for 14ms followed by a 14ms backwards pattern mask. Participants' were then asked to complete a probe location task. Participants showed a significant bias towards angry faces however the bias towards happy faces proved to be non-significant. These effects did not seem to be influenced by whether participants' had high or low anxiety. When this study was repeated using a probe classification task instead of a probe location task. As well as an overall threat bias being found with this response technique, this effect was also observed to differ between those with high and low anxiety, with this effect preserving in the high anxiety group but not in the low anxiety group. This study indicates that angry faces can capture attention when presented below the level of conscious awareness and that under some circumstances this applies to both high and low anxious participants. These findings were verified using the same design but with a population of socially anxious participants who showed a threat bias while controls did not (Mogg & Bradley, 2002).

The Visual Dot Probe and a simplification of the task (2.3.7)

These effects have also been explored using younger populations. Dalgleish et al. (2003) reported a study that used a number of cognitive biasing techniques to try to differentiate between a group of adolescents presenting with General Anxiety Disorder and Post Traumatic Stress Disorder. Participants completed a vertically presented version of a Visual Dot Probe task, where participants were presented with threat-neutral, and depression-neutral (e.g. sad-cat) word pairs for 1500ms. On test trials a dot replaced one of the words however on 100 of 196 trials no probe was presented, participants were simply asked to respond to the presence of the dot. This procedure makes the task easier as well as possibly reflecting a purer measure of attentional allocation, as no decision (i.e. location or classification) about the probe needs to be made. In this study the anxious participants showed a specific bias towards anxiety relevant stimuli, but not the depression specific stimuli. The PTSD participants however showed a bias away from depression relevant stimuli, indicating that these two disorders seem to reflect a very different cognitive aetiology. This study also indicates that the Visual Dot Probe can, when modified, be successfully used with younger participants and suggests a different response mode which can be used.

The Visual Dot Probe: examining attentional sub-components (2.3.8)

While the above literature on anxiety has interpreted the threat bias effect as a hyper vigilance for threat stimuli, recent research has suggested that some of these effects may also be explained by a difficulty disengaging from the threat stimuli (Koster, Crombez, Verschuere, & Houwer, 2004). This is based on Posner et al.'s (1984) suggestion that spatial attention has 3 operative components; disengaging from the original location, moving to the new location (which would include vigilance), and engagement with the new location. This is an important issue for the study of social vigilance in autism as disengagement of attention is a problem which has frequently been suggested to be prevalent in autism (e.g. Landry & Bryson, 2004; Casey, Gordon, Mannheim, & Rumsey, 1993; Townsend, Courchesne, & Egaas, 1996).

In addition to examining for a congruency effect Koster et al. also compared the RT's for trials including 1 threat and 1 neutral stimulus and trials including two neutral stimuli. This allowed for an examination of whether the congruency effect is best explained by vigilance for threat (which would show the trials including a threat stimulus to be faster) or a difficulty disengaging from threat (which would be shown if the trails including a threat stimuli were slower). For the current study this would allow for an understanding if attention is preferentially oriented towards social information or is preferentially held by social stimuli. The findings of Koster et al. have been supported by Cooper and Langton (2006; reviewed above), who found that their attentional bias effects were best explained by difficulty disengaging from the anger stimuli as opposed to vigilance.

Visual Dot Probe as a measure of attentional bias not related to anxiety (2.3.9)

The Visual Dot Probe task has also been used to examine for attentional biases in other motivation or drive states. Mogg, Bradley, Hyare and Lee (1998) examined the attentional allocation for food words and non-food words in groups of participants who either had eaten normally or had not eaten between the previous nights evening meal and testing the following afternoon. Participants were presented with food-transport word pairs in a vertical presentation for 500 and 14ms (14ms presentation was masked). Participants' task was to indicate the location of a probe that replaced the images. There were no significant effects observed at the sub-threshold presentation duration, suggesting that the detection of food congruent information is not an automatic bias displayed by the attentional system. There were however significant effects in the supra threshold condition; those in the hungry condition were significantly quicker to detect probes that appeared in the same spatial location as food related words than those behind transport related words. There were no significant effects in the low hunger group. This study indicates that the Visual Dot Probe task can be successfully used to examine for attentional biases in motivational states other than the detection of threat relevant stimuli.

The Visual Dot Probe task has also been used to examine the proposition that those individuals who show signs of substance abuse problems show an attentional bias towards substance congruent stimuli. Townsend and Duka (2001) examined if different attentional biases were observed, when presented with alcohol congruent and non-alcohol related stimuli between heavy and occasional social drinkers. Analysis revealed that the heavy drinkers showed a bias towards the alcohol pictures when compared to the occasional drinkers. The above study has successfully shown that the Visual Dot Probe can be used to uncover the preferential attentional allocation to desired substances.

A review of the methodological variations in the Visual Dot Probe task (2.3.10)

It is clear that within the Visual Dot Probe task there are a number of variations in task design, which may affect the results. Below is a summary of the key variables in the studies discussed above including whether images or words were used as stimuli, the duration of presentation and orientation of stimuli.

Table 2.1: To show the methodological variations in the Visual Dot Probe design

Paper	Stimuli type	Presentation orientation	Presentation time(s)	Response method
MacLeod, Mathews and Tata (1986)	Words; Threat and non-threat	Top and Bottom	500ms	Probe detection
Bradley et al. (1998)	Pictures; happy-neutral and angry-neutral face pairs	Left and Right	500ms and 1250 ms	Probe classification
Mogg and Bradley (1999a)	Pictures; angry neutral and happy faces	Left and Right	500ms	Probe location
Mogg, Bradley, De Bono and Painter (1997)	Words; threat-neutral word pairs	Top and Bottom	100, 500 and 1500 ms	Probe location
Cooper and Langton (2006)	Pictures; angry, happy, neutral and neural with gaze averted faces	Top and Bottom	100 and 500ms	Probe classification
Mogg, Bradley and Williams (1995)	Words; depression relevant-neutral, anxiety relevant-neutral and positive-neutral word pairs	Top and Bottom	500ms and 14ms followed by a backwards pattern mask of letters for 14ms	Probe location
Mogg and Bradley (1999b)	Pictures; angry-neutral and happy-neutral face pairs	Left and Right	14ms followed by a 14ms backwards pattern mask	Probe location
Dalgleish et al. (2003) Study with Children	Words; threat-neutral, and depression-neutral relevant word pairs	Top and Bottom	1500ms	Probe detection
Mogg, Bradley, Hyare and Lee (1998)	Words; food words and non-food words	Top and Bottom	500ms and 14ms followed by a backwards pattern mask of letters for 14ms	Probe location
Townsend and Duka (2001)	Pictures and Words; alcohol congruent and non-alcohol related stimuli	Left and Right	500ms	Probe location

The above table indicates that the choice of orientation of stimuli presentation appears arbitrary as no differences in the effects appear to relate to orientation. Additionally although early research and some of the modified research examined the VDP with words more recently there has been a trend towards using images within this design to increase the ecological validity of the findings. As stated in 2.3.6 one of the benefits of the VDP is that the time course of any effects can be examined because of this a variety of presentation durations have been used to examine attentional bias. Although 500ms is the most common presentation duration used in past research using the VDP the variety of durations all measure broadly different effects. Short durations (<250ms) can be argued to measure initial exogenous attentional allocation while moderate durations (250-750ms) can be argued to measure the initial conscious preference of attention, longer presentation (>750ms) appear to measure the final location that attention will settle on. However, there are some problems with this final assumption that relate to the finding that once people have expressed an initial bias for a stimuli/location they will inhibit returning to that location (Posner and Cohen, 1984; Pratt, Spalek and Bradshaw, 1999). Finally, the importance of the different response methods needs to be highlighted. Although location and classification tasks are the most popular response methods in the literature they each have shortcomings. The location task can be passed by monitoring a single location whereas the classification task involves a degree of higher cognitive processing. For this reason combined with the relative ease of responding it is felt that responding simply to the detection of a probe is the most appropriate measure of attentional allocation.

Face-in-the-Crowd (2.4)

Although the Visual Dot Probe task has provided evidence that those with high trait or state anxiety, or those with clinical levels of anxiety have a bias for threatening information, others have theorised that a bias for threatening stimuli is an evolutionary response that allows people to identify potentially dangerous situations and protect themselves from potential harm (e.g. Öhman, 1993). One reason that those with lower levels of anxiety may not have consistently shown a bias for threat stimuli on the Visual Dot Probe task is that the stimuli on this task are secondary to the task to be performed by the participant, thus making the Visual Dot Probe a conservative test of attentional biasing (Driver et al., 1999).

FITC with Images (2.4.1)

To address the conservative nature of the Visual Dot Probe Hansen and Hansen (1988) designed the Face-in-the-Crowd task, in which the stimuli are central to the task. In this task 9 images are presented to participants' in a 3x3 matrix. On half of the trials all 9 pictures displayed faces of the same emotion on the other half one of the emotions was incongruent to the others. Faces in this study displayed happy, angry and neutral emotional expressions, and were presented until participants indicated if there was an odd-one-out or not. Hansen and Hansen found that angry faces in neutral and happy crowds were found faster and with fewer errors than neutral or happy faces in angry crowds. In addition to the odd-one-out trials Hansen and Hansen also analysed the all same trials they found that participants made more errors on all angry trials than all neutral or happy trials. There were however no differences in the amount of time spent to respond to all same trials. This seems to indicate that it is harder for people to efficiently search a crowd of angry faces than happy or neutral faces, although there are no differences in the amount of time taken to perform this task.

There was however a flaw with Experiment 1 of Hansen and Hansen's study, each of the 9 faces shown to participants was of a different person meaning that effects observed could reflect a difference in the difficulty of distinguishing the valence of emotional expressions (i.e. participants may not have found angry targets faster than happy ones not because of the biases suggested in the Visual Dot Probe but because the 8 angry faces were more disparate when acting as distracters meaning that the task took longer). To address this criticism Hansen and Hansen (Experiment 2) presented participants with similar 3x3 displays, with crowds consisting of only a single individual as apposed to multiple individuals. The participants' task in this experiment was to indicate the location of the discrepant face. Hansen and Hansen found that participants responded to discrepant angry faces quicker than happy or neutral faces. In a final experiment Hansen and Hansen (1988, Experiment 3) attempted to test if the anger bias effect they observed could be explained as an automatic parallel processing (termed pop-out) or if this effect reflects a conscious serial search. Hansen and Hansen asked participants to indicate whether a display contained a discrepant image, using display sizes of 9 and 4 images. Treisman and Souther (1985) suggested that in a visual search tasks if the increase in search time necessary to detect a discrepant image does not increase as a function of the number of distracters then the effect can be seen to reflect a preattentive pop-out. Hansen and Hansen replicated the anger bias effects seen above; more importantly they found that although finding happy faces in angry crowds took significantly longer on 9 image trials than 4 image trials. There was no significant difference in the time to find angry faces in happy crowds between the 9 and 4 image trials, thus indicating a pre-attentive effect. This study indicated that a visual search paradigm can be used to uncover a bias towards angry faces in the general population. This bias would reflect an evolutionary beneficial mechanism Ohman (1993) by making people faster to identify potential threat in their environment. This suggests that the Face-in-the-Crowd task may be more sensitive to anger bias effects than the Visual Dot Probe. Additionally it is possible that the effects observed with this task are a result of a different mechanism to those in the Visual Dot Probe. In an attempt to examine the 'pop-out' effect of angry faces from neutral and happy crowds Hampton, Purcell, Hansen and Hansen (1989) replicated Hansen and Hansen's study taking account in more detail the issue of attentional 'pop-out'. They replicated the findings of Hansen and Hansen of an anger bias but were unable to replicate the 'pop-out' finding.

The 'pop-out' effect for angry faces was also criticised by Purcell, Stewart and Skov (1996). They argued that when looking at the images used by Hansen and Hansen, the technique of 'thresholding' (making all colour above a certain luminance white and all colours below that luminance black) had made certain low level shading differences highly prominent which could explain the findings of this study. Purcell, Stewart and Skov replicated Hansen and Hansen's study presenting participants with the same images used by Hansen and Hansen. However instead of using a thresholding technique they presented them in 256 grey level scale. Although the anger bias effect preserved in this study, the pop out effect was categorically contradicted with strong evidence of longer search times to nine image displays than to four image displays. In a direct comparison with Hansen and Hansen's study Purcell, Stewart and Skov tested these effects using thresholding with both the confounding areas (darker patch under the chin of the models in the angry condition) included and removed. They found that effects were much stronger when including this confound than when a similar process was used but these confounds had been removed. Based on the findings of Hampton, Purcell, Hansen and Hansen (1989) and Purcell, Stewart and Skov (1996) it seems that there is a bias towards detecting threat stimuli faster than other emotions, however this is not indicative of preattentive 'pop-out'.

It is because of the concerns about the lack of controllability over the stimuli (such at those raised by Purcell, Stewart and Skov, 1996) that most researchers have elected to use schematic stimuli due to their excellent level of experimental control (e.g. Öhman, et al., 2001). Horstmann and Bauland (2006) have however concluded that this may be an overreaction, and that the compromise in ecological validity may not justify the additional control. Horstmann and Bauland, used real images of faces that had been digitally altered so that most pixels internal to the face excepting the eyes, nose and mouth were changed to white to eliminate shadowing, faces were also presented in a standard external frame (the external outline from the happy face). Displays of 1, 6 and 12 images were used and participants were asked to indicate if a predetermined angry or happy target was present in the display. Horstmann and Bauland found that although angry faces were found faster in happy crowds than happy faces in angry crowds that the search slope was too great for search to be considered pre-attentive. When Horstmann and Bauland replicated their experiment but left faces in their original frames, search slopes for angry faces were revealed to be sufficiently shallow as to be consistent with pop-out. This suggests that search for angry faces is more efficient than search for happy faces however for pop-out to be achieved some emotional or perceptual information contained within the external part of the face may be necessary.

The ability for the Face-in-the-Crowd task to be used to differentiate between clinical groups in terms of extent of bias has been explored by Gilboa-Schechtman, Foa, and Amir (1999). In this study groups of participants with social anxiety disorder and non-anxious controls, were presented with displays of 12 faces of differing emotional expressions (angry, happy, neutral, and disgust). All emotional expressions were used as targets, while all bar the disgust expression were used as crowds. Participants were asked to indicate if all faces in the display had the same emotional expression or if there was an odd-one-out. Gilboa-Schechtman et al. found that although angry targets were found quicker in neutral crowds than neutral targets in angry crowds for both groups, this effect was stronger for the anxious group. There were no differences between response times to happy targets in neutral crowds and neutral targets in happy crowds. Additionally angry targets were found quicker in neutral crowds than happy targets for all participants and that this effect was enhanced in the socially anxious group. They also found that angry faces were found faster than neutral faces in happy crowds; however, the groups did not differ in search times for angry faces in happy crowds. When analysing the all same trials it was found that response times were longer for all angry faces than the other expressions only in the group with a diagnosis of social anxiety disorder, indicating that this group took longer to disengage from a display of all angry faces.

The findings of Gilboa-Schechtman, Foa and Amir provide further evidence that an attentional bias for threat faces exists in the general population. These findings also suggest that different magnitudes of effect can be used to differentiate groups of individuals with specific affective diagnoses. Additionally the wealth of analytical techniques which can be used with the data from the Face-in-the-Crowd task allow for a number of cognitive mechanisms to be explored which might reflect important components of different conditions (i.e. the same bias may be explained by a vigilance in one clinical group and a difficulty in disengagement in another). The above findings seem to suggest that both anxious and non-anxious participants show a bias towards attending to threat stimuli, consistent with the idea of an evolutionary vigilance for this class of stimuli, reflected in the faster detection of angry targets in non-angry crowds than non-angry targets in different non-angry crowds. However when looking at the same trials it is clear that only the anxious group showed longer latencies to all angry trials, this is consistent with ideas that attentional bias in anxiety is reflective of over attention to anxiety congruent stimuli resulting in maintenance of their anxious state.

In addition to threat faces Hershler and Hochstein (2005 Experiment 2) have examined the more fundamental question of whether faces capture attention preferentially compared to non-social stimuli. Participants were presented with displays of varying sizes in 16, 36 or 64 different image displays of faces, cars and houses. Each stimuli class could comprise the target while the other two would make up the distracters. Participants completed a blocked design task to identify the presence or absence of a predetermined target stimulus. The findings from this study indicated that faces were found significantly faster than cars or houses; an examination of the search slope indicates that finding faces took 3ms longer per additional distracter item that is clearly below the 6ms per additional item suggested by Treisman and Souther (1985) to reflect attentional pop-out. This study clearly suggests that faces have a special place in the capture of visual attention. There are however a number of potential problems with this study. Although the distracter stimuli were made up of images from the same class, their identity was not homogenous and were all taken from different angles and with varying colour contrasts. This makes it possible that the effects are not a result of the face having a special role in visual attention and that there was some other low level perceptual artefact that caused the effects. Also there is some question about whether predetermining targets could mean that the observed effects are caused by a superior priming of certain stimuli, and not a result of a spontaneous attentional bias.

Calculating detection thresholds (2.5)

Although many studies had claimed to have been conducted using presentation times outside of conscious awareness, it was not until Cheesman and Merikle's (1986) systematic examination of sub-threshold presentations that any generally accepted durations were determined. This study attempted to examine the concepts of objective and subjective thresholds and place sub-threshold processing between these two bounds. The important distinction between these two concepts was made by Cheeseman and Merikle (1986; p344), who argued that '*a subjective threshold is the level of discriminative responding at which observers claim not to be able to detect or recognize information at a better than chance level of performance, whereas an objective threshold is the level of discriminative responding corresponding to chance performance*'.

Cheeseman and Merikle determine subjective thresholds using the standard technique in the literature, which involved simply asking participants to report when they could no longer detect the stimulus being presented to them. Cheeseman and Merikle proceeded to establish that colour primes presented below subjectively reported thresholds provided both facilitatory and inhibitory effects on a Stroop task. In a second task objective thresholds were determined by giving participants a 4 forced choice task to determine which of four colour words had been presented to them. The range of detection durations for the objective task was slightly shorter than that for the subjective reports (16.7-66.7ms Vs 16.7-87.3ms). It was found by Cheeseman and Merikle that stimuli presented for sub threshold durations also produces the same effects on the Stroop priming task as those reported in the subjective thresholds.

Kemp-Wheeler and Hill (1988) refined the design of Cheeseman and Merikle to account for issues of colour response bias and to examine these effects using a different task (semantic priming). Kemp-Wheeler and Hill calculated detection thresholds by presenting participants with blocks of 10 trials comprising 5 stimuli and 5 blank cards presented in a random order. After the presentation of a backwards pattern mask participants were asked to indicate if a stimulus had been presented on the previous card or not. Stimulus cards were initially presented for 80ms and then presentation durations were reduced in increments of 10ms if correct responses were given on 6 or more trials in a block of 10. When an appropriate level had been reached (i.e. performance below 6/10) a 40 trial block was initiated. If participants' performance remained within the 95% confidence interval of chance (35%-65%) then detection level was assumed to have been reached. Kemp-Wheeler and Hill used a semantic priming task to see if information presented at the threshold durations calculated could influence processing of stimuli. In this task after a warning 'bleep' a prime word was presented for 10% shorter time than had been previously determined in the above procedure, this was followed by a 500ms backwards pattern mask. Participants were then presented with target a word. Participants had to determine if the word was a real word or a non-word. Target words could be either semantically related to the prime, semantically unrelated or non-words. Detection thresholds using this task had a mean of 56.7ms. It was found that in the lexical decision task semantically related target words were identified as real words significantly faster than semantically unrelated primes. In subsequent replications of this task the same findings were obtained on the semantic priming task however the detection thresholds were found to show a greater variation in average times (41ms, Experiment 2; 26.67, Experiment 3).

This is important as in this thesis individual detection thresholds will be calculated for each participant. Individual detection thresholds will be calculated in this study for two reasons; firstly the above research determining standard thresholds have used word stimuli, whereas in this thesis images will be used. This means we cannot be sure that the durations for these two types of stimulus will be the same. Secondly the above research has calculated threshold durations almost exclusively on students. The sample in this study is drawn from a broader age and IQ range, and includes a clinical population of individuals with autistic spectrum disorders. It is reasonable to assume that with this range of individual participant variation that the standardised thresholds might not apply.

Psychometric measures (2.6)

In addition to experimental methods, the present series of studies will also use a number of psychometric measures. These will be used to match or 'diagnose' participants as well as to examine the role of these variables in the attentional biases shown by participants.

Diagnosing autism (2.6.1)

The diagnostic criteria for autism have already been discussed at the beginning of the previous chapter (section 1.1) however due to autism being diagnosed based on behavioural criteria the range of techniques used requires consideration. Before the development of standardised diagnostic criteria for autism were included in DSM III (APA, 1980) the techniques for diagnosing autism varied greatly (e.g. Rutter, 1966; 1978). Since the standardisation of diagnostic criteria there has been a move towards more standardised, replicable and reliable diagnostic tools. The various interviews, observations, and psychometric measures used are designed not to supplant the diagnostic criteria or completely replace the old techniques but rather to develop and homogenise them.

There now exist two 'gold standard' (Filipek et al., 2000) methods for diagnosing ASDs; The Autism Diagnostic Interview-Revised (ADI-R; Lord, Rutter, and Le Couteur, 1994) and the Autism Diagnostic Observation Schedule (ADOS-G; Lord et al. 2000). The ADI-R is a semi-structured, standardised, clinician/researcher lead interview conducted with the parents or carers of individuals with ASDs. The interview asks parent/carers of those suspected of having ASDs about the behaviour displayed by the individual in everyday life. The domains measured on the ADI-R directly relate to DSM-IV diagnostic criteria. Lord et al. (1994) were able to demonstrate excellent reliability and validity of the ADI-R. Although the ADI-R represents a highly valid and reliable measure of autism, for this thesis it was unfortunately not possible to utilise this measure. Due to the nature of the ADI-R being a carer based measure that involves asking many questions about early childhood it would have proved difficult to gain access to these data due to the participants who will be participating in the current research. As high functioning adults were recruited in the current research, it was rarely possible to meet with their parent. Additionally the reliability of asking parents about the behaviour of their child as many as 40 years ago has to be questioned. The ADI-R is also not necessarily pragmatically viable for the current research; as Lord et al. point out a well practiced and experienced person can administer the ADI-R in around 1 ½ hours. This would be a large burden upon the families of those participating in the research to confirm an already known diagnosis, and may be prohibitive to participation.

This leads into the second of the two 'gold standards', the ADOS-G (Lord et al. 2000). The ADOS-G is a semi structured observation assessment of the social, and communicative interactions, as well as the imaginative use of objects of individuals suspected of having ASD. The observation involves setting up planned interactions in which any abnormal behaviour would be suspected to be observed (if it is present).

Inter-rater reliability has been shown to be very good on the ADOS-G (all items exceeding 80%). Based on the ADOS-G diagnosis was found to agree with previous diagnosis in 90% of cases on module 4 (for verbal high functioning adults). The ADOS-G was also found to have good test retest reliability. Again, this evidence suggests that the ADOS-G is a highly reliable and valid method of determining autistic diagnosis. However obtaining a place on ADOS-G training course is difficult and the administration of the ADOS can be a lengthy process, for this reason it seemed impractical to use this method to confirm an already existing diagnosis.

As the two 'gold standards' are either methodologically or pragmatically unavailable in the current research it is necessary to consider other methods of identifying individuals with autism. Although a number of psychometric measures have been developed to identify autism these have typically been aimed at child populations (e.g. the M-CHAT; Robins, Fein, Barton & Green, 2001; the Social Communication Questionnaire; Berument, Rutter & Lord, 1999). At present there is only one questionnaire designed to identify individuals with autism in an adult population, who have intellectual functioning in the normal range, allowing for self-report. The Autism Quotient (AQ; Baron-Cohen, Wheelwright, Skinner, Martin & Clubley, 2001) is a brief 50 item questionnaire split into ten questions on each of the three areas on which autism is diagnosed (Social, Communication, and Imagination) as well as ten questions on attentional switching and ten on attention to detail to address the deficits shown within these domains (e.g. Mann & Walker, 2003; Pierce, Glad, & Schriebman, 1997). On approximately half of the items on the AQ agreeing with an item reflects an autistic trait on the other half disagreeing with it would indicate an autistic trait.

In an analysis a group of 58 participants with high functioning autism and Asperger's Syndrome had a higher mean score than a control group of 174 individuals taken from the general population. A group of parents were also asked to score their child on a modified version of the AQ; parents scored their child an average of 2.8 points higher than the child showing a good agreement in scores. Baron Cohen et al. (2001) suggested that a cut-off score of 32 was most appropriate as this successfully identified 79.3% participants with ASDs while only 2% of controls scored above this threshold.

Woodbury-Smith, Robinson, Wheelwright and Baron-Cohen (2005) evaluated the effectiveness of the AQ as a screener questionnaire. This study involved administering the AQ to 100 patients referred to a clinic specialising in diagnosis of ASDs. All patients were then seen for further diagnosis using detailed clinical interviews. Again the AQ was successful in differentiating those who did and did not receive a diagnosis of ASD. Woodbury-Smith et al. suggested that a cut-off of 26 correctly identified 83% of patients.

There are unfortunately a number of problems associated with the AQ; firstly the introspective abilities of individuals with ASDs (even very high functioning individuals) can be called into question; Baron-Cohen et al. however claim to have accounted for this by validating scores against parents reports on their child's abilities. Secondly the attentional components of the AQ are a cause for concern. These are not diagnostic criteria for any ASD and therefore their inclusion of them in a screening measure has to be considered with care. Additionally an examination of the mean scores for each of the sub domains reveal that the scores of the control groups score higher for the two attentional domains than the three domains related to the diagnostic criteria, while the ASD group actually score lower on these two domains. Further concern about some of the items within the attentional domains is raised by the reporting that on two of the items on the attention to detail sub domain the control group actually outscore the ASD group, this raises concerns about the ability of the AQ to discriminate between those with and without ASD given these items has to be questioned.

Although there are concerns about the validity of the AQ as a measure of ASD it remains the only brief measure of these disorders available for use in a high functioning adult population, given that in this study it will only be used in association with a previous diagnosis by a trained clinician it is deemed adequate.

Measuring intelligence (2.6.2)

When conducting research on groups with developmental disabilities it is important to ensure that the groups are rigorously matched and that any differences observed can be attributed to this disorder and not other differences. One of the most important factors to control for when working with an ASD population is intelligence. The dispute over what intelligence is and how it should be measured already occupies a number of volumes; the following paragraphs will detail a review of the short-forms of the Wechsler Adult Intelligence Scale III (WAIS-III; Wechsler, 1997a). The Wechsler intelligence scales have long been considered the standard measures of intellectual functioning in both clinical and research settings.

As Christensen, Girad and Bagby (2007) point out the WAIS-III improves upon its predecessors by allowing for a broader number of abilities to be measured, in addition to full scale IQ, and verbal and performance IQ the WAIS-III allows for the examination of verbal comprehension, perceptual organisation, working memory and processing speed. To allow for the examination of this broad number of abilities the WAIS-III is also a very long measure because of this it has been suggested to be both clinically and pragmatically hampered (Piotrowski, 1999; Ryan, Lopez & Werth, 1998).

Because of the time consuming nature of administering the full versions of the Wechsler scales a number of means have been used to try to shorten the duration of these tests. The first short form of the Wechsler scales was developed by Rabin (1943) who selected three of the ten original Wechsler-Bellevue (Wechsler, 1939) subscales all from the verbal sub-scale. Rabin correlated a group of nurses' scores on these subscales with their overall score and found this was good. Rabin proceeded to multiply the scaled scores by 10/3 to obtain an equivalent full scale scaled score which allowed him to use the Wechsler tables to identify IQ scores (A process know as Prorating).

Others have suggested that by using only a selected number of subscales from a test the breadth of abilities that can be examined are reduced. Wolfson and Bachelis (1960) have suggested that using only a selected number of items from each subscale can be used to achieve a shorter test while still allowing a wider number cognitive processes to be considered. Using this method scores would be multiplied to give a score the equivalent of what would expected if all the items had been administered (i.e. if one in 3 items were presented then raw scores would be multiplied by 3).

The use of selected items has been criticised on a number of grounds; Zytowski and Hudsen (1965) suggested that due to the lack of internal consistency on each subscale results in a highly inaccurate profile configuration. Additionally Meikle (1968) and Luszki, Schultz, Laywell and Dawes (1970) indicated that difference between two subtest scores had a significantly higher standard error than the original scale.

Doppelt (1956) suggested an alternative to Prorating as a method of transferring scores on selected subscales to full IQ scores. Doppelt used regression equations to predict full scale scores based on the sum of scaled scores for his short form. Both the Prorating and regression equation approaches have received criticism from Tellegen and Briggs (1967) suggesting that Prorating assumes that individuals would have on the absent subscales scored an average equal to the average of the present subscales. This approach tends to artificially create scores that are more extreme than the true values by increasing the standard deviation around the mean. Techniques involving the calculation of regression equations are also flawed in the opinion of Tellegen and Briggs resulting in a reduced standard deviation that causes a lack of variation about the mean and over-estimates of the IQ of those below the mean and underestimation of the IQ of those who score above.

Tellegen and Briggs designed a deviation formula based around the same formula used by Wechsler, reasoning that this will give the closest estimate of the individuals' true IQ without artificially inflating or deflating scores as a result of simple multiplication. Although Silverstein (1990) correctly asserts that scores obtained using this formula should not be considered to be IQ scores but standardised scores of a particular short form scores using the deviation quotient (DQ; the formula suggested by Tellegen & Briggs) relate so closely to IQ scores that they are frequently considered the same. The DQ formula can be summarised as:

$$DQ= (15/S_c) * (X_c - \bar{X}_c) +100$$

Where $S_c = S_s \sqrt{n+2\sum r_{jk}}$ (The standard deviation of the composite score)

X_c = the sum of scaled scores in the short form

$\bar{X}_c$ = the normative mean (equal to the number of subtests multiplied by 10 [the mean scaled score for any Wechsler subscale])

S_s = the subtest standard deviation which in the case of Wechsler tests has a uniform value of 3.

n = the number of subtests

$\sum r_{jk}$ = the sum of the correlations between the selected component subscales.

The above paragraphs have given a brief review of literature examining the most appropriate methods for converting short forms of the Wechsler intelligence tests into IQ scores however the issue of which subscales are the most appropriate to select has yet to be addressed. When thinking about which tests to select there are more issues than just the psychometric properties that need to be considered. Kaufman (1972) argued that it is important that any short form draws upon each of the component areas that make up general IQ, while achieving the original goal of creating an efficient, brief (both in terms of administration and scoring time) short form (Kaufman et al., 1996). The importance of achieving the goal of reducing the administration time can first be addressed by thinking about how many scales to include. Spreen and Strauss (1998) indicated that at least four subscales tend to result in a greater predictive ability, but suggest that as little as a two subscale short form may provide a rough estimate.

Minshew, Turner and Goldstein (2005) systematically examined the use of short forms for individuals with ASDs. It is particularly important to consider the specific predictive validity of short forms when working with groups of individuals who have uneven intellectual profiles, such as individuals with ASDs (Siegel et al., 1996). In Minshew et al.'s study only short forms with between 2 and 5 subscales were considered. This was to ensure sufficient validity in the scales while also resulting in an adequate reduction in administration time. An examination of the regression analyses revealed that most of the short forms examined provided a good estimate of full scale IQ. In the adult ASD group the greatest predictive ability was provided by the WASI subscales (vocabulary, block design, similarities and matrix reasoning; Wechsler, 1999); this also provided a good predictive ability in the control condition explaining 89% and 81% of the variance respectively.

IQ estimates will therefore be made in this thesis based on the Wechsler Abbreviated Scale for Intelligence (WASI) subscales of the Wechsler Adult Intelligence Scale-III (WAIS-III). Age appropriate scaled scores will be transferred into IQ estimates based on the DQ formula proposed by Tellegen and Briggs (1967). This formula can now be simplified to:

$$DQ = 1.51 * (X_c - 40) + 100$$

Where X_c = the sum of scaled scores in the short form.

In addition to the importance of having a valid approximation of full scale IQ it is also important that this estimate can be considered reliable. Tellegen and Briggs (1967) suggest that this can be ascertained by examining the reliability coefficients in the Wechsler manuals and entering them into the following formula:

$$r_{cc} = (\sum r_{jj} + 2\sum r_{jk}) / (n + 2\sum r_{jk})$$

Where: $\sum r_{jj}$ = the sum of the reliability coefficients for the selected component subscales.

$\sum r_{jk}$ = the sum of the correlations between the selected component subscales.

n = the number of subtests

By entering in the data for the reliability of the Wechsler subscales the reliability of this estimate is 0.96.

Anxiety in ASD (2.6.3)

Kanner (1943) in his original paper on autism considered that the obsessions and routines observed in children with autism were potentially driven by anxiety, noting that 'the child's behaviour is governed by an anxiously obsessive-desire for the maintenance of sameness' (1943, pp245). Anxiety is however, an area of functioning that has generally been poorly considered in ASD and has been completely overlooked in terms of relations to cognitive functioning. This has been supported by Groden et al. (1994), who observed that even minor changes in the environment can result in distress in children with ASD. Howlin (1998) has suggested that stereotypical behaviours echolalia, twirling, rocking, flicking and hand flapping increase during times of distress and Thomas et al. (1998) has suggested that even more complex behaviours, such as repetitive questioning, increase at stressful times. Additionally disrupting these routines may increase levels of anxiety (Howlin 1997; 1998).

The role of anxiety in ASD goes beyond repetitive behaviours; Attwood (1998) has proposed that frequent peer rejection and social difficulties may lead to anxiety, particularly about future social engagement. Tantam (2000) has further suggested that factors such as: increased rate of negative life events, relationship difficulties, awareness of social difficulties, and victimisation may lead to increased levels of affective disorders.

It has been noted by a number of clinicians that individuals with ASDs have higher levels of anxiety, particularly in adolescence (Attwood, 1998; Szatmari, 1991; Tantam, 1991; 2000; Wing 1996). It has also been reported that individuals with ASD have elevated levels of clinically diagnosable anxiety than in the general population, in a study by Tantam (1991) 30 out of 85 participants with Asperger syndrome met clinical diagnosis for anxiety disorders, with Rumsey et al. (1985) finding 7 of 14 Asperger syndrome men suffering with chronic generalised anxiety and Szatmari et al. (1991) indicating that four of 16 participants met criteria for overanxious disorder. Kim et al. (2000) have also suggested based on clinical reports (on the OCHS-R; Ontario Child Health Study-Revised) that children with PDD have significantly more clinically relevant scores than controls on anxiety and depression sub-scales.

Although these observations have been frequently made, limited research has been conducted to examine anxiety in ASD in an experimentally control way with clear measures of anxious symptoms. Bellini (2004) examined the anxiety levels of 41 adolescents and found that participants with ASDs were shown to have significantly elevated social anxiety scores for both humiliation/fears and performance fears. Bellini (2006) further examined social anxiety in adolescents with ASDs to try to examine which variables predict social anxiety in ASD. Bellini (2006) found that social anxiety (measured using the Social Anxiety Scale for Adolescents; La-Greca, 1999) was predicted by levels of empathy, physical symptoms and assertion.

Gilliott, Furniss and Walter (2001) examined general and social anxiety in children with autism compared to children with specific language difficulty and TD controls on the Spence Children's Anxiety Scale (SCAS; Spence, 1997) and the Spence Social Worries Questionnaire (SWQ; Spence, 1995). The autism group was found to report higher levels of general anxiety than both control groups. The autism groups mean SCAS score was not as high as in norms for clinically anxious children; however seven of the autism group, out of 15, scored higher than the clinically anxious mean. In support of Bellini (2004, 2006), Gilliott, Furniss and Walter also found that the autism group scored higher than both control groups on social anxiety.

Farrugia and Hudson (2006) also examined anxiety levels in adolescents with ASD, comparing them to a typical control group and a group of adolescents with anxiety disorders. Individuals with ASD and anxiety disorders scored significantly higher than the control group on the panic, social phobia, separation anxiety, general anxiety and obsessive compulsiveness subscales of the Spence Children's Anxiety Scale (Spence, 1998). Although the ASD group scored higher than the anxiety group on all but the general anxiety subscale, these were not significant. This suggests that on average high functioning adolescents with ASD have anxiety at least of a par with adolescent with anxiety disorders.

The only study to examine anxiety in adults with ASD is that of Gilliott and Standen (2007). Thirty-four adults with autism and associated intellectual delay scored higher on overall anxiety, panic, separation anxiety, obsessive compulsiveness, and generalised anxiety disorder, than intellectually matched controls on the Spence Children's Anxiety Scale-parent version (Spence, 1999). This suggests that increased anxiety in ASD may persist into adulthood. There is however a problem with this conclusion given the intellectual delay of the participants in Gilliott and Standen's study, meaning that this finding does not truly map onto the participants in this thesis. Additionally the use of a childhood scale may not be the most appropriate measure of anxiety in low functioning adults with ASD. Although their intellectual functioning may be lower this is not to say that they are like children and the causes and manifestations of anxiety in this population may be very different to those measured using these scales.

Given that the main scales that have been used to measure anxiety in individuals with ASD have been aimed at children it is not deemed appropriate to use these in this thesis. At present there are no measures of anxiety designed for use with high functioning adults with ASDs (Ghaziuddin, 2005). This is important as the causes and manifestations of anxiety may be different in individuals with ASD to the typical population, this is of particular relevance given what is known about the resistance to change in ASD (Howlin 1997; 1998). The only measure that has been developed was by Groden et at (2001). Groden et al.'s measure was however aimed at low functioning individuals with ASD and was therefore not deemed appropriate for the current research.

As there was no available measure designed for use with ASD the most common anxiety measures used with the Visual Dot Probe were selected. To measure state anxiety the State Trait Anxiety Inventory (STAI; Spielberger, 1983) was selected. The STAI can be used to measure a person's level of trait anxiety (general level of anxiety) or their state anxiety (level of anxiety at a set time) and is a twenty item self report measure of anxiety. The state component of the STAI has been shown to have good internal reliability (alpha between .84 and .95; Cronbach, 1951) although test retest reliability is low (.27-.62; Spielberger, 1983) this is to be expected on a state measure. The STAI has been used in the Visual Dot Probe task by (Bradley et al., 1998; Ioannou, Mogg & Bradley, 2004).

In addition to state anxiety many of the studies of anxiety reviewed above have suggested that social anxiety is especially high in ASD (e.g. Bellini, 2004; 2006). To measure social anxiety the Fear of Negative Evaluation scale (FNES) and Social Avoidance and Distress (SADS; Watson & Friend, 1969) were selected. The FNES has been shown to be reliable with a mean bi-serial correlation of each item to the scale of .72 and a test-retest reliability of between .78 and .94 (Watson & Friend, 1969). The SADS has been shown to be reliable with a mean bi-serial correlation of each item to the scale of .77 and a test-retest reliability of between .68 and .79 (Watson & Friend, 1969). The SADS and FNES have been used to predict attentional bias in experiments using the Visual Dot Probe task by Bradley et al. (1998).

Methodological conclusions (2.6.5)

Based on the above review it would appear that both the Visual Dot Probe and Face-in-the-Crowd tasks are reliable tasks for measuring attentional bias. Both of these tasks appear to be reliable when minor changes in design are made. For the duration of the present thesis in the Visual Dot Probe task both a sub-threshold and supra-threshold presentation duration will be used to measure attentional bias outside of conscious control. Sub-threshold durations will be individually calculated for each participant based on the research of Cheesman and Merikle (1986) and Kemp-Wheeler and Hill (1988) whereas a standard 200ms duration will be used for supra-threshold presentation. The Face-in-the-Crowd task will be used to measure attentional bias under conscious control.

Photographic stimuli will be used throughout this thesis as opposed to word or schematic stimuli. To keep the task as simple as possible participants will be asked to make simple presence absence decisions both about the dot probe in the Visual Dot Probe task and about if there is an odd-one-out in the Face-in-the-Crowd.

Before completing the cognitive tasks participants will be screened using the WASI subscales of the WAIS to asses their IQ and the AQ to examine the severity of their autistic symptomology. In addition to using these for screening purposes, they will be combined with scores on the STAI, FNES and SADS to predict attentional bias.

Chapter 3

Attentional bias for faces compared to non-face stimuli: Visual Dot Probe.

The following chapter re-examines previous literature on social attention in ASD before presenting the application of the Visual Dot Probe task to measure the capture of attention by faces in individuals with and without ASD. The most appropriate design of the Visual Dot Probe for the present population and research question is then considered. Participants were presented with two images (in the top and bottom half of a computer display) for either 200ms or an individually calculated sub-threshold duration. Images were faces (social targets) and houses or cars (non-social distracters). On some displays, this was followed by the presentation of a dot in the same spatial location as one of the previously displayed images. It was the participants' task to respond to the presence or absence of the dot by a forced choice button press. Response times were used as an indicator of attentional allocation, assuming faster reaction times to a dot presented at a previously attended to location.

General introduction (3.1)

Previous research discussed in the literature review has established that TD individuals show a preference for social information over inanimate or abstract objects. For example in young children, face shapes are looked at preferentially to scrambled or inverted face shapes (e.g. Goren, Sarty, & Wu, 1975; Johnson, Dziurawic, Ellis & Morton, 1991) and this effect has been shown to continue into adulthood (e.g. Bindeman, Burton, Langton, Schweinberger & Doherty, 2007). Johnson and Morton (1991) have theorised that superior attentional capture by faces may be the starting point of a social developmental process. This process results in the face processing and social expertise observed in normal human development. If faces fail to capture the attention of individuals with ASDs then that may explain why the processing of faces, and by inference a plethora of other social cues, are noticeably impaired in ASDs (e.g. Langdell, 1978; Pelphrey et al., 2002). A more comprehensive review of social salience and attentional preference in TD individuals can be found in section 1.2.

Klin (1989) and Dawson et al. (1998) have suggested that, conversely, social information may not be judged as salient by autistic individuals and therefore not preferentially attended to. Williams, Goldstein and Minshew (2005) found a selective memory impairment for faces in high functioning adults with autism on both immediate and delayed recall and autistic individuals are less susceptible to the face inversion effect than non-ASD controls (Langdell; 1978; Hobson, Ouston, & Lee 1988). In addition to this, neurological studies have indicated that individuals with ASDs process face stimuli using the Inferior Temporal Sulcus not the highly specialised Right Fusiform Gyrus used to process faces by non-ASD individuals (Schultz et al., 2000). This difference in processing region does not appear to relate to a structural problem in the Right Fusiform Gyrus as individuals with ASD appear to process information they have a special interest in (i.e. recognising Digimon characters from a cartoon program) using this area (Grelotti et al., 2005). This suggests that the social deficit in ASD relates to a difference in social learning and the acquisition of social expertise. A more comprehensive review of face processing literature in ASD can be found in section 1.3.2.

In the literature review it was suggested that the social deficit in ASD might be best conceptualised not as a result of functional damage to neurological areas related to social expertise but that for some other reason the processing of social stimuli does not reach an expert level (Grelotti et al., 2005; Critchley et al., 2000). One potential suggestion, based on the models of Johnson and Morton (1991) could be that if ASD individuals spend less time attending to social information then less information will be learned about faces and other key social cues, and incidentally a similar level of expertise will not be achieved. Studies looking at social orienting in ASD have shown mixed results.

Kylliäinen and Hietanen found that in a pre-cueing task in which the eyes of a face were directed left or right both ASD and TD participants were faster to respond to dots which were presented in the location previously 'looked at' by the face. Dawson et al. (1998, 2004) examined the social orienting of ASD and TD children in a more realistic setting, using stimuli with greater ecologically validity. Observations were made of the number of times each child turned towards social and non-social noises played through speakers during free play. Both studies indicated that autistic children have a general deficit in orienting to auditory stimuli, and that this is most pronounced for orientation to social stimuli. The above studies highlight the conflicting nature of research on social orienting in ASD, with Kylliäinen and Hietanen indicating that this is an area of cognition that is preserved in autism. Whereas, Dawson et al. (1998, 2004) not only suggests a clear deficit in social attention but through their use of video analysis (Osterling & Dawson, 1994) they have suggested that this might be one of the earliest observable deficits in this population. There has however been little research looking at the attentional capture for social stimuli presented in a purely visual modality. The contradiction between the above studies reflects the disagreement in the literature about this important cognitive tendency, with some methodologies and populations reporting that this might be a central deficit in ASD and others suggesting no deficit at all. In this thesis, attentional bias for faces, compared to non-face stimuli, will be examined using a variety of presentation durations and using tasks which involve participants both consciously controlling their attention and tasks in which participants do not have conscious control of attention. By examining these effects taking the level of conscious control into account is it possible that an explanation for this contradiction in previous findings will emerge.

The examination of attentional bias to different stimuli classes is commonplace within anxiety and phobia research, and a number of experimental designs have been used to examine for these attentional biases. Studies using the Visual Dot Probe design suggested that attention was biased towards threat stimuli (e.g. Mathews, Macleod & Tata, 1986). A review of the methods used to examine these biases can be found in Chapter 2. The basic Visual Dot Probe paradigm involves presenting two images concurrently to participants, once these disappear a dot appears in the same spatial location as one of the two images, the participants task is to respond to the dot. Attentional allocation is inferred from response latencies to the dot dependent on the image that preceded it. The rationale being that if attention is already allocated to an image (e.g. a picture of a face) then the response latency will be shorter to a dot that appears in the same spatial location as this image. A modification of this design has been used by Bindemann et al. (2007) where participants were presented with a face and a non face object (e.g. toy car, teapot or dolls house) on either side of a computer display for 100, 500 or 1000 ms. Participants were asked to indicate the location (left or right) of a subsequent dot probe by forced choice response. When the probe appeared with equal frequency behind faces and objects participants responded significantly faster to probes that replaced faces than probes which replaced objects at all presentation durations. This indicates that in typical development faces appear to capture attention preferentially over other familiar non-social stimuli.

This study will use the Visual Dot Probe to explore the ability of faces to capture the attention of individuals with ASD as well as non-affected controls, when participants are aware of the stimuli (supra-threshold presentation) as well as when this information is presented outside of conscious awareness (sub-threshold presentation). Iarocci and Burack (2004) have shown that covert attentional orienting to peripheral cues appears to be intact in individuals with ASDs. It is therefore of interest to explore if social information can capture attention preferentially at these brief presentation durations.

This study will also adopt the analytical procedures of Koster, Crombez, Verschuere, and Houwer (2004) to examine whether any biases in attention can be best explained by a hyper-vigilance for that stimuli or a difficulty in disengaging from that stimuli (see Chapter 2.3.8 for details).

Given the findings of Klin et al (2002a, b) it is hypothesised that ASD individuals will show a reduced bias for faces when compared to non-ASD controls. Additionally based on the findings of Bindemann et al. (2007) it is predicted that the control group will show a bias for face stimuli compared to non-face stimuli.

Method (3.2)

Participants (3.2.1)

Nineteen high functioning participants with autistic spectrum disorders (17 Asperger's Syndrome, 2 autism; 13 male, 6 female) were recruited from support groups, educational establishments, and supported housing schemes. ASD participants had a mean age of 26.47 years with a standard deviation of 9.50. Participants had all previously received a diagnosis of autism or Asperger's syndrome from a trained clinician. The name of the diagnosing clinician or location of diagnosis and age of diagnosis was recorded in all cases and where possible copies of diagnostic notes were examined. Symptom severity was assessed using the Autism Quotient (Baron-Cohen, Wheelwright, Skinner, Martin & Clubley, 2001). Baron-Cohen et al. (2001) suggested that a cut off score of 32 would capture 80% of all individuals with ASDs while only 2% of controls score above this point. However Woodbury-Smith, Robinson, Wheelwright, and Baron-Cohen (2005) suggested that a cut-off score of 26 was the most sensitive. The average AQ score in the ASD population in this study is 32.47 indicating that on average participants scored above both thresholds. The range of scores on the AQ for the ASD group was 20-47 with 8 of the 17 participants who completed the AQ scoring below the cut-off of 32 suggested by Baron -Cohen et al.

(2001), and two scoring below the cut-off of 26 suggested by Woodbury-Smith, Robinson, Wheelwright, and Baron-Cohen. Even though some of the participants with ASD scored below the thresholds suggested above these participants have all received a diagnosis based on rigorous examination, for this reason it was considered appropriate to include them in this thesis. Participants' IQ was tested using the subscales of the Wechsler Adult Intelligence Scale (WAIS) which make up the Wechsler Abbreviated Scale for Intelligence (WASI; Wechsler, 1999); these consist of the vocabulary, block design, similarities and matrix reasoning subscales of the Wechsler intelligence scales. Scores on the WASI have been shown to have a high correlation with full scale IQ scores on the WAIS for both autistic and TD individuals (r= .94, r=.90 respectively; Minshew, Turner, & Goldstein, 2005).

Nineteen age, gender and IQ matched controls were recruited from a university participant pool, and adverts through local educational establishments. Control participants had a mean age of 28.58 years with a standard deviation of 7.31 and consisted of 13 men and 6 women. The range for the typical population on the AQ was 5-26 with only one participant scoring within the lower of the two thresholds. Additionally four of the control group obtained higher scores on the AQ than the lowest scoring ASD participant. However this was largely explained by elevated scores on the attentional subscales of the AQ, because of the concerns raised about these 'subscales' in Chapter 2 this was not considered a significant problem. See table 3.1 for breakdown of participant demographics.

Participants were matched using a stratified group match; this involved splitting participants into three sub groups based on IQ. All participants with an IQ below 100 made up one group, all those between 100 and 116 (one standard deviation above the standard mean) made up a second group and all those above 116 made up the third. Each sub group was comparable on age, gender and IQ. All participants reported having normal or corrected to normal vision.

Table 3.1: Summary of means and standard deviations for age, scaled scores for WAIS subscales and subscale scores on the Autism Quotient (AQ)

	Age	*Vocabulary*	*Similarities*	*Block design*	*Matrix reasoning*	*IQ*	*AQ social*	*AQ attention switching*	*AQ attention to detail*	*AQ communication*	*AQ imagination*	*AQ*
ASD	26.47	11.53	11.26	12.53	12.78	111.79	6.47	7.88 (1.76)	6.53 (1.59)	6.35 (2.23)	5.24 (1.86)	32.47
	(9.50)	(2.72)	(2.79)	(3.19)	(3.32)	(13.17)	(2.10)					(6.76)
Control	28.58	13.16	10.32	12.63	12.78	112.50	1.37	3.58 (2.43)	4.84 (2.95)	2.47 (2.12)	2.68 (1.70)	14.89
	(7.31)	(3.74)	(1.86)	(3.24)	(2.18)	(11.82)	(1.12)					(6.50)
t-scores	t(36)=.77, p=.449					t(36)=.18, p=.862						t(34)=7.50, p<.001

Design (3.2.2)

This study employed a 2 (ASD Vs TD) X 3 (Pair type: Car-face Vs House-Face Vs Car-House) X 2 (Face location: Top Vs Bottom) X 2 (Probe location: Top Vs Bottom) mixed factorial design, at both a sub and supra threshold Stimulus Onset Asynchrony (SOA). Although three levels exist for the pair type variable all the main analyses only involve the two pairs involving faces. This is because the research question in this study relates to the capacity of faces to capture attention. The purpose of the car-house trials was to allow for the analysis designed by Koster Crombez, Verschuere, and Houwer (2004) to test the role of vigilance and disengagement in the attentional allocation of each of the groups.

The review of methodologies presented in the previous chapter revealed a number of variations in the operationalisation of the Visual Dot Probe design, based on this review a number of methodological decisions were made. Firstly, it was decided to use a vertical presentation of the stimuli (one stimuli in the top half of the screen, the other in the bottom half). Secondly, it was decided to use sub-threshold and 200ms supra-threshold presentation times. Although a 500ms presentation time is the standard supra threshold duration using this design, this study is interested in early automatic attentional allocation, and Eriksen (1990) has indicated that attention, without eye-movement reaches its peak at approximately 200ms which allows for exogenous (automatic) cueing to be examined. Thirdly, the response method chosen in this study was a simple presence-absence decision about the probe. It was felt that given the broader intellectual range used in this study, combined with the use of a clinical population that task simplicity was imperative.

As stated above the supra-threshold condition was operationalised by a 200ms presentation of the stimulus pair. Whereas the sub-threshold condition had the stimulus pair presented for the participants threshold time (method explained below) followed by a pattern mask. The duration of the pattern mask brought total display time up to 200ms (i.e. if a persons' detection threshold was calculated as 30ms they would see the mask for 170ms). An inter stimulus interval (ISI) of 500ms was given between the end of each trial and the commencement of the next trial. The sub-threshold condition was always presented before the supra-threshold condition, to reduce the likelihood of priming (Fox, 1996).

Calculation of detection thresholds (3.2.3)

Individual detection thresholds were calculated in this study for two reasons; firstly past research determining standard thresholds have used word stimuli (e.g. Cheeseman & Merikle, 1986; Kemp-Wheeler & Hill, 1988), whereas in this study images will be presented. Thus, we cannot be sure that the stimulus durations for these two types of display will be the same. Secondly, past research has calculated threshold durations almost exclusively on North American college students. The sample in this study is drawn from a broader age and IQ range, and includes a population of individuals with autistic spectrum disorders. It is reasonable to assume that with this range of individual participant variation that the standardised thresholds might not apply.

In this study each participant's individual detection threshold was determined using four tasks: two tasks measuring 'objective' threshold and two measuring 'subjective' threshold. Cheeseman and Merikle (1986) classified an objective threshold as when a participant is no longer able to perform a discrimination task at a level above chance level and a subjective threshold is the level at which participants report that they can no longer detect a stimuli. Cheeseman and Merikle furthermore suggested that it is between these two boundaries of performance that the sub-threshold phenomenon is best conceptualised, being the border of the conscious and unconscious.

In this study, subjective thresholds were operationalised as the presentation time at which participants' ability to identify the presence or absence of an image was below 65% accuracy. 65% accuracy was selected based on Kemp-Wheeler and Hill's (1988) proposition that for information to be truly below threshold it should be within the 95% confidence intervals of chance [50%], in this case between 35% and 65%. Objective thresholds were operationalised as the presentation time at which participants' ability to identify which of two classes of stimuli (flowers and chairs) was presented was below 65% accuracy.

Objective and subjective thresholds were each calculated using two tasks based on the 'method of limits' technique which has frequently been used to measure detection threshold (e.g. Ellemberg, Lewis, Liu, & Maurer, 1999). This involves the presentation of a stimulus initially at either a clearly supraliminal level (in this study 80ms) and reducing stimulus intensity (or time) until it can no longer be detected or presenting stimuli for the fastest available duration (in this study 10ms) and increasing intensity until they can first be detected. The mean of these times is then considered to be the participants detection threshold (either subjective or objective dependent on the method employed).

Detection threshold materials (3.2.3.1)

Images of chairs and flowers were taken from searches of the internet, and background information was removed using Microsoft Photoshop Pro to ensure that only the image could attract attention, and not any feature of the background. These images were chosen as they bear no distinct resemblance to the test stimuli (faces, cars and houses). This was to ensure that no priming for the test stimuli occurred (See Appendix 2 for examples). A total of 5 pictures of flowers and 5 pictures of chairs were used as stimuli in this experiment.

Images were displayed in monochrome (256 colour greyscale pallet) on a white background, and were displayed using e-Prime software (Schneider, Eschman & Zuccolotto, 2002). Images were 198 X 128 pixels, subtending approximately 4.5° of horizontal visual angle at a distance of 90cms and were placed in the centre of the screen. Images were displayed on an Iiyama, 19 inch, Vision Master 1451, CRT Monitor at a resolution of 1024 x 768 creating a maximum refresh rate of 118 Hz, and were powered by a Viglen Genie desktop computer with a 1.7GHz Pentium 4 processor and 512Mb of RAM. The processor power and screen resolution allow for a reliable screen refresh every 10ms ensuring that stimuli could be presented fast enough to reach a sub-threshold duration. Participants sat approximately 90cm from the screen, and the height of both the chair and the monitor was altered until the participant reported that the centre of the screen was at eye level.

Detection threshold procedure (3.2.3.2)

Participants were told that they would first be taking part in a task to find out when they could see pictures, and that this would be done in four quick tasks. They were told that they could take breaks for as long as they wished between each task. Participants were first asked to sit on a chair, which was 90cm from the screen.

After any questions had been answered, participants completed the subjective threshold stage of the experiment. Participants were instructed that they would see a central fixation cross for half a second and that when this disappeared they would either see a picture for a short time or the screen would go blank and they would see no picture. After this a pattern mask, which was described to participants as a blur (this was shown to the participants on a card so that they were familiar with this image) was presented to participants. Participants were told that the researcher was only interested in what they saw before the mask and were asked to indicate by forced choice key press the perceived presence or absence of a stimulus. If they were unsure they were instructed to guess. Finally, they were told that there was no time limit and that for this task it was only the accuracy of response that the researcher was interested in. Figure 3.1 shows an example of detection threshold trials.

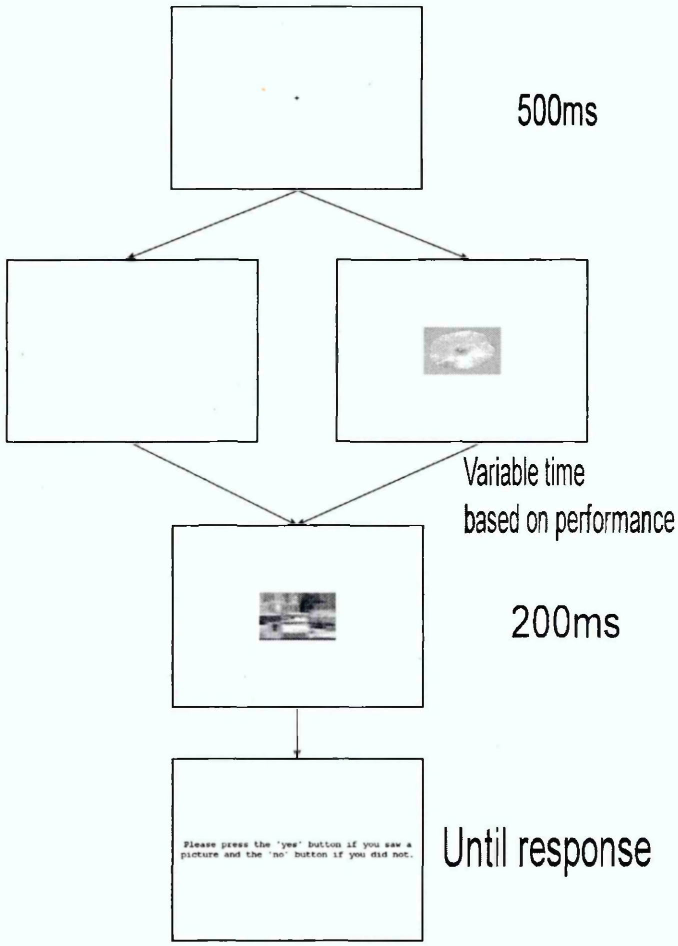


Figure 3.1: Detection threshold trial.

Participants responded at each presentation time to 10 stimuli (5 pictures, 5 blank screens). Presentation time was changed until participants accuracy was deemed to have reached 'threshold' (explained below). When this level was reached participants completed 40 presentations at this duration to ensure that performance was truly at threshold. This method is consistent with the technique of Kemp-Wheeler and Hill (1988).

This process was completed twice by each participant; once starting at 80ms and reducing in 10ms intervals, and once starting at 10ms increasing in increments of 10ms, until threshold was reached. On the reducing trials presentation time continued to be reduced until performance was at 60% accuracy or below. When this level was reached, the participant completed a 40 trial series; threshold was accepted if performance was below 65% for the 40 trial series. During the increasing trials presentation time continued to increase until performance was above 60%. When this level was reached, the participant completed a 40 trial series; threshold was accepted if performance was above 65% for the 40 trial series. The mean of these two presentation times was taken to be the participant's subjective threshold (i.e. the level at which they are able to discriminate between items). Each of the four detection threshold procedures took approximately 5 minutes, meaning that the total time for this task was approximately 20 minutes.

The only difference in determining objective threshold was that for this task it was the participants' ability to determine the type of stimuli that had been presented to them that was measured. Thus, on half of the trials a chair was presented before the mask and on the other half a flower was presented. Participants responded to which stimulus was presented by pressing either a key marked chair or a key marked flower. The mean final presentation duration of the increasing and decreasing trials was taken to be the person's objective threshold. The mean of the persons objective and subjective thresholds was then taken to be the level at which they will be aware that stimuli have been presented to them, but will be unaware of what they have seen. This is deemed to be their detection threshold and this time was used to present the images in the sub-threshold dot probe.

Visual Dot Probe Materials (3.2.4)

Materials used in this study were a variation on a standard dot probe task discussed in Chapter 2. Two images were presented on a computer screen one in the middle of the top half, one in the middle of the bottom half. Images were 198 X 128 pixels and were placed 186 pixels apart and 93 pixels from the top and bottom edges of the screen. Participants sat approximately 90cm from the screen therefore each image occupied approximately 4.5° of horizontal visual angle and the whole display occupied approximately 9.8° of vertical visual angle. The participants' chair was placed approximately 90cms from the screen, and participants were encouraged to sit back in the chair however all participants' moved a little, therefore viewing distance is approximate.

All stimuli were designed and displayed using E-Prime software (Schneider, Eschman & Zuccolotto, 2002) and were presented on an liyama, 19 inch, Vision Master 1451, CRT Monitor at a resolution of 1024 x 768 creating a maximum refresh rate of 118 Hz, and were powered by a Viglen Genie desktop computer with a 1.7GHz Pentium 4 processor and 512Mb of RAM. Responses were made using a PST model 200a serial response box. Buttons one and five were marked 'no' and 'yes' respectively which the participant used to indicate the presence ('yes') or absence ('no') of a dot.

Stimuli (3.2.5)

Photographs of faces used in this study were taken from Ekman and Matsumoto (1993) JACNEUF (Japanese and Caucasian Neutral Faces). These were used as they have been verified as being accurate depictions of the emotions they are intended to portray (e.g. Biehl et al., 1997). Pictures of cars and houses were obtained from searches of the internet. All images were presented in monochrome (256 colour greyscale pallet).

Non-social stimuli consisted of both houses and cars; these were selected as both have the same basic layout as a face (symmetrical, central mouth like object at the bottom, and two eye like shapes near the top). These have also been used in the past as control stimuli for faces in the case of houses (Nunn, Postma & Pearson, 2001) and both houses and cars (Hershler & Hochstein, 2005). Individual images of houses and cars were selected for inclusion by eight independent judges who agreed that the images selected met the criteria of having a face like configuration.

Newly created stimuli pairs were generated for each participant, 120 displays were used. These consisted of 40 face-car pairs, 40 face-house pairs and 40 car-house pairs. Each pair type consisted of 24 probed trials and 16 catch trials (no probe trials). The purpose of the catch trials was to ensure that participants were really responding to the presentation of the dot and not the offset of the pictures. Each image appeared with equal frequency in the top and bottom locations, in the experimental trials the probe appeared with equal frequency in the top and bottom locations. Image pairs were presented in a newly created random order for each participant. Eight postgraduate students indicated any of the original images they felt were of poor quality, where the image was obscured, or where the face like nature of the stimuli was unclear (windows/headlamps as eyes and a central door/bumper to act as a mouth).

Procedure (3.2.6)

Participants were told that the researcher was examining attentional bias in autistic and TD individuals. Participants were informed that this task would involve them seeing two pictures on a computer for a short time, these would then disappear and sometimes a small black dot would remain in the place of one of the pictures, but at other times no dot would appear. Participants were instructed to press one key marked yes, to indicate the presence of a dot and another, marked no, to indicate its absence. They were asked to respond as quickly as possible while trying not to make mistakes.

Participants were informed of their rights to confidentiality and their right to withdraw from the study at any stage. They were asked if they had any questions and when all questions were answered participants were asked to commence the experiment by reading the instructions for the dot probe (instructions were also explained verbally to participants to protect against differences resulting from differences in reading ability; instructions are available in Appendix 3), and to take part in 10 practice trials (5 probed, i.e. involving the presentation of a dot probe; and 5 catch i.e. without probe). Once participants had correctly passed all the practice trials they continued onto the experimental trials. If a participant did not complete all of the practice trials successfully they were instructed again how to carry out the task and asked to try the practice trial.

After completing the practice trials, the participants were again asked if they had any questions and they were given a short break if they felt they needed it. Participants began with the sub-threshold condition. Each experimental trial started with a central fixation cross presented for 500ms after which a randomly selected stimuli pair (as described above i.e. face-house, face-car, or car-house) immediately flashed onto the screen. After the offset of the stimuli pair a pattern mask emerged for an amount of time to bring the total presentation time up to 200ms (i.e. if their detection threshold was 30ms then the mask would be presented for 170ms). In the test trials a dot probe emerged in the location where one of the pictures had been, on catch trials no dot was present. Participants were asked to respond by a forced choice button press. If a dot was presented then they were asked to press a key marked 'yes', if no dot was present they were asked to press a button marked 'no' All pictures appeared in the top and bottom location with equal frequency, as did the dot probe (See figure 3.2 for a sample supra threshold trial).

When participants had finished the sub-threshold trials, they were advised to take a short break but asked to stay in the same room so that their eyes did not have to adjust to new lighting conditions. After the break participants completed the supra-threshold trials. The procedure for this was largely the same; the stimuli pair was presented to participants for 200ms in a newly created random order for each participant, and this time no pattern mask was displayed. After the offset of the images a dot appeared on 60% of trials, on the remaining 40% of trials no dot was presented (catch trials). Participants respond by a forced choice button press. If a dot was presented then they were asked to press a key marked 'yes', if no dot was present they were asked to press a button marked 'no'. All pictures appeared in the top and bottom location with equal frequency, as did the probe.

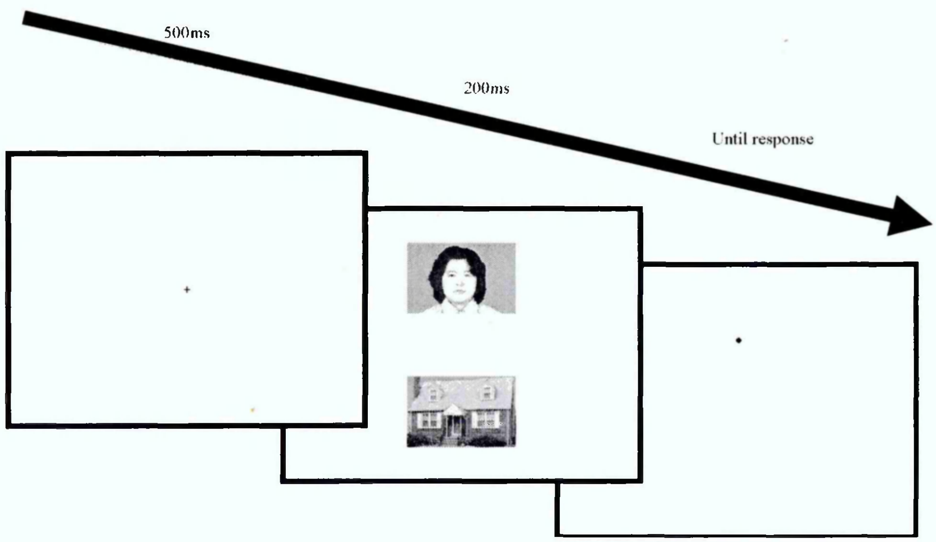


Figure 3.2: Sample display for face-house pair presentation with subsequent presentation of a probe in the upper (face congruent) location for the supra-threshold Visual Dot Probe.

Results (3.3)

Sub-threshold analysis (3.3.1)

Reaction times were recorded for all probed experimental trials (catch and practice trials were discarded). Data was then screened to exclude all incorrect responses and all reaction times less than 200ms. Reaction times of less than 200ms were removed as these are considered to be too fast to reflect genuine responses (anticipatory responses; e.g. Bradley, Mogg & Lee, 1997). There were no differences between groups in terms of number of errors or anticipatory responses made on either sub or supra-threshold trials (error data is presented in appendix 4). Individual participant median values were taken for each repeated measures condition within the experiment. Median values were used to reduce the influence of the positive skew often observed in reaction time studies (e.g. Bindemann et al., 2007; Langton & Bruce; 1999).

To test the main hypothesis group mean reaction times were calculated for each condition for both the ASD and TD groups, based on individual participant median times, to simplify the data presented and aid interpretation data is collapsed across probe location to present only mean values for the congruent and incongruent images (See tables 3.2 and 3.3 for means, complete set of means is presented in Appendix 5). These were entered into 2 x 2 x 2 x 2 Mixed design ANOVA with 1 between (diagnosis: ASD Vs control) and 3 within participant variables (pair: face-car Vs face-house; face location: top Vs bottom; probe location: top Vs bottom). Where a significant interaction term is observed involving face location and probe location these will be broken down by calculating bias scores using a formula proposed by Mathews, MacLeod and Tata (1986):

(target top & probe top +target bottom & probe bottom – target top & probe bottom –target bottom & probe top)/2.

The above formula works by subtracting target incongruent presentations (i.e. target top & probe bottom) from target congruent presentations. Therefore, biases towards target stimuli are indicated by negative bias scores. This technique of analysis is standard in Visual Dot Probe studies (e.g. Mogg & Bradley, 1999a; b; Bradley at al, 1998).

Given the complexity of the analysis reported, and the number of necessary comparisons which are not relevant to the research questions only the theoretically relevant comparisons will be reported here. Theoretically relevant comparisons are those which include the face location x probe location interactions. These allow for the hypothesis that probes which appear behind faces will be detected faster than probes that appear behind non-face stimuli to be tested (a face bias effect). The theoretically non-relevant are available in Appendix 6).

Alpha rates were held at 0.05, and was not adjusted for familywise error for a number of reasons. Firstly, due to the small sample sizes it was felt that an adjustment of alpha rates would require an unreasonably large effect size to consider an effect significant. Secondly, Perneger (1998) suggested that bonferroni adjustments are statistically unsound. Perneger cites a variety of concerns around the use of bonferroni adjustments including a concern that although reducing the likelihood of type I errors due to their conservative nature they unreasonably inflate the probability of type II errors. Perneger also points out that because of the post hoc testing of a secondary hypothesis, and the subsequent necessity of a change in alpha level, this may render an earlier primary hypothesis non-significant. Finally, as highlighted above the a-priori predictions within this research are specific to a single interaction (face location x probe location) and therefore testing can be considered to have a-priori grounds rather than simple post hoc exploration. This procedure is consistent throughout the research in this thesis.

Table 3.2: Means & standard deviations for reaction times on sub-threshold trials.

Congruent *Incongruent*	*Face* *Car*	*Car* *Face*	*Face* *House*	*House* *Face*	*Car* *House*	*House* *Car*
ASD Mean RT	502.15	492.82	502.84	497.97	494.85	473.54
ASD SD	109.36	101.18	125.69	92.16	92.22	90.63

Control Mean RT	429.72	429.96	444.01	432.76	465.38	444.99
Control SD	71.93	74.98	87.48	75.83	104.37	88.10
Difference (ASD-Control)	72.43	62.86	58.83	65.21	29.47	28.55

Individual participants' median data was checked to ensure that it met with parametric assumptions; group mean data was shown to be approximately normally distributed (all skewedness values between -2.56 and 2.56; Clark-Carter, 2004). Data was then examined for outliers (participants mean scores greater than three standard deviations about the group mean; Stevens, 1996). There were no outlying data points. An examination of variances revealed that these were approximately homogenous.

Data was entered into a 2 x 2 x 2 x 2 mixed design ANOVA (as described above). Importantly all theoretically relevant interactions were non-significant; face location x probe location $F(1,36)=.936$, $p=.340$, face location x probe location x diagnosis $F(1,36)=.462$, $p=.501$, face location x probe location x pair $F(1,36)=.570$, $p=.455$ and face location x probe location x pair x diagnosis $F(1,36)=1.750$, $p=.194$. This indicates that neither group showed an attentional bias for or away from faces when presented at sub-threshold durations.

Supra-threshold analysis (3.3.2)

To prepare participants data for analysis at supra threshold durations the same data cleaning and analytical methods were used as in the sub-threshold trials.

Table 3.3: Means & standard deviations for reaction times on supra-threshold trials.

Congruent *Incongruent*	*Face* *Car*	*Car* *Face*	*Face* *House*	*House* *Face*	*Car* *House*	*House* *Car*
ASD Mean RT	517.79	531.78	524.40	635.76	517.20	536.08
ASD SD	130.02	194.42	139.76	208.35	146.57	189.54
Control Mean RT	462.28	459.90	462.00	560.70	459.26	456.04
Control SD	83.35	77.95	73.79	111.55	83.23	87.95
Difference (ASD-Control)	55.51	71.88	62.4	75.06	57.94	80.04

Data was checked to ensure that it met with parametric assumptions; positive skew was observed in the face-car trials where the face appeared at the top of the screen and the probe appeared at the top of the screen in the autism group. Data was therefore subjected to a Log10 transformation (Tabachnick & Fidell, 1997; used by Senju, Tojo, Dairoku & Hasegawa, 2004), which corrected for the skewedness (all skewedness values between -2.56 and 2.56; Clark Carter, 2004). Transformed data was then examined for outliers (participants mean scores greater than three standard deviations about the group mean; Stevens, 1996). One participant in the ASD condition was observed to have reaction times which appeared to be a statistical outlier, his mean was 3.11[1] standard deviations above the group mean for presentations of faces in the top half of the screen and cars in the bottom half, when the probe subsequently appeared in the top half. Due to the limited statistical power of the current experiment and the observation that the outlying scores were only slightly above the cut-off coupled with the assumption that there was no cause to believe that these times did not reflect genuine responses in the population, the decision was made to leave these responses in the analysis.

Data was entered into a 2 x 2 x 2 x 2 mixed design ANOVA (as described above). When considering theoretically relevant interactions this revealed a significant three-way interaction between diagnosis, face location and probe location F(1,36)=4.488, p=.041. All other theoretically interesting interactions were non-significant; face location x probe location F(1,36)=1.646, p=.208, face location x probe location x pair F(1,36)=.693, p=.411 and face location x probe location x pair x diagnosis F(1,36)=.468, p=.498.

The significant three way interaction between face location, probe location and diagnosis was broken down using bias scores (see Table 3.4 for bias scores). To examine if there was a difference between the ASD and control groups in their bias scores an independent samples t-test was performed. This revealed that the control group showed a significantly greater bias towards faces than the ASD group t(36)=2.174, p=.036. To examine if either of the groups showed any significant bias towards either face stimuli or non-face stimuli independently one sample t-test were run for each group to see if their bias differed from 0. This revealed that the ASD group showed no significant bias for either stimulus class t(18)=.889, p=.386. The control group however showed a significant bias for face stimuli t(17)=2.190, p=.042.

Table 3.4: Means and standard deviations of bias scores for the ASD and control groups for supra threshold presentations for Study One.

Bias Pair	*Face-Car*	*Face-House*	*Total*
ASD	15.84 (54.39)	-1.00 (49.75)	7.42 (36.39)
Control	-16.67 (48.04)	-19.66 (41.60)	-18.16 (36.15)

Supra threshold analysis: Breaking down attentional sub-components (3.3.2.2)

To examine whether the attentional bias of the TD group observed in the supra-threshold condition was a result of vigilance for faces when they are congruent or a difficulty disengaging from them when they are incongruent the data was subjected to a

[1] If this participants data is removed then results remain the same

repeated measures t-test. This compared the mean of all trials where a face was present (either as the congruent or incongruent stimuli) to trials where a car-house paring was presented (Koster Crombez, Verschuere, & Houwer, 2004). This revealed no significant difference between face absent (Mean 456.16, SD 80.38) and face present trials (Mean 457.34, SD 74.08) $t(18)=.174$, $p=.864$. This indicates that the bias for faces observed in the TD group in the present study cannot be attributed specifically to any particular attentional function, and can therefore be assumed to be a result of a general attentional bias.

Discussion (3.4)

Experiment 1 revealed that when faces are presented outside of conscious awareness, with backwards masking (the presentation of the blurred image), this information does not appear to capture selective attention for either the ASD or control group. However, when these stimuli are presented at supra-threshold duration there was a clear bias toward responding to probes faster and more accurately when they had been preceded by faces in the control group, consistent with the social bias that was predicted for this group. The data for the ASD group however revealed no significant face bias in this group. Based on this it would appear that when control participants are consciously aware of faces their attention is biased towards this information, however faces do not appear able to capture attention outside of conscious awareness. In the ASD group however, faces do not appear to capture attention under either conscious awareness or outside of awareness. This attentional bias could not specifically be explained in terms of facilitated engagement or difficulty disengaging from the stimuli. This suggests that the effect was a general attentional bias effect in which facilitated engagement and difficulty disengaging probably both played a role, or alternatively the bias reflects a more rapid shift in attention, which cannot be tested in this analysis.

These findings provide further evidence that faces capture attention in TD adults. Faces have been shown to be resistant to attentional blindness and are detected when presented shortly after a cueing stimulus in the attentional blink paradigm (Mack, Pappas, Silverman & Gay, 2002) and are also perceived more frequently than non-face objects when viewed under conditions of metacontrast masking (Shelley-Tremblay & Mack, 1999). More relevant to the current research faces can also capture attention in competition with other stimuli (Ro, Russel & Lavie, 2001; Theeuwes, Stefan & Strigchel 2006; Bindemann, Burton, Langton, Schweinberger & Doherty, 2007).

Based on the findings of the studies discussed above and those of the present study there is some disagreement about the level of conscious control that people have over attention to face stimuli. Theeuwes, Stefan and Strigchel found that the participants showed an inhibition of return to cues that oriented attention to a location that had previously been occupied by a face. The inhibition of return effect has been shown to occur only when cueing was a result of exogenous (automatic) orienting, outside of the control of the participant. This suggests that the attentional capture elicited by faces is an automatic process. Bindemann et al. however showed that when participants are told that a probe is more likely to appear in the same location previously occupied by an object than the location of a face then participants show faster response times to probes presented in the location previously occupied by the object. This suggests that people are able to override the attentional capture by faces when this is not beneficial, and that therefore this bias is under the control of the person. The current study suggests that the attentional capture caused by faces occurs early in the time-course of the attentional process (i.e. present by 200ms); however preconscious capture of attention for faces in this experiment was not reliably found. The findings of the current experiment therefore suggest that the bias for faces occurs early in the attentional process, however the proposition that this effect can be observed when stimuli are presented outside of consciousness cannot be supported.

The current study's findings that a reliable bias for faces cannot be confirmed when these images are presented under conditions of pattern masking suggests potential limitations about the findings of Shelley-Tremblay and Mack (1999). Shelley-Tremblay and Mack suggested that faces are detected more accurately than an inverted face and a scrambled image when presented for 16ms, followed after a short delay, by a pattern mask. The present study however suggests face stimuli may not have the ability to capture attention to a peripheral location when presented outside of conscious awareness even if they are easier to detect when presented under backwards pattern masking when attentional focus is already at the location the image as suggested by Shelley-Tremblay and Mack. This difference may relate in part to differences in the stimuli used in the present study and the research of Shelley-Tremblay and Mack. The stimuli in this thesis were photographs of facial stimuli whereas Shelley-Tremblay and Mack used schematic representations of face stimuli. It is possible that although the extremely clear schematic stimuli were detected outside of conscious awareness but that more realistic stimuli were not able to attract this attention.

There are some obvious differences between these studies, firstly Shelley-Tremblay and Mack presented stimuli for 16ms whereas participants in the present study had an individualised threshold calculated, which was often much shorter (most participants threshold was 10ms). Therefore, the stimuli in the current study were usually presented for a considerably shorter time. In addition to this in Shelley-Tremblay and Mack's study participants' task was to identify the image presented to them when under masking. In the present study the masked stimuli were secondary to the task (the task being to respond to a dot). This study therefore raises questions about the extent to which faces operate on the attentional system of typical adults when these stimuli are presented outside of conscious awareness.

With reference to the autistic population, the findings of the present study provide support for the proposition of Dawson et al. (1998; 2004) that individuals with ASD show a fundamental lack of the social bias observed in typical development. The present study also indicates that differences between these populations can be observed in adulthood, therefore indicating that in ASD the social inattention is pervasive into adulthood, even after improvements have been shown in a number of other social functions (Howlin, Goode, Hutton and Rutter, 2004; Szatmari et al., 2003). This is an important distinction as although it is possible to learn compensatory skills to aid in certain social situations the endogenous capture of attention is outside of conscious control, and based on this it would appear that social cues capture attention to a lesser extent for those with ASDs.

The findings of this study also support research by Klin et al. (2002a, b) by indicating that a lack of bias for social stimuli can be observed using a design with higher experimental control as well as their more ecologically valid eye-tracking study. In Klin et al.'s studies participants with autism spent less overall time looking at the people in the scene and in particular less time looking at the characters eyes. Klin et al.'s use of eye-tracking for their study provided a number of important advancements in our understanding of social capture in ASD. In particular Klin et al's. research showed that in dynamic emotionally complex scenes individuals with ASDs do not follow the same gaze pattern as typical individuals. What could not be concluded from this study however was the initial allocation of attention to scenes involving social and non-social stimuli. The findings of the present study seem to indicate that faces do not capture attention on an initial presentation and that this might underlie Klin et al.'s findings of reduced tracking of social stimuli.

This study also raises key questions about the findings of Kylliäinen and Hietanen (2004) and Chawarska, Klin, and Volkmar (2003); in these experiments ASD participants showed the same cueing advantage as controls to centrally located faces with eyes directing attention to either the left or right of the screen. From this both groups concluded that ASD individuals are able to use fine social cues from the eyes to orient attention, to the same extent as in typical development. There are a number of key differences between these studies and this thesis; the first of these is that in the eye-gaze cueing studies participants' attention is allocated at the location where the stimuli will be presented. Assuming that the participant is motivated to participate in the research, it is possible that they showed the same performance as controls as they were already attending to the location of the stimuli. A related problem with the social cueing studies is because there is only a single stimuli being presented participants may be more likely to attend to it and use the information contained, in the absence of any other cue (therefore we do not know if the eyes of the face would be any more powerful in orienting attention in the ASD group than any other potential cue). Based on the comparison between studies of social pre-cueing and the current study it would seem that although individuals with ASDs are able to orient to social cues when they are presented in isolation, and within the focus of current attention that faces do not capture attention preferentially when competing with another stimulus. An interpretation of these findings could be that although those with ASDs are capable of learning certain social cues/rules (such as to follow the eyes of another) that these skills are not automatic and are a result of a more 'intellectualised' process.

There are weaknesses in this study; although this study demonstrates that differences exist in the capacity of faces to capture the attention of ASD and non-ASD individuals, one has to ask about how 'social' a static, neutral face presented out of any context are. Our typical experience with faces is of them as moving stimuli used to convey emotional, and therefore social, information. Knowing the emotional state of an individual can provide us with important information about the person and their intentions. Therefore recognising emotions can be seen to be a highly beneficial skill for the avoidance of threat and identification of potential friendship (Schupp et al., 2004; Palermo & Rhodes, 2007). As with attention to faces in general, the spontaneous allocation of attention to emotional expressions has been shown to be important to learning about emotions as well as the ability to make inferences about the desires, beliefs and intentions of others (Harris, 1989). Future research needs to address the above issues, and examine the influence of a face's emotionality. This will be examined in Chapter 5 and 6 of the present thesis and provide important data relating to how more socially informative facial cues effects attention in the TD and ASD populations.

It needs to be acknowledged that although one interpretation of these findings is that a lack of attentional bias for faces and other social stimuli operates from early in the developmental process of those with autism and results in the later social deficits observed in this group that the population tested does not allow for this to be directly concluded. For this hypothesis to be more directly tested it is necessary to conduct research with younger populations and across development to examine the developmental trends with this cognition. It is also possible that due to other social problems and the stress that may be associated with social encounters for individuals with ASD face stimuli are avoided in tasks such as this. If people have learned that faces cause distress or that they cannot use information from faces effectively then it is possible that attentional bias will dissipate as a result of this. The role of anxiety in attentional bias in ASD will be examined in Chapter 7.

An additional consideration within this study is that the spread of reaction times in the ASD group was very broad. This suggests large variability in responding in the ASD group, it is therefore possible that rather than the ASD group performing in a uniformed manner that there is variability within subgroups within the ASD sample. This suggests that the ASD group may consist of subgroups performing differently, this will be examined in Chapter 7.

The findings from this study support the proposition that ASD individuals are not 'geared up' to become experts in face processing (e.g. Critchley et al., 2000; Klin 1989; Dawson et al., 1998; Mundy, 1995). The lack of face processing expertise might be a consequence of an absence of the assumed cognitive mechanism which seems to be responsible for the almost implicit social orienting observed from birth in typical neonates (e.g. Goren, Sarty, & Wu, 1975; Johnson, Dziurawic, Ellis & Morton, 1991; Johnson & Morton, 1991; Morton & Johnson, 1991) and may somehow be dysfunctional in ASD.

Chapter 4

Attentional bias for faces compared to non-face stimuli: Face-in-the-Crowd.

Chapter Overview (4.1)

The following experiment was designed to address the allocation of attention to facial and non facial stimuli at a conscious level. The purpose of this study was to address some of the concerns about the sensitivity of the Visual Dot Probe task and to use a design which allows for a more direct comparison with the limited previous research on autistic individual's attention to social stimuli within a visual modality (Klin et al., 2002a, b; van der Geest et al. 2002). In the current experiment participants were presented with nine image displays. On some of these displays all images were the same whereas on others one was an odd-one-out. Images were made up from the same selection used in Experiment 1 (neutral faces, houses and cars). Participants' task was to indicate if all the images were the same or if there was an odd-one-out. This data is then analysed based on the rationale that if any attentional bias exists for a particular stimulus class then these images will be found faster when acting as a target than the other stimuli (e.g. a bias for image of a face in an array of cars will be reflected by finding faces faster in car arrays than cars in face arrays). This allows for an examination of the allocation of attention to competing social and non-social stimuli in a task which draws on greater level of conscious control of attention (i.e. due to the longer presentation durations and the suggested serial search used in this task, e.g. Purcell, Stewart & Skov, 1996). This is important as it will allow inferences to be drawn about the preferences that ASD individuals show for stimuli when given a greater time to process these stimuli.

Introduction (4.1.1)

Driver et al. (1999) concluded that the Visual Dot Probe task is too conservative a measure of attentional bias as this task uses one set of stimuli to orient attention (the images/words of interest) but asks for a response to a second stimuli (the probe). Therefore, alternative measures of attentional bias have been developed which have been argued to have higher ecological validity (Bryne & Eysenk, 1995), and to test the attentional allocation caused by the stimuli more directly (Driver et al., 1999). The Visual Dot Probe task, utilised in the previous experiment, has been used to examine a more automated capture of attention, which is appropriate for indicating early attentional allocation. However, when using the Visual Dot Probe task with the presentation of simple task irrelevant stimuli pairs it is harder to examine how conscious attention is preferentially allocated.

The Face-in-the-Crowd is a visual search task that explores attentional bias by examining the speed at which a discrepant image is detected within a visual field. The rationale in this task is that if attention is biased towards a particular stimulus then this will be detected faster as an odd-one-out than other stimuli. This is argued to be a more realistic task than the dot probe as it involves scanning a visual field. In a modification to this design Hershler and Hochstein (2005, Experiment 2) indicated that neutral facial expressions were found significantly faster and more efficiently in crowds of houses and cars than cars or houses in incongruent crowds. This indicates that in typical populations the Face-in-the-Crowd task can be used to indicate an attentional bias towards faces when compared to non-face stimuli.

This study will adapt the Face-in-the-Crowd task to incorporate a further exploration of the findings of Experiment 1. By using the same stimuli classes as Experiment 1 this experiment will begin to explore the visual search of a display for discrepant social or non-social information. This task also allows for the contribution of the various components of attentional orienting discussed in Chapter 2 (disengagement, shifting and reengagement; Posner et al. 1984) to be examined separately. Although there were no significant effects found when breaking down attentional orienting in Study One (Chapter 3) using the analytical technique of Koster et al. (2004) it was felt that re-examining the separate effects of the components of attentional orientation was valuable.

Based on previous research, visual search ability in ASD appears to be a preserved skill. Plaisted, O'Riordan, and Baron-Cohen (1998b) explored autistic children's (age 7-10 years) ability to conduct both feature search (measured by finding a red S in a display of red T's and green X's) and a conjunctive search (finding a red X in a display of red T's and green X's). Both groups performed at ceiling on the feature task, and as such no difference was observed. However on the conjunctive search task autistic individuals found the target faster, and with fewer errors that the control group. This suggests that the visual search ability of participants with ASD was superior to controls. A criticism of this study is that although participants were matched for verbal ability on the British Picture Vocabulary Scale (BPVS; Dunn, Dunn, Whetton, & Pintile, 1982), the children with autism had significantly higher spatial ability than controls, as measured on the Block Design subtest of the Wechsler Intelligence Scale for Children-Revised (WISC-R; Wechsler, 1974). Given that visual search tasks draw on spatial more than verbal abilities it is quite possible that the effects in this study are a result of differences between the groups that do not relate to diagnosis. For this reason the groups in this thesis will be carefully matched for both verbal and spatial intelligence to reduce the likelihood of general cognitive ability influencing the results of this research.

To test the possibility that the difference in search reflects differences in the overall non-verbal abilities of the above participants O'Riordan (2004) explored autistic participants' ability to search for a discrepant letter in a display. O'Riordan found that high functioning adults with autism could identify the discrepant letter significantly faster than matched controls. Based on this it was postulated that autistic individuals have a greater capacity to discriminate between items. This is an important finding as it indicates that the advantage that individuals with ASDs have in visual search perseveres when intellectual functioning is comparable, it also indicates that these effects persist into adulthood.

Less is known about what strategies are used by individuals with ASD when the scene they are searching contains social and non social cues. Research by Klin et al. (2002a, b) and van der Geest et al. (2002) has provided conflicting findings through the use of eye tracking. van der Geest et al. examined the visual attention of children with and without ASD to static cartoon like images containing people and objects (e.g. car, barn). This study found that there was no difference between the groups in attention to people. Conversely Klin et al.'s (2002a, b) participants watched dynamic film clips taken from the socially charged film 'Who's afraid of Virginia Woolf'. Adults with ASD attended significantly less to the eyes and significantly more to the mouths, bodies and objects than IQ matched controls. The findings of these two studies provide contradictory findings about the nature of social attention in ASD when presented with complex visual scenes. Therefore the present study will help to provide further evidence about the nature of social attention using a visual search task.

From the above literature it is unclear if there will be a bias in the attention of the ASD population. Hershler and Hochstein (2005 Experiment 2) have shown typical individuals show faster search times for faces in displays of cars and houses, compared to search times for cars or houses in displays of faces. Based on the findings of Experiment 1 that there was a bias for face pictures in the control group and no bias in the ASD group it would be reasonable to assume a similar pattern of findings in the present experiment. The present study however will improve upon that of Hershler and Hochstein (2005 Experiment 2) by using a single exemplar of each stimulus class as opposed to a number of different stimuli within each display. This will ensure that any effects observed are a result of attentional bias for the stimuli as opposed to other factors related to the ease of discriminating between the stimuli.

This study will further explore attentional bias (or lack thereof) in an autistic population. In the present study this will be examined at a conscious level. Participants will be presented with displays of 9 photographs (in 3X3 matrices). Some of these displays will contain 9 identical photographs; others will contain 8 identical pictures and one odd-one-out. Participants' task will be to indicate if all images are the same or if one is discrepant. Attention to faces will be measured by examining whether reaction times are faster to displays of 8 houses or cars and a face odd-one-out than to 8 faces and a discrepant house or car.

The hypothesis for this study is that the ASD and control groups will differ in the strength of the bias that they show for faces.

Method (4.2)

Participants (4.2.1)

Participants in this experiment were the same as those who took part in Experiment 1. Studies One and Two were conducted at the same time.

Materials (4.2.2)

This task employed the use of a modified Face-in-the-Crowd task: participants were shown nine images (in a 3X3 matrix). These displays either presented all of the same pictures, or eight identical pictures and one target picture, from a different class (e.g. 8 houses and a face target; see fig 4.1 for an example). The matrices were presented in a random order with participants giving their responses using keys on a PST model

200a serial response box. The keys were marked 'yes' to indicate that yes there was an odd image out and 'no' to indicate no odd-one-out.

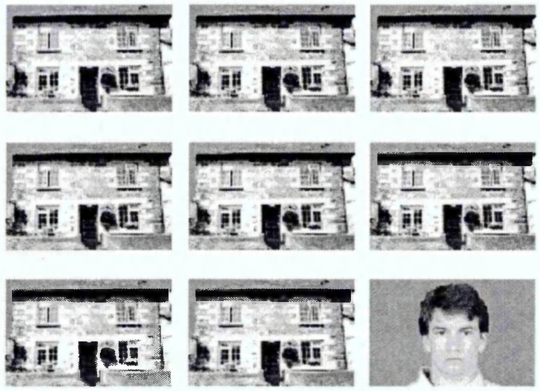


Figure 4.1: Sample display of a face target in a house crowd in the Face-in-the-Crowd task

The program was designed and run using E-Prime software (Schneider, Eschman and Zuccolotto, 2002) and was displayed on an Iiyama, 19 inch, Vision Master 1451, CRT Monitor at a resolution of 1024 x 768 creating a maximum refresh rate of 118 Hz, and were powered by a Viglen Genie desktop computer with a 1.7GHz Pentium 4 processor and 512Mb of RAM.

Stimuli (4.2.3)

Pictures used in this experiment were taken from the same selection used in Experiment 1. The face was taken from Ekman and Matsumoto's (1993) JACNEUF (Japanese and Caucasian Neutral Faces; image 7 file N7.JH.1C01), (Ekman & Matsumoto © 1993) whereas pictures of car fronts and houses were obtained from searches of the internet.

A total of 90 displays were presented to participants. Of these 54 involved an odd-one-out and 36 involved all stimuli presented being the same. Of the odd-one-out trials each potential permutation of the displays (e.g. face as target/car as crowd, car as target/house as crowd etc) was presented 9 times with the target appearing once in each of the possible locations. On the 'same' trials each crowd was presented an equal (12) number of times. Displays were presented in a newly created random order for each participant.

Procedure (4.2.4)

Participants were told that in this experiment they would see nine pictures displayed in a 3x3 grid. They were told that on some trials, all 9 of the pictures would be identical and on other trials one picture would be different from the remaining 8 pictures. It was made clear to participants that the difference would be readily apparent, and that different images would belong to different classes e.g. an odd-one-out trial would be 8 faces and a car, not 8 faces and one different face). Participants were informed that their task involved indicating, as quickly and accurately as possible, whether all the pictures were the same or if one was an odd-one-out. Participants were informed that before the main trials they would get 10 practice trials, which they had to complete successfully to start the main trials (standardised instructions are presented in Appendix 7).

A 500ms fixation cross preceded the presentation of the test displays which remained on the screen until the participant made a response. An inter-stimulus-interval (ISI) of 500ms was introduced before the start of the next trial. All trials were presented in a single block, which took approximately 8 minutes to complete.

Results (4.3)

Reaction times were recorded for all experimental trials (practice trials were discarded). Data was then screened to exclude all incorrect responses and all reaction times less than 200ms (anticipatory responses; e.g. Bradley, Mogg & Lee, 1997). There were no differences between groups in terms of number of errors made (error data is presented in appendix 8). Individual participant median values were taken for each repeated measures condition within the experiment. Median values were used to reduce the influence of the positive skew often observed in reaction time studies (e.g. Bindemann et al., 2007; Langton & Bruce; 1999).

To test the main hypothesis mean reaction times were calculated for each condition (e.g. face targets with car distracters) from individual participant median reaction times for both the ASD and control groups (See table 4.1 for means). A series of analyses were conducted on the data.

Table 4.1: Means & standard deviations for reaction times (in msec) for each target-distracter pairing on the Face-in-the-Crowd task in the ASD and control groups

Target	*Face*	*Face*	*Face*	*Car*	*Car*	*Car*	*House*	*House*	*House*
Distracter	*Face*	*Car*	*House*	*Face*	*Car*	*House*	*Face*	*Car*	*House*
ASD RT	746.70	637.13	649.02	672.25	677.86	683.68	696.39	725.82	635.00
ASD SD	371.53	139.20	184.70	201.40	164.49	193.46	313.50	240.57	151.79
Control RT	673.79	597.53	580.71	610.34	622.61	635.76	629.29	661.45	643.53
Control SD	175.51	87.94	112.13	67.69	103.53	116.39	106.72	121.34	140.95
Difference (ASD-Control)	72.91	39.6	68.31	61.91	55.25	47.92	67.1	64.37	-8.53

Data was checked to ensure that it met with parametric assumptions; positive skews were observed in the all face trials and the house target, face distracter trials. Data was therefore subjected to a Log10 transformation (Tabachnick & Fidell, 1997), which corrected for the skewedness (all skewedness values between -2.56 and 2.56; Clark Carter, 2004). Transformed data was then examined for outliers (participants mean scores greater than three standard deviations about the group mean; Stevens, 1996). Two participants, both in the ASD condition, were observed to have reaction times that appeared to be statistical outliers; these were 3.05 for the condition of all face trials and

3.03 for the condition of house targets among face crowds. Due to the limited statistical power of the current experiment and the observation that the outlying scores were only slightly above the cut-off coupled with the assumption that there was no cause to believe that these times did not reflect genuine responses in the population, the decision was made to leave these responses in the analysis[2].

Target present analysis (4.3.4.1)

To assess whether participants showed a bias for finding faces faster than non faces, target present data was initially entered into a 2 (Diagnosis: ASD Vs control) X 2 (stimuli pair: faces and cars Vs faces and houses) X 2 (face role: face as target Vs face as distracter) mixed design ANOVA. This revealed a significant main effect of face role $F(1,36)=7.553$, $p=.009$, such that reaction times were significantly shorter for faces among non social crowds than non-social targets among face crowds, indicating a bias for faces stimuli overall compared to non-face stimuli. This was not mediated by participants' diagnosis $F(1,36)=.199$, $p=.659$. The main effects of pair $F(1,36)=.005$, $p=.946$ and diagnosis $F(1,36)=.963$, $p=.333$ were non-significant, as were all interactions, pair X diagnosis $F(1,36)=.089$, $p=.767$, pair X face role $F(1,36)=.689$, $p=.412$ pair X face role X diagnosis $F(1,36)=.585$, $p=.449$. This indicates that both groups showed a bias for finding social stimuli faster than non-social stimuli when presented in a display of stimuli from the opposing class. However, as stated in section 2.1, attentional orienting is now assumed to have three separate sub-processes of disengagement from a location, switching of attention, and later reengagement at the newly attended location. Therefore, it is possible that the above differences reflect a faster search for faces in non-social crowds or a slower search through face crowds for non-social targets.

[2] Findings were not changed if analysis was run without these outliers.

To examine these effects in more detail further analyses were conducted. First, the standard interpretation, that these effects reflect a vigilance for face stimuli, was tested. It was reasoned that if participants found, for example, faces among car distracters quicker than houses among car distracters then it could be said that this was a result of an increased vigilance for faces (based on the suggestions of Horstmann, Scharlau and Ansorge, 2006). To test this data were entered into a 2 (diagnosis: ASD Vs control) X 2 (distracter type: car Vs house) X 2 (target: faces Vs non-social stimuli) ANOVA. This revealed a significant main effect of target $F(1,36)=30.149$, $p<.0001$ indicating that faces are found faster than non social stimuli among different non-social crowds. This effect was not mediated by participants' diagnosis $F(1,36)=.148$, $p=.703$. All other main effects and interactions were non-significant; distracter $F(1,36)=.2.29$, $p=.139$, diagnosis $F(1,36)=1.147$, $p=.291$, distracter x diagnosis $F(1,36)=.130$, $p=.721$, distracter x target $F(1,36)=.416$, $p=.523$, and distracter x target x diagnosis $F(1,36)=.290$, $p=.593$. This provides strong evidence for social vigilance in both control and ASD groups.

The role that difficulty disengaging attention from faces may play in the social bias found in this study was examined using a third analysis. In this instance it was reasoned that if, for example, car targets were found faster among house distracters than among face distracters then this would reflect a difficulty in disengaging from the faces in the display (based on the suggestions of Horstmann, Scharlau & Ansorge, 2006). To test this the data was subjected to a 2 (target: cars Vs houses) X 2 (distracter: social Vs non-social) X 2 (diagnosis: ASD Vs control) mixed design factorial ANOVA. This revealed a significant main effect of distracter $F(1,36)=7.006$, $p=.012$, indicating that there was a faster response to non social targets when the distracting crowd was made up of faces than when the crowd was made up of other non-social stimuli. This is consistent with the counter intuitive idea that face distracters are rejected quicker than non-social stimuli.

Target absent analysis (4.3.4.2)

As the target present data examining disengagement was counter to what might have been expected, the target absent data was also analysed to examine the effect of each stimuli class on disengagement of attention (Hansen & Hansen, 1988; Gilboa-Schechtman, Foa, & Amir, 1999 have suggested the use of this analysis to examine disengagement of attention). This analysis assumes that if a participant has a difficulty in disengaging from a particular stimulus class that the process of classifying this display as containing all of the same stimulus will take longer than if the participant can quickly disengage attention from each stimulus and search though the display. A 2 (diagnosis: ASD Vs control) X 3 (display: Faces Vs Cars Vs Houses) mixed design ANOVA was conducted. An examination of Mauchly's test of sphericity revealed that this assumption had been violated ($p=.001$), therefore the Greenhouse-Geisser adjustment is reported. This revealed a significant main effect of display $F(1.51, 54.356)=3.787$, $p=.040$. This effect was explored further using pairwise comparisons with a Sidak adjustment. None of the effects were found to reach statistical significance, a trend was found towards longer latencies for all face trials than for all house trials ($p=.091$), no differences were found between face and car trials ($p=.209$) or between the car and house trials ($p=.676$). The main effects of diagnosis was non significant $F(1,36)=.243$, $p=.625$, as was the interaction $F(1.51, 54.356)=1.414$, $p=.250$.

Discussion (4.4)

The findings of the present study revealed that both the control and ASD groups showed faster response latencies to face targets among non-social distracters than non-social targets among face distracters. This is consistent with both populations showing a bias for faces. When examining these effects in more detail it was found that both populations showed a hyper-vigilance for faces when compared to non-social stimuli indicated by faces being found faster amongst non-social displays than non-social targets amongst conflicting non-social displays. Further examination of the target present trials revealed that participants were quicker to reject displays in which the distracters are faces than when they are non-face distracter displays. This indicates that not only are participants faster to detect discrepant face stimuli that they also process this faster and are able to disengage attention from facial information rapidly. To further test the effect of disengagement on attentional bias target absent trials were analysed, these revealed the opposite pattern of findings with all face trials showing the longest response latencies.

This experiment therefore suggests that both groups employ the same attentional mechanisms. Both groups showed vigilance for faces as well as a faster search through crowds of faces than through non-social crowds, consistent with a faster disengagement from these stimuli. This may reflect that once engaged in a task involving social stimuli such as this one the relatively low cognitive demands needed for this task (i.e. identifying clearly different stimuli) mean that ASD individuals are able to use the social cues with comparative ease. It is unexpected that the same attentional mechanisms were used by both groups of participants in the present study as previous research has found that autistic individuals often have a difficulty in disengaging attention from a stimulus once fixated (e.g. Landry & Bryson, 2004). This finding therefore suggests that disengaging from faces is not impaired in ASD.

The findings of the present study also have implications for the normative literature on social attention, supporting previous research indicating that faces hold a 'special place' in the attentional and broader cognitive systems of typical individuals. This includes providing support for the findings of Hershler and Hochstein (2005 Experiment 2), that in typical development people show a search asynchrony when looking for faces compared to other commonly encountered stimuli. The present study also improves upon that of Hershler and Hochstein in imposing stricter experimental control over the presentation of stimuli. Where Hershler and Hochstein presented a variety of different photographs with a specific scene the present study used an individual image to represent each stimulus class. The present study therefore indicates that the differences observed in Hershler and Hochstein's study are unlikely to be a result of intra-class differences in the stimuli making some of the search tasks easier or harder. The present experiment also shows that the faster attentional capture for faces is also found when the participants' task is to indicate the presence of a discrepant image in a display, and is not specific to when they have been asked to identify the presence of a predetermined target. This suggests that the face advantage operates without priming participants to the task.

The findings of the present study also support van der Geest et al.'s (2002) eye tracking findings that when presented with a scene displaying social and non-social information that there is no significant difference between participants with ASD and those without in terms of their attention to the social stimuli in the scene. This contrasts with the findings of Klin et al. (2002a, b) who indicated reduced attention to the most social elements of dynamic film scenes for ASD participants compared to TD controls.

There are a number of potential reasons why the present study might have supported the findings of van der Geest et al. rather than those of Klin et al. Firstly, both van der Geest et al. and the present study used static displays as compared to Klin et al. who used dynamic stimuli. There are some suggestions that rather than revealing a deficit in social attention Klin et al.'s findings reflect a motion processing deficit (Kemner & van Engeland; 2003). Gepner (2004) claimed that findings that autistic children are relatively capable at identifying emotional expression based on biological motion when movement is slowed down, however show impairments when presented at full speed (Gepner, Deruelle & Grynfeltt, 2001). Based on this Gepner pointed to his visual-motion integration hypothesis of autism (Gepner & Mestre, 2002). This is the hypothesis that autistic individuals have a major motion processing disorder that causes rapid physical and biological movement to be highly aversive, therefore causing a disruption in social attention. Gepner (2004) suggested that this might have caused the incongruence between van der Geest et al. (2002) and Klin et al.'s (2002a, b) findings.

Secondly, the scenes used by Klin et al. were highly emotionally charged in comparison to those in the present study and those used by van der Geest et al. that were largely neutral. Although the present study and research by Hershler and Hochstein (2005 Experiment 2) indicate that the FITC task is capable of detecting a face bias in comparison to non-face stimuli the major purpose of this task is to examine the attentional bias for emotional expressions (e.g. Hansen & Hansen, 1988). It is possible therefore, that the emotional nature of the scenes used by Klin et al. contributed to the reduced social bias in their study in comparison to the intact social biases observed in the present study.

An additional interpretation of the findings of the present study is that high functioning adults with autism develop a conscious preference for attending to faces later in life; this would be reflected in the acute interest in friendship, which often develops in adolescence for those with ASD (APA, 2000). However this is not an implicit process and would therefore be consistent with an intellectualised social capacity (Grandin, 1999). This would also explain why high functioning adults with ASD are able to use eye gaze cues to orient their attention under experimental circumstances (Kylliäinen & Hietanen, 2004).

The findings of the present study differ to those in Study 1 (Chapter 3), in which a bias in attention for faces was limited to the control group with the ASD group showing no bias for faces. It is possible that this reflects the different role played by the face stimuli. In the Visual Dot Probe task the stimuli (both facial and non-social) are secondary to the task requirement (to respond to the presence or absence of a dot), and the attentional bias is measuring the capacity of the stimuli to 'distract' the participant from the task. However, in the Face-in-the-Crowd task the stimuli are central to the tasks requirements, as they must be searched through to identify if all are the same or there is an incongruent image. This raises the possibility that individuals with ASDs do not preferentially attend to (are not vigilant for) faces, however once attention has been engaged explicitly, over longer duration these stimuli are processed more speedily/readily than non-face stimuli.

Support for the greater level of conscious processing involved in the Face-in-the-Crowd task comes from the inspection time participants have for the images. In the Visual Dot Probe tasks used in the previous study stimuli were presented to participants for between 10ms and 200ms where as in the present study stimuli were presented on average about three times longer than that. This supports the idea that participants were able to process stimuli with a greater level of awareness and that this may contribute to the social bias seen in participants with ASD in the Face-in-the-Crowd task but not in the Visual Dot Probe tasks used earlier.

There are other potential mechanisms by which the present experiments findings could have been obtained. It is possible that faces were found faster in the present study by one or both of the groups as a result of some low-level feature of the images (i.e. the greater contrast in colour between the hairline and facial features on the face stimuli), and not a result of the social meaning that the face holds. This seems unlikely as images used as non-social images were matched as well as possible for complexity, were familiar and are also usually only seen in mono-orientation (i.e. houses and cars are similar to faces in that they are usually seen on a single orientation and rarely on their roofs). Although it is possible to gain greater experimental control over stimuli by using schematic line drawings to represent faces, this significantly compromises the ecological validity of the research and introduces a variety of additional problems about what is being measured.

In conclusion, this study indicates that when consciously engaging with face stimuli in a visual search paradigm, individuals with ASD appear to show the same bias for finding faces faster among non-face distracters than non-face targets among face distracters. This appears to indicate that when consciously engaging with faces these stimuli are given preferential attention within cognitive tasks. This is consistent with some research findings (e.g. van der Geest et al., 2002; Kylliäinen & Hietanen, 2004) however, inconsistent with others (Klin et al., 2002). There are however limitations to this study as it fails to address the influence of motion or emotion on these effects. This is a problem as faces are rarely seen in a static neutral state. It is possible therefore that the greater social communication, and the different social message that individual emotional expressions imply, might cause differences in patterns of social bias between TD and ASD participants. This is also important as the rapid recognition of emotions in typical development can be seen to be a highly beneficial skill for the avoidance of threat and identification of potential friendship (Schupp et al., 2004; Palermo & Rhodes, 2007). To address the problem with ecological validity the following study will introduce emotional expressions into the task to examine whether these have a role in attentional bias.

Chapter 5

Attentional bias for emotional (angry, happy, and neutral) faces vs. non-social stimuli (teapots): Visual Dot Probe.

The following study was designed to address one of the concerns raised in the first two studies, that neutral facial expressions might not truly convey enough social significance to capture attention sufficiently. One of the most important pieces of information which is identified when processing information from faces is the emotional expression of the face (Palermo a& Rhodes, 2007). In the present study participants were presented with image pairs made up of happy, angry or neutral facial expressions and non-social images (in the form of teapots) to examine the influence of emotional expressions on attentional bias in individuals with ASD and typical controls. The remaining elements of the design were kept constant from the first experiment.

Introduction (5.1)

The findings of the first two studies, which compared attentional bias to neutral facial expressions compared to non-face stimuli, did not address some aspects of the nature of attention to faces in adults with and without ASD. Faces are rarely seen in the rather unnatural 'neutral' state presented in Studies One and Two. Much of the information that it is important to obtain when engaging with faces is to do with the emotional state of the individual (Palermo a& Rhodes, 2007). Knowledge of the emotional state of an individual tells us much about the person and their intentions(Palermo a& Rhodes, 2007). Therefore, the rapid recognition of emotions in typical development can be seen to be a beneficial skill for the avoidance of threat and identification of potential friendship (Schupp et al., 2004; Palermo & Rhodes, 2007). As with attention to faces in general, the spontaneous allocation of attention to emotional expressions appears critical to learning about emotions as well as the ability to make inferences about others desires, beliefs and intentions (Harris, 1989).

Palermo and Rhodes (2007) pointed out that a face is a salient object in our environment, regardless of expression, and that even the neutral face communicates some emotional content. There is however evidence that lower thresholds are required to detect faces when they are unambiguously emotional as compared to neutral in typical development (Calvo & Esteves, 2005), and that emotions such as anger and fear may be processed automatically (Vuilleumier et al., 2001).

The potential influence of emotionality on any attentional capture effect is of particular interest when considering an ASD population. Although previous research suggests that individuals with ASD show a deficit in processing information from faces (e.g. Klin et al., 1999; Langdell, 1978) others have suggested that in high functioning older individuals with ASDs that the processing of faces may be much more similar to TD individuals (e.g. Boucher & Lewis, 1992; Ozonoff, Pennington, & Rodgers, 1990), possibly reflecting a delay rather than an absence of these abilities. There is however a broad literature examining the ability of ASD individuals to process emotional information, with a particular interest in processing emotions displayed in the face. This is especially important as previous research has shown that when the task demands are increased or elements of emotional processing are implemented, the impaired performance of individuals with ASD becomes more evident (Davies, Bishop, Manstead, & Tantum, 1994; Tantum, Monaghan, Nicholson, & Stirling, 1989).

As indicated in the literature review, in addition to a general difficulty with face processing in ASD, one of the most noticeable manifestations of this might be a difficulty distinguishing emotional expressions and making appropriate decisions about them (e.g. Hobson, 1986a; b; Boraston et al., 2007). It is important to consider the criticisms highlighted in Chapter 3 that the neutral face does not necessarily truly communicate a great deal of social meaning. The ability to effectively pass and receive emotional signals has an obvious survival value, so much so that this part of the human perceptual system is highly practiced to these skills if not hard wired to detect human faces (e.g. Purcell & Stewart, 1981; 1986). Taken together research suggested that the ability to identify and classify emotional faces is extremely efficient in typical development.

Ashwin, Wheelwright and Baron-Cohen (2006a) have examined the attentional bias of high functioning adolescents with ASD using a pictorial version of the emotional Stroop task. Angry and neutral faces were presented as well as pictures of chairs with different colour overlays which participants were instructed to indentify. In Ashwin et al.'s study TD participants were slower to indicate the colour of the overlays when the image presented was an angry face than when it was a neutral face or chair. This is indicative of the typical threat bias effect. Participants with ASD however were slower to identify the colour of the overlays for all faces compared to the pictures of chairs. This would appear to indicate that participants with ASD showed a bias for attending to all faces. There are however a number of problems with this study, most notably that it cannot be truly inferred that this is an attentional bias as these findings could also reflect a slower processing speed for these stimuli and not a preferential attentional capture by them. It is therefore important to further explore these effects to allow firm conclusions to be drawn about this research.

The present study will utilise the Visual Dot Probe task to examine the effect of faces depicting happy, angry, or neutral emotional expressions and non-social images (teapots) on attentional bias. The first reason for examining these effects using emotional faces was to increase the social significance of the face stimuli. The second reason was to allow for comparisons between attentional capture by specific emotional expressions to be examined. These emotional expressions were selected for two reasons, first they have been used most frequently in the normative literature (e.g.

Mogg & Bradley, 1999a; b) and secondly they are emotional expressions that individuals with ASD have been suggested to be able to identify (Davies et al., 1994; Loveland et al., 1997). This will again allow attentional bias to be examined outside of conscious control (by presenting stimuli for less than 200ms). Additionally the present study will examine these effects at both sub and supra threshold presentation durations. Given the findings of the previous study that adults with ASD showed a reduced social bias compared to controls, (when presented for supra-threshold durations) it would appear logical to conclude that this finding will be replicated in the present study. This however runs contrary to the findings of Ashwin, Wheelwright and Baron-Cohen (2006a) using a pictorial Stroop task, in which they found that adults with ASD showed a bias in attention for all face stimuli compared to non-face stimuli. In contrast, controls showed a selective bias for threat faces. Based on Ashwin et al.'s study it is possible that the ASD group will show attentional capture for all face stimuli.

The first hypothesis for this study is that control participants will show a bias for faces when compared to non-face stimuli, this bias will be significantly different to the bias seen in participants with ASD. This first hypothesis will allow for the findings of the first study to be retested. The second hypothesis is that participants with ASD will differ from controls in the nature of their bias for emotional faces compared to neutral faces and non-face stimuli. This hypothesis will be tested by examining whether the groups differ from each other in the size of their bias for any individual emotional expression compared to each of the others.

Method (5.2)

Participants (5.2.1)

Eighteen high functioning participants with ASD (16 Asperger's Syndrome, 2 autism; 12 male) were recruited from support groups, educational establishments, and supported housing schemes. All ASD participants had previously taken part in Experiments 1 and

2. Eighteen age, gender and IQ matched controls were recruited from a university participant pool, and adverts through local educational institutions, 16 of whom had taken part in Experiments 1 and 2. See table 5.1 for participant demographics. There was a minimum gap of 4 months between participants taking part in Studies Two and Three.

Table 5.1: Means and standard deviations for group matching variables (WASI, AQ and age)

	Age	*Vocabulary (range 0-18)*[1]	*Similarities (range 0-18)*[1]	*Block design (range 0-18)*[1]	*Matrix reasoning (range 0-18)*[1]	*IQ*	*AQ social (Range 0-10)*	*AQ attention switching (Range 0-10)*	*AQ attention to detail (Range 0-10)*	*AQ Communication (Range 0-10)*	*AQ imagination (Range 0-10)*	*AQ (Range 0-50)*
ASD	27.00 (9.70)	11.22 (2.23)	10.67 (2.77)	12.50 (3.22)	12.67 (2.33)	110.68 (12.51)	6.12 (2.00)	7.65 (1.73)	6.41 (1.54)	6.24 (2.25)	5.29 (1.83)	31.71 (6.48)
Control	27.50 (7.47)	12.28 (2.35)	10.06 (1.70)	12.11 (3.39)	12.72 (1.93)	110.84 (10.17)	1.50 (1.04)	3.83 (2.50)	4.72 (2.65)	2.39 (2.23)	2.61 (1.72)	15.00(6.10)
t-scores	$t(34)=.173$, $p=.863$					$t(34)=.044$, $p=.965$						$t(33)=.7.86$, $p<.001$

1 WASI scores are given in scaled scores

Design (5.2.2)

The supra-threshold condition was operationalised by a 200ms presentation of the stimulus pair, whereas the sub-threshold condition had the stimulus pair presented for the participant's threshold time (method explained in Chapter 3.2.3) followed by a pattern mask. In the present study detection thresholds were recalculated using the same technique as in the previous study (to ensure the robustness of the design and that information is presented below conscious threshold) however the starting presentation duration was reduced to 30ms from 80ms as all participants were able to perform the task at this duration. An inter stimulus interval (ISI) of 500ms was given between the end of each trial and the commencement of the next trial.

The sub-threshold condition was always presented before the supra-threshold condition, to reduce the likelihood of priming (Fox, 1996). Additionally two different intensities of emotion were used in this experiment; open and closed mouthed (with the open mouthed appearing to be more intense expressions). The closed mouthed expressions were always shown in the first block with the open mouthed expressions appearing in the second block. The reason that two stimulus intensities were used in the present study was to increase the number of different stimuli that could be used within the available stimulus battery. Stimulus intensity was not entered as a separate variable in the present analysis. When this variable was added to the analysis it did not mediate any of the biases. This variable was therefore omitted from the analysis to make the analysis easier to interpret[3].

Newly created stimuli pairs were generated for each participant, 216 displays were used. These consisted of 6 sets of 36 pairs for each stimulus pairing (e.g. angry-happy, happy-teapot). Each pair type consisted of 24 probed trials and 12 catch trials. The purpose of the catch trials was to ensure that participants were really responding to the presentation of the dot and not just the offset of the pictures. Each image appeared with equal frequency in the top and bottom locations. In the experimental trials the probe appeared with equal frequency in the top and bottom locations. Image pairs were presented in a newly created random order for each participant. For each stimulus pair a total of 6 probed trials were used (3 using the closed mouth expressions and 3 using the open mouth expressions).

Materials (5.2.3)

Materials were the same as those used in Experiment 1: Attentional bias for faces compared to non-face stimuli: Visual Dot Probe.

Stimuli (5.2.4)

Photographs of faces used in this study were taken from MacBrain stimuli (Tottenham et al., 2009). These were used as they have been verified as being accurate depictions of the emotions they are intended to portray (Tottenham et al., 2002). The MacBrain stimuli were used in the present study instead of the Ekman and Matsumoto (1993) stimuli to increase the number of available emotional images as the Ekman and Matsumoto stimuli contain only 8 faces depicting each emotional expression. Given that it was necessary to use a different database of face stimuli for the present study it also seemed reasonable to change the non-face stimuli. To achieve this images of teapots were taken from searches of the Internet. Teapots were used as non-face stimuli in the present study as they have the same basic shape as faces and share some characteristics (e.g. a nose as a spout). Teapots have also been used as a control for faces in previous research (e.g. Bindeman, et al., 2007). All images were presented in monochrome (256 colour greyscale pallet).

[3] Although no differences were observed it is important to note that the small number of possible comparisons (3 for each pair) may have masked differences.

Procedure (5.2.5)

The procedure for this experiment was identical to that used in Experiment 1 except that half way through the trials there was a pause in the program on both tasks and participants were told to press the start button when they were ready to continue. The pause was added due to the increased duration that the extra trials added, to reduce the chance of fatigue effects.

Results (5.3)

Reaction times were recorded for all probed experimental trials (catch and practice trials were discarded). Data were then screened to exclude all incorrect responses and all reaction times less than 200ms (anticipatory responses; e.g. Bradley, Mogg & Lee, 1997). There were no significant differences between groups in number of errors in either sub or supra-threshold presentations (error data can be found in appendix 9). Individual participant median values were taken for each repeated measures condition within the experiment. Median values were used to reduce the influence of the positive skew often observed in reaction time studies (e.g. Bindemann et al., 2007; Langton & Bruce; 1999).

To test the main hypothesis group mean reaction times were calculated for each condition for both the ASD and TD groups, based on individual participant median times. To simplify the data presented and aid interpretation, data is collapsed across probe location to present only mean values for the congruent and incongruent images (See tables 5.2 and 5.3 for means, see Appendix 10 for full descriptive data). To examine the varying effects of interest group means were entered in a series of mixed design ANOVAs these all involved diagnosis (ASD Vs control) as a between participants factor and target location (top Vs bottom); and probe location (top Vs bottom) as within participant variables. Where a significant interaction is observed this will be broken down using bias scores as discussed in Study One. The designation of targets was dependent on which research questions were being tested. For the purposes of the analysis the 'stronger emotion', the emotion that past literature suggests most likely to capture attention, was designated as the 'target', however the analysis is able to detect bias towards either stimulus: The order of emotion strength for the use in the ANOVAs presented below is: angry, happy, neutral, teapot. This is the standard analysis used in Visual Dot Probe studies (e.g. Mogg & Bradley, 1999a; b).

Given the complexity of the analysis reported, and the number of necessary comparisons that are not relevant to the research questions, only the theoretically relevant comparisons are reported here. Theoretically relevant comparisons are those that include the target location x probe location interactions. These allow for the hypothesis that probes which appear behind faces will be detected faster than probes that appear behind non-face stimuli (a face bias effect). These will also allow for the hypothesis about differences in attentional biases for emotional expressions to be tested. Non-theoretically relevant results are presented in Appendix 11.

Analysis for sub-threshold presentation (5.3.1)

Table 5.2: Means & standard deviations for reaction times on sub-threshold trials (Msec).

Congruent	*Angry*	*Angry*	*Angry*	*Happy*	*Happy*	*Happy*	*Neutral*	*Neutral*	*Neutral*	*Teapot*	*Teapot*	*Teapot*
Incongruent	*Happy*	*Neutral*	*Teapot*	*Angry*	*Neutral*	*Teapot*	*Angry*	*Happy*	*Teapot*	*Angry*	*Happy*	*Neutral*
ASD Mean RT	448.60	455.58	453.92	455.92	456.93	471.46	477.83	472.63	448.56	457.69	460.22	466.93
ASD SD	130.27	137.75	142.54	137.04	152.97	167.14	179.63	156.66	125.58	143.89	151.95	141.42
Control Mean RT	401.64	406.97	395.03	402.71	400.56	409.83	399.26	394.08	393.14	401.86	410.42	408.81
Control SD	55.16	50.78	52.59	59.15	47.14	58.98	53.72	45.96	52.37	68.35	58.72	47.67
Difference (ASD-Control)	46.96	48.61	58.89	53.21	56.37	61.63	78.57	78.55	55.42	55.83	49.8	58.12

Retesting the findings of Study One (5.3.1.1)

To retest the hypothesis from the first study (and the first hypothesis for this study) that faces would capture attention preferentially when compared to non face stimuli composite scores were calculated for each presentation of a face (irrespective of emotion) compared to teapots. Individual participants' median data was checked to ensure that it met with parametric assumptions. Group mean data was shown to be approximately normally distributed (all skewedness values between -2.56 and 2.56; Clark Carter, 2004). No outlying reaction times were found (participants mean scores greater than three standard deviations about the group mean; Stevens, 1996). An examination of variances revealed that these were approximately homogenous.

Data was entered into a 2 (diagnosis; ASD Vs control) x 2 (face location; top Vs bottom) x 2 (probe location; top Vs bottom) mixed design ANOVA. This revealed no theoretically relevant interactions: face location x probe location $F(1,34)=3.369$, $p=.075$ and diagnosis x face location x probe location $F(1,34)=.431$, $p=.516$.

Although the diagnosis x face location x probe location interaction was non significant in this analysis, given the findings of Study One and the a priori hypothesis that the groups would differ in terms of their attentional bias this effect was broken down using bias scores (See table 5.3). To examine if there was a difference in bias scores between the ASD and control groups an independent samples t-test was conducted. Consistent with the findings of the ANOVA presented above this revealed no significant difference between the ASD and control groups bias scores $t(34)=.657$, $p=.516$. To examine if either of the groups showed any significant bias towards either face stimuli or teapots independently one sample t-tests were run for each group to establish if their bias differed from 0. This revealed that the ASD group showed no significant bias for either stimulus class $t(17)=.808$, $p=.430$. The control group showed a trend towards a significant bias for face stimuli $t(17)=1.821$, $p=.086$.

Table 5.3: Means and standard deviations for bias scores for the ASD and control groups for sub-threshold presentations for Study Three

Bias Pair	*Angry-Happy*	*Angry-Neutral*	*Angry-Teapot*	*Happy-Neutral*	*Happy-Teapot*	*Neutral-Teapot*	*Face-Teapot*	*Emotion-Neutral*
ASD	-7.32	-22.25	-3.78	-15.69	11.24	-18.38	-3.64	-18.97
	(30.86)	(66.98)	(36.30)	(37.63)	(59.47)	(44.98)	(19.10)	(40.85)
Control	-1.07	7.71	-6.83	6.47	-0.58	-15.67	-7.69	7.09
	(35.85)	(41.87)	(32.70)	(24.60)	(28.78)	(31.35)	(17.92)	(24.27)

Emotion (5.3.1.2)

To test the second hypothesis that groups would differ in their attentional bias for emotional and neutral faces, angry and happy faces were combined in comparison to neutral faces (e.g. angry top-neutral bottom-dot bottom and happy top-neutral bottom-dot bottom were combined into emotional top-neutral bottom-dot bottom). Individual participants' median data met all assumptions for parametric testing.

Data was entered into a 2 (diagnosis; ASD Vs control) x 2 (emotional face location; top Vs bottom) x 2 (probe location; top Vs bottom) mixed design ANOVA. This revealed a theoretically relevant significant three way diagnosis x emotional face location x probe location $F(1,34)=5.146$, $p=.026$ interaction. The emotional face location x probe location $F(1,34)=1.126$, $p=.296$ interaction was however non-significant.

The diagnosis x emotional face location x probe location was broken down using bias scores. To examine if there was a difference in bias scores between the ASD and control groups an independent samples t-test was conducted. Consistent with the findings of the ANOVA this revealed a significant difference between the ASD and control groups in their bias scores $t(34)=2.327$, $p=.026$. To examine if either group showed any significant bias towards either emotional faces or neutral faces independently one sample t-test were run for each group to establish if their bias differed from 0. For the ASD group this revealed a non-significant trend towards a bias for emotional faces compared to neutral faces $t(17)=1.971$, $p=.065$. However the control group showed no significant bias in either direction $t(17)=1.239$, $p=.232$.

Individual comparisons (5.3.1.3)

To examine whether any of the stimuli alone captured attention when compared to another stimulus class each pair was entered into diagnosis (ASD Vs control) x target location (top Vs bottom) x probe location (top Vs bottom) interactions. For the purposes of the analysis the 'stronger emotion' (the emotion that past literature suggests most likely to capture attention) will be called the 'target' however the analysis is able to detect bias towards either stimulus; the order of this was angry, happy, neutral, teapot.

Individual participants' median data was checked to ensure that it met with parametric assumptions; group mean data was shown to be approximately normally distributed (all skewedness values between -2.56 and 2.56; Clark Carter, 2004). Data was then examined for outliers (participants mean scores greater than three standard deviations about the group mean; Stevens, 1996). Outlying values were found for; angry face top-teapot bottom-probe top (3.26), neutral face top-teapot bottom-probe top (3.05), teapot top-happy face bottom-probe top (3.12), and teapot top-neutral face bottom-probe top (3.27). An inverse transformation of data was used to reduce the influence of outlying data and this was found to bring all values into an acceptable range (Tabachnick & Fidell, 1997). An examination of variances revealed that these were approximately homogenous.

The analysis for angry faces Vs happy faces revealed no theoretically relevant interactions; target location x probe location $F(1,34)=.593$ $p=.447$ and diagnosis x target location x probe location $F(1,34)=.144$, $p=.707$.

The analysis for angry faces Vs neutral faces revealed no theoretically relevant interactions; target location x probe location $F(1,34)=.016$ $p=.899$ and diagnosis x target location x probe location $F(1,34)=1.342$, $p=.255$.

The analysis for angry faces Vs teapots revealed no theoretically relevant interactions; target location x probe location $F(1,34)=.267$, $p=.609$ and diagnosis x target location x probe location $F(1,34)=.009$, $p=.924$.

The analysis for happy faces Vs neutral faces revealed a significant three way diagnosis x target location x probe location interaction $F(1,34)=4.350$, $p=.045$. The target location x probe location $F(1,34)=.243$, $p=.625$ was non-significant.

The significant diagnosis x target location x probe location interaction was broken down using bias scores. To examine if there was a difference in bias scores between the ASD and control groups an independent samples t-test was conducted. This revealed a significant difference between the ASD and control groups in their attentional bias for happy faces compared to neutral faces $t(34)=2.092$, $p=.044$ consistent with the ASD group showing a greater bias for happy face stimuli compared to the control group. To examine if either of the groups showed any significant bias towards either happy faces or neutral faces independently one sample t-test were run for each group to see if their bias differed from 0. This revealed that the ASD group showed a trend towards a significant bias for the happy face stimuli $t(17)=1.770$, $p=.095$ whereas the control group showed no bias for happy or neutral faces $t(17)=1.116$, $p=.280$.

The analysis for happy faces Vs teapots revealed no theoretically relevant interactions; target location x probe location $F(1,34)=.159$ $p=.692$ and diagnosis x target location x probe location $F(1,34)=.161$, $p=.691$.

The analysis for neutral faces Vs teapots revealed a significant interaction between target location and probe location $F(1,34)=7.681$, $p=.009$. The diagnosis x target location x probe location $F(1,34)=.417$, $p=.523$ was however non-significant. To examine the direction of the target location x probe location interaction and if this was significant the data was converted to a bias score and this was analysed using a one sample t-test. This revealed a significant bias for faces compared to teapots across the whole population $t(35)=2.671$, $p=.011$.

Again given the findings of Study One and the a priori hypothesis that the groups would differ in terms of their attentional bias this effect was broken down using bias scores. To examine if there was a difference in bias scores between the ASD and control groups an independent samples t-test was conducted. Consistent with the findings of the ANOVA there was no significant difference between the ASD and control groups in their bias scores $t(34)=.210$, $p=.835$. To examine if either of the groups showed any significant bias towards either neutral face stimuli or teapots independently one sample t-tests were run for each group to establish if their bias differed from 0. This revealed that the ASD group showed no significant bias for either stimulus class $t(17)=1.733$, $p=.101$. The control group however showed a significant bias for face stimuli $t(17)=2.120$, $p=.049$.

Summary of sub-threshold (5.3.1.4)

The findings for the sub threshold analysis indicate that the control group show a general non-significant bias for faces in comparison to non-face stimuli (teapots) with this bias becoming significant when neutral faces are compared to teapots. However, this does not appear to extend to a bias for emotional faces, either in comparison to neutral faces, or teapots. Therefore, the bias that control participants show for face stimuli has to be considered limited to neutral faces and not to emotional faces. The ASD group in contrast appear to show a bias for emotional images, and in particular happy faces, over neutral faces but no bias for faces compared to teapots.

Supra-threshold analysis (5.3.1.5)

The same analytical procedures were used for the supra-threshold analysis as in the sub-threshold.

Table 5.3: Means & standard deviations for reaction times on supra-threshold trials.

Congruent	*Angry*	*Angry*	*Angry*	*Happy*	*Happy*	*Happy*	*Neutral*	*Neutral*	*Neutral*	*Teapot*	*Teapot*	*Teapot*
Incongruent	*Happy*	*Neutral*	*Teapot*	*Angry*	*Neutral*	*Teapot*	*Angry*	*Happy*	*Teapot*	*Angry*	*Happy*	*Neutral*
ASD Mean RT	435.14	434.64	441.11	429.35	430.50	433.50	428.74	423.64	435.42	433.39	438.78	440.63
ASD SD	98.94	84.94	108.42	75.96	89.40	76.53	71.85	72.45	108.69	88.04	85.38	86.07
Control Mean RT	406.42	399.28	409.53	413.53	409.39	413.81	405.11	408.92	409.31	424.06	409.82	414.97
Control SD	54.02	56.14	51.92	54.09	61.37	48.97	49.23	59.45	51.65	69.05	53.61	62.79
Difference (ASD-Control)	28.72	35.36	31.58	15.82	21.11	19.69	23.63	14.72	26.11	9.33	28.96	25.66

An examination of the descriptive data for supra-threshold presentations concurs with the data for sub-threshold presentations indicating longer mean reaction times to all trial types by the ASD group when compared to controls. The ASD group also showed more variation in scores around the mean than the control group.

Retesting the findings of Study One (5.3.1.6)

To retest the hypothesis from the first study that faces would capture attention preferentially when compared to non face stimuli composite scores were calculated for each presentation of a face (irrespective of emotion) compared to teapots. Individual participants' median data was checked to ensure that it met with parametric assumptions; group mean data was shown to be approximately normally distributed (all skewedness values between -2.56 and 2.56; Clark Carter, 2004). No outlying reaction times were found (participants mean scores greater than three standard deviations about the group mean; Stevens, 1996). An examination of variances revealed that these were approximately homogenous.

Data were entered into a 2 (diagnosis; ASD Vs control) x 2 (face location; top Vs bottom) x 2 (probe Location; top Vs bottom) mixed design ANOVA. This revealed no theoretically relevant interactions: face location x probe location $F(1,34)=.578$, $p=.453$ and diagnosis x face location x probe location $F(1,34)=.290$, $p=.594$.

Although the diagnosis x face location x probe location interaction was non significant in this analysis given the findings of Study One and the a priori hypothesis that the groups would differ in terms of their attentional bias a face location x probe location repeated measures ANOVA was run for each of the ASD and control groups.

For the ASD group the face location x probe location interaction $F(1,17)=.022$, $p=.884$ was non-significant. The same was true for the controls group, the face location x probe location interaction $F(1,17)=.958$, $p=.341$ was non-significant.

Emotion (5.3.1.7)

To test the hypothesis that emotional faces would elicit a bias over non-emotional stimuli angry and happy faces were combined in comparison to neutral faces (e.g. angry top-neutral bottom-dot bottom and happy top-neutral bottom-dot bottom were combined into emotional top-neutral bottom-dot bottom). Individual participants' median data met all assumptions for parametric testing.

Data was entered into a 2 (diagnosis; ASD Vs control) x 2 (emotional face location; top Vs bottom) x 2 (probe location; top Vs bottom) mixed design ANOVA. This revealed no theoretically relevant interactions: emotional face location x probe location $F(1,34)=.164$, $p=.688$ and diagnosis x emotional face location x probe location $F(1,34)=.983$, $p=.328$.

Individual comparisons (5.3.1.8)

To examine whether any of the emotional expression/teapots resulted in a bias of attention each stimulus category was paired with each other stimulus and these were entered into diagnosis (ASD Vs control) x target location (top Vs bottom) x probe location (top Vs bottom) interactions.

Individual participants' median RT data was checked to ensure that it met with parametric assumptions; group mean data was shown to be approximately normally distributed (all skewedness values between -2.56 and 2.56; Clark Carter, 2004). Data was then examined for outliers (participants mean scores greater than three standard deviations about the group mean; Stevens, 1996). Outlying values were found for; teapot top-angry face bottom-probe bottom (3.05), and happy face top-neutral face bottom-probe top (3.03). An inverse transformation of data was used to reduce the influence of outlying data and this was found to bring all values into an acceptable range (Tabachnick & Fidell, 1997). An examination of variances revealed that these were approximately homogenous.

The analysis for angry faces Vs happy faces revealed no theoretically relevant interactions; target location x probe location $F(1,34)=.610$, $p=.440$ and diagnosis x target location x probe location $F(1,34)=.575$, $p=.453$.

The analysis for angry faces Vs neutral faces revealed no theoretically relevant interactions; target location x probe location $F(1,34)=.099$, $p=.755$ and diagnosis x target location x probe location $F(1,34)=1.565$, $p=.220$.

The analysis for angry faces Vs teapots revealed no theoretically relevant interactions; target location x probe location $F(1,34)=.326$ $p=.572$ and diagnosis x target location x probe location $F(1,34)=.324$, $p=.573$.

The analysis for happy faces Vs neutral faces revealed no theoretically relevant interactions; target location x probe location $F(1,34)=.098$, $p=.756$ and diagnosis x target location x probe location $F(1,34)=.002$, $p=.969$.

The analysis for happy faces Vs teapots revealed no theoretically relevant interactions; target location x probe location $F(1,34)=.157$, $p=.694$ and diagnosis x target location x probe location $F(1,34)=.964$, $p=.333$.

The analysis for neutral faces Vs teapots revealed no theoretically relevant interactions; target location x probe location $F(1,34)=1.398$, $p=.245$ and diagnosis x target location x probe location $F(1,34)=.736$, $p=.397$.

Summary of supra-threshold (5.3.1.9)

The findings at supra-threshold duration reveal that neither the ASD or control groups appear to display any significant biases in attention under any of the comparisons.

Discussion (5.4)

The findings of the present study indicate that when stimuli of differing social and emotional content were presented to participants for a sub-threshold duration, control participants showed a non-significant bias for a composite score for faces compared to non social stimuli (teapots). When neutral faces where compared to teapots the control participants showed a significant bias for faces. This pattern was not seen in the ASD group, who showed no clear attentional bias in either direction when presented with faces and teapots. Participants with ASD appear to show a bias for faces with emotional expressions and in particular happy emotions when compared to neutral facial expressions. This indicates that participants with ASD show a heightened attentional bias for emotional stimuli presented outside of conscious awareness. Participants with ASD however only showed this preference for emotional faces when compared to neutral faces and not when compared to teapots. This cannot therefore be considered an emotional bias per se but rather a bias within face processing. Due to the specific nature of this bias it is not clear whether the bias seen in the ASD group reflects a bias towards emotional faces or away from neutral ones. When presented for supra threshold durations neither faces (of any emotional content) or teapots captured attention in either group, indicating that social stimuli did not affect attentional allocation when participants were consciously aware of them.

The findings of the present study provide partial support for the results of Study One that the control group have an underlying bias for neutral faces over non-social stimuli. Additionally this study suggests that control participants show an attentional bias for a composite score for all faces compared to non-face stimuli. In this study however, a bias was not observed for the emotional stimuli independently compared to teapots.

Study Three however, indicates that this bias is observed at a sub-threshold duration rather than a supra-threshold duration as in Study One. This cannot be explained simply in terms of the increased social salience provided by the emotional aspects of the displays as the control group also showed a sub-threshold bias for neutral faces compared to teapots, which is almost identical to the presentations used in Study One. It is clear from this inconsistency that the effects observed in Studies One and Three need to be re-examined with larger samples to validate these findings. Additionally the presentation times needed to observe these effects needs to be examined in greater detail to understand better the social-emotional attention of individuals with ASD. These findings also suggest that the added social qualities that emotionality brings to the face are not enough to call for added attentional bias in the control participants, however there are some indications that when presented for sub-threshold durations participants with ASD show a greater bias for emotional faces, especially happy compared to neutral faces, than the control group.

Based on the findings of the first three studies it appears that faces capture attention in TD adults supporting previous research (Bindemann, et al. 2007; Hershler & Hochstein, 2005), however these effects have to be considered sensitive to a number of factors as they have been selectively found at supra and sub threshold durations in Studies One and Three (respectively). Additionally in the present study these effects were only uniquely observed for neutral faces and not for emotional expression. Given that the pattern of findings on the non-significant sub-threshold presentations in Study One (Dot probe: neutral faces) and supra-threshold presentations in the present study was towards a bias for faces, although clearly non-significantly, it is possible that a combination of large standard deviations and small samples sizes resulted in a lack of power to detect these effects.

With reference to the normative literature the control group did not show the predicted bias for threat stimuli (i.e. angry faces; e.g. Cooper & Langton, 2006). This is not however entirely surprising as the majority of the literature has indicated that the bias for threat in a typical population is related to heightened levels of anxiety either clinically (e.g. Mogg, Bradley & Williams, 1995) or in the general population (e.g. Mogg & Bradley, 1999b). It is possible that the lack of any specific bias for emotional images in the control group in the present study reflects the variability in their affective states and that a pattern of bias may be seen when this factor is examined in more detail in Chapter 7.

The findings that emotional (and in particular happy) face stimuli presented at a sub-threshold duration captures attention selectively in individuals with ASD is contrary to the findings of Hall, West & Szatmari (2007). Hall et al. showed that neutral and fearful faces presented below conscious threshold did not cause ASD participants to rate the friendliness of subsequently presented faces differently, whereas control participants rated faces preceded by fearful faces as less friendly. The present study however suggests that individuals with ASD are faster to detect emotional stimuli presented in the periphery of their visual attention compared to non-emotional social stimuli. There are however clear differences between these two studies. The present study examined the capacity of emotional information presented outside of conscious awareness to capture attention to a spatial location in individuals with and without ASD. Hall et al.'s study however examined the capacity of emotional stimuli presented for sub-threshold durations to alter the subsequent decision making in these groups. It is therefore possible that emotional stimuli are able to capture attention to a location in individuals with ASD but once attention has been captured the interpretation of these stimuli is different from that of control participants.

The findings of the present study run contrary to Ashwin, Wheelwright and Baron-Cohen's (2006) study using a pictorial Stroop task to examine attentional bias for faces with differing emotional expressions. Ashwin et al. found that adults with ASD showed longer latencies for faces (regardless of emotional expression) than for chairs. The TD control participants in Ashwin et al.'s study however showed longer response times to angry faces than neutral faces or chairs. In the present study the bias that participants with ASD showed was specific to emotion and particularly happy faces, participants with ASD did not show this bias when compared to non-social stimuli but specifically when compared to neutral faces. Ashwin et al. explained their findings in terms of difficulty of processing, suggesting that participants with ASD took longer to respond to faces as it took them longer to process this information. The findings of this study cannot be explained in these terms as the bias for happy faces was compared to neutral faces which where very similar and therefore can be considered to be equally difficult to process. It therefore appears that the nature of attentional bias to social cues in ASD is more complex than suggested by Ashwin et al.

It seems on the surface that the absence of an angry face bias in the control group is counter to previous research. However, individual differences variables (particularly relating to anxiety) have been shown to relate to bias in attention for particular emotional expressions (e.g. Bradley, Mogg, Falla & Hamilton, 1998). To examine for this in the current research, these data will be reanalysed in Chapter 7 to examine the role of individual differences and specifically the role of anxiety on the cognitive biases for faces in individuals with ASD. This analysis will also help to address the wide variety of performance in participants with ASD. Given that the complexity of social situations has been shown to invoke anxiety in many individuals with ASD (Gillott & Standen, 2007) it is possible that the pattern of attentional bias observed in Studies Two and Three may be explained in similar terms as the typical threat bias effects seen for angry faces (e.g. Mogg & Bradley, 2002). It is possible that happy faces have become associated with anxiety in some individuals with ASD as these reflect an expectation of social interaction and that those individuals who display a particularly strong bias for these stimuli will display the highest levels of anxiety and social anxiety. This will be further examined in Chapter 7.

It is also possible that the converse is true and that a bias for happy faces in the ASD group reflects that this stimulus is the image that these participants are most familiar with. Given that infants will usually be exposed more frequently to positive emotional expressions than negative ones (Malatesta & Haviland, 1982) it is likely that familiarity of positive expressions will develop faster than for negative emotions. This is supported by research that suggests that children aged 4-6 months will spend more time looking at happy faces than angry ones in a preferential looking time experiment (LaBarbera et al., 1976). It is therefore possible that individuals with ASD show this bias as they have the most familiarity with this expression.

The present study provides long needed data about the allocation of attention to competing emotional stimuli in individuals with ASD, which has long been overlooked, with only Ashwin et al. (2006a, b) having examined these effects before. However, it needs to be acknowledged that the emotional expressions presented in the present study are all from the class of 'basic' emotions. Loveland et al. (1997) suggested that the processing of the 'basic' emotions is relatively well preserved in ASD. It has been suggested that it is in the processing of mental state emotions that the deficit in ASD is most prevalent such as surprise (Baron-Cohen et al., 1993), pride (Kasari et al., 1993) jealousy (Bauminger, 2004) and shame/embarrassment (Capps et al., 1992; Heerey et al., 2003). It would therefore be valuable for future research to examine how emotions such as surprise and pride compare to basic ones, such as happiness and anger in their ability to capture attention in ASD and differentiate those with ASD from controls.

One reason for the lack of consistency in findings between the first and third study (a supra threshold face bias in Study One with no sub-threshold bias, and a sub-threshold face bias in Study Three with no supra-threshold bias for controls) might relate to the reliability of the Visual Dot Probe design. In a recent study Schmukle (2005) examined internal, split half and test-retest reliability of the Visual Dot Probe. All measures of reliability were found to be low. These inconsistencies might, in part, relate to a low reliability of the Visual Dot Probe. Another reason for this lack of consistency might relate to the change in stimuli used between the two studies. Firstly there was a difference in the non-face stimuli used between Studies One and Three. Study One used houses and cars, these were used due to the matched internal structure of the stimuli (i.e. eyes/ window/ headlamps then a mouth/ door/ grill). The use of the teapot in Study Three reflected the general outline of the face with the spout of the teapot reflecting a nose. It is possible that Study One using the houses and cars (with the matched internal structure) found a bias for faces on longer presentation as the faces were clearly visible but failed to find a bias when presented for sub-threshold durations as the basic face structure was still intact. Therefore, the non-social stimuli in Study One conformed to the face Conspec (Johnson & Morton, 1991). However, in Study Three the internal structure of the face was not found in the non-face stimuli therefore allowing for a sub-threshold bias. It is however difficult to explain the lack of a conscious bias within this explanation.

As well as the change in non-face stimuli the first study used face stimuli taken from Ekman and Matsumoto (1993), whereas in Study Three they were taken from the MacBrain Stimuli (Tottenham et al; in press). Although both sets of stimuli have been well validated it is possible that the change in images affected attentional bias. This might be of significance as Ekman and Matsumoto (1993) faces included both Caucasian and Japanese faces whereas the MacBrain Stimuli contained only Caucasian faces (in the stimuli selected in this thesis). It is possible that the race of the faces used affected the way that participants attended to these stimuli. Given that the Conspec-Conlern theory of face processing predicts that our expertise in face processing is a result of learning about familiar faces then it is possible that a stronger bias will be seen for faces when they are of the same race as ours (as we will have more experience of these) when compared to other races.

Similar to the previous studies participants with ASD showed a wider distribution of reaction times to the presentation of probes than the control group, this might indicate that there was some overlap between the ASD and control groups in their bias for or away from each stimulus class. It is therefore important that each participant's individual pattern of bias be explored separately to examine the range and variation in participants' reactions by group. This will be considered in Chapter 7.

The findings of the present study again raise the issue of the level of conscious control that individuals have over their attentional biases for face stimuli. The findings that faces capture attention preferentially to teapots at sub-thresholds duration provides support to the notion that the bias for these stimuli is outside of conscious control in TD participants (i.e. when stimuli are presented for less than 250ms). The lack of an attentional bias for faces (of any emotional expression) compared to teapots in the ASD group supports the findings of Experiment 1 that faces do not capture attention in individuals with ASD when presented outside of conscious control. However, ASD individuals show an attentional bias for faces which did not differ from TD controls using the Face-in-the-Crowd task in Study Two, which assesses attentional bias under conscious control. Given that this study has shown that emotional, and in particular happy, faces capture attention compared to neutral faces it seem valuable to examine ASD participant's attentional allocation to faces displaying emotional expressions using the Face-in-the-Crowd task. This will allow for bias for emotional expressions to be examined when they are presented for a duration consistent with conscious control of attention. To address this Chapter 6 will examine attention to faces depicting emotional expressions using the Face-in-the-Crowd task.

Chapter 6

Examining attentional bias for emotional (angry, happy, and neutral) faces and non-social stimuli (teapots) using the Face-in-the-Crowd task.

The following study was designed to further investigate the conscious allocation of attention to facial and non-face stimuli. This study will also build upon the findings of Study Three (which examined the way that emotional faces capture attention in the Visual Dot Probe task) by examining the role that presenting emotional stimuli has on allocation of attention to emotional and non-emotional crowds of faces. This was achieved using the Face-in-the-Crowd task in which participants were presented with a series of displays of 9 images some of which contained a single incongruent image. The participants' task was to indicate if all the stimuli were identical or if one stimulus was different. A bias in attentional allocation is indicated based on a faster detection time for this stimulus when presented as a target. For example if participants have a bias for angry faces then it would be predicted that they would find angry faces faster in a crowd of neutral faces rather than a neutral face in a crowd of angry faces.

Experiment 4: Face-in-the-Crowd (6.1)

As with the Visual Dot Probe task, a common use of the Face-in-the-Crowd task is to examine differences between attentional biases for different emotional expressions. The findings of Experiment 2 did not show a difference between a group of individuals with ASD and controls in their conscious search for faces versus non-face objects. The findings of this study indicated that both groups showed a bias for faces compared to non-face stimuli. Previous research (Hansen & Hansen, 1988) has indicated a distinctive search pattern with faces displaying emotional expressions, showing faster search times for angry expressions than neutral or happy ones, although there have been suggestions that this effect might be mediated by anxiety (Gilboa-Schechtman, Foa, & Amir, 1999).

The capacity of individuals with ASD to detect discrepant images based on its affect has been studied far less. Tantum et al. (1989), examined the capability of low functioning autistic and mentally retarded children to differentiate between different types of stimuli. This task involved presenting the child with four photographs and asking them to identify the odd-one-out. This was conducted in two conditions; the emotion condition involved identifying a disparate emotional expression, and the person condition entailed detecting the odd-person-out in the set. While both groups were significantly better at identifying the odd person out than the odd emotion out, autistic children were worse than controls at both tasks, even though they were as good as controls at naming objects. This suggests that autistic children show a deficit in sorting information based on emotional information. Unfortunately, due to the lack of an appropriate non-social control sorting task these conclusions must be tentative.

The above effects have also been examined in high functioning individuals with ASD. Ashwin, Wheelwright and Baron-Cohen, (2006b) utilised a version of the Face-in-the-Crowd task to explore attentional search for faces depicting emotional expressions. Ashwin et al. asked groups of ASD and IQ matched TD controls to identify the odd-one-out from various displays of line drawings depicting angry, happy and neutral faces. Ashwin et al. found that angry faces were found faster than happy faces amongst neutral distracters when presented for either one or two seconds for both groups, and that both groups were slower to search through emotional distracters than neutral ones. Although this study suggests that ASD and TD adults do not differ in their attentional bias for angry facial expressions, the findings need to be considered with caution due to the use of schematic stimuli resulting in reduced ecological validity.

The rationale for the present experiment is to further examine the nature of attentional bias in participants when presented with emotional facial and non-face stimuli. The present study will differ from Experiment 3, which used the Visual Dot Probe to examine the attentional capture by emotional facial expressions, in using the Face-in-the-Crowd task (used in Study Two). The Face-in-the-Crowd task will be used in the present study to examine attentional bias to emotional faces when the participants are consciously controlling their attentional allocation. The examination of this effect will allow greater knowledge to be gained about conscious preference for social and emotional stimuli in individuals with ASD. This is important as faces are usually seen for more than 200ms and with emotional expressions. This experiment will therefore provide more understanding about difference between ASD and TD groups in attentional engagement with emotional expressions. Based on the results of the previous chapters within the present thesis it seems reasonable to predict that control participants will show a bias for faces compared to non-face stimuli, however what is less clear is how the groups will allocate attention towards emotional expression. Based on Experiment 3 it would be predicted that participants with ASD would show a greater bias for emotional expressions, and in particular happy expressions compared to control participants. However the study by Ashwin et al. (2006b) using a similar design to the one employed in this experiment found that both ASD and control participants showed a bias for threat consistent with findings from general population studies (e.g. Hansen & Hansen, 1988).

In the original Hansen and Hansen (1988) study photographic stimuli were used as test stimuli. However, Purcell, Stewart and Skov (1996) suggested that there were confounds in the images and that the effects observed in Hansen and Hansen's study may have been a result of low-level artefacts in the stimuli rather than the emotionality. In response to this most researchers began to use schematic stimuli instead of photographs due to the greater level of experimental control available with these stimuli (e.g. Fox et al., 2000; Horstmann, Scharlau & Ansorge; 2006). This has been suggested to be an overreaction by Horstmann and Bauland (2006), who suggested that this has a negative effect on the ecological validity of the study. Horstmann and Bauland suggested that if sufficient control is taken over the images to ensure that low-level artefacts are controlled for then photographs are appropriate stimuli for this task. In Horstmann and Bauland's study real images of faces which had been digitally altered so that most pixels internal to the face excepting the eyes, nose and mouth were changed to white to eliminate shadowing. Faces were also presented in a standard external frame (the external outline from the happy face). Horstmann and Bauland found that although angry faces were found faster in happy crowds than happy faces in angry crowds this was still consistent with a conscious search through the stimuli. When this experiment was replicated but faces were left in their original frames search appeared to be consistent with pop-out. This suggests that search for angry faces is more efficient than search for happy faces however for pop-out to be achieved some emotional or perceptual information contained within the external part of the face may be necessary.

The hypotheses for the present study are (1) that the ASD and control group will differ in the extent of their attentional bias when presented with faces compared to non-face stimuli (teapots) and (2) that the ASD and control groups will differ in the extent of their attentional bias when each of the emotional expressions is compared to the others.

Method (6.2)

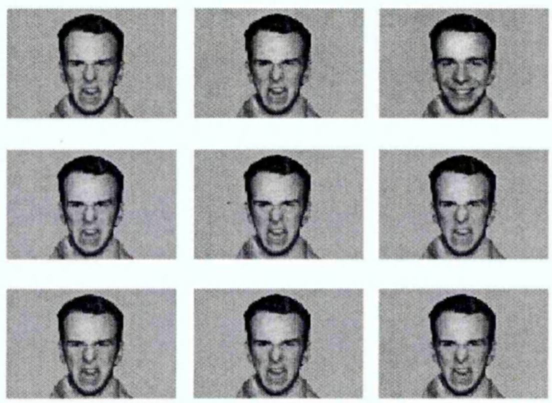
Participants (6.2.1)

Participants in this experiment were the same as those who took part in Study Three: Attentional bias for emotional (angry, happy, neutral) faces and teapots: Visual Dot Probe. Studies Three and Four were conducted at the same time.

Materials (6.2.2)

This task employed the use of a Face-in-the-Crowd task: participants were shown nine images (in a 3X3 matrix). These displays either presented all of the same pictures, or eight pictures the same and one target picture, from a different class (i.e. 8 faces displaying a neutral face and one displaying an angry face; see fig 6.1 for an example). The matrices were presented in a random order with participants giving their responses using keys on a PST model 200a serial response box.

Figure 6.1: Example display for a happy face target-angry face crowd trial in the face-in-the crowd-task (target top right)



The program was designed and run using E-Prime software (Schneider, Eschman and Zuccolotto, 2002) and were displayed on an Iiyama, 19 inch, Vision Master 1451, CRT Monitor at a resolution of 1024 x 768 creating a maximum refresh rate of 118 Hz, and were powered by a Viglen Genie desktop computer with a 1.7GHz Pentium 4 processor and 512Mb of RAM

Stimuli (6.2.3)

Face stimuli were taken from the MacBrain stimuli Tottenham et al. (in press). Actor 24M was used with an open mouthed expression, this was to ensure that the emotion was of maximum intensity to provide the best the chance of observing any effects if they are present. In line with the recommendations of Horstmann and Bauland (2006) that experimental control over photographic stimuli is extremely important to ensure that findings are not altered by low level artefacts in the images, images were altered to standardise them. In the present study an oval containing the central features of the face was removed from the emotional images and Paint-shop Pro was used to place the oval into the frame of a neutral expression. This meant that the decision that an expression was discrepant could only be made based on the internal facial features. Additionally a single image of a teapot was selected to act as a non-social stimulus. All images were presented in monochrome (256 colour greyscale pallet).

A total of 180 displays were presented to participants; of these 108 displays involved an odd-one-out and 72 displays involved all stimuli presented being the same. Of the odd-one-out trials each potential permutation of the displays (e.g. angry face as target neutral face as crowd, neutral face as target angry face as crowd etc) was presented 9 times with the target appearing once in each of the possible locations. On the same trials (i.e. when all photographs are the same) each crowd was presented an equal (18) number of times. Displays were presented in a newly created random order for each participant.

Procedure (6.2.4)

Participants were told that in this experiment they would see nine pictures displayed in a 3x3 grid. They were told that on some trials all 9 of the pictures would be identical and on other trials one picture would be different from the remaining 8 pictures. Participants were shown each stimulus on its own prior to the experiment and told that although all of the faces were of the same person that if eight faces of one emotion were shown with one image of another then this was still an odd-one-out trial. Participants were informed that their task involved indicating, as quickly and accurately as possible, whether all the pictures were the same or if one was an odd-one-out.

Participants were informed that before the main trials they would get 10 practice trials in which they had to perform at 100% accuracy in order to begin the main trials. All participants were able to complete the practice trials with 100% accuracy indicating that they understood the task and were able to perform the task.

Participants indicated their responses by pressing keys marked yes (odd-one-out) and no (all the same) on a PST model 200a serial response box. A 500ms fixation cross preceded the presentation of the test displays which remained on the screen until the participant made a response. An inter-stimulus-interval (ISI) of 500ms was introduced before the start of the next trial.

Results (6.3)

Reaction times were recorded for all experimental trials (practice trials were discarded). Data was then screened to exclude all incorrect responses and all reaction times less than 200ms (anticipatory responses; used by Bradley, Mogg & Lee, 1997). There were no significant differences between groups in number of errors (error data is presented in appendix 12). Individual participant median values were taken for each repeated measures condition within the experiment. Median values were used to reduce the influence of the positive skew often observed in reaction time studies (e.g. Bindemann et al., 2007; Langton & Bruce; 1999). To test the main hypotheses mean reaction times for each of the ASD and control groups were calculated for each condition (See table 6.1 for means). A series of analyses were conducted on the data.

Table 6.1: Means & standard deviations for reaction times (msec) on the Face-in-the-Crowd task in the ASD and control groups

Target	*Angry*	*Angry*	*Angry*	*Angry*	*Happy*	*Happy*	*Happy*	*Happy*	*Neutral*	*Neutral*	*Neutral*	*Neutral*	*Teapot*	*Teapot*	*Teapot*	*Te*
Distracter	*Angry*	*Happy*	*Neutral*	*Teapot*	*Angry*	*Happy*	*Neutral*	*Teapot*	*Angry*	*Happy*	*Neutral*	*Teapot*	*Angry*	*Happy*	*Neutral*	*Te*
ASD RT	2815.17	2089.50	2050.61	803.75	2143.69	2863.89	2208.50	779.67	2006.56	2204.44	2623.56	845.67	792.78	760.17	751.17	9
ASD SD	888.36	333.66	422.00	225.20	453.78	859.03	507.57	163.35	392.58	638.68	638.30	380.26	195.92	163.31	147.26	5
Control RT	2544.74	1748.57	1902.26	710.10	1858.87	2498.76	2006.99	743.70	1810.88	1790.32	2373.61	759.36	682.01	704.87	705.13	8
Control SD	545.25	448.21	496.27	157.95	452.36	584.10	489.39	175.56	363.03	393.17	584.04	209.13	109.91	135.63	184.87	1
Difference (ASD-Control)	270.43	340.93	148.35	93.65	284.82	365.13	201.51	35.97	195.68	414.12	249.95	86.31	110.77	55.3	46.04	15

Data was checked to ensure that it met with parametric assumptions. The distribution was found to be positively skewed in the ASD group for all angry trials, neutral target-teapot distracter trials, teapot target-happy distracter trials, and all teapot trials. Data was therefore subjected to an inverse transformation (Tabachnick & Fidell, 1997), which corrected for the skewedness (all skewedness values between -2.56 and 2.56; Clark Carter, 2004). Transformed data was then examined for outliers (participants mean scores greater than three standard deviations about the group mean; Stevens, 1996). Transformed data showed no outlying data points. An examination of variances revealed that these were approximately homogenous.

Retesting the hypothesis from Study One (6.3.1)

To retest the hypothesis that ASD and TD control groups would differ on their attentional bias for faces when compared to non face stimuli, composite scores were calculated for each presentation of a face (irrespective of emotion) compared to teapots. To assess whether participants showed a bias for finding faces faster than non-faces, target present data was initially entered into a 2 (Diagnosis: ASD Vs control) X 2 (face role: face as target Vs face as distracter) mixed design ANOVA. This revealed non-significant main effects of diagnosis $F(1,34)=2.802$, $p=.103$ and face role $F(1,34)=3.326$, $p=.077$ and a non-significant interaction between diagnosis and face role $F(1,34)=.205$, $p=653$.

Emotion (6.3.2)

To test the hypothesis that ASD and control groups would have different attentional biases for emotional faces compared to non-emotional stimuli angry and happy faces were combined in comparison to neutral faces (e.g. happy target-neutral crowd and angry target neutral crowd were combined to become emotional target neutral crowd). This was entered into a 2 (Diagnosis; ASD Vs Control) x 2 (emotional face role; Target Vs Distracter) mixed design ANOVA. This revealed trends towards significant main effects of diagnosis $F(1,34)=2.955$, $p=.095$ and emotional face role $F(1,34)=3.510$, $p=.070$. These effects were consistent with the control group being faster than the ASD group to discriminate between emotional faces and neutral faces and all participants being faster to respond to neutral face targets in emotional face crowds than finding emotional face targets in neutral face crowds. There was however no significant interaction between diagnosis and face role $F(1,34)=.517$, $p=.470$.

Individual comparisons (6.3.3)

To examine whether the groups differed in their attentional bias to any specific stimulus class compared to others (e.g. a bias for angry faces compared to happy faces) a series of mixed designed ANOVAs was performed. Each stimulus class was paired with each other stimulus type and these were entered into a number of 2 (diagnosis; ASD Vs Control) X 2 (Target role; target Vs Distracter) mixed design ANOVAs. For the purposes of the analysis the 'stronger emotion' (i.e. the emotion that past literature suggests most likely to capture attention will be called the 'target' however the analysis is able to detect bias towards either stimulus: The order of this is: angry, happy, neutral, teapot).

For angry faces Vs happy faces there was a significant main effect of diagnosis $F(1,34)=8.230$, $p=.007$ consistent with controls being generally faster across all trials. There was no significant main effect of target role $F(1,34)=1.044$, $p=.314$ and no diagnosis x target role interaction $F(1,34)=.468$, $p=.499$.

For angry faces Vs neutral faces there were no significant main effects of diagnosis $F(1,34)=2.106$, $p=.156$ or target role $F(1,34)=.488$, $p=.490$ and no significant interaction between diagnosis and target role $F(1,34)=.000$, $p=1.000$.

For angry faces Vs teapots there was a trend towards a main effect of diagnosis $F(1,34)=4.067$, $p=.052$ consistent with control participants being faster to discriminate between angry faces and teapots. There was no significant main effects of target role $F(1,34)=.667$, $p=.420$ and no significant interaction between diagnosis and target role $F(1,34)=.344$, $p=.562$.

For happy faces Vs neutral faces there was no significant main effect of diagnosis $F(1,34)=3.113$, $p=.087$. However there was a significant main effect of target role $F(1,34)=4.679$, $p=.038$ this was consistent with neutral faces being found in happy displays faster than happy faces among neutral distracters. The interaction between diagnosis and target role was not significant $F(1,34)=1.220$, $p=.277$.

For happy faces Vs teapots there were no significant main effects of diagnosis $F(1,34)=1.606$, $p=.214$ or target role $F(1,34)=1.372$, $p=.250$ and no significant interaction between diagnosis and target role $F(1,34)=.144$, $p=.707$.

For happy faces Vs teapots there were no significant main effects of diagnosis $F(1,34)=1.606$, $p=.214$ or target role $F(1,34)=1.372$, $p=.250$ and not significant interaction between diagnosis and target role $F(1,34)=.144$, $p=.707$.

For neutral faces Vs teapots there were no significant main effects of diagnosis $F(1,34)=1.773$, $p=.192$ or target role $F(1,34)=2.318$, $p=.137$ and not significant interaction between diagnosis and target role $F(1,34)=.010$, $p=.922$.

Target absent analysis (6.3.4)

As stated in Chapter 4, Hansen and Hansen (1988) and Gilboa-Schechtman, Foa, and Amir (1999) suggested that by comparing target absent trials we can infer whether participants showed any difficulty in disengaging from a particular stimulus class (a difficulty in disengaging from a stimulus class would be indicated by longer search times for those stimuli compared to others). Data was therefore entered into a 2 (diagnosis: ASD Vs Control) x 4 (emotion: all angry Vs all happy Vs all neutral Vs teapots). An examination of Mauchly's test of sphericity revealed that this assumption had been violated ($p<.001$), therefore the Greenhouse-Geisser adjustment is reported. This revealed no significant main effect of diagnosis $F(1,34)=1.335$, $p=.256$ and no interaction between diagnosis and emotion $F(1.106, 37.618)=.446$, $p=.528$. There was however a significant main effect of emotion $F(1.106, 37.618)=430.786$, $p<.001$. This effect was explored further using pairwise comparisons with a Sidak adjustment. This revealed that participants responded to all teapot displays significantly quicker than angry ($p<.001$), happy ($p<.001$) or neutral faces ($p<.001$). When comparing the search times through various all face displays it appears that all neutral displays are searched through faster than either happy ($P=.009$) or angry displays ($p=.005$) however there was no significant difference between search times for all angry and all happy displays ($p=.984$).

Summary of target present analysis (6.3.5)

The analyses presented above reveal that neither the ASD or control group showed a bias for faces compared to teapots in either the combined analysis or the individual analyses. Additionally emotional faces were not found faster amongst non-emotional distracters than non-emotional targets amongst emotional distracters. The only significant bias observed in the above analysis was towards neutral faces when happy faces were used as distracters. An additional significant effect was that ASD participants were significantly slower than the control group to search through displays containing angry and happy faces.

Discussion (6.4)

The findings of the present study reveal that unlike in the previous experiments neither group of participants showed a bias for faces compared to non-social stimuli. There was also a trend towards an attentional bias for neutral faces compared to a composite measure of emotional faces which was present in both groups. When examining the individual comparisons between the stimuli groups the only bias observed was for neutral faces compared to happy faces, and this was present in both groups, all other comparisons between emotions were non-significant. The only other significant main effects were main effect of diagnosis in the angry face Vs happy face and trends towards the ASD group being slower to respond to emotional face Vs neutral faces and angry face Vs teapot trials. These indicated that the ASD group took significantly longer than controls to differentiate between angry faces and distracters. An examination of target absent trials partially supports the idea that emotional stimuli require longer examination durations as searching though all angry or all happy displays took significantly longer than searching through all neutral displays. Unsurprisingly searching through all teapot displays was significantly faster than any of the all face displays, given that these stimuli were so much more distinct than the face stimuli.

This study therefore failed to replicate the findings of Study Two (Chapter 4) that face stimuli capture attention preferentially to non-face stimuli when engaging in a conscious search task. Although Experiments 2 and 4 were extremely similar, with participants being instructed to perform the same odd-one-out task and presentation of stimuli being held constant in a 3x3 grid there were other differences. One change in design which may explain the lack of any bias for any of the facial expressions over the teapot relates to the novelty of the stimuli. Given how similar the facial expressions were the teapot was a highly novel and visual distinct (in comparison to the homogonous face stimuli) stimulus only presented on one in four displays. Evidence from the visual oddball task (In which both common and rare stimuli are presented to participants and the task is to respond to the rare stimuli) indicates that a novel stimulus will tend to occupy more attention than a repeated one (Campanella et al., 2002). Therefore, one potential explanation for the present study's findings is that the novelty of the presentation of the teapots disrupted the attentional capture by the faces. This is supported by the observation that, although non-significant, not only did none of the facial expressions capture attention over the teapots but in fact the teapots were detected faster as targets among face displays than face targets among teapot displays. Additionally, if the task is being performed in terms of participant's performance on perceptual discrimination of the stimuli then it may be that a bias for teapots was seen as they were the most visual distinct. Although this problem may explain these findings with retrospect there was no reason to suspect this problem before the commission of the research and the process of designing this out of the task would have involved a much longer task which would not have been pragmatic.

The present study also failed to replicate the findings of Study Three in showing that participants with ASD showed a bias for emotional stimuli over neutral faces. It is possible that the added task difficulty of using highly similar stimuli impaired task performance particularly in the group with ASD. The Face-in-the-Crowd task can be argued to rely on a number of executive demands such as shifting set and updating task demands given that the task is to continually change the target of the search task. Given that individuals with ASD have been shown to be impaired on set shifting compared to TD controls (Ozonoff & Jensen, 1999) it is possible that this would have especially negative consequences for their performance. There are however problems with this explanation, individuals with ASD have been shown to perform well on visual search tasks, which involved finding predetermined target letters among irrelevant distracters (O'Riordan, 2004), and finding the location of embedded figures in larger displays (Shah & Frith, 1993).

The present study also failed to replicate the findings of Ashwin, Wheelwright and Baron-Cohen, (2006b) using a very similar Face-in-the-Crowd task. In Ashwin et al.'s task participants were shown line drawings depicting angry, happy and neutral facial expressions. These were presented in various display sizes and as in the present study participants were asked to indicate if one stimulus was an odd-one-out. Ashwin et al. found that both participants with ASD and controls found angry targets faster among non-angry (happy or neutral) distracters than non-angry targets among angry distracters. In the present study however the only bias observed was for neutral faces amongst happy distracters. The most obvious difference between the two studies is that the present study used photographs of facial expressions whereas Ashwin et al. used line drawings of faces. It is possible that although the clearly presented line drawings with prototypical indicators of anger were able to preferentially capture attention, the more naturalistic and complex stimuli are unable to replicate this effect.

Given the evidence from the previous literature, the bias that both groups showed for neutral faces over happy faces is unexpected. There are two possible explanations for this finding: one is that the neutral expressions were interpreted as a negative or threat stimulus, as it is possible that a forward staring face displaying no emotional expression could represent a negative social cue. This however seems unlikely to provide a full explanation given that a bias was not seen for the angry faces. Therefore if this is the explanation for this finding it seems likely that it might be seen to relate to levels of social anxiety in the population. Because of this it is important to examine the role that individual variables might play in the bias observed in the present studies. This will be examined in the following chapter. The second explanation is that because the external frame on which the emotional expressions were superimposed were taken from the neutral face in the present study that the neutral face was the most 'natural' of the facial expressions and therefore was more likely to capture attention. Again, this seems unlikely to be the entire explanation as the stimuli were prepared with great care and did not have any features that made them obviously altered (see figure 6.1 for sample stimuli).

The finding that participants with ASD spent significantly longer than controls identifying odd-ones-out on trials involving angry and happy stimuli indicates that they appeared to find it harder to differentiate between emotional expressions. This supports the findings of Tantum, Monaghan, Nicholson and Stirling (1989), which showed that children with ASD and associated intellectual delay were impaired at identifying which of four images was an odd-one-out especially when this was based on emotional expression. This finding also fits with a large body of literature which suggests that individuals with ASD may be impaired in differentiating emotional expressions (e.g. Braverman, Fein, Lucci, & Waterhouse, 1989; Hobson, 1986). Although some have suggested that the processing of emotional facial expressions in high functioning adults is similar to typical controls (Humphreys, Minshew, Leonard, & Behrmann, 2007) this development of these processes might be delayed in individuals with ASD. It is possible that although high functioning adults with ASD are able to perform the identification of some emotions presented in isolation with relatively low task demands that this process is slowed and not automatic as expected in typical development (Vuilleumier et al., 2001). There is however a problem with this interpretation as there was a trend towards the ASD group also being slower to respond to emotional face Vs neutral face trials and angry face Vs teapot trials. The trend towards the ASD group being slower not only on discriminating between emotional faces but also trials including teapots suggests that this result may also relate to a general slowing of response rather than a specific emotion processing deficit.

The idea that the processing of emotional expressions is slowed compared to neutral faces does however receive some support from the finding that on the target absent trials all angry and all happy trials were responded to slower than all neutral trials. This analysis does not provide full support for the above point however as a slowed response to emotional displays on these trials was observed in both the ASD and control groups. It is possible therefore that emotional expressions afford greater attentional resources than neutral expressions in all individuals under some conditions

(Calvo & Esteves, 2005). It seems reasonable to conclude that although in all individuals emotional stimuli occupy greater attentional resources it is specific to ASD that this is a result of a difficulty in emotional discrimination.

The absence of an anger bias effect in the control group has additional implications for the normative literature. Since Hansen and Hansen (1988) conducted their original examination of the Face-in-the-Crowd effect a bias for threat stimuli has been consistently found in the general population. This is been consistently shown with both photographs (Hansen & Hansen, 1988; Gilboa-Schechtman, Foa, & Amir, 1999) as well as with schematic face stimuli (e.g. Fox et al., 2000). Although Purcell, Stewart and Skov (1996) have raised concern about the use of photographic stimuli, suggesting that biases may be a result of low level features of the stimuli, Horstmann and Bauland (2006) found that all but the internal features of the emotional faces could be held constant and the biases could still be observed. The present study has failed to replicate Horstmann and Bauland's findings using a similar level of experimental control over the external features of the stimuli. This indicates that a substantial part of the biases observed in previous research on general population may be a result of either the low-level features of the stimuli or the clarity of the line drawings used. It therefore is important for future research to consider these low-level effects when conducting similar research and address these issues when considering bias for threat stimuli.

Future research using both clinical and typical populations needs to consider some of the concerns raised in the present study. These include the novelty of stimuli used. If as suggested in the visual-odd-ball task a novel stimulus will capture attention above others then the number of stimuli that can be said to belong to any particular 'class' of objects need to be held constant (i.e. in Study Two, Chapter 4, an equal number of houses, cars and faces were used however arguably three times more faces were used in the present study than teapots). In addition to this these effects need to be re-examined taking into consideration the level of experimental control over the contents of the stimuli to understand under precisely what circumstances these effects are observed.

Chapter 7

Exploring individual variation in scores

Chapter overview (7.1)

The previous chapters contained within this thesis have not provided conclusive findings relating to the attentional biases of individuals with ASD (or those without) for social and emotional facial expressions. Studies One and Three supported the proposition that individuals with ASD would show a reduced social bias compared to TD controls, as opposed to Studies Two and Four which indicated no differences. The following chapter therefore is designed to examine this data in more depth. This chapter will begin by exploring the reliability of the measures used and the consistency of participants' performance across the studies. This will be performed by first correlating participants' bias for face stimuli across the 4 studies and then examining participants biases on an individual level to see if a participant who showed attentional bias for faces in one study also showed this bias in others. This chapter continues by beginning to explore how the biases observed in participants might relate to individual differences variables. This will first be achieved by using psychometric variables to attempt to predict participants' bias scores in a group based multiple regression. Again participant's data will then be examined on an individual level to see if sub-groups with different attentional bias profiles might exist and if these groups can be classified based on their psychometric scores.

Introduction (7.2)

Consistency of bias (7.2.1)

The findings of the four studies conducted during this research indicate a mixed pattern of results. One explanation for the lack of consistency in the findings in the present thesis is that the tasks used do not reliably measure attentional bias. In a recent study Schmukle (2005) examined the reliability of the Visual Dot Probe. All measures of reliability were found to be low. It is therefore possible that these inconsistencies might, in part, relate to a low reliability of the Visual Dot Probe and Face-in-the-Crowd tasks. Within the present chapter the consistency of participants' biases will be examined to test whether bias was reliable across participants. It does however seem unlikely that the reliability of the task is as low as reported by Schmukle given the number of studies that have suggested that attentional biases on the Visual Dot Probe task can differentiate between groups in a theoretically relevant way. There were also a number of problems with Schmukle's study. Firstly, the tasks used for the test-retest statistics were different (with one using images and the other using words) and therefore cannot be considered to really be testing test-retest reliability. Secondly, when images were used these were of positive and negative valenced images but not necessarily 'threat' and therefore do not test the reliability of the dot probe in its original form. Finally, the measure of Cronbach's Alpha was calculated by separate bias for each quarter of the trials and looking for consistency within these. This assumes that for each participant each quarter of the trials would relate in the same degree of attentional capture, which is not necessarily the case. Given that only a single study has questioned the reliability of the Visual Dot Probe task, and there are a number of flaws with this study it seems premature to reject this task as unreliable. However it seems prudent to examine the consistency of the biases observed in this thesis in light of Schmukle's findings.

Subgroups in ASD (7.2.2)

The second aim of the present analysis is to address the performance of individual sub groups of participants and which psychometric variables might relate to the performance of these groups. ASD is a heterogeneous class of disorders with a great deal of variation between individuals' presentations. The findings from the previous experiments indicate that the picture of social attention in ASD is not conclusive. It is therefore important to examine what other variables might relate to the biases in the previous studies.

This has been supported by research in a number of areas, which suggest that autism may not be a unitary condition. Factor analytic studies of screening and diagnostic measures of ASD have indicated that individuals can independently vary on between three and six independent factors within diagnostic criteria for ASD (e.g. Miranda-Linne & Melin 2002; Lecavalier, 2005; van Lang et al., 2006). Additionally recent genetic findings indicates that different loci may explain presentations of the social deficit in ASD (e.g. Lijam et al., 1997; Brune et al. 2006) and that these may be distinct from the non-social aspects (e.g. Gharani et al., 2005). Additionally low correlations between cognitive measures used to examine the core cognitive deficits in ASD suggest that the cognitive presentation of an individual on the spectrum may vary from person to person (e.g. Ozenoff et al. 1991; Happé, 1994, 1997).

It has been shown in a variety of previous studies that a small percentage of individuals with ASD are able to pass standard tasks that are argued to tap into cognitive abilities that are typically associated with deficits in this population. For example in Baron-Cohen, Leslie and Frith's (1985) seminal paper on Theory of Mind in ASD 20% of participants were able to pass the Sally-Ann false belief task. Baron-Cohen (1989) claimed that although these individuals manage to 'hammer out' an answer to these standard or first order ToM tasks they cannot answer more complex second order ToM tasks. Baron-Cohen demonstrated individuals who passed the Sally-Ann task failed more complex, second order ToM tasks. It does however need to be considered that this 20% may reflect a sub-group who have some Theory of Mind abilities and that this sub-grouping might be seen in other designs. An analysis of individual cases is therefore advised within the ASD population as crude group level analyses may be masking the performance of individual cases.

The importance of this phenotypic sub-typing can be seen in a number of developments in autism research. Amaral (2005) proposed that a number of cognitive phenotypes might be present in ASD and that by examining the correlation between cognitive, biological, behavioural, genetic, neurological, and environmental factors will allow for the presentation of these subtypes to be identified. Examining subgroups within the autistic population has also begun to be considered within the broader research literature on autism (e.g. Heaton, Williams, Cummins & Happé, 2008).

There is also a historical basis to the idea of sub grouping individuals with ASD. Wing and Attwood (1987) suggested that the social deficit in autism should be understood under 3 distinctive labels and subtypes. Wing and Attwood believed that although the autistic child may display all 3 behaviours that they could still be regarded as a particular type based on their predominant behaviour. These were the aloof or avoidant child, the passive or avoidant child and the active but odd child, who would make social approach but in an inappropriate way. Based on Wing and Attwood's suggestion that subgroups exist in the social presentation on ASD it is possible that if participant's data are analysed separately different groups will be found. These would reflect those who show social avoidance, social ambivalence and social approach.

Variables which might relate to attentional bias (7.2.3)

During the studies contained in this thesis, various psychometric measurements were administered to participants which have been shown to relate to attentional bias in previous research or that have a sound theoretical basis to be associated with any bias in attention. The first of these potential relationships is to the severity of the individual's ASD. This was measured by their score on the Autism Quotient (AQ; Baron Cohen et al., 2001). Although this can only provide an approximate measure of diagnostic severity it has been shown to differentiate well between those with and without an existing diagnosis of ASD (Baron Cohen et al., 2001) and be effective as a predictor of

ASD when used as a screener questionnaire (Woodbury-Smith, Robinson, Wheelwright & Baron-Cohen, 2005). It will be of interest to test whether severity of autistic symptoms relates to social attention as Klin et al. (2002b) found that participants with ASD who showed greater autistic symptomology also attended more to objects compared to people during an eye tracking study. In addition to this Ashwin et al. (2006a; b) have examined attentional bias in ASD for faces with emotional expressions using the Stroop and Face-in-the-Crowd tasks and indicated that adults with ASD have an attentional bias for faces. These findings are at odds with the Visual Dot Probe Task findings of this thesis, although the Face-in-the-Crowd used in this thesis did suggest no difference between ASD and TD participants in social attention. However, Ashwin et al. were not able to examine the role that levels of anxiety had in relation to the biases they observed.

The traditional use of the Visual Dot Probe and Face-in-the-Crowd tasks has been to examine if threatening facial expression capture attention differently in individuals with different levels of anxiety (e.g. Bradley et al., 1998; Mogg & Bradley, 1999b). It therefore is relevant to examine the role that general anxiety may play in the attentional capture of faces especially as anxiety has been suggested to be elevated in many individuals with ASD (Kim et al., 2000; see Chapter 2 for a more comprehensive discussion). In addition to general anxiety a more pertinent form of anxiety, social anxiety, has been shown to be elevated in ASD (Bellini, 2004; 2006). Social anxiety is also associated with attentional bias for social threat words in the emotional Stroop task (Maidenberg et al., 1996) and the Visual Dot Probe task (Asmundson & Stein, 1994) and for angry faces in the Visual Dot Probe (Mogg & Bradley, 2002) and Face-in-the-Crowd tasks (Gilboa-Shechtman, Foa & Amir, 1999). No studies examining the role of anxiety on attentional or social cognitive performance in ASD populations have been identified. Therefore, this might provide additional understanding about the performance of this population. As there are presently no appropriate measures of anxiety which can be used with high functioning adults with ASD the Spielberger State-

Trait Anxiety Inventory (STAI; Spielberger, 1983), Fear of Negative Evaluation scale (FNES, and Social Avoidance and Distress (SADS; Watson & Friend, 1969) were used to measure anxiety. These have been frequently used to measure anxiety to predict attentional bias to threat stimuli in the typical population (e.g. Bradley et al., 1998).

The rationale for the present analysis is twofold; first, to explore the consistency of the data related to bias for faces collected throughout the completion of the thesis to examine the consistency of the results. Secondly, to address whether attentional bias towards any class of stimuli related to a number of psychometric measures collected throughout the research. This is important as previous research has indicated that anxiety relates to attentional biases for threat stimuli (Asmundson & Stein, 1994; Mogg & Bradley, 1999a; b) and there is good reason to think that autistic symptomology and IQ might relate to attentional bias for face stimuli. Additionally this is important to examine for cognitive subtypes in ASD.

As the present chapter seeks to examine the individual variation in participants' biases no clear hypothesis are set due to the exploratory nature of the analysis.

Methods (7.3)

Participants (7.3.1)

In the present thesis the same participants were used for all phases of the research where possible. Nineteen ASD and 19 age and IQ matched controls were recruited in the first phase of this thesis. Of these participants 18 of the ASD group were retained for the second phase of testing and no further ASD participants were recruited. For the control group 16 of the participants from Studies One and Two where retained for Studies Three and Four. As the control group was reduced to 16 for the second phase of the research two new participants were recruited to keep the groups the same size. For this reason in the ASD group there is only a single participant who has not completed the whole program of research whereas there are three members of the control group for whom a complete data set is unavailable. The strength of having conducted this program of research with a single population is that it reduces the amount of within participants variation. By conducting the research with a single population this has also allowed for the consistency of the participants bias to be generated and for sub-group to be examined within the sample.

Materials (7.3.2)

Data from four scales was collected during the experimental research contained within this thesis. Data from the AQ was collected during the screening phase of the research and the STAI was collected during all four experiments. In addition during Studies Three and Four (Visual Dot Probe and Face-in-the-Crowd, respectively, using emotional faces) measures of social anxiety were also collected.

State-Trait Anxiety Inventory (STAI) (7.3.2.1)

The STAI (Spielberger, 1983) is one of the most commonly used measures of anxiety in the general population for research purposes. The STAI can be used to measure a person's level of trait anxiety (general level of anxiety) or their state anxiety (level of anxiety at a set time), in this study the STAI was used as a measure of state anxiety. The STAI is a twenty item self report measure of anxiety in which the participant is asked to indicate the extent to which they agree with each statement on a four point scale from 'not at all' to 'very much so'. Questions are both positive, e.g. 'I feel calm' and negative ' I feel frightened'. The range of potential scores is between 20 and 80 with higher scores indicating higher anxiety. The state component of the STAI has been shown to have good internal reliability (alpha between.84 and .95; Cronbach, 1951) although test retest reliability is low (.27-.62; Spielberger, 1983) this is to be expected on a state measure. There are no known papers using the STAI in an ASD population, it is therefore possible that scores may lack validity with this scale, particularly in light of concerns about self report of affect in individuals with ASD.

Fear of Negative Evaluation scale (FNES) (7.3.2.2)

The FNES (Watson & Friend, 1969) is a 30 item self evaluation measure related to social anxiety. The FNES asks participants to indicate if a series of statements are true or false of them e.g. 'I worry a lot about what my superior's think of me'. The range of potential scores on the FNES is 0-30 with a higher score indicating higher levels of social anxiety. The FNES has been shown to be reliable with a mean bi-serial correlation of each item to the scale of .72 and a test-retest reliability of between .78 and .94 (Watson & Friend, 1969). There are no known papers using the FNES in an ASD population, again raising questions about the validity of asking ASD individuals about affect.

Social Avoidance and Distress (SADS) (7.3.2.3)

The SADS (Watson & Friend, 1969) is a 28 item self evaluation measure related to social anxiety. The SADS asks participants to indicate if a series of statements are true or false of them e.g. 'I try to avoid situations that force me to be sociable'. The range of potential scores on the SADS is 0-28 with a higher score indicating higher levels of social anxiety. The SADS has been shown to be reliable with a mean bi-serial correlation of each item to the scale of .77 and a test-retest reliability of between .68 and .79 (Watson & Friend, 1969). There are no known papers using the SADS in an ASD population.

Autism Quotient (AQ) (7.3.2.4)

The AQ (Baron Cohen et al., 2001) is a 50 item questionnaire consisting of ten questions on each of the three areas on which autism is diagnosed (Social, Communication, and Imagination) as well as ten questions on attentional switching and ten on attention to detail. Approximately half of the items on the AQ reflect autistic traits e.g. (I am fascinated by dates), agreeing with these items scores one point (no difference is made between strongly agreeing with a statement and agreeing with a statement). On the other half disagreement with the statement reflects an autistic trait (e.g. I find social situations easy). Scoring of the AQ involves associating a score of one to each item on which participants indicate autistic symptomology on. A score of one is given whether participants indicate that they just (dis)agree or strongly (dis)agree.

Analysis (7.4)

To allow for the individual variation in the data to be explored bias indices were calculated. For the Visual Dot Probe scores were created for each stimulus pairing at each presentation duration using a formula proposed by Mathews, MacLeod and Tata (1986).

(target top & probe top +target bottom & probe bottom – target top & probe bottom – target bottom & probe top)/2.

The above formula works by subtracting target incongruent presentations (e.g. target top & probe bottom) from target congruent presentations. Therefore, biases towards target stimuli are indicated by negative bias scores. The purpose of calculating bias scores is to provide a single data point for each comparison. This allows for a measure of participants bias to be compared to various other measures. Bias scores have been used to assess the relationship between attentional bias and anxiety in a number of previous studies (Bradley, Mogg, Falla & Hamilton, 1998; Mogg & Bradley, 2002).

For the Face-in-the-Crowd task no pre-existing bias index formula has been published, because of this the mathematical principles of the formula proposed by Mathews, MacLeod and Tata were used as a guide to create the following formula:

(S_1 Target & S_2 distracter – S_2 Target S_1 distracter) / 2

Where

S_1= the stimulus expected to capture attention (face or most expressive facial expression)

S_2= a comparison stimulus.

The principles are the same as in the dot probe, of subtracting 'incongruent' trials from 'congruent ones'. Therefore, as above, a negative bias score indicates a bias for face stimuli. Although this formula has not previously been used to examine attentional bias in the Face-in-the-Crowd task the mathematical principles are the same as for the Visual Dot Probe bias scores and should therefore be reliable. Additionally the Face-in-the-Crowd task has typically been used to show a bias for threat faces in the general population (e.g. Hansen & Hansen, 1988) without taking into consideration if these effects vary as a result of psychometric variables. The reason for the use of the bias scores in the Visual Dot Probe is to examine the role of anxiety in attentional bias, given that these effects have not been examined frequently in the Face-in-the-Crowd task it is unsurprising that an existing bias score formula has not been developed.

A number of comparisons will be made in the present analysis: Initially the patterns of participant's biases across the studies will be examined (where possible) to see whether participants who show social bias in one experiment continue to show this throughout the thesis and if separate groups might emerge from this. An exploration of the levels of anxiety in each of the groups will allow for a comparison with past research that has indicated elevated anxiety levels in ASD (Bellini, 2004; Kim et al., 2000). The relationship between anxiety and bias scores/ groups will then allow for the role of anxiety to be considered in relation to these variables.

Results (7.5)

Table 7.1: To show the mean bias scores (and standard deviations) for the ASD and control groups for each of the four studies of this thesis. Negative scores indicate a bias for faces.

Study	*Study 1*	*Study 2*	*Study 3*	*Study 4*
ASD	2.86 (31.99)	-20.62 (70.61)	-2.28 (18.30)	8.33 (38.21)
Control	-13.94 (23.35)	-15.35 (22.25)	-6.55 (13.94)	17.63 (68.03)

An examination of bias scores across the four studies indicates that the control group showed a bias for face stimuli in the first three studies however their attention appeared to be away from faces in Study Four. The ASD group however showed an overall bias for faces in Studies Two and Three but away from faces in Study One and Four. An examination of the bias scores appears to support the findings throughout the thesis that the ASD group showed a bias for face stimuli when under conscious control of attention in Study Two but that bias was very close to 0 when attentional capture was automatic. By comparison the control group showed a more consistent pattern of attentional bias for faces across the first three studies. In Study Four both ASD and control participants showed a bias away from faces, as was discussed in the previous chapter there were methodological differences in this study which might have contributed to this difference.

Consistency of bias (7.5.1)

As the standard deviations of participant's biases suggest there was a lot of variation in participant's attentional biases. This indicates that within the groups there was a lot of variation in performance, however what is not clear is if there is a wide variation in performance within individual participant's biases. To examine the consistency of participant's biases to faces Vs non-face objects throughout the four studies within the thesis a number of bivariate correlations (Pearson's product moment coefficient and Spearman's Rho, where appropriate) were run. Bias scores were calculated for each participant for each comparison based on the formulae above. The bias scores considered in the following analysis are bias for faces compared to non-face stimuli.

Pearson's product moment coefficient revealed no significant relationships between the overall biases for faces in Study One and either Study Three r(n34)=.245, p=.162, or Study Four r(n34)=-.027, p=.878. There was also no significant relationship between the bias for faces in Study Three and Study Four r(n36)=-.015, p=.930. In addition to this Spearman's Rho correlations revealed no significant correlations between bias for faces in Study Two and Studies One r(n38)=.193, p=.247, Two r(n34)=.129, p=.469 and Four r(n34)=-.127, p=.473.

When the correlations are run separately for each group differing patterns of correlations were found. For the control group there was a trend towards a positive correlation between biases for faces on the two dot probe tasks (Studies One and Three) r(n16)=.477, p=.062 indicating that 22.75% of the variance in bias scores for the dot probe tasks is shared. There was also a weak non-significant positive correlation between the bias for faces in the Visual Dot Probe using faces and non-faces and the equivalent Face-in-the-Crowd task (Studies One and Two) r(n19)=.321, p=.180. The correlation between face bias in Studies Two and Three was also weak and positive r(n16)=.279, p=.295. Bias for faces in Study Four however showed almost no correlation with any of the other face biases; Study One r(n16)=-.026, p=.924, Study Two r(n16)=-.124, p=.649, and Study Three r(n18)=.047, p=.853.

The ASD group however showed almost no correlations between any two bias scores; Study One and Two r(n19)=-.049, Study One and Three r(n18)=.098, p=.698, p=.842 Study One and Four r(n18)=.018, p=.943, Study Two and Three r(n19)=.005, p=.984, Study Two and Four r(n18)=-.051, p=.842, Study Three and Four r(n18)=-.073, p=.772.

The above analysis indicates that when the groups were considered together there were no significant correlations between any two sets of bias scores. This indicates that the reliability of the Visual Dot Probe and Face-in-the-Crowd tasks is quite poor. The Visual Dot Probe task however did show greater reliability, although not exceptionally good, when examined in the control group alone, with a moderate positive correlation between biases for faces on these two tasks. In comparison there appeared to be almost no consistency in the performance of the ASD group.

Consistency of bias in individual cases (7.5.2)

Although the correlations did not indicate a good relationship in the extent of participants' bias to faces across the four studies in the current thesis it is also of interest whether participants who showed a bias for faces in one study also showed this in other studies. Due to the methodological problems (i.e. the distinctiveness of the teapots potentially interrupting any bias for faces) with Study Four (emotional Face-in-the-Crowd) causing an inconsistency with the findings of the remaining studies this was excluded from these examinations to facilitate the clarity of the analysis. Figure 7.1 shows the bias for faces shown by the ASD group where as Figure 7.2 shows control participants' performance. As indicated before negative scores are indicative of biases for faces and positive scores show attentional bias away from faces.

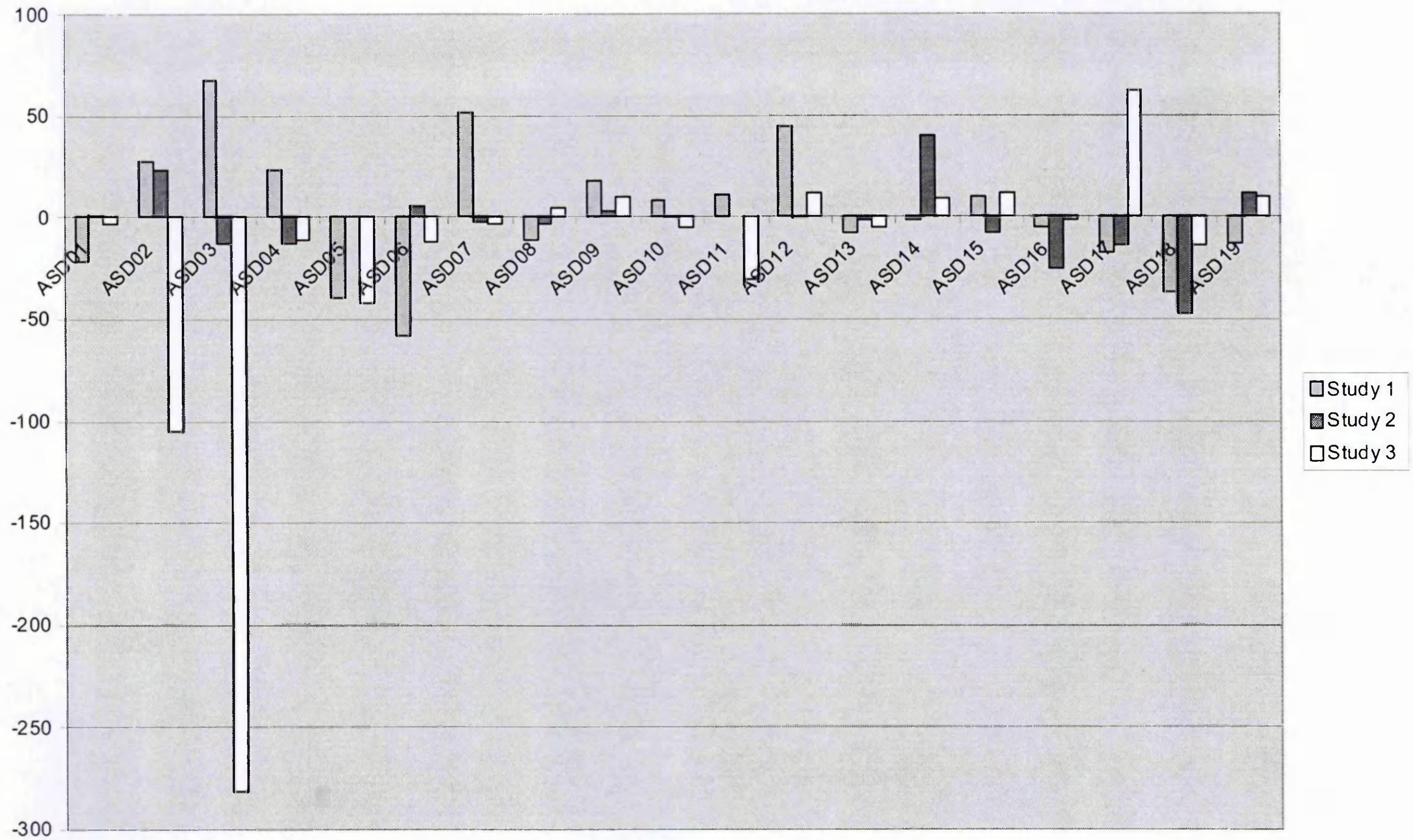


Figure 7.1: Bias for face stimuli compared to non-face stimuli across Studies One, Two and Three (Visual Dot Probe and Face-in-the-Crowd with neutral faces, cars & houses and Visual Dot Probe with emotional faces) in the ASD group. Negative scores indicate a bias for faces.

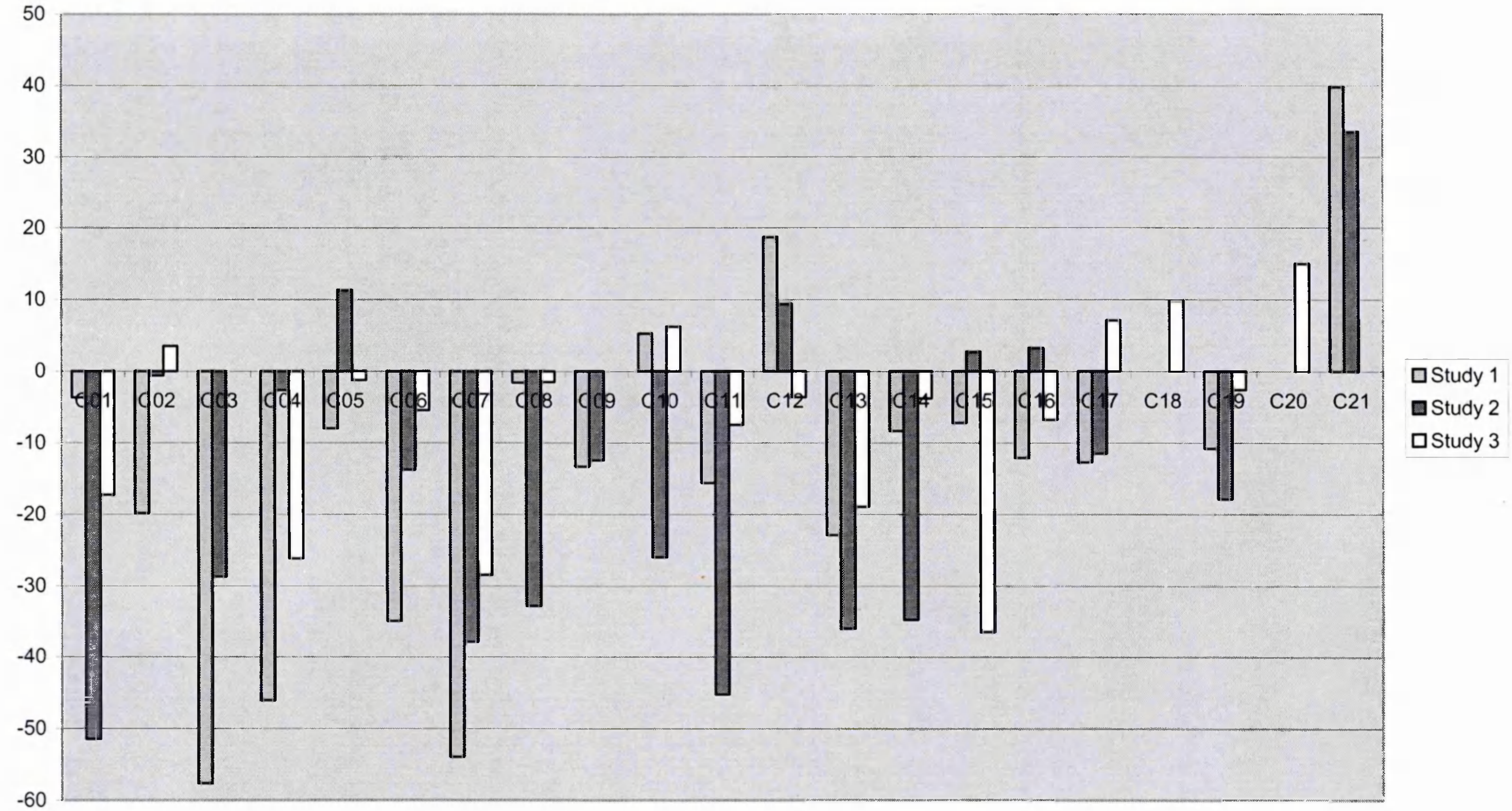


Figure 7.2: Bias for face stimuli compared to non-face stimuli across Studies One, Two and Three (Visual Dot Probe and Face-in-the-Crowd with neutral faces, cars and houses and Visual Dot Probe with emotional faces) in the control group. Negative scores indicate a bias for faces.

Figure 7.3: Consistency of participants' performance and breakdown by pattern of bias across tasks in the ASD group

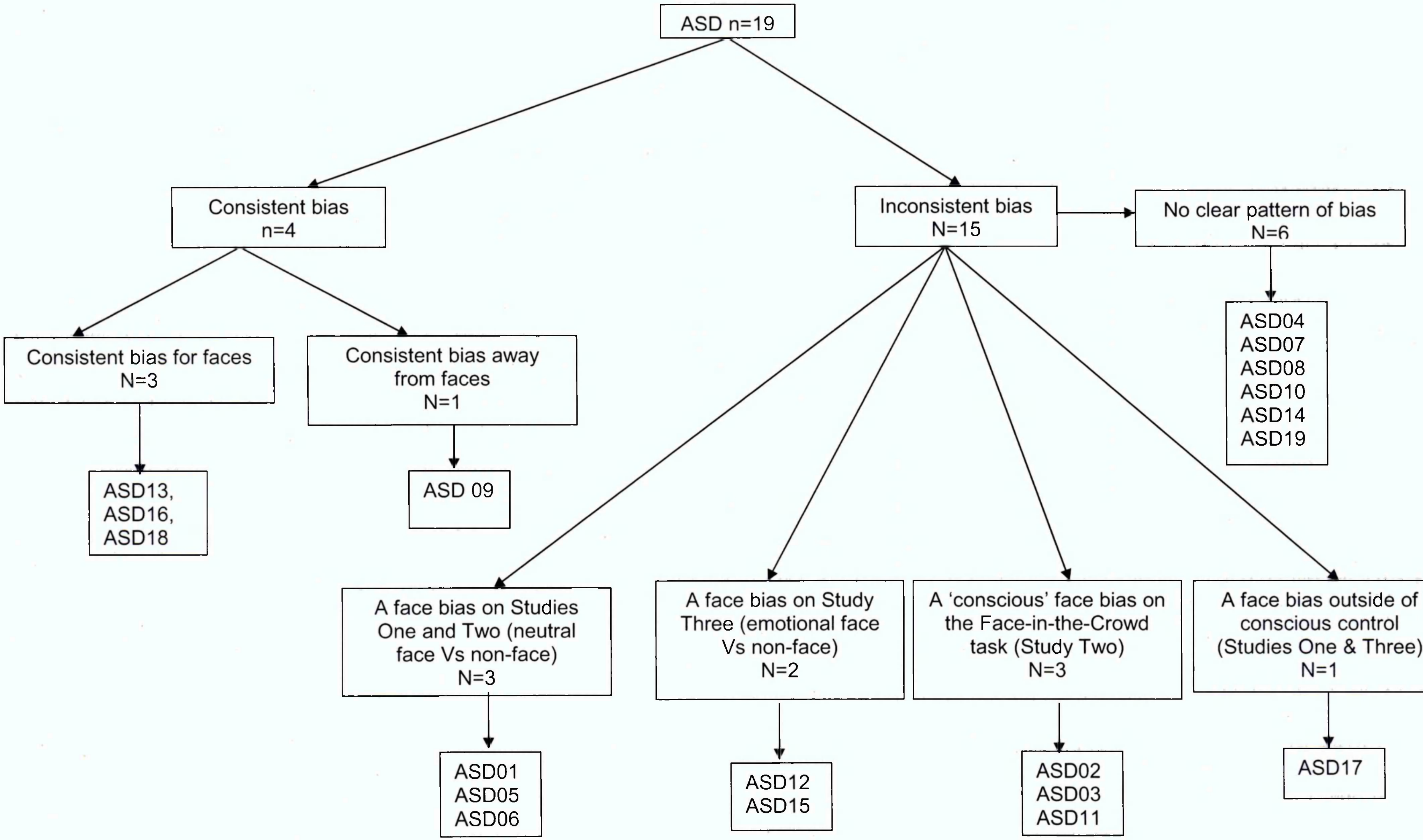
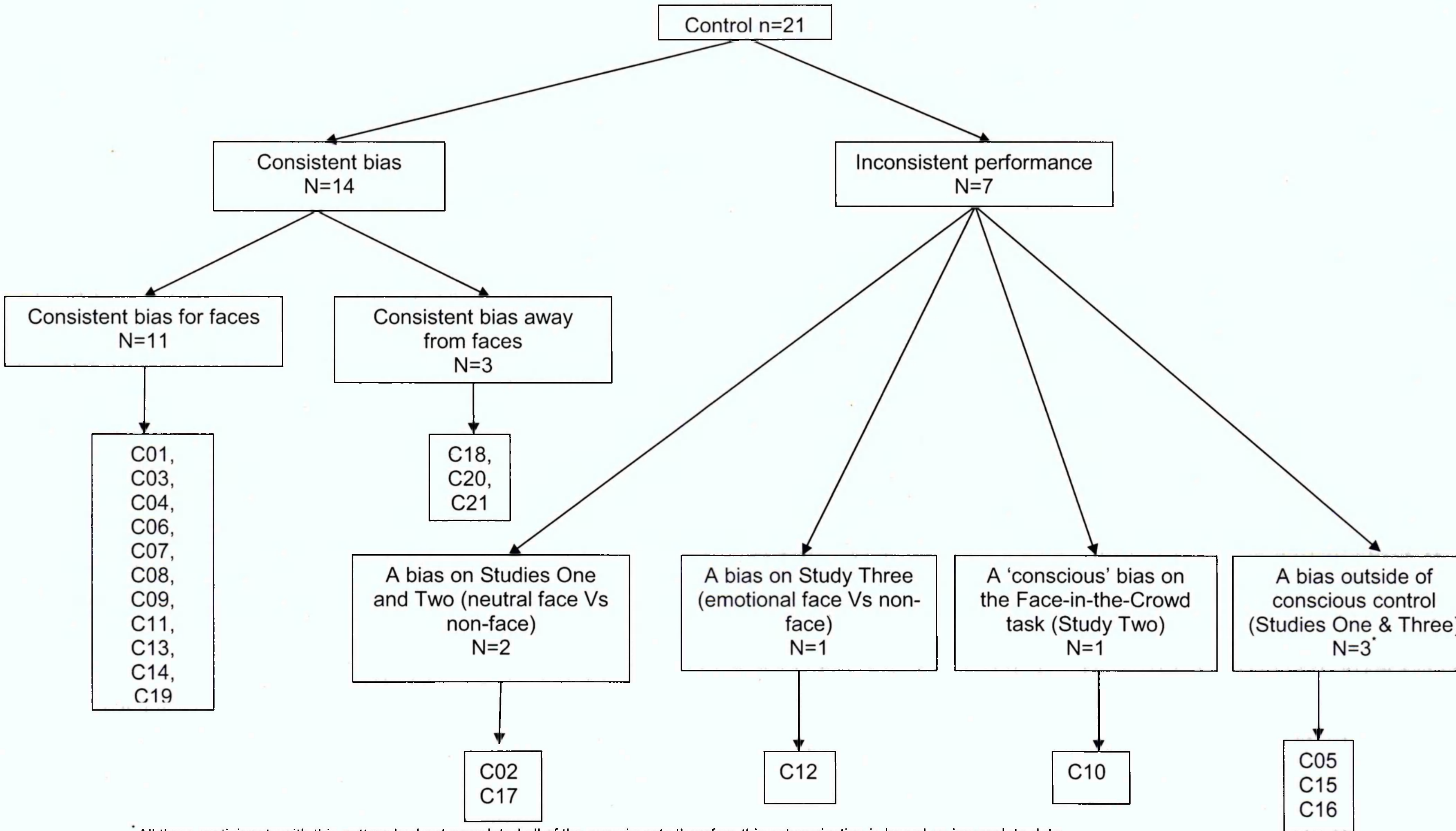


Figure 7.4: Consistency of participants' performance and breakdown by pattern of bias across tasks in the Control group



*All three participants with this pattern had not completed all of the experiments therefore this categorisation is based on incomplete data

Figures 7.1 and 7.3 shows that participants with ASD were largely inconsistent in their attentional biases. Only four, of 19, participants showed a consistent bias with three of them showing a bias for faces and one showing a bias away from faces. In contrast 15 participants with ASD showed an inconsistent pattern of attentional bias. This supports the correlation findings that the performance of the ASD population is mixed across studies in regard to attentional bias. In comparison, the control group's performance (Figures 7.2 and 7.4) was much more consistent, with 14 of 21 participants showing a consistent bias. Eleven participants (over half the sample) showed a consistent bias for faces and three showed a consistent bias away from faces. Only seven control participants showed inconsistent performance, five of whom showed a face bias in two of the three considered designs. This supports the tentative findings in the above correlations that the attentional bias for faces in the control group being much more consistent than in the ASD group. Additionally these findings indicate that the control group were generally more likely to directed their attention towards faces than the ASD group.

Anxiety (7.5.3)

Additionally it is of interest to examine which variables might relate to attentional bias for faces in ASD and TD control participants. Previous research has indicated that individuals with ASD have higher levels of anxiety than in the typical population (e.g. Tantam, 1991; Gilliott, Furniss & Walter, 2001) so this will be explored before examining whether anxiety relates to attentional bias. To examine if the ASD and control groups differed in their levels of anxiety independent t-tests were used to compare participants on the three measures of anxiety collected during this thesis (see table 7.2 for means and standard deviations.

Table 7.2: Means and standard deviations for participant's anxiety scores for STAI, FNES and SADS.

	STAI (Studies One and Two)	*STAI (Studies Three and Four*	*FNES*	*SADS*
ASD	45.76 (10.77)	35.39 (10.68)	17.49 (9.66)	16.38 (6.23)
Control	41.36(6.78)	33.94 (7.84)	11.56 (9.35)	5.39 (5.75)

There were no significant differences between the ASD and control groups on mean score on the state version of the STAI in Studies One and Two t(34)=1.482, p=.147 or Studies Three and Four t(34)=.463, p=.646. When examining differences between groups on measures of social anxiety no difference was observed between groups on the Fear of Negative Evaluation Scale t(32)=1.249, p=.221, however, the ASD group was shown to have significantly higher t(34)=5.50, p<.001 SADS scores than the control group. Based on this it appears that although the ASD group consistently scored higher than the control group on measures on anxiety this was only significant in terms of the general measure of Social Anxiety and Distress.

Compared to Published norms for the STAI (Knight et al., 1983) and the SADS and FNES (Stopa & Clark, 1983) the anxiety levels of individuals with ASD appeared elevated in this thesis. For STAI scores for Studies One and Two 15 participants with ASD had higher than normal levels of state anxiety (2 had lower than normal). Anxiety appeared to go down by the time of studies three and four, and was distributed much closer to normal, with 10 participants having higher than average state anxiety and 8 under based on published norms (Knight et al., 1983). The state anxiety scores for controls in this thesis were similar with 17 controls scoring over the norm in Studies One and Two (2 under) and 8 scoring over the norm in Studies Three and Four (10 under). Additionally when examining social anxiety 10 ASD participants scored over the 50^{th} percentile on the FNES (7 below) and all 18 ASD participants scoring above the 50^{th} percentile on the SADS, and 6 scored above the 95^{th} percentile. For the control group 8 scored above the 50^{th} percentile on the FNES (9 below) and 9 scoring above the 50^{th} percentile (9 below). This indicates that with the exception of the first collection of the STAI scores the control group's anxiety score were well distributed around published norms. However the ASD group's scores were typically shifted above the norm and this was particularly the case with SADS scores, where all participants scored above the norm.

Predicting bias scores (7.5.4)

Given that attentional bias for emotional facial expressions has previously been shown to relate to anxiety (e.g. Bradley et al., 1998) the following analysis used available psychometric measures to predict the bias scores calculated throughout the thesis. For Studies One and Two available measures were IQ, Autism Quotient and scores on State-Trait Anxiety Inventory (STAI; Spielberger, 1983). For Studies Three and Four data was also available for the Social Avoidance and Distress scale (SADS) and Fear of Negative Evaluation scale (FNES; Watson & Friend, 1969). An examination of the multicoliniarity revealed that all predictors were measuring distinct constructs (all Pearson's $r < 0.8$; Dancey & Reidy 2007; Correlations available in Appendix 13). The ability for bias score in each study to be predicted by the available psychometric measures was analysed using multiple regression analysis. In order to get a measure of the amount of variation in attentional bias explained by the predictors they were all forced into the equation using the Enter method for multiple regression.

First, the ability for these measures to predict overall bias for faces in each study (to minimise the number of analyses bias in the Visual Dot Probe studies was combined across sub and supra threshold) was examined. For Study One it was found that scores on the AQ, STAI and participants IQ significantly predicted bias score $F(3,32)=3.573$, $p=.025$ with a correlation of $r=.501$ and an adjusted R^2 of .181 indicating that 18.1% of variance in participants attentional bias could be explained based on these predictors. Inspection of the regression coefficients and associated t-values suggest that only scores on the STAI were a significant unique predictor of bias score ($t=2.08$, $p=0.046$), however both scores on the AQ ($t=1.88$, $p=0.069$) and participants' IQ ($t=1.79$, $p=0.082$) approached significance. Examination of the unstandardised Beta coefficients revealed that an increase of 1 on the STAI resulted in a bias of an additional 1.015ms towards faces, and increases of one on the AQ and IQ resulted in biases .712ms away from faces and .628ms towards faces respectively. When this analysis was run separately for the ASD and control groups the effect was preserved for the ASD group $F(13,3)=3.560$, $p=.045$ but not for the control group $F(13,3)=.738$, $p=.546$ for whom the predictor variables did not predict attentional bias for faces. The correlation between the predictors and attentional bias in the ASD group was $R=.672$ with and adjusted $R^2=.324$ indicating that for the ASD group 32.4% of the variance in bias scores could be explained by the predictors. This was explained primarily by scores on the STAI ($t=2.30$, $p=0.039$) but not significantly by either AQ ($t=1.26$, $p=.229$) or IQ ($t=1.46$, $p=.168$), Unstandardised Beta indicated that an increase in STAI score of 1 resulted in an increase in bias towards faces of 1.374 seconds. Overall this indicates that higher levels of anxiety in the ASD population predict a greater level of attentional engagement with face compared to non-face stimuli.

For Study Two it was found that scores on the AQ, IQ, and STAI did not significantly predict bias for faces $F(3,32)=.902$, $p=.451$. No significant relationship was found when the analysis was run separately for the ASD $F(3,13)=1.125$, $p=.375$ or the control group $F(3,13)=.671$, $p=.583$.

For Study Three (emotional Visual Dot Probe) it was found that scores on the AQ, IQ, STAI, FNES and SADS did not significantly predict overall bias for faces $F(5,30)=1.086$, $p=.386$. No significant relationship was found when the analysis was run separately for the ASD $F(5,12)=2.181$, $p=.131$ or the control group $F(5,12)=.488$, $p=.779$.

For Study Four it was found that scores on the AQ, IQ, STAI, FNES and SADS did not significantly predict bias for faces $F(5,30)=.765$, $p=.583$. No significant relationship was found when the analysis was run separately for the ASD $F(5,12)=.164$, $p=.971$ or the control group $F(5,12)=.920$, $p=.504$.

The above set of analyses indicate that for ASD participants an increased attentional bias for faces in the first study was related to an increase in levels of state anxiety. Attentional bias for faces could not be predicted based on the psychometric data available in the other experiments. Additionally bias for faces did not appear to relate to available psychometric data in the control group.

Examining individual patterns of data (7.5.6)

In addition to the group based analyses above it is also important to recognise the heterogeneity of individuals with ASD. Therefore, the pattern of scores in each of the ASD and control groups will next be examined on an individual level looking for similarities between participants in terms of their attentional biases and mapping those onto other factors that might indicate particular cognitive sub-types. Presented below in tables 7.5 and 7.6 is data about individual participant's levels of anxiety (social and general) scores on the AQ and individual IQ scores to facilitate the interpretation of the individual profile presented below.

Table 7.3: To show demographic information about individual participants with ASD.

Participant	Age	Sex	AQ Social	AQ Attention Switch	AQ Attention to Detail	AQ Communication	AQ Imagination	AQ Total	IQ Vocabulary	IQ Similarities	IQ Block Design	IQ Matrix reason	IQ	S1&2 STAI	S3&4 STAI	S3&4 FNES	S3&4 SADS
ASD01	25	female	8	8	5	9	7	37	13	10	11	13	110.59	54	44	6	22
ASD02	16	male	5	9	6	5	3	28	11	15	11	13	115.13	40	34	18	26
ASD03	23	male	5	8	7	7	6	33	9	7	6	10	87.9	30	23	14.23*	10.85*
ASD04	19	male	9	10	8	6	6	39	11	10	18	15	112.18	64	29.31*	19.04*	22.16*
ASD05	17	male	6	7	6	5	7	31	14	14	17	13	127.24	#	34	10	12
ASD06	43	female	6*	14*	7*	12*	5*	46*	9	11	12	13	107.57	53	51	#	13.15*
ASD07	41	female	8	7	5	3	6	29	10	9	8	9	93.95	37	20	12	17
ASD08	25	female	8	10	6	9	7	40	14	11	13	13	116.64	46	47	29	27
ASD09	47	male	5	8	7	7	5	32	8	12	12	9	101.51	36	26	2	9
ASD10	20	male	5	7	9	5	4	30	8	8	11	7	90.92	43	30	13	14
ASD11[1]	34	male	8	9	8	7	7	39	9	15	12	14	115.13	53	#	#	#
ASD12	30	male	4	7	7	1	6	25	11	8	8	13	100	#	48	20	17
ASD13	21	male	4	6	5	4	1	20	16	15	17	14	133.29	49	55	11	11
ASD14	37	male	10	10	9	9	9	47	13	13	13	14	119.67	36	36	27	26
ASD15	23	female	9	9	6	8	4	36	18	14	16	15	134.8	31	23	4	13
ASD16	24	male	3	3	6	8	4	24	13	14	14	15	124.2	52	34.64*	22	13
ASD17	16	male	7	9	8	6	4	34	10	9	12	14	107.57	40	25	18	11.6
ASD18	23	female	7	7	3	6	5	28	12	12	12	15	116.64	68	31	22	8
ASD19	19	male	5	7	6	8	5	31	10	7	15	14	109.08	46	46	28	22

* Data imputed using Expectation Maximisation imputation based on other available psychometric measures (Tabachnick & Fidell, 1997).

Data Missing (imputation impossible/ not appropriate)

1 Participation in studies one and three only

Table 7.4: To show demographic information about individual control participants.

Participant	Age	Sex	AQ Social	AQ Attention Switch	AQ Attention to Detail	AQ Communication	AQ Imagination	AQ Total	IQ Vocabulary	IQ Similarities	IQ Block Design	IQ Matrix reason	IQ	S1&2 STAI	S3&4 STAI	S3&4 FNES	S3&4 SAD
C01	22	male	0	3	2	2	5	12	15	10	9	11	107.57	38	46	0	1
C02	19	female	1	1	3	0	2	7	11	11	11	14	110.59	40	32	19	7
C03	25	male	0	2	2	1	0	5	16	13	14	16	128.75	42	#	#	#
C04	33	male	1	5	9	3	4	22	14	8	12	11	107.57	47	49	0	0
C05	33	female	1	1	1	0	3	6	10	10	10	13	104.54	36	33	11	16
C06	22	male	1	2	4	1	3	11	10	10	17	10	110.59	30	21	7	0
C07	24	female	0	3	7	2	0	12	9	8	7	10	90.92	42	43	21	4
C08	32	male	1	6	2	1	1	11	10	8	11	10	98.49	50	40	6	2
C09[1]	30	male	2	2	10	2	4	20	16	12	16	15	128.75	36	#	#	#
C10	39	female	3	7	1	5	2	18	12	9	15	12	109.08	51	33	21	1
C11	23	female	3	4	3	8	4	22	15	11	14	14	121.18	39	33	21	5
C12	19	male	0	7	7	2	2	18	12	9	10	13	106.05	44	32	14	2
C13	21	male	2	5	8	5	5	25	11	10	12	14	110.59	46	26	11	11
C14	27	male	3	9	6	5	3	26	24	9	12	15	115.13	51	32	28	19
C15	33	female	2	4	2	2	0	10	13	14	10	13	115.13	48	33	16	2
C16	34	male	2	0	4	4	3	13	14	11	15	14	121.18	47	30	3	12
C17	24	male	3	1	9	1	4	18	18	13	18	11	130.26	34	42.94*	#	9.04
C18[2]	19	male	2	3	6	2	5	18	10	9	7	13	98.49	#	30	21	4
C19	42	male	1	2	5	0	1	8	12	12	18	17	128.75	35	20	11	1
C20[2]	20	male	1	6	6	0	0	13	11	9	10	14	106.05	#	35	5	1
C21	41	male	0	4	7	3	5	19	8	8	9	10	92.43	30	#	#	#

* Data imputed using Expectation Maximisation imputation based on other available psychometric measures (Tabachnick & Fidell, 1997).

Data Missing (imputation impossible/ not appropriate)

1 Participation in studies one and three only

2 Participation in studies two and four only

ASD participants who showed a face bias in all three studies (ASD13, ASD16, ASD18) tended to have lower AQ scores across all domains. On total AQ scores they were 3 of the four lowest scorers and included both of the participants who scored lower than the cut-off of 26 recommended by Woodbury-Smith, Robinson, Wheelwright, and Baron-Cohen (2005). They also tended to have higher IQ's with all scoring above 116 (1SD above the standard mean). These participants also had slightly higher state anxiety than the majority of other participants, particularly in the first two studies, where they scored in the top quartile. They also scored in the top quartile on fear of negative evaluation, but did not score higher on social anxiety and distress. In comparison participant ASD09 who showed social avoidance on all three studies scored average on the AQ had an IQ of 101 that places him towards the lower end of the scale for the participants in this thesis although just above average for the general population. Participant ASD09 indicated very low levels of anxiety on all measures (bottom quartile of this population on all measures). Compared to published norms participant ASD09 scored approximately average on the STAI (Knight et al., 1983) in the 75th percentile on the SADS and the 5th percentile on the FNES (Stopa & Clark, 2001). Although participant ASD09 scored in the 75th percentile on the SADS his score was still the second lowest in the sample, suggesting a general level of social anxiety in ASD in which this participant scored comparatively low.

Participants ASD01, ASD05 and ASD06 who showed a bias for faces in Studies One and Two (the dot probe and FITC task involving only faces and non-faces) but not on Study Three (which involved emotional faces) demonstrated no obviously apparent pattern of findings. Participant ASD05 had low AQ high IQ and low anxiety scores and participant ASD06 had high AQ low IQ and high anxiety scores. This same disparate pattern of associated psychometric findings was seen for participants ASD12 and ASD15 who showed an attentional bias away from faces on Studies One and Two and a bias for faces on Study Three. This indicates that the pattern of bias towards or away from faces on the tasks involving only neutral faces does not appear to be associated with any particular psychometric or demographic factors measured. This appears to indicate that the complexity of the task does not relate to any particular psychometric factors in this examination. Participants ASD02 and ASD11 who showed a selective conscious bias for faces in Study Two but not in the Visual Dot Probe used in Studies One or Three did not show any consistent psychometric profile. Participant ASD17 who showed a bias for faces in the Visual Dot Probe tasks but not on the Face-in-the-Crowd task scored approximately average on all tasks.

In examining the pattern of findings for the control group it did not prove to be possible to identify a pattern for social bias on all tasks as this made up too large a percentage of the sample. The three participants who showed a 'consistent' bias away from faces in the control group had not taken part in the all of the experiments in the present thesis, therefore this categorisation is based on incomplete data, it is therefore possible that the reason that no bias for faces is seen in this group is a result of the incomplete data. When examining their psychometric profiles the only distinguishing feature was that these participants all had an IQ in the bottom quartile (with two scoring below 100). Although they also had relatively high AQ scores these were not among the top scores in the control population. It is possible therefore that the lack of bias in this subgroup related to a more general reduction in cognitive functioning which possibly effected general task performance, although intellectual functioning was not greatly impaired and IQ was still in the normal range. No patterns emerged for the other bias sub-types. This possibly indicates that for the control group a bias for faces is a much more common pattern of bias, which does not directly relate to other factors, and may possibly be seen as a normal trait of typical development.

Discussion (7.6)

Consistency of bias (7.6.1)

An examination of correlations between bias scores for faces across the four studies showed no significant correlations between face biases for any two studies. When this was broken down by group the ASD participants continued to show no significant correlations. However the control group showed a trend towards a significant correlation between bias for faces in the two Visual Dot Probe studies and a non-significant small positive correlation between face bias in the two studies using just faces and non-face stimuli (Studies One and Two). This indicates that the biases observed in the control group appear to be more consistent than those for the ASD group. This indicates that the control group's bias may reflect a typical attentional bias whereas the biases observed in the ASD group may be a result of more situational or state factors and possibly that of chance.

Although there was a correlation between the control group's bias scores for faces in the two Visual Dot Probe studies used in this thesis this was still small explaining only 22.75% of the variance in the effect. This suggests that Schmukle's (2005) claim that the Visual Dot Probe task has poor test retest reliability when used in the traditional threat vigilance paradigm might extend into its use within general attentional bias for faces. The lack of significant correlations between biases on the Face-in-the-Crowd or between the Visual Dot Probe and Face-in-the-Crowd tasks suggests that this lack of internal consistency extends to the Face-in-the-Crowd task. This indicates that possibly the Visual Dot Probe and Face-in-the-Crowd tasks have a poor ability to reliably and consistently chart individual attentional patterns and instead operate on a group level capturing grosser patterns in performance. The other possible explanation for the inconsistency in findings is that these tasks are highly sensitive to the relatively minor changes in presentation stimuli and task length. It is possible that because Studies Three and Four were longer than Studies One and Two that participant's performance changed during the research. Additionally both the face and the non-face stimuli changed between the two phases of the research which may have affected the consistency of the results. It is clear that whatever the explanation for this inconsistency that these effects need to be examined in much greater detail and the reliability of tests need to be established before firm conclusions can be drawn from these measures. It does however, need to be highlighted that although both the present findings and Schmukle suggest that the reliability of these measures may not be exceptionally high, that changes in design between phases have occurred in both of these pieces of research and that therefore concluding that the measures are not reliable is highly premature.

More telling perhaps was the findings that when the participants were categorically allocated to either consistent or inconsistent groups (and further into subclasses) this indicated that 4/19 ASD participants showed consistent performance compared to 14/21 in controls. This suggests that for control participants the nature of social attention is relatively consistent however for the ASD group there appeared to be a number of sub-groups.

Anxiety (7.6.2)

In the present analysis participants with ASD showed increased levels of social anxiety compared to control participants on the Social Avoidance and Distress Scale. However, ASD participants showed no differences from controls on the Fear of Negative Evaluation Scale or the state measure of the State-Trait Anxiety Inventory. Compared to published norms for the STAI (Knight et al., 1983) and the SADS and FNES (Stopa & Clark, 1983) the anxiety levels of individuals with ASD appeared elevated in this thesis. With the exception of the first collection of the STAI scores the control group's anxiety score were well distributed around published norms. However the ASD group's scores were typically shifted above the norm and this was particularly the case with

SADS scores, where all participants scored above the norm. This provides partial support for previous research that has suggested that individuals with ASD have elevated social anxiety (Bellini, 2004; 2006), however this was limited to the scores on the SADS and did not generalise to the FNES. Additionally unlike Farrugia and Hudson (2006) the present analysis failed to show elevated general anxiety.

Predicting attentional bias (7.6.3)

An examination of the multiple regressions used to predict bias scores from demographic and individual differences variables indicated that for Study One that a stronger bias for faces in the ASD group was associated with a greater level of state anxiety. This supports the suggestion posed in Chapter 5 (Study Three) that an increased bias for faces in the ASD group might not reflect social seeking behaviour but rather the rapid identification of a threat stimulus to that person. It is possible therefore that anxiety relating to social engagement in some individuals with ASD (Gillott & Standen, 2007) can cause a threat bias effect in participants with ASD for faces in general which is similar to that seen with typical controls for angry faces (e.g. Bradley et al., 1998). This finding does however have to be considered with caution as it was not replicated in any of the subsequent studies.

When considering bias for emotional faces over neutral faces it was found that a stronger bias for emotional faces was associated with higher scores on the STAI in the control group, indicating that control participants with greater levels of state anxiety during Study Three were more likely to show stronger biases for emotional faces. This can be partially explained in terms of the standard threat bias effect (e.g. Bradley et al., 1998), whereby participants with greater levels of anxiety show a bias for threat faces consistent with their anxiety either due to stronger schema (Beck, 1976), or more developed semantic networks (Bower, 1981) surrounding these stimuli. There is however a problem with this interpretation as the emotional stimuli that make up this index are made up of both angry and happy faces therefore this cannot be as simple as a threat bias effect.

Examining individual pattern of biases (7.6.4)

In addition to considering the capacity of psychometric variables to predict attentional bias on a group level it is also important to consider the way that individuals' psychometric profiles might relate to the profile of attentional bias. When the psychometric profiles of the sub-groups in the control sample was examined there were very few clear patterns that emerged. The only profile that could be observed in the control group was that the three participants who showed no bias for face stimuli across all studies had not taken part in all studies indicating that these participants may have shown bias for faces if a more comprehensive selection of scores was available. All other sub groups in the control sample showed no clear pattern of psychometric scores.

Although the lack of any pattern of findings may not appear to reveal anything about the control group, it appears reasonable to infer that this is indicative that the bias for face stimuli in typical development is a general trait of the developmental process and therefore is not related to other psychological or developmental factors. This idea that social bias in the typical population is more akin to a trait supports the above correlations showing a greater level of consistency in the control group's attentional bias compared to the ASD group. The idea that TD individuals have a basic bias for faces has received a great deal of support from previous research using designs which map well onto the Visual Dot Probe (Bindemann, Burton, Langton, Schweinberger & Doherty, 2007; Theeuwes, Stefan & Strigchel, 2006), the Face-in-the-Crowd (Hershler & Hochstein, 2005 Experiment 2; Ro, Russell & Lavie, 2001), and that suggest that faces are processed under conditions usually associated with processing outside of conscious awareness (Shelley-Tremblay & Mack, 1999, Mack, Pappas, Silverman & Gay, 2002).

In examining the psychometric profile of the above subgroups with ASD a number of patterns emerged. ASD participants who showed consistent face biases tended to have lower AQ scores and higher IQ. These participants also showed slightly higher levels of state anxiety during the experiments but no increase in social anxiety. This appears to indicate that social attentional bias in individuals with ASD is related to a reduced number of autistic symptoms, possibly indicating that these participants were on the less severe end on the autistic spectrum. This finding is broadly in agreement with that of Klin et al. (2002b) that participants with ASD who showed greater autistic symptomology also attended more to objects compared to people during an eye tracking study. In Klin et al.'s study reduced autistic symptoms were associated with increased attention to mouths but not eyes. In the current analysis it was not possible to break down what aspect of the face captured attention in those three participants with ASD who showed a bias for faces throughout. The increased IQ seen in these participants also possibly indicates that a certain level of intellectualisation may be operating in the observed biases, and that these participants have made a conscious effort to learn social skills (Grandin, 1999). It is possible, although not directly testable, that this might have spilled over into some attentional bias. When this is compared to the participant who showed social avoidance he was the oldest participant in this thesis, showed very low levels of anxiety and relatively low IQ for this thesis (101 IQ), although a typical AQ score for the ASD group (32). It is possible, though speculative that the avoidance of social stimuli by this participant might reflect an attempt to reduce the anxiety, which can be associated with social information in ASD (Gillott & Standen, 2007). All other patterns of attentional bias did not appear to be associated with any psychometric profile.

Limitations (7.6.5)

There are however limitations to the present analysis. The first is the fact that the analysis in the present chapter is underpowered. It was not possible to recruit the required number of participants for some of the present analyses. For the multiple regressions to detect a medium effect size with .9 power and the two predictors used for the data in Studies One and Two it would have been necessary to recruit 88 participants unlike the 38 in the groups overall and 19 when these were broken down into individual groups based on G-power (Buchner, Erdfelder, & Faul, 1997). This rises to 108 participants for Studies Three and Four in which 36 participants were recruited (18 in each group). This should be considered when interpreting the findings of the present analysis, as some of the effects tested might have been significant with larger samples. It also needs to be considered that some findings may have resulted from extreme scores by some participants.

A problem specific to the analysis involving the Face-in-the-Crowd task relates to the method used to calculate bias scores with this group. Although this formula was based on the one designed to calculate bias scores with the Visual Dot Probe by Mathews MacLeod and Tata (1986), this formula has not previously been used with the Face-in-the-Crowd task. It therefore is possible that the lack of any effects in the present analysis relate to a lack of reliability of the computed scores and possibly not that there were no findings observable. The reliability of this index of bias needs to be confirmed before firm conclusions can be drawn.

In addition to this the nature of the analysis of individual patterns needs to be considered as a relatively subjective analysis of the data. Although patterns were based on examination of objective reaction times and well validated psychometric data, clusters of participants and interpretation of the psychometric properties of these clusters were not based on any inferential technique and were based on an 'eyeball' examination of the data. It is therefore possible that different clusters or different interpretations of clusters may have emerged using different criteria. In addition to this some participants (particularly in the ASD group) were not classified into any meaningful cluster, as no theoretically logical explanation for their pattern of bias could be developed. This analysis therefore did not acknowledge their contribution, which reduces the variability in findings.

An additional limitation with the current analysis is that although the STAI, FNES and SADS have been well validated in typical participants (Spielberger, 1983; Watson & Friend, 1969) these may not be measuring the true level of anxiety in individuals with ASD. Groden et al. (2001) pointed out that questions on standard measures of anxiety may not relate to the most common causes and symptoms of anxiety in this group and may produce unreliable results. Additionally it is not clear how able individuals with ASD are to use introspection to consider their own emotional states. Given that individuals with ASD have frequently been shown to have a difficulty in understanding emotion in others (e.g. Grossman et al., 2000) it cannot be assumed that they will be able to infer their own emotions. It is therefore possible that the association that state anxiety had with face bias in study one or the lack of biases in other studies might be partially a product of a lack of reliability of the measures. Future research examining the important influence that anxiety and other psychological factors associated with ASD has on cognitive functioning needs to consider the importance of the development of more reliable measures for assessing these constructs in complex clinical populations. An important consideration in the development of measures of anxiety for individuals with ASD is the individual's ability to introspect about there own affect. To address potential difficulties in introspection it is important that scores are validated against professional or parent scores for the individual to examine if these scores are reliable. The need for more reliable measures of anxiety and social anxiety with an ASD population is supported by the higher variability in the scores in this group.

Implications (7.6.6)

The implications of the findings of the present study are many and varied from both a methodological and theoretical perspective. From a methodological perspective the lack of consistency in findings between the Visual Dot Probe and Face-in-the-Crowd tasks appears to indicate that these are measuring different aspects of attentional bias. This needs to be considered in future research using these designs with greater emphasis on what is actually being measured. More worrying is the lack of agreement between the two manipulations of the designs when compared with each other (e.g. the comparison between the two Visual Dot Probes). This raises questions about the reliability of the Visual Dot Probe and Face-in-the-Crowd designs as measures of attentional allocation if relatively minor changes in task demands can create such a discrepancy in findings.

From a theoretical perspective the findings of the present analysis indicate that a social bias in ASD may represent a threat bias related to a heightened level of anxiety. This raises questions about the findings of previous research examining social attentional biases that have not accounted for this factor. It is therefore possible that part of the discrepancies between those who suggest that dyadic social attention is intact (e.g. van der Geest et al., 2002) and those who suggest that it is impaired (e.g. Klin et al., 2002) could be explained by different levels of anxiety in these groups. If this finding is shown to be consistent across more studies then it seems that this would be one potentially important factor in social processing in individuals with ASD.

The finding that the three participants with ASD who showed a consistent social bias were also among the four who reported the fewest number of autistic symptoms indicates that measures of social attention may be promising for examining the severity of autistic symptomology. If social attention can be shown to predict the severity of autistic symptoms using more objective measures of autistic symptoms and during earlier stages of development then this could be considered as a part of the assessment process.

In conclusion the findings of the present analysis suggest that attentional bias related to social/emotional and non-social stimuli is more consistent in typical development than in ASD. In addition to this the control group were more likely as a group (as well as more likely on an individual level) to show a bias for faces than the ASD group, in agreement with the past findings in this thesis. Of greater interest was the finding that when the ASD group as a whole showed an increased bias for faces this appeared to be related to an increase in state anxiety. It is possible therefore that the bias for faces in the ASD group was not a social bias as predicted in the control group but hyper vigilance for threat as seen for angry faces in typical participants (e.g. Bradley et al., 1998; Mogg & Bradley, 1999). In addition to this when increased bias for faces was examined on an individual level the participants with ASD who showed a consistent face bias, in addition to elevated state anxiety, had fewer autistic symptoms and higher IQ indicating that this social tendency might relate to an intellectualised sociability (Grandin, 1999). Although attentional biases related to emotional faces did not appear to be particularly related to any particular psychometric profiles in the ASD group the control group showed some evidence for the threat vigilance effect seen to be associated with increased anxiety (e.g. Bradley et al., 1998).

Chapter 8

General Discussion

Chapter Overview (8.1)

The studies in this thesis have sought to provide a comprehensive review and investigation of attentional bias for faces and facial expressions of emotion in individuals with Autistic Spectrum Disorders. Three major considerations have been made in conducting this research, the role of conscious awareness, the role of emotionality and how individual variances in the population might relate to social attentional bias. The level of conscious control participants had over attention was varied by altering the time that stimuli were presented to participants and the task used. As discussed in Chapter 2 short durations (<250ms) can be argued to measure exogenous (automatic) attentional allocation while moderate durations (250-750ms) can be argued to measure the initial conscious preference of attention. Longer presentation (>750ms) appear to measure the final location that attention will settle on. Therefore in the Face-in-the-Crowd both conscious allocation and final preference were observed whereas, in the Visual Dot Probe used in this thesis exogenous (automatic) attention is engaged. Two levels of attention were examined using the Visual Dot Probe task: images were presented outside of conscious awareness using an individually calculated sub threshold duration, additionally images were presented for a supra threshold duration of 200ms, which allows for participants to be aware of the images, but not able to control their allocation of attention. These designs have however also been used to examine for bias for faces in the typical population (Bindemann et al., 2007; Hershler & Hochstein; 2005), and the Face-in-the-Crowd has been used to examine for emotional bias in ASD populations (Ashwin et al., 2006b). Additionally in the first two studies attentional capture by neutral faces was examined in comparison to non-social images, whereas in Studies Three and Four faces with emotional expressions (angry, happy and neutral) were compared to non-social images. This allowed for the role of emotion to be examined in attention to faces. Finally, during the research measures of state anxiety (STAI) and social anxiety (FNES, SADS) were collected and these were combined with IQ and autistic severity (measured using the AQ) to examine whether attentional bias related to individual differences variables. After an overview of the findings of the studies conducted, this research will be considered in relation to previous research in the area. Following this the limitations of this thesis will be considered and finally future directions that would follow from this work will be outlined.

Findings from thesis (8.2)

Table 8.1: Summary of findings.

Experiment	*Method*	*Stimuli/variables*	*Results*
One: Attentional bias for faces compared to non-face stimuli: Visual Dot Probe.	Visual Dot Probe sub-threshold (individual calculation)	Neutral face, houses and cars	No bias in attention was observed in either group
	Visual Dot Probe supra-threshold	Neutral face, houses and cars	The control group showed a bias for faces compared to non-faces, there was no significant bias in the attention of participants with ASD.
Two: Attentional bias for faces compared to non-face stimuli: Face-in-the-Crowd.	Face-in-the-Crowd task. Nine images presented until response.	Neutral face, houses and cars	Both groups showed a bias for faces compared to non-face stimuli.
Three: Attentional bias for emotional (Angry, Happy, and Neutral) faces and teapots: Visual Dot Probe.	Visual Dot Probe sub-threshold (individual calculation).	Angry faces, happy faces, neutral faces and teapots	The control group showed a bias for faces (summed over all emotions) compared to non-faces. When this was examined based on individual comparison this bias for faces was observed only for neutral faces compared to teapots. The ASD group showed a bias for happy faces compared to neutral faces. No biases for emotional faces were seen in the control group.
	Visual Dot Probe supra-threshold	Angry faces, happy faces, neutral faces and teapots	No bias for faces or emotions was found compared to non-face stimuli in either group.
Four: Attentional bias for emotional (Angry, Happy, and Neutral) faces and teapots: Face-in-the-Crowd.	Face-in-the-Crowd task. Nine images presented until response.	Angry faces, happy faces, neutral faces and teapots	No bias in attention was observed in either group.

The purpose of Experiment 1 was to look for evidence of a reduced capture of attention by face stimuli (compared to non-face stimuli) in adults with ASD when compared to TD age, gender and IQ matched controls. This was achieved using the Visual Dot Probe task, which also allowed for hypotheses about levels of vigilance and difficulty in disengaging from stimuli to be tested. This experiment also sought to examine these effects at durations that would limit the ability of participants to exercise conscious control over the allocation of their attention (i.e. presentations less than 250ms). Based on previous literature it was hypothesised that controls would show an attentional bias for the faces (Bindeman, et al., 2007) however findings with children with ASD have indicated that this bias may be absent in this group (Dawson et al., 1998; 2004).

Results from this study indicated that when faces are presented outside of conscious awareness, with backwards masking (the presentation of the blurred image), this information does not appear to capture attention for either group. However, when these stimuli are presented for 200ms the attention of the TD group was biased towards responding to probes faster and more accurately when they had been preceded by faces. This was consistent with the social bias that was predicted for this group. The data for the ASD group however revealed no significant bias in attention either towards or away from faces. This effect could not specifically be explained in terms of hyper-vigilance or difficulty disengaging from the stimuli.

The second experiment examined bias for faces when attention is under conscious control (i.e. presentation times greater than 250ms). This study was designed to address some of the concerns about the sensitivity of the dot probe task. By using a visual search task the research was also more comparable to the previous research on attention to social stimuli within a visual modality in ASD (Klin et al., 2002a; b; van der Geest et al., 2002). This experiment used the Face-in-the-Crowd task to examine the speed that participants found a discrepant image in a display dependent on if the image was a face, or a non-social image. Based on the findings of Study One it was predicted that the ASD group would show reduced bias for faces compared to controls.

The findings of this study indicated that both the ASD and control group showed a bias for faces over non-social stimuli. When examining these effects in more detail it was found that both populations showed hyper-vigilance for social information compared to non-social stimuli. Participants were also faster to reject distracter displays of faces to find non-social targets than finding non-social targets among differing classes of non-social targets. This indicates that when under conscious control the pattern of social attention in adults with ASD is not significantly different to those who have developed typically.

The third study in this thesis was designed to examine if presenting faces with emotional expressions resulted in stronger attentional biases in either group. This also aimed to examine whether different expressions in facial stimuli capture attention more or less effectively in either the ASD or control groups. This was examined using the Visual Dot Probe task. Given that this task was originally designed to measure attentional bias for affective stimuli this seemed like a good opportunity to examine these effects in those with ASD to allow for comparison to past research (e.g. Mogg & Bradley, 1999a, b). Based on the findings of Experiment 1 it was predicted that the autism group and the controls would differ in their pattern of attentional allocation to emotional faces.

The findings of this third study were more equivocal than those of Experiment 1. It was found that when emotional face, neutral face and non-face stimuli were presented below conscious threshold that control participants showed an overall bias for faces over non-face stimuli (teapots) when a composite of emotional expressions was used. The control groups also showed a bias for neutral faces individually over teapots. No bias was observed on either of these comparisons for the ASD group. Participants in the ASD group showed a bias for emotional faces (happy and angry) and in particular happy faces in comparison to neutral faces when they were presented for sub-threshold durations. No biases were seen in either group when stimuli were presented for supra-threshold duration. The findings of this study appear to indicate that the control group showed a bias for faces at a sub-threshold duration similar to that seen in the first study at a supra threshold duration with no such bias being observed in the ASD group in either instance. The ASD group however showed a bias for emotional faces when compared to neutral faces not seen in the control group.

Experiment 4 expanded on the previous experiments by introducing the influence of emotional faces on the search times for discrepant images using the Face-in-the-Crowd task. This study was based on two of the previous studies in this thesis. Firstly, the findings of Study Three that faces capture attention in the control group compared to non-faces but that this is not mediated by the emotionality of the stimuli. Secondly, the findings that emotional faces capture attention preferentially to neutral faces in the ASD group and finally the findings of Study Two that no differences were seen between the ASD and control groups' bias for faces when engaging in a conscious visual search task. Based on this it was felt that the conscious search through emotional faces might elicit a unique search pattern in the ASD group. This was of particular interest given Ashwin, Wheelwright and Baron-Cohen's (2006b) findings that angry faces were found faster than happy faces among neutral distracters by both ASD and control groups suggesting no difference in bias.

The findings of this fourth study indicated that neither of the groups showed a significant bias for faces compared to non-face stimuli. This is the only study in the thesis where this was the case. This study also showed no significant biases for emotional faces either overall or individually compared to neutral faces, in either group. When comparing the individual stimuli pairs the only bias observed was for neutral faces compared to happy faces, and this was present in both groups. All other comparisons between emotions were non-significant. An additional finding was that the ASD group were overall slower on the angry-happy stimulus pairs indicating a slowed responding to discriminating between emotional faces. An analysis of target absent trials provides partial support for the idea that emotional stimuli require longer examination durations as searching though all angry or all happy displays took significantly longer than through all neutral displays in both groups.

The analysis in Chapter 7 examined the consistency of attentional bias for face stimuli compared to non-face stimuli throughout the studies in this thesis. This was considered at both a group and individual level. This was used to examine the reliability of the measures used in this thesis. Following this, multiple regression analysis was used to examine whether the bias scores seen in either group could be predicted by available psychometric data. Finally, participants were considered as individuals and their bias scores were considered in relation to psychometric information gathered about participants during testing. The relationship between attentional bias and levels of state anxiety, social anxiety and severity of autistic symptomatology were also considered.

This showed that the consistency of bias observed in this thesis was relatively weak with no significant correlations between biases for faces found between any two studies either overall or in the groups separately. Although non-significant the control group did show a trend towards a positive correlation between face bias scores on the two Visual Dot Probe (Studies One and Three) tasks and a weak but non-significant positive correlation between Studies One and Two that both used faces Vs non-face stimuli but excluded emotional content. This suggests that the tasks used to examine attentional bias are more consistent with controls than the ASD population. When examining the ability of individual differences variables to predict the biases for faces it was found that for the ASD group their level of state anxiety at the time of the first study predicted their bias towards faces in this study. This was consistent with higher levels of anxiety predicting stronger biases for faces in this group. The most apparent explanation of this finding is that as in typical populations the Visual Dot Probe is traditionally used to examine for participants showing attentional biases for threatening stimuli. If individuals with ASD have developed a perception of faces and other people as threatening (suggested by elevated social anxiety; e.g. Bellini, 2004) then it would be expected that they would show an attentional bias for this 'threat'.

Summary of overall findings (8.2.1)

Over all, the experiments contained within the present thesis have provided some evidence that TD adults show a preference for attending to faces compared to non-face stimuli. This is however not a conclusive finding, control participants showed an attentional bias for faces presented for a supra threshold duration in Study One, and when presented for a sub threshold duration in Study Three and over all in Study Two, however this bias was not seen in Study Four, or sub threshold in Study One and supra threshold in Study Three. Although this is not a universal finding TD participants showed some signs of a significant bias for faces in 3 experiments and a non significant pattern of social bias in two more. Additionally when participants' data were analysed individually in Chapter 7 of the fourteen TD participants who showed a consistent bias throughout the research 11 showed bias for faces compared to only three showed a bias away (none of whom had taken part in all studies). Additionally of the seven participants who showed an inconsistent pattern of bias five showed a bias for faces more than half the time (i.e. 2 out of the 3 studies). Participants with ASD in contrast showed a bias for faces only when presented at a conscious level on the simplistic faces Vs non-face Face-in-the-Crowd task (Study Two). In addition to this the analysis performed in Chapter 7 indicated a trend towards greater levels of state anxiety predicting bias for faces in participants with ASD, at least in Study One. Previous findings indicate that higher levels of anxiety in the general population relate to an attentional bias for threatening faces (e.g. Bradley et al., 1998) and attentional bias for images of spiders/snakes relate to a phobia of these stimuli (e.g. Öhman, Flykt, & Esteves, 2001). This suggests tentatively that when participants with ASD show a bias for faces that this may reflect a bias for identifying perceived threat rather than a social preference observed in the typical population. This is a potentially important finding given that individuals with ASD have been shown to have elevated levels of both general and social anxiety (e.g. Tantam, 1991; Gilliott, Furniss & Walter, 2001). In this thesis the finding that anxiety is elevated in individuals with ASD was replicated for social anxiety compared to the control group and there was some indication that the ASD group showed elevated social and generalised anxiety compared to published norms (Knight et al., 1983, Stopa & Clark, 1983).

Results relating to bias for particular emotional expressions are less conclusive, in Study Four (emotional Face-in-the-Crowd task) no biases were observed in either group for any stimuli. Additionally in Study Three (emotional Visual Dot Probe task) the only effect observed was an overall bias for emotional faces compared to neutral ones in the ASD group when they were presented for a sub threshold duration. Upon further inspection this appeared to be mainly driven by a bias for happy faces compared to neutral faces. The only predictor of emotional bias in the analysis in Chapter 7 was state anxiety in the control group. Although this can be partly explained in terms of the threat vigilance hypothesis (e.g. Bradley et al., 1998) this cannot provide a full explanation for these findings as the emotional images used comprised both happy and angry expressions and this hypothesis only predicts bias for angry faces.

Relation of findings to past research (8.3)

Research with typically developing (TD) populations (8.3.1)

The findings contained within this thesis, although not conclusive, can be seen to broadly support previous research and theory about the nature of social attention in typical development. Previous research with TD adults has examined the special role that faces play in attentional processing (Shelley-Tremblay & Mack, 1999; Ro, Russel & Lavie, 2001; Theeuwes, Stefan & Strigchel 2006; Bindemann et al., 2007). The present series of studies has provided some support for the proposition that facial stimuli have a processing advantage when faces and non-face stimuli are presented in competition for attentional resources. Using the Visual Dot Probe paradigm, the findings of this thesis provided support for the findings of Bindemann et al. (2007). Both of these studies used similar designs, with the only meaningful differences between this thesis and that of Bindemann et al. (2007) being the presentation durations and number of repetitions of each stimuli. Participants in Bindemann et al.'s study had shorter response times to probes that replaced pictures of faces than probes that replaced non-face stimuli when images were presented for 100, 500 or 1000ms. In the present set of studies a similar design was employed however probes were responded to faster when they replaced faces presented for 200ms in Experiment 1 and when they were presented for individually determined sub-threshold durations in Experiment 3. It is possible that the consistency of Bindemann et al.'s findings compared to the present one might relate, in part, to the repetition of stimuli. In this thesis using the Visual Dot Probe no stimuli was presented more than three times during any test. However, in Bindemann et al.'s research each image was presented on 18 occasions. It is also therefore possible that the familiarity of the repeated faces contributed to the greater consistency of the findings in the Bindemann et al. study.

In addition to the research of Bindemann et al. this thesis has also furthered research in the area of facial bias within the Face-in-the-Crowd Paradigm. Hershler and Hochstein (2005 Experiment 2) used a variant on this design and showed that TD individuals show faster search times for faces in crowds of houses or cars than in the inverse case. There were however a number of problems with this design; Hershler and Hochstein presented a variety of photographs for each class of stimuli, therefore meaning that the displays were made up of images with different colours, angles of image presentation and complexity. The present studies in contrast used an individual image to represent each stimulus class. Using the present version of the Face-in-the-Crowd task, which had greater experimental control than that used by Hershler and Hochstein findings were less conclusive. In Study Two, which compared faces and non-face stimuli on the Face-in-the-Crowd task a face advantage was observed, however in Study Four which introduced competing emotional faces no bias for face stimuli compared to non-face stimuli was observed. This raises questions about the reliability of the Face-in-the-Crowd task as a measure of attentional bias in this context. The reason that this more controlled approach to the Face-in-the-Crowd was used in this thesis rather than the approach used by Hershler and Hochstein was to ensure that any bias observed was a result of the stimuli and did not related to the clarity of discrimination between the stimuli.

This thesis is also comparable to a number of other studies within the normative literature. Theeuwes, Stefan and Strigchel (2006) used the inhibition of return design to show that attention is biased to faces in direct competition with non-face stimuli. The research of Theeuwes, Stefan and Strigchel can be seen to be similar to the design of the Visual Dot Probe used in Studies One and Three in the present thesis. The phenomenon of inhibition of return operates based on the observation that once attention has been oriented to a spatial location and has been reoriented away then redeploying attention to that location will be delayed. When an arrow instructed participants to saccade to the location previously occupied by a face response durations were significantly longer than when saccades were made to the previous location of an object. The findings of this thesis support those of Theeuwes et al. in indicating that ability of facial stimuli to capture attention to their location occurs in the early stages of processing, with Studies One and Three finding that 200ms is sufficient to capture attention, although these findings are not entirely consistent in this thesis. An additional implication of Theeuwes et al.'s findings is that the inhibition of return effect operates when the initial orientation of attention was automatic but not when it was conscious (Posner & Cohen, 1984). This suggests that that facial capture of attention is a reflexive process.

This raises the question of the automaticity of the effects observed in this thesis. The Visual Dot Probe tasks used in Studies One and Three focused on the presentation of stimuli for brief durations (200ms or less) designed to examine attentional capture outside of conscious control. In addition to looking at attentional capture without conscious control, sub-threshold presentations were also used to examine attentional capture outside of conscious awareness. Methodologically this has to be considered a major strength of this thesis as individual thresholds of consciousness were calculated for each participant rather than relying on pre calculated durations (e.g. Cheeseman & Merikle 1986; Kemp-Wheeler & Hill, 1988). The implications of this are that we can be confident that stimuli were truly presented on the border of conscious awareness for every participant. The findings with sub-threshold presentations in the Visual Dot Probe in this thesis suggest an inconsistent pattern. In Study One faces presented outside of conscious awareness did not significantly capture attention in either control or ASD group. By contrast in Study Three the composite measure of all face stimuli (made up of faces with angry, happy and neutral emotional expressions) captured attention in the control group when presented for sub-threshold durations compared to pictures of teapots. Furthermore, this effect was also observed independently when neutral facial expressions were compared to teapots for the controls. There have been two previous studies that have examined how face stimuli are processed under conditions usually associated with unconscious processing. Shelley-Tremblay and Mack (1999) examined the processing of faces under conditions of metacontrast masking. In Shelley-Tremblay and Mack's study three targets were displayed for 17ms (a face icon, an inverted face and a scrambled image) and after a variable duration (0, 20, 60, 100 or 136ms) a mask was presented for 33ms. The key finding of this study was that the detection of the happy face icon as well as reports of its brightness were significantly greater than the other two icons (which did not differ from each other) across all mask durations. This indicates that in an adult population face stimuli have a superior capacity to capture attention even under conditions where this information is presented below conscious threshold. Additionally Mack et al. (2002) have shown that faces are able to overcome the phenomenon of the attentional blink. This again strengthens support for the findings of Study Three, indicating that in typical development faces capture attention outside of awareness, however this was not found in Study One. It should be noted that the face in Mack et al.'s study displayed a symbolic representation of a happy emotional expression. This might in part explain the reason that a sub-threshold bias was observed in Study Three but not Study One in the present study, as faces in Study Three displayed emotional expressions, including happy. This however cannot provide a full explanation as the only expression to capture attention individually in Study Three was the neutral face.

In summary the findings of the present set of studies broadly supports the normative literature, although the present findings are less consistent. Previous studies using designs similar to the Visual Dot Probe (e.g. Theeuwes et al. 2006; Bindemann et al., 2007) and the Face-in-the-Crowd (e.g. Ro, Russell & Lavie, 2001; Hershler & Hochstein, 2005) have indicated that faces have an advantage over non-face stimuli in attentional processing. This thesis has provided a degree of support for this with Studies One and Three, using the Visual Dot Probe, suggesting independently that faces capture attention when presented for brief supra and sub-threshold durations (Studies One and Three respectively). However, this is not conclusive as neither effect was repeated. The findings of Study Three also provided support for the proposition that faces capture attention outside of conscious awareness (Shelley-Tremblay & Mack, 1999; Mack, Pappas, Silverman & Gay, 2002). This effect however, was not observed in the first study, which again raises the concern of whether this effect can be reliably repeated. In addition to this Study Two replicated previous findings with search tasks (e.g. Ro, Russell & Lavie, 2001; Hershler & Hochstein, 2005) of a search advantage for faces, however this was not replicated in Study Four. The lack of consistency with these tasks raises the previously discussed question of whether these tasks can be considered reliable measures of attentional bias. It is clear that the reliability of these tasks needs to be carefully considered if they continue to be regarded as measures of attentional bias in the future.

It is possible that other factors contributed to the lowered consistency in the findings in the present series of studies. There were a number of other factors which changed between Studies One and Two using neutral faces compared to cars and houses and Studies Three and Four, which compared emotional faces (angry, happy, neutral expressions) to teapots. Firstly there was a difference in the non-face stimuli used between the two experimental phases. In the first two studies houses and cars were used as non-face stimuli, these have been used in studies by (Nunn, Postma & Pearson, 2001; Hershler & Hochstein, 2005) due to the internal structure of the stimuli having clear similarities (i.e. eyes/ window/ headlamps then a mouth/ door/ grill). The use of the teapot in Studies Three and Four was to reflect the general outline of the face with the spout of the teapot reflecting a nose; teapots have been used as a comparison stimulus to faces by Bindemann et al. (2007). It is possible that the change of non-social stimuli had an effect on the nature of the bias seen across the studies in this thesis. It is possible therefore that the biases observed in the first two studies using the houses and cars (with the matched internal structure of windows/headlamps representing eyes and the door/grill representing the mouth) indicated a bias for faces with supra-threshold presentation as all stimuli were clearly visible and distinguishable. However, when stimuli were presented below conscious threshold the face conspecific (three blobs conforming to the eyes and mouth; Johnson & Morton, 1991) was intact in all stimuli resulting in no bias being observed. However in the latter studies the internal structure of the face was not found in the non-face stimuli therefore allowing for a sub-threshold bias. It is however difficult to explain the lack of a conscious bias within this explanation. Although this change might have contributed to some of the differences in this thesis, the change in non-social stimuli was deemed necessary because of the changes which where made in the face stimuli. If the same non-social stimuli had been used in Studies Three and Four the familiarity of some of the stimuli might have contributed to changes in the findings.

As well as the change in non-face stimuli the battery of faces used in the two halves of the research contained in this thesis was changed. In the first two studies face stimuli were taken from Ekman and Matsumoto (1993), whereas in Studies Three and Four they were taken from the MacBrain Stimuli (Tottenham et al; in press). Although both sets of stimuli have been well validated, it is possible that the change in images affected attentional bias. This might be of significance as Ekman and Matsumoto (1993) faces included both Caucasian and Japanese faces whereas the MacBrain Stimuli contained only Caucasian faces (in the stimuli selected in this thesis). It is possible that the race of the faces used affected the way that participants attended to these stimuli. Given that faces of other races are less familiar it is possible that bias for these will be less than with own race faces (e.g. Lindsay, Jack & Christian, 1991; Gross, 2009). Again, although this change may have affected the findings in this thesis it was necessary as the Ekman and Matsumoto (1993) faces did not include sufficient exemplars of each emotional expression.

There where also a number of clear consistencies between the studies contained within this thesis, which can be considered as strengths of the research. The use of the same participants throughout the research allowed for an examination of how differences in the attentional demands of a task and the emotionality of the stimuli related to the biases observed in a single population. Additionally the designs used in the present series of studies remained consistent throughout with only minor changes that were necessary to test the specific hypothesis. As such, the visual dot probe tasks used throughout the research presented the same size images, with the same degrees of visual angle between them, controlled with the same colours and backgrounds and relied on the same response methods. Therefore, any variation in performance can be seen to relate to the independent variables and not confounds. Additionally the same experimental control was applied to the Face-in-the-Crowd task in which the same number of stimuli and the same size displays were used throughout.

An additional factor which may have contributed to the difference between the findings in the studies is the number of repetitions of each stimulus and task length. In the first dot probe experiment each stimulus was presented twice however due to limited stimulus availability in the second dot probe task, using emotional faces, each stimulus was presented three times. It is possible that the increased number of repetitions altered the effects observed. Additionally the tasks involving emotional faces had a greater number of trials that may have affected the results.

Research with ASD populations (8.3.2)

Unlike in typical development previous findings have been mixed regarding the nature of attention to social cues in participants with ASD. This has in part been a result of populations consisting of individuals at different stages of development, poor group matching, reliance on tasks that tap different attentional skills, levels of processing or task demands, and failure to maintain sufficient control over stimuli presentation.

Research examining the orienting of attention towards social information in adults with ASD is limited. However, Klin et al. (2002a, b) used eye-tracking data based on first an individual case and then a group of high functioning adults with ASD while watching scenes taken from the emotionally charged film 'Who's afraid of Virginia Wolf'. In Klin et al.'s studies participants with ASD showed a reduction in social attention during these tasks. In particular, participants with ASD spent less than half as long looking at the eyes of the protagonists in the film compared to control participants. The findings of this thesis may be interpreted to suggest that this effect may be a result of a lack of automatic attentional bias for social cues. Using the Visual Dot Probe task in Studies One and Three, this thesis indicated that when stimuli are presented for brief enough durations to restrict conscious control that participants with ASD showed no indication of bias for faces compared to non-face stimuli, whereas most control participants showed a relatively reliable bias for faces. An interpretation of this is that the absence of an automatic mechanism resulting in social attention (suggested in this thesis) would cause a difficulty in monitoring the ever changing social scenes used in Klin et al.'s task. The dynamic highly ecologically valid task used by Klin et al. requires a constant shift in attention to track the social exchange.

In contrast no differences were observed between the ASD and control groups on the Face-in-the-Crowd task used in Studies Two and Four. This finding is more consistent with the similar study of van der Geest et al. (2002). Van der Geest et al. also used eye-tracking to examine social attention in children with ASD. These findings indicated no differences between ASD and TD control children in attention to social stimuli, measured by total time spent looking at, and number of fixations for social stimuli (i.e. a person), as well as the time taken to make the first fixation for a person. In contrast to Klin et al.'s studies, van der Geest et al. used static cartoon like stimuli which participants were asked to look at for 10 seconds. This task is arguably more similar to the Face-in-the-Crowd task using simple static displays and providing longer inspection times for each display. Consistent with the findings of van der Geest et al., using the Face-in-the-Crowd task in the current research it was not possible to differentiate between ASD and control participants in terms of social attention.

The contrast between these two designs within the current research and the studies of Klin et al. and van der Geest et al. suggest that when tasks require fast orientation of attention or tracking of complex stimuli that social attention is impaired in ASD. However, when greater conscious control is exerted over attention and longer inspection times are allowed attention is preferentially allocated to social stimuli. The analysis performed in Chapter 7 suggests that increasing attentional bias for faces in individuals with ASD might relate to other factors rather than a simple implicit face bias. This analysis suggests two possible explanations; increasing face bias could be explained as either an increased level of anxiety that may result in a threat bias effect as seen for faces in typical development (e.g. Bradley et al., 1998). Alternatively increasing social bias was also observed to be related to higher intellectual functioning. Therefore it is possible that individuals with ASD (particularly in more conscious attentional tasks) have learned skills of social engagement through a higher cognitive process. For example intellectually able individuals may learn that social engagement is 'normal' and try to develop this skill based on conscious learning rather than an implicit mechanism used in typical development.

Ashwin, Wheelwright and Baron-Cohen (2006a) indicated using a modified Stroop paradigm that control participants showed selectively longer response latencies for angry faces compared to neutral faces or pictures of chairs. However, participants with ASD showed longer latencies for all faces compared to chairs. The findings of this study appear to indicate that individuals with ASD have an attentional bias for faces in general, irrespective of expression. Ashwin et al. however were not able to explain if this reflected a threat bias, as the analysis in Chapter 7 indicated that increasing bias for faces was related to increased levels of anxiety. It is also possible that individuals with ASD had greater difficulty processing the complexity of the face but not the chair. This thesis used designs that have been suggested to have greater validity in measuring attentional bias. These findings have indicated some evidence for attentional bias for faces compared to non-faces in typical populations, however limited evidence of a similar effect in ASD. Participants with ASD appeared to show no reliable bias for faces and when comparing emotions the only bias observed was for happy faces compared to neutral ones on the Visual Dot Probe task used in Study Two.

This thesis has indicated a general lack of consistent, signifincant social attention in ASD within the visual sensory modality. Similar results have been obtained within the auditory modality. Klin (1991, 1992) found that children with ASD show no preference for listening to their mothers' voice compared to the sounds of 'babble'. This is compared to control groups who all showed a bias for their mothers' voice. This provides an early indication that in addition to social inattention in visual processing, this is also observed in other sensory modalities.

The findings of this thesis supports the notion that the social inattention observed in childhood (e.g. Dawson et al., 1998, 2004; Osterling & Dawson 1994) persists into adulthood in the majority of individuals with ASD. On a group level this effect was observed using the Visual Dot Probe task at supra-threshold durations in Study One and sub-threshold duration in Study Three however on the Face-in-the-Crowd task differences between ASD and control groups was not observed. Additionally the analysis in Chapter 7 revealed some participants with ASD did show a social bias. This is an important finding as it indicates that although social inattention may be typical in ASD that some with this diagnosis may develop an attentional bias for faces. However, this appeared to relate to either higher levels of anxiety in the first Visual Dot Probe study using neutral facial expressions and non-face (cars and houses) stimuli, suggesting that this might reflect a bias for stimuli perceived as threatening and not a social bias as seen in controls. The analysis in Chapter 7 also revealed that those ASD participants who showed a social bias had higher IQs possibly indicating that social attention can be learned in more intellectually able participants.

As well as social inattention, outside of conscious control, in adulthood suggested in this thesis, previous research has indicated that ASD children attend less to social stimuli. In structured observation Dawson et al., (1998, 2004) found that children with ASD oriented attention no more to social sounds (e.g. mothers voice) played through speakers at the ends of the room than non-social sounds (e.g. a rattle). This is in comparison to control children who showed a clear bias to attending to social sounds. In addition to this Osterling and Dawson (1994) indicated using a retrospective analysis of video footage from children's first birthday party that a reduced tendency to look at others was the single best predictor of later autistic diagnosis. This finding has been shown to be robust at the age of 6 months (Maestro et al., 2002), when controlling for mental age (Baranek, 1999) and when the children with ASD have IQs in the normal range (Osterling, Dawson & Munson, 2002). This is an important finding as it suggests that the social inattention seen in early childhood is not merely a delay, but that this tendency to attend less to face is still present in adulthood.

Relation of findings to other psychological hypotheses of ASD (8.4)

In addition to the proposition of a direct link between social attention and the development of ASD it is also important to examine how the findings obtained within this thesis fit within the three major psychological frameworks hypothesised to underlie the cognitive processing of individuals with ASD. There are two levels on which these existing theories can explain performance in the present thesis. The first explanation is that the existing theories might relate to the underlying constructs argued to be operating within the present data. A second level of explanation is that these theories might explain the performance on the specific tasks used in this thesis.

Weak Central Coherence and enhanced perceptual functioning (8.4.1)

The Weak Central Coherence theory proposes that, unlike TD individuals, people with ASD tend to process information in a piecemeal manner, and fail to integrate the component parts of stimuli into a global image (Frith, 1989; Happé & Frith, 2006). From a learning perspective this theory can provide an explanation for the findings of this thesis.

Considering the theoretical framework of Johnson and Morton (1991) which proposes that a Conspecific stimulus of a triangle of blobs of two eyes and the mouth in the configuration of the human face receives preferential processing early in the life of the infant. If the predictions of the Weak Central Coherence theory that individuals with ASD have a difficulty integrating component parts of a face into a whole face gestalt are accurate, which has been supported by Langdell (1978) among others. Then this triangle of 'blobs' which is assumed to be the Conspecific for face may not be interpreted as a salient object in infants with ASD and would therefore not attract attention.

Although later experience of human interaction might lead to an intellectualised (Grandin, 1999) social skill which might present itself as intact processing when conscious tasks are performed (such at the conscious Face-in-the-Crowd task used in Study Two). If the component parts of the faces were not integrated then an attentional bias would not be seen in automatic tasks as the Conspecific of a face would be absent. This absence of a face Conspecific (triangle of three blobs representing eyes and mouth) would lead to the lack of bias observed in participants with ASD on the automatic attention capture tasks of the Visual Dot Probe in Studies One and Three.

From this it can be seen that the Weak Central Coherence hypothesis can provide a clear explanation for the findings obtained within this thesis in combination with the breakdown of the Conspec-Conlern theory of social learning proposed by Johnson and Morton (1991). The relationship between the findings of this thesis and the Weak Central Coherence hypothesis however cannot be directly examined within this thesis, as this was not a consideration the research set out to test. There are however good reasons to think that this might be a potential explanation for this process of development and should be further considered in the future.

Another related theory which might provide an eloquent explanation for the findings of the present thesis is that of Enhanced Perceptual Functioning (EPF; Mottron & Burack, 2001). The EPF theory also proposes a local processing advantage however EPF explains this through superior perceptual abilities of ASD individuals rather than these individuals having a deficit in global processing. This theory might give a better account of the findings in the present thesis as participants did not show evidence of Week Central Coherence (i.e. they did not have a peek performance on the Block Design task on the WAIS). Mottron, Dawson, Soulieres, Hubert and Burack (2006) provided an update to the EPF model focusing on eight key principles by which this theory can be seen to operate. Within principle three Mottron et al. discus the role that early behaviours have in later social development. In particular Mottron et al. discuss the findings that in a prospective study of children 'at risk' of developing autism Zwaigenbaum et al. (2005) found that longer fixations on objects discriminated those who later developed autism from those who did not from as early as one year of age. The most common atypical visual behaviour was lateral glancing at moving stimuli. Lateral vision is most associated with high spatial frequency processing suggesting that this processing for detail approach is being used to limit the excessive amount of information being processed. If children with ASD are using a high detail processing style to process faces the same difficulties as predicted by the WCC theory can be seen to emerge.

Executive functioning (8.4.2)

The executive functioning account of ASD proposes that a selection of those cognitions involved in guiding meaningful actions within the environment and include planning, mental flexibility, working memory, attentional switching, impulse control and monitoring of self are dysfunctional in ASD (Hill, 2004a; b). The Executive functioning account of ASD is better able to explain specific task performance in this thesis. There are clearly a number of executive demands present in completing the tasks. The Face-in-the-Crowd task can be seen to draw on both set shifting and updating when having to change the focus of the odd-one-out. However this is a relatively weak explanation and cannot provide a holistic explanation of these findings. It is difficult to see how these findings can be placed within an executive functioning framework. The deficit in executive functioning may be able to explain generally increased reaction times in the ASD group, as participants' executive deficit might have caused a general difficulty with the task. This deficit could not however explain the lack of within participants effects as even if response is generally slowed it would still be predicted that if attention was biased for a stimulus class the within participants effect would still be observed however this would be slower overall than in the TD group.

Theory of Mind (8.4.3)

Baron-Cohen (1995; 2005) proposed a model ToM which included the social developmental precursors to ToM. This model proposes that two initial systems operate in combination, which develop into an understanding of Theory of Mind. An 'Intentionality Detector' first operates by assuming a goal to be present in the direction of an agent's movement. Secondly an 'Eye Direction Detector' (EDD) develops with three functions, ascertaining if eyes are directed at the self or something else, inferring that if another's eyes are directed towards something then that item can be seen by the agent, and attributing a perceptual state to other individuals. These lead into a 'Shared Attention

Mechanism' similar to joint attention, the process of shared attention then allows for the understanding of others beliefs to develop and the individual finally develops Theory of Mind. In a more recent modification of this model Baron-Cohen (2005) proposed the development of an Emotion Detector alongside the 'Intentionality Detector' and 'Eye Direction Detector' and an empathising system alongside the Theory of Mind Mechanism.

If the Eye Direction Detector were however to be replaced with a more general face detector then it is clear how this model might fit within the findings of the present series of results. It is logical to assume that for an individual to detect and make inferences about an individual's eye direction they must first detect their face. Therefore the learning processes that take place in early facial attention seeking can be seen to underlie knowledge of eye direction, intention, sharing of attention and ultimately Theory of Mind.

Developing a theoretical theme of the present findings in relation to ASD (8.5)

The current research has some consistency with previous literature. The findings of these experiments provides some support for the long held assumptions that TD members of the general population show a cognitive bias which results in greater attention for faces (e.g. Goren Sarty & Wu, 1975; Bindeman et al., 2007). It should be noted that the findings regarding social attention in the control participants in this thesis were not conclusive and some control participants did not show this bias, however findings were suggestive of this bias.

At first glance, this thesis provides contradictory evidence about the nature of social attention in ASD. There was no evidence for a bias for faces in the ASD group in the Visual Dot Probe task however, in Study Two using the Face-in-the-Crowd task the ASD group showed a bias for faces. There are however important distinctions between the Visual Dot Probe and Face-in-the-Crowd tasks which warrant consideration. Firstly, the role played by the face stimuli differs greatly between the two tasks. In the Visual Dot

Probe task the stimuli (both facial and non-social) are secondary to the task requirements (to respond to the presence or absence of a dot), and the attentional bias is measuring the capacity of the stimuli to 'distract' the participant from the task. However, in the Face-in-the-Crowd task the stimuli are central to the tasks requirements, as they must be searched through to identify if all are the same or there is an incongruent image. This raises the possibility that individuals with ASD do not spontaneously attend to faces, however once attention has been engaged faces are treated in a superior fashion to non-face stimuli. This is consistent with the idea that as high functioning individuals develop they may begin to desire social relationships (e.g. APA, 2000; shown by a conscious engagement with faces in the FITC task) however this is not an implicit process and would therefore be consistent with an intellectualised social capacity (Grandin, 1999).

This proposition could be argued to explain a number of previous contradictions in the literature on ASD as well as observations of the behaviour of ASD individuals. Most notably there has been conflict in the findings of the research some of which has suggested that individuals with ASD use of social stimuli as a source of preferential orienting is intact (e.g. Kylliäinen & Hietanen, 2004; Van der Geest et al., 2002) and those who suggest that this ability is impaired (Dawson et al., 1998; 2004; Klin et al., 2002a; b). The above contradiction in findings maps onto those of the present study. In previous research that has suggested no deficit in social attention the stimuli has been placed clearly within the currently attended location, and is central to task completion. While in the studies of Dawson, et al. and Klin et al. the social nature of the task was secondary and therefore was not central to any task, resulting in this information not being attended to preferentially. This therefore suggests that social attentive behaviours can be elicited in individuals with ASD when these are explicitly required for a task and will be seen at a conscious level. This is supported by the findings of Study Two in the present thesis in which both TD and ASD participants showed a significant bias for face stimuli in the Face-in-the-Crowd task. However this is not supported by the findings of Experiment 4 in which neither TD or AS participants showed a bias either for or away from faces. There were however methodological problems with Experiment 4 that may have resulted in the lack of significant results in this study. However, when spontaneous social attention and behaviour is required these behaviours will be impaired.

The idea that the orienting to social cues seen in ASD is a result of an effortful intellectualised process and not an automatic social engagement process is supported by the findings of Ristic et al. (2005). Ristic et al., found that TD adults show faster response times to probes presented in a location pre-cued by the direction of the eyes on a centrally located face both when they knew it predicted the location of a subsequent probe (80% congruency) and when they knew that it did not predict the location of the probe (50% congruent). This is in contrast to ASD participants who showed reduced response latencies only when the direction of the eyes was spatially predictive. The findings of Ristic et al.'s study appears to be consistent with the current study in indicating that when social cues are not beneficial to task performance they are not used by those with ASD. However, for most TD individuals social engagement is an automatic process and social cues will continue to capture their attention even with this is not advantageous to performance. It needs to be acknowledged however that the analysis of individual participant biases in this thesis indicated that this finding is not a universal finding with TD individuals.

As Loveland (1991) points out although we may all inhabit the same physical environment our perception of what this environment affords us may be very different. It appears that for individuals with ASD, faces, and possibly more broadly people, are not afforded the same significance as in typical development, and that this may operate throughout life. Within Johnson and Morton's (1991) framework of face expertise, the consequences of a lack of an implicit mechanism that resulted in an engagement with conspecifics, such as faces, would have the effect of the neural system of the individual failing to prepare for expertise within that domain. This would result in a lack of social learning and reduced expertise in face processing, as observed in ASD (e.g. Langdell, 1978; Williams, Goldstein & Minshew, 2005). This implication of a lack of early experience with these face Conspecifics was highlighted by Le Grand et al. (2003) who indicated that infants with congenital cataracts which blocked visual input to the right hemisphere were significantly impaired in the holistic processing of faces years after these visual impairments had been removed. Johnson (2005) suggested that with particular reference to autism a lack of a broader social saliency might underlie many of the deficits in this group.

Given what is known about the social brain and the atypicalities within this network in ASD it would be beneficial to examine the neural correlates with the Dot Probe and Face-in-the-Crowd tasks in typical and ASD participants. The amygdala has been implicated in emotional learning (e.g. Gaffen, Gaffen & Harrison, 1988), signalling the emotional salience of events (e.g. Aggleton, 1993), social behaviour (Brothers & Ring, 1993), social cognition (Castelli, Happe, Frith & Frith, 2000), and the perception of facial expressions (Adolphs, Tranel, & Damasio, 1998). Whereas neuroimaging studies conducted during emotional perception tasks have shown that the amygdala is less active than in ASD participants than in TD controls (e.g. Critchley et al., 2000). Given that the tasks utilised in this thesis are designed to examine the attentional capture (salience) of stimuli of interest, particularly faces and facial expressions, it might be predicted that during these tasks reduced amygdala activation would be observed relating to the orienting of attention to social cues. In addition to this Grelotti et al. (2005) showed that the right Fusiform Gyrus usually associated with face processing in TD (e.g. Kanwisher et al; 1997) but not in ASD (e.g. Schultz et al., 2000) showed greater activation for Digimon characters in an autistic child who had a restricted interest based on the Digimon cartoon. Furthermore when exploring activation of the amygdala the TD child had greater activation for faces than Digimon characters and vice versa for the autistic child obsessed with Digimon. This supports the proposition that the reason that ASD individuals do not show greater activation of the right Fusiform Gyrus when processing faces is not because of damage to this region but because face stimuli do not have the same significance for individuals with ASD and therefore are not processed in an area associated with expert processing.

Limitations (8.6)

There are however limitations to this thesis which need to be considered in interpreting the results. One limitation that has been raised throughout the chapters is that of statistical power. In line with previous research using the Visual Dot Probe and Face-in-the-Crowd tasks the analysis of the data collected required a complex multi-factorial analysis (e.g. Mogg & Bradley, 1999a; b). Due to the population of interest in this thesis being members of a clinical group whose age and intellectual functioning made them independent and the requirements of appropriate matching of controls, it was not possible to recruit sufficient participants to achieve an appropriately powered series of studies. Although this thesis was underpowered from a strictly statistical point of view the sample size was at least in line with the published literature and was larger than much of the available research. It does however need to be acknowledged that some of the effects tested might have been significant with larger samples. It also needs to be considered that some findings may have resulted from extreme scores by some participants. The possibility of some effects being a result of type one error is potentially heightened by the decision not to adjust alpha for familywise error. Many claim that statistical convention is to accept significant findings based on a more conservative alpha level when performing multiple statistical comparisons (e.g. Shaffer, 1995). There are however problems with this approach Perneger (1998) cites a variety of concerns around the use of bonferroni adjustments including their inflation of the probability of type II errors, that because of the post hoc testing of a secondary hypothesis this may render an earlier primary hypothesis non-significant. The issues raised by Perneger combined with the small sample sizes and the specific a-priori predictions about effects of interest were the rationale for not adjusting of alpha rate to account for potential familywise error. To address this future research needs to be conducted on a larger scale to counter the low power seen in this design. Although this would be difficult given the limited pool of potential participants it is possible that through connection to diagnostic services or larger scale service providers increased recruitment may be possible.

A second potential weakness in this thesis relates to the ability to confirm the diagnosis of participants. Although all participants had previously been diagnosed based on ICD/DSM criteria and this was checked where possible by examining doctors reports, diagnosis could not be confirmed independently in this thesis. In this thesis it was not possible to confirm diagnosis using validated diagnostic tools, such as the ADI-R (Lord, Rutter, & Le Couteur, 1994) or ADOS-G (Lord et al. 2000). Although scores on the Autism Quotient (AQ; Baron Cohen, Wheelwright, Skinner, Martin & Clubley, 2001) were used as an approximation to autistic severity this scale has some flaws. Although the AQ has been shown to differentiate ASD individuals from controls (Baron Cohen et al., 2001) and predict later diagnosis of ASD reliably (Woodbury-Smith et al., 2005) it cannot be recognised as a clinical tool which can be used to diagnose ASD. As stated in Chapter 2 (2.6.1) the AQ is also a problematic tool as it relies on participants' introspection, which may be a problem for individuals with ASD and includes two attentional domains that do not relate to clinical criteria for ASD.

Within the present population there were also some specific problems with the AQ data presented. Almost half (8/17) of the ASD group had full AQ scores lower than those suggested as a cut off by Baron Cohen et al. (2001) and two scored lower than the cut off of 26 suggested by Woodbury-Smith et al. (2005). In addition to this one control participant had an AQ score of 26 and two controls scored higher than the lowest scoring ASD participant. The data of Baron Cohen et al. would predict that 79.3% of ASD individuals with ASD would score 32 or above whereas only 53% of participants in this thesis scored above this value. Based on this the participants in this thesis have fewer autistic symptoms than in Baron Cohen et al.'s group. In Baron Cohen et al.'s group 2.3% of controls scored above the cut off of 32 whereas in the present sample none scored above this cut off. Therefore, the controls in this thesis appear to be consistent with those of Baron Cohen et al. In the data of Woodbury-Smith et al. 94.5% of participants with ASD scored above 26, compared to 88% of participants in the present study. Therefore, again the current population appear to have few ASD symptoms than in the published norms, however the difference from Woodbury-Smith et al.'s data is smaller than from Baron-Cohen et al. Although the population used in this thesis do score slightly lower on the AQ than published norms there is no reason to doubt the diagnoses given to participants taking part in this thesis. Given that participants had previously been diagnosed using well validated methods by train clinicians, these diagnosis should be assumed to be reliable.

The potential problems with the AQ are particularly important for consideration in the analysis in Chapter 7; in this chapter scores on the AQ failed to predict attentional bias for faces in any of the comparisons (although a trend towards higher scores predicting bias away from faces was observed in the data from study one). If however a better validated measure such as the ADOS or ADI-R had been used it is possible that autistic severity might successfully predict attentional bias. When participants' biases were considered on an individual level those participants with the lowest AQ scores did however show a consistent bias for faces.

An additional problem with this thesis relates to the potential that the findings do not reflect the specific deficit in social attention proposed, but instead a motor dysfunction impairing response. Goldstein, Johnson and Minshew (2001) examined the attentional processing of high functioning adolescents and adults with ASD. Using the Halstead Finger Tapping Test (Reitan & Wolfson, 1993) as a covariate, significant differences between ASD and control groups on the Stroop test and Letter Cancellation test were co-varied out. The same procedure using the Klove Grooved Pegboard test (Mathews & Klove, 1964) removed the significant difference between groups on the Stroop effect and greatly reduced the differences on the Letter Cancellation test and Trails A and B. This suggests that performance on standard attentional tasks including the Stroop task, which involves only a simple button press response, can be attenuated by motor performance. It is therefore possible that motor dysfunction contributed to the differences observed in this thesis. Importantly however, these may have contributed to the differences between the groups, a motor deficit cannot explain within group differences.

A second potential non-social related explanation for the findings in this thesis comes from the possibility that for individuals with ASD 200ms is too fast for any stimulus to capture attention or cause an attentional shift. Wainwright-Sharp and Bryson (1993) used the Posner pre-cueing task to examine endogenous (consciously controlled) attentional shifts in individuals with ASD. When the cues were displayed 100 ms before the target TD controls showed faster reaction times for the valid cues, however autistic participants did not show the same cue validity effect. However autistic participants did show an even larger cue validity effect than controls when the cue was presented 800ms before the target. This raises the possibility that the reason that no bias for faces was seen in the Visual Dot Probe task was that 200ms was not long enough for any stimulus to capture attention in ASD and not because faces fail to attract attention in ASD. If this were the case then this would explain why attention was not captured by faces when presented for the short durations used in the Visual Dot Probe however no differences were found between ASD and control groups on the Face-in-the-Crowd task, which uses longer presentation times. This explanation however also has its weaknesses; the findings of Wainwright-Sharp and Bryson (1993) were based on a poorly matched population with controls being in the 90-99th percentile (mean 94.9) compared to the ASD group who's scores were in the 5-95th percentile (mean 48.4) on the Raven's progressive matrices (RPM, Raven, 1947). It is therefore possible that the null findings on 100ms presentations in Wainwright-Sharp and Bryson's study reflect lower intellectual functioning in the ASD group not impaired attentional functioning in the ASD population. In addition to this in Study Three, using the Visual Dot Probe task, emotional faces (in particular happy faces) presented outside of conscious awareness (usually for less than 20ms) captured attention in individuals with ASD. This suggests that the broad attentional deficit or motor deficit accounts cannot explain the findings in this thesis and that there is something more specific about facial attentional processing involved.

An additional limitation specifically relating to Study Four was how similar the facial expressions were. This made the teapot a highly novel stimulus only presented on one in four displays. Based on evidence from the visual odd-ball task (In which both common and rare stimuli are presented to participants and the task is to respond to the rare stimuli) novel stimuli tend to occupy more attention than familiar ones (Campenalla et al., 2002). Therefore one potential explanation for the findings in Study Four is that the novelty of the presentation of the teapots disrupted the attentional capture by the faces. It is clear from this that future research using these designs needs to consider the novelty of the stimuli when examining attentional bias.

Future Directions (8.7)

There are four major future directions that the findings of this research appear to suggest, which will be discussed in the following section. 1) Further examining the role that the automaticity of bias plays in social inattention in ASD. 2) Examining the nature of social inattention in ASD and developing reliable measures for discriminating between individuals with and without ASD. 3) Examining further the role of affect, and in particular anxiety in the cognitions and emotional processing of individuals with ASD 4) An examination of social attention in 'at risk' (i.e. siblings of children with ASD, or children of parents with ASD) individuals to examine the development of social attention prior to diagnosis.

The findings of the present thesis are suggestive of a difference between ASD and control participants in their attentional biases. Tentative evidence suggests that while control participants show some indication of a bias for face stimuli on both the Visual Dot Probe and Face-in-the-Crowd tasks that the ASD group only show this bias on the Face-in-the-

Crowd task. Although the findings with the control group provide some evidence of an attentional bias for faces outside of conscious control, having indicated a bias for faces on supra-threshold presentations in Study One and a bias for faces on sub-threshold permutations in Study Three, these are not conclusive findings given that they were not shown on all comparisons. This alone suggests that further examination of these effects would be valuable to examine the reliability of attention for faces in TD individuals. There are two major differences between these designs; in the Visual Dot Probe the stimuli are secondary to the task and are there to distract participants whereas in the Face-in-the-Crowd the stimuli are primary to task requirements. This suggests that an expatiation for these findings is that participants have a difficulty engaging and detecting faces (i.e. in the Visual Dot Probe) however once engaged show a bias for faces (i.e. Face-in-the-Crowd). A second explanation is that because the Visual Dot Probe, as used in this thesis, is presumed to activate automatic attentional bias whereas the Face-in-the-Crowd task activates a more conscious effect that the difference between tasks reflects an issue of automaticity. By examining the nature of social attention using a variety of tasks that vary in terms of cognitive demand, level of automaticity and role of social stimuli it may be possible to build a more detailed understanding of the nature of any deficit present in ASD. This could then be used to develop a task, or a battery of tasks that would discriminate between individuals with ASD and those without and provide a clear understanding of what cognitive factors relate to any deficits. There are a number of potential designs that could be adapted to examine social inattention at a more implicit level, including greater use of masked stimuli, the attentional blink and the inhibition of return task. Additionally by using other paradigms that have been adapted to examine bias for faces (e.g. the flicker paradigm or Inhibition of Return) it will be possible to examine attentional bias for faces in more detail, when these stimuli are presented under conscious control.

In addition to automaticity and presentation duration, there are a number of methodological considerations which need to be addressed in order to fully understand the effects seen with the Visual Dot Probe and Face-in-the-Crowd tasks, which will also help with the design of other studies. As stated previously, the stimuli presented to participants changed throughout this thesis. It is possible that the changes in the social and non-social stimuli used in this thesis altered the findings observed. For the first two studies neutral faces of both Caucasian and Japanese ethnicity and non-social images of cars and houses. Studies Three and Four use only Caucasian faces which displayed neutral, angry and happy emotional expressions and non-social images of teapots. It is therefore important that the role of these stimuli in biases is systematically examined in future research. As stated above whether the non-social stimuli broadly match the internal features of the face of the external structure of the face might effect whether attentional bias is seen outside of conscious control or not. Additionally the full effects on attentional bias for faces of presenting faces displaying a range of emotional expressions compared to faces displaying only neutral faces needs to be further explored. The findings with emotional Vs neutral faces in this thesis were conflicting and further exploring these effects are important for future research.

To extend the validity of the examination of social attention in the development of ASD a valuable future direction in research within this field would be to examine social attention in more than a single sensory modality. Previous research (including the present thesis) has typically examined social attention either in the visual (e.g. the present thesis; van der Geest et al., 2001; Kylliäinen & Hietanen, 2004) or the auditory domain (e.g. Dawson et al., 1998, 2004; Klin, 1991; 1992). The examination of social attention in multiple sensory modalities will allow for a more ecologically valid measure of social attention in this group. This will also allow for the reliability of social inattention to be examined in a single population across modalities. Given that some autistic-like symptoms have been observed in populations who have sensory difficulties (e.g. Le Grand, Mondloch, Maura & Brent, 2003; Peterson, 2004) a consistency of atypical social processing across sensory modalities might be what differentiates children with ASD from those with impaired processing in a single modality.

In addition to examining social attention across sensory modalities future research needs greater consideration of the possibility that the process of social orienting in adults with ASD appears to have some 'intact' components (possibly more explicit), while other (more implicit) ones are impaired, and may even be causing an avoidance of social stimuli. Previous research has typically considered social attention at a more conscious level (e.g. Dawson et al., 1998, 2004; Klin 1991, 1992; van der Geest et al., 2002).

A limitation of the research contained within this thesis is the inability to test the developmental effects relevant to this area. If the presumption that face processing expertise is obtained through learning, which begins in early infancy is accurate (Johnson & Morton, 1991; Morton & Johnson, 1991) then it is clear that these effects need to be studied in greater detail with greater experimental control and with younger participants. This would allow for the developmental time course of any effects to be appropriately examined and if it were possible to show that a lack of social attention is present from birth then this would support the proposition of a causal mechanism. However, if social inattention develops later in childhood then this suggests that a lack of attention to faces is a learned process, and caused by something else. If social inattention were shown to be a causal cognitive mechanism in the development of ASD then this would aid in narrowing down the biological systems that may underlie ASD. Future research is needed to examine the early social attention of children who are genetically vulnerable to developing ASD, such as children of ASD parents or who have siblings with ASD to examine whether social attention is reduced in those who go on to develop ASD compared to those who no signs of ASD. To be most effective this research should be conducted as early in infancy as possible. Based on the design of Goran, Sarty and Wu (1975) an initial testing face 'at birth' using the tracking of simple schematic stimuli and following up with later preferential looking tasks based on the research of Maurer and Barrera (1981) at approximately 2 month of age. These participants could then be asked to attend a follow up at ages 2-5 for assessment of symptoms of ASD. If some participants who had reduced social attention at birth went on to develop ASD then this would provide evidence for a causal link between social inattention and the potential development of ASD. It does however need to be acknowledged that there was some overlap between the ASD and control participants in their attentional bias in this thesis and before social inattention was used to diagnose ASD the sensitivity and specificity of this measure would have to be considered.

The development of measures that could be used to detect differences between children with and without ASD in infancy would benefit those working in a clinical setting with individuals with ASD. Such measures could provide them with greater information about early behavioural markers, which may help in the reliability of early diagnosis for this condition. This is particularly important as at present autism is not normally diagnosed until the child is around age 5 (e.g. Wiggins, Baio & Rice, 2006) with Asperger's Syndrome being diagnosed at an average age of 11 years (Howlin & Ashgarian, 1999). Parents however often report that they suspected a problem before 1 year of age (Ornitz, Guthrie, & Farley, 1977) and retrospective analysis of video tapes from children's first birthdays suggest that it may be possible to identify these children at this age (e.g. Osterling & Dawson, 1994). Evidence for the stability of diagnoses made before the age of two however, are varied. Some accounts suggest that those diagnosed with a spectrum disorder at this age retain a diagnosis of autism or related disorder (e.g. Charman et al., 2005, Lord et al., 2006). However Turner and Stone (2007) have suggested that almost a third of all diagnoses made before age two are later reclassified as either developmentally delayed or having language impairment. Improving the reliability of early markers of ASD is important as research has suggested that 75-87% those diagnosed at two years of age develop functional language (Charman et al., 2005; Eaves & Ho, 2004; Turner et al., 2006), far greater than the 50% suggested in ASD more generally (Volkmar et al., 1994). Additionally Krantz (2000) suggested that social skills training for ASD children should begin before the age of 5 years to have a good chance to be effective.

Although differences were apparent between the control and ASD groups on the Visual Dot Probe task there are potential problems with using social attention as an early diagnostic indicator of ASD based on such data. Within this population some of the ASD participants showed a consistent bias for faces compared to non-face stimuli and some controls showed a bias away from faces. Therefore based on the current findings it would appear that using these methods to examine social attention as a diagnostic indicator of ASD may result in failed diagnosis and false positives in a number of cases. However, the reason that there was overlap between the groups may be in part explained by participants being older and therefore having had a number of experiences that would have affected their learning and cognition. Therefore it is clear that more work needs to be done in early childhood before social attention can be used reliably in diagnostic systems.

Final Conclusions (8.8)

The aim of this thesis was to examine how face stimuli capture attention in comparison to non-face stimuli in a single population of adults with ASD in comparison to neuro-typical controls. Furthermore within this thesis the role of conscious attentional control in attentional bias was considered, this was achieved by using the Face-in-the-Crowd task to measure attentional bias under conscious control, whereas the Visual Dot probe task was used to examined automatic attentional capture outside of conscious awareness. Overall, though not exclusively, this research supported the hypothesis that TD participants would show a bias for faces across paradigms that measure attentional bias outside of conscious control (Studies One and Three) and with a greater level of conscious control (Study Two), however in Study Four no bias was observed. The lack of an attentional bias in Study Four may however have been caused by methodological factors. In comparison ASD participants appeared to show no bias for faces in the Visual Dot Probe task however their performance did not significantly differ from controls in the Face-in-the-Crowd task. This suggests that adults with ASD have the ability to use simple social cues when they are already engaged with these stimuli and are given time to process them.

However, this bias does not appear to result from an automatic process. The analysis in Chapter 7 supports the idea that attentional bias in the presence of face stimuli is not driven by the same mechanisms as in typical development. In the ASD group increasing social attention appeared to be related to both increased anxiety indicating that this bias might be more similar to threat bias effects seen in typical development for angry faces (e.g. Bradley et al., 1998). Bias for faces was also associated with higher IQ's in this group suggesting that there may be some intellectualisation of social processing in ASD. It is clear from this that future research needs to be conducted which will allow for the role of factors relating to anxiety and other individual differences to be examined in relation to cognitive biases in ASD.

These findings fit well with previous research that suggests that faces capture attention in typical development (e.g. Bindeman et al., 2007). This thesis is also situated within an interesting and key debate within the literature looking at social attention in ASD. The findings of this thesis suggest that adults with ASD do not attend to faces when presented for durations outside of conscious control (i.e. 200ms in the Visual Dot Probe) however there was no difference between ASD and control participants social attention when tasks measured social attention under conscious control. This provides a potential explanation for the conflicting findings that individuals with ASD use social stimuli as a source of preferential orienting is intact (e.g. Kylliäinen & Hietanen, 2004; Van der Geest et al., 2002) and research which suggest that social stimuli do not capture attention preferentially (e.g. Dawson et al., 1998; 2004, Klin et al., 2002a, b). This is a great advantage of the methods used in this thesis as they allow these complex effects to be examined with only minor modifications to the design. In the Dawson et al. and Klin et al. research, the social stimuli were not task relevant and therefore would not automatically capture attention however the research of Kylliäinen and Hietanen and others require attention to these stimuli to pass the task and therefore autistic individuals conscious learned mechanisms may take over. This provides the basis for a potential theoretical framework for autistic development based around Johnson and Morton's (1991) learning theory of social development. There are however limitations to this research; the small sample sizes may have resulted in some findings being reported as non-significant as a result of low power or extreme scores by some participants driving a non-significant effect to be significant. It is also not possible to test the role of learning in early autistic development given that participants were adults in the presented research. Given these limitations it is suggested that future research needs to consider these effects in younger populations with greater experimental control than has been used in previous research. Future research also needs to consider social attention across sensory modalities as previous findings have been based on either visual or auditory stimuli.

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Appendices

Appendix 1: Diagnostic criteria for Autism

The social criteria consists of:

- Marked impairment in non verbal behaviours including: lack of eye contact with others, Facial expression, body posture and gestures to regulate social relations.
- Failure to develop developmentally appropriate peer relations.
- Lack of spontaneous search to share with others enjoyment, interest, or achievement.
- Lack of social or emotional reciprocity

The deficit in communication consists of:

- Delay or lack of development of spoken language (not accompanied by attempt to compensate by other means, i.e. mime)
- If the individual has speech, a marked impairment in ability to initiate or sustain conversation with others.
- Stereotyped and repetitive use of language or idiosyncratic language
- Lack of varied, spontaneous make believe play or socially imaginative play at the developmentally appropriate level.

The behavioural criteria consists of:

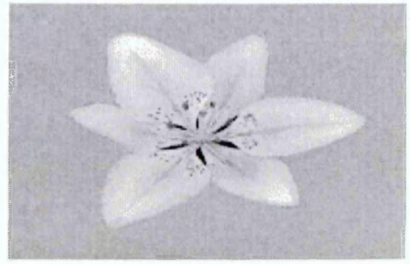
- Encompassing preoccupation with one or more stereotyped and restrictive pattern that is either abnormal in intensity or focus.
- Apparently inflexible obedience to specific, non-functional routines or rituals.
- Stereotyped and repetitive motor mechanisms (i.e. hand flapping or twisting)
- Persistent preoccupation with parts of objects.

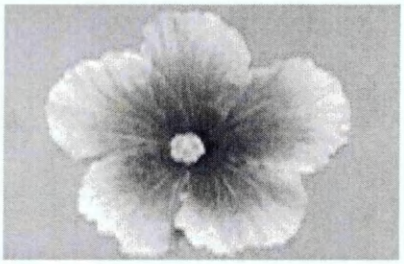
DMS IV-TR (pp75).

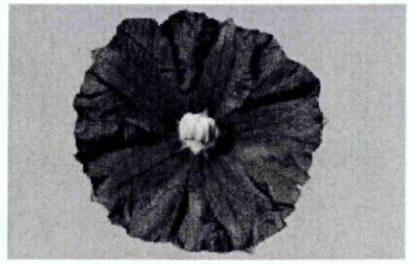
Appendix 2: Sample stimuli for calculation of detection thresholds

Chairs

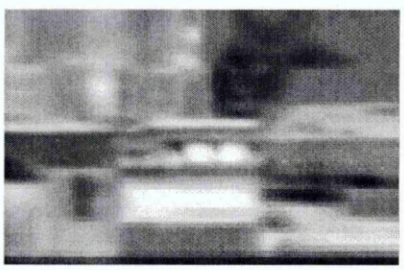
Flowers







Mask



Appendix 3.1 Subjective threshold

This task begins with a cross (+) in the centre of the screen

Please look at this cross every time you see it on the screen.

The cross will then for a short time be changed for a picture in the middle of the screen on some trials and a blank screen on others.

After this you will see a 'blurred' picture, which you will have already been shown.

It is important that you only look to see what happens before the blur.

If you see a picture on the screen please press the YES key

If you do not please press the NO key.

After 10 goes you will either try again at a {harder/easier} level or you will go onto the same task but with 45 goes.

Please be sure to press the correct button, the amount of time you take is not important for this task.

Before starting, please ask any questions that you have

When you are ready to start please press the START button.

Appendix 3.2 Objective threshold

This task begins with a cross (+) in the centre of the screen

Please look at this cross every time you see it on the screen.

The cross will then for a short time be changed for a picture in the middle of the screen.

After this you will see a 'blurred' picture, which you will have already been shown.

It is important that you only look to see what happens before the blur.

If you see a Flower on the screen please press the FLOWER key

If you see a Chair on the screen please press the Chair key

After 10 goes you will either try again at a harder level or you will go onto the same task but with 45 goes.

Please be sure to press the correct button, the amount of time you take is not important for this task.

Before starting, please ask any questions that you have

When you are ready to start please press the START button.

Appendix 4: Error data for Study One: Visual Dot Probe with neutral faces, cars and houses

Sub-threshold analysis

Accuracy data was entered into the same 2 x 2 x 2 x 2 mixed design ANOVA with 1 between (diagnosis: ASD Vs control) and 3 within participant variables (pair: face-car Vs face-house; face location: top Vs bottom; probe location: top Vs bottom). This revealed no significant main effects: pair $F(1,36)= 1.70$, $p=.201$; face location $F(1,36)=.051$, $p=.823$; probe location $F(1,36)=.05$, $p=.825$; diagnosis $F(1,36)=.022$, $p=.884$. There was however a significant probe location x diagnosis interaction $F(1,36)=4.519$, $p=.040$, this is not a theoretically interesting finding and will therefore not be discussed further. This analysis revealed no other significant interactions: pair x diagnosis $F(1,36)= 1.70$, $p=.201$; face location x diagnosis $F(1,36)= .458$, $p=.503$; pair x face location $F(1,36)= 1.302$, $p=.261$; pair x face location x diagnosis $F(1,36)= .052$, $p=.821$; pair x probe location $F(1,36)= 1.314$, $p=.259$; pair x probe location x diagnosis $F(1,36)= 1.314$, $p=.259$. Importantly there were no theoretically important interactions: face location x probe location $F(1,36)= .290$, $p=.593$; face location x probe location x diagnosis $F(1,36)= 1.581$, $p=.217$; face location x probe location x pair $F(1,36)= .042$, $p=.839$; face location x probe location x pair x diagnosis $F(1,36)=.377$, $p=.543$.

Supra-threshold

Accuracy data was entered into the same 2 x 2 x 2 x 2 mixed design ANOVA with 1 between (diagnosis: ASD Vs control) and 3 within participant variables (pair: face-car Vs face-house; face location: top Vs bottom; probe location: top Vs bottom).

This revealed no significant main effects: pair $F(1,36)= 2.102$, $p=.156$; face location $F(1,36)=.580$, $p=.451$; probe location $F(1,36)=.05$, $p=.648$; $F(1,36)=.022$, $p=.426$. There was however a theoretically relevant interaction between face location and probe location

F(1,36)=4.217,p=.047. Importantly this was not moderated by any other factors as there were no other theoretically relevant interactions: face location x probe location x diagnosis F(1,36)= 1.566, p=.219; face location x probe location x pair F(1,36)=3.176, p=.083; face location x probe location x pair x diagnosis F(1,36)=1.108, p=.300.

When the face location x probe location interaction was broken down using simple main effects analysis this revealed no significant effects: when faces were presented at the top of the screen there was no difference between probes at the top and bottom (.054) when faces were presented at the bottom of the screen there was no difference between probes at the top and bottom (.403). When probes where presented at the top of the screen there were no difference between when the faces were presented at top and bottom of the screen (.072) when probes where presented at the top of the screen there were no difference between when the faces were presented at top and bottom of the screen (.374).

This analysis revealed no other significant interactions: pair x diagnosis 2.102, p=.156; face location x diagnosis F(1,36)=.000, p=.991; probe location x diagnosis F(1,36)=2.553, p=.119; pair x face location F(1,36)= 3.805, p=.059; pair x face location x diagnosis F(1,36)=.937, p=.339; pair x probe location F(1,36)= .580, p=.441; pair x probe location x diagnosis F(1,36)= .000, p=.991.

Appendix 5: Full demographic data for Study one: Visual Dot Probe with neutral faces, houses and cars

Table 3.2: Means & standard deviations for reaction times on sub-threshold trials. (Face congruent trials shown in Bold)

Top image	***Face***	*Face*	*Car*	***Car***	***Face***	*Face*	*House*	***House***	*Car*	*Car*	*House*	*House*
Bottom image	***Car***	*Car*	*Face*	***Face***	***House***	*House*	*Face*	***Face***	*House*	*House*	*Car*	*Car*
Probe location	***Top***	*Bottom*	*Top*	***Bottom***	***Top***	*Bottom*	*Top*	***Bottom***	*Top*	*Bottom*	*Top*	*Bottom*
ASD	**497.21**	501.01	508.13	**516.43**	**470.67**	496.17	488.68	**488.30**	458.78	488.42	488.68	525.74
	(143.54)	(91.25)	(130.30)	**(78.42)**	**(110.23)**	(101.36)	(112.40)	**(110.37)**	(85.69)	(81.51)	(112.40)	(133.81)
Control	**424.01**	469.39	436.42	**433.53**	**428.72**	423.01	461.37	**444.12**	445.86	435.91	461.37	447.45
	(83.56)	(117.64)	(76.26)	**(80.15)**	**(94.79)**	(72.07)	(99.55)	**(93.08)**	(100.96)	(79.08)	(99.55)	(68.37)

Table 3.3: Means & standard deviations for reaction times on supra-threshold trials (Face congruent trials shown in bold).

Top image	***Face***	*Face*	*Car*	***Car***	***Face***	*Face*	*House*	***House***	*Car*	*Car*	*House*	*House*
Bottom image	***Car***	*Car*	*Face*	***Face***	***House***	*House*	*Face*	***Face***	*House*	*House*	*Car*	*Car*
Probe location	***Top***	*Bottom*	*Top*	***Bottom***	***Top***	*Bottom*	*Top*	***Bottom***	*Top*	*Bottom*	*Top*	*Bottom*
ASD	**527.58**	512.00	509.16	**525.26**	**524.82**	526.42	523.05	**522.66**	549.50	535.97	522.39	525.74
	(223.61)	(158.66)	(147.96)	**(131.27)**	**(123.36)**	(120.99	(153.37)	**(162.94)**	(221.41)	(171.64)	(138.57)	(133.81)
Control	**442.68**	464.58	448.24	**436.79**	**447.61**	476.32	476.55	**465.95**	446.13	477.11	453.95	447.45
	(84.20)	(83.38)	(75.95)	**(72.89)**	**(72.90)**	(96.13)	(94.23)	**(96.05)**	(88.10)	(92.75)	(100.30)	(68.37)

Appendix 6: findings not theoretically relevant from Chapter 3: Attentional bias for faces compared to non-face stimuli: Visual Dot Probe.

Sub-threshold

Data was entered into a 2 x 2 x 2 x 2 mixed design ANOVA (described in Chapter 3). This revealed two significant effects; a main effect of pair $F(1,36)=6.323$, $p=.017$ explained by a faster reaction time to face house pairs than face car pairs. Also a significant three way interaction between pair, face location and diagnosis was observed $F(1,36)=6.973$, $p=.012$. This was broken down into separate 2 (pair) by 2 (face location) ANOVAs for the control and ASD groups. In the ASD group this revealed only a significant main effect of pair $F(1,18)=5.678$, $p=.028$ which is explained by the same faster reaction time to face house pairs than face car pairs observed in the whole group. The main effect of face location $F(1,18)=.565$, $p=.462$ and the pair by face location interaction $F(1,18)=1.457$, $p=.243$ were both non-significant. In the control group the main effects of both pair $F(1,18)=.965$, $p=.339$ and face location $F(1,18)=.123$, $p=.730$ were non-significant. However there was a significant interaction between pair and face location $F(1,18)=7.266$, $p=.015$. This was analysed further using four repeated measures t-tests, these indicated that the interaction was explained by faster reaction times when faces appeared at the top of the screen on face-house trials than face-car trials $t(18)=2.163$, $p=.044$ all other tests were not significant. Given that this finding is not theoretically important it will not be discussed in more detail.

In the original ANOVA there was also a trend towards the control group responding faster than the ASD group $F(1,36)=3.956$, $p=.054$. All other main effects were non-significant; face location $F(1,36)=.626$, $p=.434$ and probe location $F(1,36)=3.214$, $p=.081$. All remaining Interactions were non-significant; pair x diagnosis $F(1,36)=1.918$, $p=.175$, face location x diagnosis $F(1,36)=.102$, $p=.752$, probe location X diagnosis $F(1,36)=.048$, p=.827, pair x face location F(1,36)=.595, p=.445, pair x probe location F(1,36)=.106, p=.746, pair x probe location x diagnosis F(1,36)=1.946, p=.172.

Supra threshold

The same 2 x 2 x 2 x 2 mixed design ANOVA (described in Chapter 3) was run on the supra threshold data. This revealed a significant main effect of pair F(1,36)=7.287, p=.011 indicating that participants were quicker to respond to face-car trials than face-house trials. All other main effects were non significant. Face location F(1,36)=.032, p=.860, probe location F(1,36)=.987, p=.327 and diagnosis F(1,36)=2.812, p=.102.

All remaining interactions were also non-significant; pair x diagnosis F(1,36)=.717, p=.403, face location x diagnosis F(1,36)=.006, p=.938, probe location X diagnosis F(1,36)=.101, p=.752, pair x face location F(1,36)=.091, p=.752, pair x probe location F(1,36)=.093, p=.763, pair x face location x diagnosis F(1,36)=1.969, p=.169, pair x probe location x diagnosis F(1,36)=.328, p=.570.

The control group showed a significant main effect of pair F(1,18)=10.348, p=.005 with face-car trials being responded to quicker than face-house pairs.

Appendix 6: Instructions for Face-in-the-Crowd Task

This experiment begins with a cross (+) in the centre of the screen. Please look at this cross every time you see it on the screen.

The cross will then be changed for a group of 9 pictures in the centre of the screen. On some of the trials one picture will be different from the group, please press the YES key if there is a different picture in the group and NO if all the pictures are the same.

To help you prepare for the main task, you will be given a few practice attempts. You will need to be 100% correct in the practice trials in order to proceed to the main task. Please try to press the button as quickly as possible when you see the picture groups to avoid mistakes.

Before attempting the practice trials, please ask any questions that you have. When you are ready to start the practice trials, please press the START button.

Appendix 7: Error data for Study Two, Face-in-the-Crowd with faces, cars and houses

To assess whether participants showed differences in the number of errors made by condition, target present data was entered into a 2 (Diagnosis: ASD Vs control) X 2 (stimuli pair: faces and cars Vs faces and houses) X 2 (face role: face as target Vs face as distracter) mixed design ANOVA. This revealed no significant main effects: pair $F(1,36)=0$, $p=1$, face role $F(1,36)=1.259$, $p=.269$, diagnosis $F(1,36)=.056$, $p=.814$. This also revealed no significant interactions: pair location x diagnosis $F(1,36)=1.992$, $p=.167$, face role x diagnosis $F(1,36)=.141$, $p=.710$, pair x face role $F(1,36)=.300$, $p=.587$, pair x face location x pair $F(1,36)=.297$, $p=.589$.

Appendix 8: Visual Dot probe task with emotional faces (angry, happy and neutral) compared to teapots

To examine the varying effects of interest accuracy data was entered in a series of mixed design ANOVAs these all involved diagnosis (ASD Vs control) as a between participants factor and target location (top Vs bottom) and probe location (top Vs bottom) as within participant variables. The designation of targets was dependent on which research questions were being tested. For the purposes of the analysis the 'stronger emotion', the emotion that past literature suggests most likely to capture attention, was called the 'target' however the analysis is able to detect bias towards either stimulus: The order of this is: Angry, Happy, Neutral Teapot. This is the standard analysis used in Visual Dot Probe studies (e.g. Mogg and Bradley, 1999a; b).

Sub threshold analysis

The analysis for angry faces Vs happy faces revealed a significant main effect of target location $F(1,34)=6.944$, $p=.013$, this was consistent with participants responding faster when angry faces had been presented at the top of the screen than when they had been presented at the bottom. There were no main effects of probe location $F(1,34)=3.059$, $p=.089$ or diagnosis $F(1,34)=.147$, $p=.703$. There were also no significant interactions: target location x diagnosis $F(1,34)=741$, $p=.395$; probe location x diagnosis $F(1,34)=.754$, $p=.391$; target location x probe location $F(1,34)=.2.690$, $p=.110$; diagnosis x target location x probe location $F(1,34)=.001$, $p=.981$.

The analysis for angry faces Vs neutral faces revealed no significant main effects; target location $F(1,34)=.003$, $p=.960$ probe location $F(1,34)=.385$, $p=.539$ or diagnosis $F(1,34)=.977$, $p=.330$. There were also no significant interactions: target location x diagnosis $F(1,34)=1.277$, $p=.276$; probe location x diagnosis $F(1,34)=.385$, $p=.539$; target location x probe location $F(1,34)=.350$, $p=.558$; diagnosis x target location x probe location $F(1,34)=.311$, $p=.581$.

The analysis for angry faces Vs teapots revealed no significant main effects; target location $F(1,34)=.414$, $p=.524$ probe location $F(1,34)=2.717$, $p=.109$ or diagnosis $F(1,34)=.858$, $p=.361$. There were also no significant interactions: target location x diagnosis $F(1,34)=.368$, $p=.548$; probe location x diagnosis $F(1,34)=.279$, $p=.601$; target location x probe location $F(1,34)=.000$, $p=.990$; diagnosis x target location x probe location $F(1,34)=2.993$, $p=.093$.

The analysis for happy faces Vs neutral faces revealed no significant main effects; target location $F(1,34)=1.069$, $p=.308$ probe location $F(1,34)=.000$, $p=.990$ or diagnosis $F(1,34)=2.042$, $p=.162$. There were also no significant interactions: target location x diagnosis $F(1,34)=.276$, $p=.602$; probe location x diagnosis $F(1,34)=1.650$, $p=.208$; target location x probe location $F(1,34)=1.140$, $p=.293$; diagnosis x target location x probe location $F(1,34)=.311$, $p=.581$.

The analysis for happy faces Vs teapots revealed no significant main effects; target location $F(1,34)=.000$, $p=1$ probe location $F(1,34)=1.115$, $p=.298$ or diagnosis $F(1,34)=1.581$, $p=.271$. There were also no significant interactions: target location x diagnosis $F(1,34)=.000$, $p=1$; probe location x diagnosis $F(1,34)=.000$, $p=1$; target location x probe location $F(1,34)=1.581$, $p=.271$; diagnosis x target location x probe location $F(1,34)=.000$, $p=1$.

The analysis for neutral faces Vs teapots revealed a significant main effect of probe location $F(1,34)=5.931$, $p=.020$, this was consistent with participants responding faster to probe at the top of the screen than the bottom. There were no main effects of target location $F(1,34)=1.097$, $p=.302$ or diagnosis $F(1,34)=1.214$, $p=.278$. There was also a significant interaction between target location and diagnosis $F(1,34)= 4.387$, $p=.044$, as this is not a theoretically interesting effect it will not be investigated further. There were no other significant interactions: probe location x diagnosis $F(1,34)=.000$, $p=1$; target location x probe location $F(1,34)=1.000$, $p=.324$; diagnosis x target location x probe location $F(1,34)=1.000$, $p=.324$.

Supra threshold analysis

The analysis for angry faces Vs happy faces revealed a significant main effect of probe location $F(1,34)=5.241$, $p=.013$, this was consistent with participants responding faster to probes at the top of the screen than at the bottom. There were no main effects of target location $F(1,34)=.740$, $p=.396$ or diagnosis $F(1,34)=.449$, $p=.507$. There were also no significant interactions: target location x diagnosis $F(1,34)=1.930$, $p=.174$; probe location x diagnosis $F(1,34)=.058$, $p=.811$; target location x probe location $F(1,34)=.1990$, $p=.167$; diagnosis x target location x probe location $F(1,34)=.087$, $p=.770$.

The analysis for angry faces Vs neutral faces revealed no significant main effects; target location $F(1,34)=.508$, $p=.481$, probe location $F(1,34)=.114$, $p=.738$ or diagnosis $F(1,34)=1.308$, $p=.261$. There were also no significant interactions: target location x diagnosis $F(1,34)=.056$, $p=.814$; probe location x diagnosis $F(1,34)=2.852$, $p=.100$; target location x probe location $F(1,34)=.056$, $p=.814$; diagnosis x target location x probe location $F(1,34)=2.852$, $p=.100$.

The analysis for angry faces Vs teapots revealed no significant main effects; target location $F(1,34)=1.395$, $p=.246$, probe location $F(1,34)=.032$, $p=.859$ or diagnosis $F(1,34)=.4408$, $p=.511$. There were also no significant interactions: target location x diagnosis $F(1,34)=.053$, $p=.819$; probe location x diagnosis $F(1,34)=2.828$, $p=.102$; target location x probe location $F(1,34)=1.491$, $p=.230$; diagnosis x target location x probe location $F(1,34)=.616$, $p=.438$.

The analysis for happy faces Vs neutral faces revealed no significant main effects; target location $F(1,34)=1.466$, $p=.234$ probe location $F(1,34)=.948$, $p=.337$ or diagnosis $F(1,34)=.063$, $p=.803$. There were also no significant interactions: target location x diagnosis F(1,34)=.519, p=.476; probe location x diagnosis F(1,34)=.097, p=.757; target location x probe location F(1,34)=1.054, p=.312; diagnosis x target location x probe location F(1,34)=.974, p=.331.

The analysis for happy faces Vs teapots revealed no significant main effects; target location F(1,34)=.486, p=.491, probe location F(1,34)=.548, p=.464 or diagnosis F(1,34)=2.782, p=.105. There was however a significant interaction between probe location x diagnosis F(1,34)=4.935, p=.00 this is not a theoretically relevant effect and will therefore not be explored further. There were no other significant interactions: target location x diagnosis F(1,34)=.486, p=.491; target location x probe location F(1,34)=.486, p=.491; diagnosis x target location x probe location F(1,34)=.486, p=.491.

The analysis for neutral faces Vs teapots revealed no significant main effects; target location F(1,34)=.271, p=.606, probe location F(1,34)=.610, p=.440 or diagnosis F(1,34)=.004, p=.953. There were also no significant interactions: target location x diagnosis F(1,34)=1.611, p=.213; probe location x diagnosis F(1,34)=.002, p=.964; target location x probe location F(1,34)=2.252, p=.143; diagnosis x target location x probe location F(1,34)=.285, p=.597.

Appendix 9: Full demographic data for Study Three: Visual Dot Probe with Emotional faces (angry, happy, neutral) and teapots

Table 5.2: Means & standard deviations for reaction times on sub-threshold trials.

Top image	*Bottom image*	*Probe location*	*ASD*	*Control*
Angry	Happy	Top	436.28 (124.32)	386.83 (60.84)
Angry	Happy	Bottom	470.33 (139.82)	407.25 (63.17)
Happy	Angry	Top	441.50 (138.86)	398.17 (71.87)
Happy	Angry	Bottom	460.91 (143.17)	416.44 (69.06)
Angry	Neutral	Top	353.25 (140.64)	403.33 (64.71)
Angry	Neutral	Bottom	485.81 (184.67)	418.08 (58.08)
Neutral	Angry	Top	469.86 (182.27)	380.44 (59.75)
Neutral	Angry	Bottom	457.92 (138.78)	410.61 (51.81)
Angry	Teapot	Top	454.64 (146.23)	387.19 (57.33)
Angry	Teapot	Bottom	458.58 (159.27)	402.19 (71.55)
Teapot	Angry	Top	456.81 (134.41)	401.53 (70.28)
Teapot	Angry	Bottom	453.19 (143.46)	402.86 (56.54)
Happy	Neutral	Top	445.47 (157.02)	396.78 (61.33)
Happy	Neutral	Bottom	483.14 (163.26)	398.06 (47.48)
Neutral	Happy	Top	462.11 (157.37)	390.11 (64.01)
Neutral	Happy	Bottom	468.39 (154.29)	404.33 (46.51)
Happy	Teapot	Top	455.36 (155.37)	400.19 (61.95)
Happy	Teapot	Bottom	472.03 (177.95)	414.11 (59.02)
Teapot	Happy	Top	448.42 (135.98)	406.72 (75.07)
Teapot	Happy	Bottom	487.56 (184.00)	419.47 (74.05)
Neutral	Teapot	Top	432.69 (126.11)	402.19 (60.82)
Neutral	Teapot	Bottom	484.89 (174.52)	408.47 (54.25)
Teapot	Neutral	Top	448.97 (126.95)	409.14 (55.19)
Teapot	Neutral	Bottom	464.42 (131.64)	384.08 (51.20)

Table 5.3: Means & standard deviations for reaction times on supra-threshold trials.

Top image	Bottom image	Probe location	ASD	Control
Angry	Happy	Top	430.03 (90.70)	401.06 (61.83)
Angry	Happy	Bottom	424.75 (71.95)	419.61 (60.01)
Happy	Angry	Top	433.94 (91.84)	407.44 (61.25)
Happy	Angry	Bottom	440.25 (110.40)	411.78 (58.22)
Angry	Neutral	Top	427.03 (81.97)	397.61 (56.87)
Angry	Neutral	Bottom	438.92 (76.13)	405.72 (55.12)
Neutral	Angry	Top	418.56 (80.66)	404.50 (56.41)
Neutral	Angry	Bottom	442.25 (89.91)	400.94 (66.60)
Angry	Teapot	Top	432.94 (98.65)	406.72 (58.33)
Angry	Teapot	Bottom	442.25 (88.85)	428.06 (82.46)
Teapot	Angry	Top	424.53 (91.07)	420.06 (65.18)
Teapot	Angry	Bottom	449.28 (131.55)	412.33 (51.38)
Happy	Neutral	Top	433.33 (115.16)	400.78 (58.25)
Happy	Neutral	Bottom	420.61 (73.03)	404.64 (53.27)
Neutral	Happy	Top	426.78 (79.79)	413.19 (82.19)
Neutral	Happy	Bottom	427.67 (74.62)	418.00 (69.30)
Happy	Teapot	Top	432.58 (79.95)	424.36 (54.88)
Happy	Teapot	Bottom	426.36 (70.43)	413.31 (63.81)
Teapot	Happy	Top	451.19 (109.22)	413.31 (63.81)
Teapot	Happy	Bottom	434.42 (80.45)	403.25 (52.62)
Neutral	Teapot	Top	426.78 (109.95)	410.56 (60.45)
Neutral	Teapot	Bottom	439.81 (93.89)	410.00 (63.42)
Teapot	Neutral	Top	441.44 (84.76)	419.94 (80.22)
Teapot	Neutral	Bottom	444.06 116.66)	408.06 (52.68)

Appendix 10: findings not theoretically relevant from Chapter 5: Attentional bias for emotional (Angry, Happy, and Neutral) faces vs. non-social stimuli (teapots): Visual Dot Probe

Sub-threshold analysis.

Retesting the findings of Study one

Data was entered into a 2 (diagnosis; ASD Vs control) x 2 (face location; top Vs bottom) x 2 (probe location; top Vs bottom) mixed design ANOVA. This revealed no significant main effects; Diagnosis F(1,34)=2.488, p=.123, Face location F(1,34)=.060, p=.808, Probe location F(1,34)=3.065, p=.089. This also revealed no significant interactions; diagnosis x face location F(1,34)=.036, p=.850, diagnosis by probe location F(1,34)=1.387, p=.247.

When the face location x probe location x diagnosis effect was broken down by group, in the ASD group the main effects of face location F(1,17)=.001, p=.974 and probe location F(1,17)=3.144, p=.094 were non significant. For the control group the main effects of face location F(1,17)=.147, p=.706 and probe location F(1,17)=.258, p=.618 were non significant.

Emotion

Data was entered into a 2 (diagnosis; ASD Vs control) x 2 (emotional face location; top Vs bottom) x 2 (probe location; top Vs bottom) mixed design ANOVA. This revealed a significant main effect of probe location F(1,34)=6.336, p=.017 consistent with probes being detected faster in the top (425.17 ms) half of the screen than the bottom (440.79 ms). However, there were no significant main effects of diagnosis F(1,34)=2.977, p=.094 or emotion face location F(1,34)=.923, p=.343. No significant interactions were found between the other variables diagnosis x emotional face location F(1,34)=.262, p=.612, diagnosis x probe location F(1,34)=.007, p=.934.

When the emotional face location x probe location x diagnosis effect was broken down by group, in the control group the main effects of emotional face location F(1,17)=.931, p=.348 and probe location F(1,17)=4.039, p=.061 were non-significant. For the ASD group the main effects of emotional face location F(1,17)=.121, p=.732 and probe location F(1,17)=2.269, p=.121 were non-significant.

Individual comparisons

The analysis for angry faces Vs happy faces revealed a significant main effect of probe location F(1,34)=10.127, p=.003 with probes being found significantly faster in the top half of the screen than the bottom half. There were no significant main effects of diagnosis F(1,34)= 1.192, p=.283 or target location F(1,34)=.017, p=.897. This also revealed no significant interactions; diagnosis x target location F(1,34)=1.070, p=.308, diagnosis x probe location F(1,34)=.004, p=.951.

The analysis for angry faces Vs neutral faces revealed a significant main effect of probe location F(1,34)=8.711, p=.006 with probes being found significantly faster in the top half of the screen than the bottom half. There were no significant main effects of diagnosis F(1,34)=1.563, p=.220 or target location F(1,34)=2.591, p=.117. This also revealed no significant interactions; diagnosis x target location F(1,34)=.932, p=.341, diagnosis x probe location F(1,34)=2.958, p=.095.

The analysis for angry faces Vs teapots revealed no significant main effects; diagnosis F(1,34)=1.757, p=.194, target location F(1,34)=.866, p=.359, probe location F(1,34)=.451, p=.506. This also revealed no significant interactions; diagnosis x target location F(1,34)=1.091, p=.304, diagnosis x probe location F(1,34)=1.560, p=.220.

The analysis for happy faces Vs neutral faces revealed a significant main effect of probe location F(1,34)=4.119, p=.050 with probes being found significantly faster in the top half of the screen than the bottom half. There were no significant main effects of diagnosis

$F(1,34)=2.061$, $p=.160$ or target location $F(1,34)=.073$, $p=.789$. All other interactions were non significant; diagnosis x target location $F(1,34)=.153$, $p=.699$, diagnosis x probe location $F(1,34)=.023$, $p=.879$. When the target location x probe location x diagnosis was broken down by group this revealed that the control group showed no significant main effects; target location $F(1,17)=.005$, $p=.945$ or probe location $F(1,17)=1.365$, $p=.259$. additionally the ASD group showed no significant main effects; target location $F(1,17)=.436$, $p=.518$ or probe location $F(1,17)=3.351$, $p=.085$.

The analysis for happy faces Vs teapots revealed a significant main effect of probe location $F(1,34)=4.557$, $p=.040$ with probes being found significantly faster in the top half of the screen than the bottom half. However, no significant main effects of diagnosis $F(1,34)=.886$, $p=.353$ or target location $F(1,34)=.317$, $p=.577$. This also revealed no significant interactions; diagnosis x target location $F(1,34)=.028$, $p=.869$, diagnosis x probe location $F(1,34)<.000$, $p=.990$.

The analysis for neutral faces Vs teapots revealed no significant main effects; diagnosis $F(1,34)=1.730$, $p=.197$, target location $F(1,34)=.034$, $p=.854$, probe location $F(1,34)=.608$, $p=.441$. This analysis revealed significant interaction between diagnosis and probe location $F(1,34)=5.595$, $p=.024$ (This will not be further explored as it is not theoretically relevant) and a significant interaction between target location and probe location $F(1,34)=7.681$, $p=.009$. The remaining interactions were non-significant; diagnosis x target location $F(1,34)=1.175$, $p=.286$, and diagnosis x target location x probe location $F(1,34)=.417$, $p=.523$. When the target location x probe location x diagnosis was broken down by group this revealed that the ASD group showed no significant main effects of target location $F(1,17)=.311$, $p=.585$ or Probe location $F(1,17)=4.267$, $p=.054$. For the control group no significant main effects were found target location $F(1,17)=1.150$, $p=.299$, Probe location $F(1,17)=1.494$, $p=.238$.

Supra-threshold analysis

Retesting the findings of Study One

Data was entered into a 2 (diagnosis; ASD Vs control) x 2 (face location; top Vs bottom) x 2 (probe location; top Vs bottom) mixed design ANOVA. This revealed no significant main effects; diagnosis $F(1,34)=.950$, $p=.337$, face location $F(1,34)=.563$, $p=.458$, probe location $F(1,34)=.000$, $p=.997$. This revealed no significant interactions; diagnosis x face location $F(1,34)=1.297$, $p=.263$, diagnosis x probe location $F(1,34)=.638$, $p=.430$. When this was broken down by group for the ASD group the main effects of face location $F(1,17)=1.638$, $p=.218$ and probe location $F(1,17)=.352$, $p=.561$ were non significant. For the control group, all main effects; face location $F(1,17)=.083$, $p=.777$ and probe location $F(1,17)=.292$, $p=.596$ were non-significant.

Emotion

Data was entered into a 2 (diagnosis; ASD Vs control) x 2 (emotional face location; top Vs bottom) x 2 (probe location; top Vs bottom) mixed design ANOVA. This revealed no significant main effects; diagnosis $F(1,34)=1.164$, $p=.288$, emotional face location $F(1,34)=.840$, $p=.366$, probe location $F(1,34)=.642$, $p=.428$. This also revealed no significant interactions; diagnosis x emotional face location $F(1,34)=1.672$, $p=.205$, diagnosis x probe location $F(1,34)=.053$, $p=.820$.

Individual comparisons

The analysis for angry faces Vs happy faces revealed no significant main effects; Diagnosis $F(1,34)=.335$, $p=.567$, target location $F(1,34)=.040$, $p=.843$, probe location $F(1,34)=1.508$, $p=.228$. This also revealed no significant interactions; diagnosis x target location $F(1,34)=.029$, $p=.866$, diagnosis x probe location $F(1,34)=1.169$, $p=.287$.

The analysis for angry faces Vs neutral faces revealed no significant main effects; diagnosis $F(1,34)=1.193$, $p=.290$, target location $F(1,34)=.217$, $p=.645$, probe location

F(1,34)=2.588, p=.117. This also revealed no significant interactions; diagnosis x target location F(1,34)=.148, p=.703, diagnosis x probe location F(1,34)=1.838, p=.184.

The analysis for angry faces Vs teapots revealed a significant main effect of probe location F(1,34)=4.222, p=.048 with probes being found significantly faster in the top half of the screen than the bottom half. There were no significant main effects of diagnosis F(1,34)=.153, p=.698 or target location F(1,34)=.183, p=.672. This also revealed no significant interactions; diagnosis x target location F(1,34)=.549, p=.464, diagnosis x probe location F(1,34)=.323, p=.574.

The analysis for happy faces Vs neutral faces revealed no significant main effects; Diagnosis F(1,34)=.321, p=.575, target location F(1,34)=1.683, p=.203, probe location F(1,34)=.274, p=.604. This also revealed no significant interactions; diagnosis x target location F(1,34)=.113, p=.739, diagnosis x probe location F(1,34)=.366, p=.549.

The analysis for happy faces Vs teapots revealed no significant main effects; diagnosis F(1,34)=.635, p=.431, target location F(1,34)=.002, p=.964, probe location F(1,34)=2.314, p=.137. This also revealed no significant interactions; diagnosis x target location F(1,34)=1.669, p=.205, diagnosis x probe location F(1,34)=.286, p=.596.

The analysis for neutral faces Vs teapots revealed no significant main effects; diagnosis F(1,34)=.432, p=.516, target location F(1,34)=1.137, p=.250, probe location F(1,34)=.044, p=.836. This also revealed no significant interactions; diagnosis x target location F(1,34)=.505, p=.482, diagnosis x probe location F(1,34)=.217, p=.645.

Appendix 11: Error data for Study Four: Face-in-the-Crowd: Emotional faces (angry, happy neutral) compared to teapots.

Individual Comparisons

For each of the individual comparison a 2 (target role) by 2 (diagnosis) mixed design ANOVA was run for each of the stimuli pairs (as described in Chapter 6).

The analysis for angry faces Vs happy faces revealed no significant main effects of target role $F(1,33)=.020$, $p=.889$ or of diagnosis $F(1,33)=.024$, $p=.878$, and no interaction between target role and diagnosis $F(1,33)=.015$, $p=.904$.

The analysis for angry faces Vs neutral faces revealed no significant main effects of target role $F(1,33)<.001$, $p=.986$ or of diagnosis $F(1,33)=.116$, $p=.736$, and no interaction between target role and diagnosis $F(1,33)=1.645$, $p=.209$.

The analysis for angry faces Vs teapots revealed no significant main effects of target role $F(1,33)=.005$, $p=.945$ or of diagnosis $F(1,33)=.814$, $p=.373$, there was however a significant interaction between target role and diagnosis $F(1,33)=5.938$, $p=.020$. This interaction was broken down using simple main effects analysis with a Sidak correction, although none of the comparisons was significant all comparisons appeared to indicate that the ASD group were less accurate when faces where targets and that control participants were less accurate when teapots where targets. The control group where more accurate on face target trials compared to teapot target trials ($p=.099$) the ASD group where more accurate on teapot target trials than face target trials ($p=.090$). The control group where also more accurate than the ASD group when faces where targets ($p=.344$) and the ASD where more accurate than the control group when teapots where targets ($p=.054$).

The analysis for happy faces Vs neutral faces revealed no significant main effects of target role $F(1,33)=.009$, $p=.923$ or of diagnosis $F(1,33)=.073$, $p=.789$, and no interaction between target role and diagnosis $F(1,33)=.009$, $p=.923$.

The analysis for happy faces Vs teapots revealed no significant main effects of target role $F(1,33)=.693$, $p=.411$ or of diagnosis $F(1,33)=1.729$, $p=.198$, and no interaction between target role and diagnosis $F(1,33)=.693$, $p=.411$.

The analysis for neutral faces Vs teapots revealed significant main effects of target role $F(1,33)=4.580$, $p=.040$ and of diagnosis $F(1,33)=4.580$, $p=.040$, as well as a significant interaction between target role and diagnosis $F(1,33)=4.580$, $p=.040$. These significant effects can all be explained because other than for the teapot target neutral crowd trials for the control group performance was at ceiling.

Appendix 12: correlations for multicoliniarity

Table AP 11.1 to show Pearson's r values between predictor variables in the analysis in Chapter 7 for Studies 1 & 2

	IQ	STAI
AQ	-.008	.243
IQ		.087

Table AP 11.1 to show Pearson's r values between predictor variables in the analysis in Chapter 7 for Studies 3 & 4

	IQ	STAI	FNES	SADS
AQ	-.027	.109	.445	.701
IQ		.151	-.208	.117
STAI			.148	.138
FNES				.405