Eye-tracking explorations of attention to faces for communicative cues in Autism Spectrum Disorders

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Abstract

Background

Individuals with Autism Spectrum Disorder (ASD) have been reported to show socio-communicative impairments which are associated with impaired face perception and atypical gaze behaviour. Attending to faces and interpreting the important socio-communicative cues presented allows us to understand other's cognitive states, emotions, wants and desires. This information enables successful social encounters and interactions to take place. Children with ASD not attending to these important social cues on the face may cause some of the socio-communicative impairments observed within this population. Examining how children with ASD attend to faces will enhance our understanding of their communicative impairments.

Aim

The present thesis therefore aimed to use eye-tracking methodology to examine attention allocation to faces for communicative cues in children with ASD.

Method

The first line of enquiry examined how children with ASD (n = 21; age = 13y7m) attended to faces presented within their picture communication systems compared to typically developing children matched on chronological age, verbal ability age and visuo-spatial ability age. The next investigation was conducted on the same group of children and examined how children with ASD attended to faces of different familiarity including, familiar, unfamiliar and the child's own face. These faces were also presented with direct gaze or averted gaze to investigate how this would impact on the

children's allocation of attention. The final exploration highlighted how children with ASD (n = 20; age = 12y3m) attended to socially salient information (faces) and non-socially salient information (objects) presented within social scenes of varying complexity, compared to typically developing controls. Again groups were matched based on chronological age, verbal ability age, and visuo-spatial ability age.

Results

Children with ASD were shown to allocate attention to faces presented within their picture communication symbols similarly compared to their typically developing counterparts. All children were shown to fixate significantly longer on the face images compared to the object images. The children with ASD fixated for similar amounts of time to the eye and mouth regions regardless of familiarity and gaze direction compared to their controlled matches. All groups looked significantly longer at the eye areas compared to the mouth areas of the faces across all familiarity types. The children also fixated longer on the eye and mouth regions of direct gazing faces compared to the regions presented on the averted gazing faces. The children with ASD fixated on the faces and objects presented within social scenes similar to their typically developing counterparts across all complexity conditions. The children were shown to fixate significantly longer on the objects compared to the faces.

Conclusions

Children with ASD showed typical allocation of attention to faces. This suggests that faces are not aversive to them and they are able to attend to the relevant areas such as eye and mouth regions. This may have been influenced by the inclusion of high functioning children with ASD. However these results may also suggest that attention allocation and gaze behaviour are not the only factors which contribute to the socio-communicative impairments observed in ASD.

Author's Declaration

I declare that this thesis is my original work and has been carried out in accordance with the Regulations of Stirling University. No part of this thesis has been submitted for another degree at the University of Stirling or other institutions. The views expressed in the thesis are the authors and do not represent the University of Stirling.

Signed:…………………………………………………………………..

Date:……………………………………………………………………..

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Chapter 1 - General Introduction

This thesis will use eye-tracking explorations to highlight how attention is allocated to communicative cues presented on faces in Autism Spectrum Disorders (ASD). This is an important skill needed during everyday social interactions. Efficient scanning of a face and interpreting the communicative cues such as mental states, desires and feelings enables us to make decisions about engaging in and maintaining a social interaction. By attending to and understanding the socio-communicative cues presented on the face we are able to monitor and modify our own behaviours to suit the social interactions we engage in. This thesis aims to examine how children with ASD scan and attend to faces which convey these communication cues. Eye-tracking methodology will be applied to highlight if atypical attention allocation to the face by children with ASD impacts on their social and communicative abilities.

Rather than simply comparing children with and without ASD, as done in many studies, this work seeks to relate the severity of ASD to the eye-gaze behaviour approach and examines children with ASD of varying functioning and social abilities. This is unlike previous eye-tracking research which tends to focus on specific levels of functioning in participant populations of ASD. Therefore the research presented here is proposed to be more representative of the heterogeneous population with ASD. Theories which are proposed to explain the causes of ASD alongside the cognitive theories which aim to explain the behavioural and socio-communicative impairments are also discussed with specific reference to face processing research. Face processing research will be presented and how it has highlighted the importance of attending to facial communicative cues for efficient social and everyday interaction in typical populations. This approach is then used to emphasise how atypical attention to the face and impaired face processing impacts on socio-communicative abilities in ASD.

Face processing will be used as a vehicle to explore the socio-communicative impairments observed in ASD. Attention to facial communicative cues will be highlighted to show how these socio-communicative skills are particularly relevant in this disorder which has been proposed to show a socio-cognitive phenotype associated with atypical gaze behaviours when orienting to faces. Using eye-tracking methodology to explore gaze behaviours during face perception will provide insight of how children with ASD may allocate attention to the faces they encounter during their daily lives. The following section will detail the structure of the thesis.

Thesis Structure

Chapter 2 will put forward the relevant background theories of ASD as a developmental disorder which has debilitating effects on social interaction and communication. The more relevant theories relating to predictions and formation of studies will be provided in the relevant experimental chapters throughout. However it is important to convey the debate that still continues on the exact pattern of eye gaze and face perception impairments in ASD. Providing the levels of social functioning that are associated with each subtype which exists under the Autism Spectrum umbrella term shows the variability and heterogeneous nature of this disorder. It was important to discuss the different sub-groups within ASD as these varying populations may account for some of the discrepancies within research of the socio-communicative impairments.

Face processing and gaze behaviours will be highlighted as important tools in Chapter 3, which not only contribute to the diagnosis of ASD but may also be used to investigate how individuals with ASD attend to the information presented in their environment. A key question addressed in this thesis is to highlight how this atypical attention to faces and other socially salient information may hinder their abilities to successfully use communication aids or interpret communicative cues from faces they encounter during real-life situations.

The first line of research investigates how individuals with ASD attend to an image used in picture communication systems. These communication systems or aids are applied within the learning and home environments. These communication aids rely on the ability of an individual with ASD to attend to the relevant information presented on the image. How an individual with ASD attends to these images is examined in Chapter 5, the wider implications of these findings are also considered. This is a particularly interesting line of enquiry as these images have reduced ecological validity and are cartoon-like. Two different levels of ecological validity will be examined by highlighting how attention is allocated to realistic PECS images compared to less realistic Boardmaker images. Spontaneous eye gaze behaviour during the presentation of face images is also compared to object images as previous research has implicated a preference for inanimate objects (Klin, Jones, Schultz, Volkmar, & Cohen, 2002) compared to people. Level of functioning is also explored alongside fixation time on these communication aids to see if level of functioning is associated with the eye gaze behaviour used to attend to these images (as been reported in previous studies i.e. Riby and Hancock (2008).

Chapter 6 addresses the effects of familiarity and self image on face fixation time in children with ASD. Previous eye-tracking research has typically examined how attention is allocated on unfamiliar faces by children with ASD. This chapter examines if this atypical gaze behaviour persists even when familiarity of a face is increased.

This chapter did not only examine the role of familiarity on attention allocation in ASD but also how 'self' impacted on gaze behaviour. Populations with ASD have been reported to be impaired in self-referential ability (Lombardo et al 2010) however it is not known how they attend to visual 'self' information such as their own image. Therefore familiar and unfamiliar faces are presented with the images of the child's own face to highlight if children with ASD attend to their own faces similar to typical matches.

The final enquiry presented in Chapter 7 uses insight gained from the initial two experimental studies. It investigates if there is a variation of eye gaze behaviour when the number of persons and objects presented on the same image are manipulated. The results shown in this study may provide evidence of how children with ASD allocate attention when perceiving their real social environment which is naturally complex and varied. An easy memory task is also given to participants to allow exploration between task driven attention and spontaneous attention to images.

The general discussion presented in Chapter 8 considers how all these different factors impacted on gaze behaviour and how this may have implications for how children with ASD encounter real people presented within communicative images and how this may enhance our understanding of how they attend to persons in the real environment. Tentative recommendations are made regarding the design and content of augmentative visual communication system for ASD.

In summary the key questions of this thesis are:

- In ASD are images, of the sort used in augmentative visual communication systems, attended to in a way that allows perception of key features of the image?

- Does familiarity of faces presented in these images influence how they are attended to?

- Does the complexity of the image alter visual attention patterns

- What implications do the above issues have for the design of images for augmented visual communication systems?

The following chapter introduces the reader to ASD as a heterogeneous population which present a range of socio-communicative abilities. This will allow a greater understanding of the difficulties faced by clinicians in diagnosing ASD largely due to the behavioural nature of the diagnosis. Research is still developing to enhance our understanding of the biological and psychological factors which play a role within some of the socio-communicative impairments observed across this spectrum. These will now be highlighted.

Chapter 2 – Autism Spectrum Disorder

2.1 Introduction

This thesis will examine children functioning at various levels across the autism spectrum Therefore it is relevant to detail the differences between the ‘sub-types’ that come under the umbrella term of ‘Autism Spectrum Disorder.’   Diagnosing Autism Spectrum Disorder (ASD) is particularly difficult largely due to the behavioural nature of diagnosis and the heterogeneous behavioural phenotype associated with the spectrum. The diagnostic criteria for each sub-type within Spectrum Disorder are detailed below alongside the prevalence rates associated with the sub-types. .

2.1.1 Diagnosis of ASD

The first published account of ASD was by Leo Kanner in 1943. Kanner recognised common behavioural patterns in a number of children referred to his clinic. These behaviours included lack of affective contact with others, elaborate routines and abnormality of speech. He emphasised that this condition which he named ‘early infantile autism,’ was present from birth or within the first 30 months of life. Similarly, in 1944 Hans Asperger published a paper on a group of children and adolescents who displayed atypical behavioural patterns. Despite the similarities to Kanner’s infantile autism, for example monotonous speech and awkward social behaviours, Asperger proposed this was a separate and distinct syndrome, i.e. Asperger’s syndrome.   The features of this syndrome were similar to infantile autism; however behavioural traits were believed to appear in children over 3 years old, much later than the population described by Kanner. After Kanner’s published work, interest in ASD grew alongside an increase of research (Frith, 2003).   As a consequence disagreements of the definition of ASD surfaced (Wing 1996). The main definition issues arose following further observations of ASD made by numerous researchers. For example, Eisenberg & Kanner (1956) wished to determine the essential features of ASD and reduced the original symptomology highlighted by Kanner in the 1943 publication. They claimed that the essential features which must be present include; 'extreme aloneness' and 'preoccupation with the preservation of sameness'. This completely excluded the impaired communicative abilities such as atypical language that had first drawn Kanner's attention to this population in his original 1943 article. Their efforts to clarify diagnosis were used as a licence at times to change the criteria of ASD and not refer to the descriptions of the original clinical phenomena (Rutter 1978). For example Tinbergen and Tinbergen (1972) placed high emphasis on the avoidance of eye gaze as the main clinical feature and ignored all of the other clinical features described by Kanner. Schain and Yannet (1960) removed the 'preservation of sameness' from their diagnostic criteria and Rendle-Short (1969) produced a list of 14 manifestations many of which did not include any of Kanner's earlier criteria, for example use of gestures, over-activity and lack of fear. As a result of these varying diagnostic criteria the literature became full of clinical accounts and pieces of research which deal with really different kinds of issues and disorders all under the term 'autism'. This issue of various clinical criteria being applied to the diagnosis of ASD in research was clarified by an important study in 1979 by Wing and Gould.

To examine the reliability of the existing definition of ASD, Wing and Gould (1979) carried out an investigation focusing on the presence of autistic symptoms within a population of children. The study found that Autism and Asperger's syndrome were sub-groups within a spectrum of disorders affecting communication, interaction and development of imaginative play. Wing and Gould (1979) found that these three impairments occurred together, forming a triad of impairments. These impairments manifested in varying degrees and in different behaviours, and were found to be dependent on developmental age and ability (Frith 2003). The findings by Wing and Gould (1979) encouraged clinicians to widen their diagnostic criteria as the triad of impairments more efficiently described the different combinations of behaviours observed and their differing developmental trajectories (Frith, 2003).

Despite these improvements in diagnostic criteria, the diagnosis of Autistic Spectrum Disorder can still prove problematic for the clinician due to the behavioural nature of diagnosis and the heterogeneous behavioural phenotype observed across the spectrum. Difficulties arise for clinicians trying to decide which sub-group within the autism spectrum an individual belongs to, as there are many who display symptoms and features of more than one subgroup of ASD (Wing 1996). Diagnosis difficulties have implications for the individuals involved as early and appropriate diagnosis of ASD is important so they may gain access to the relevant services provided by local authorities or receive effective early interventions, (Hillman, Snyder and Neubrander 2007).

Classic Autism

The Diagnostic and Statistical Manual of Mental Disorders revised 4th edition (DSM IV - American Psychiatric Association APA, 2000) states that to receive a diagnosis of Autism there must be abnormal functioning and delays present in social interaction, social communication and imaginative play with onset prior to 3 years old.

The criteria for Autism in the International Classification of Diseases and Health Related Problems 10th edition (World Health Organisation-WHO 1993) is similar except within the ICD 10 the disorder is known as “Childhood Autism” unlike the DSM IV where the symptoms are under the category of “Autistic Disorder”. Similar to the DSM IV the ICD 10 explains that for a diagnosis of autism there must be at least two symptoms of qualitative impairment in social interaction present, alongside, one symptom of impairment in communication and one symptom of restricted repetitive behaviour, (WHO 1993; APA 2000).

Autism is four times more common in boys than girls (Fombonne 1998); recently this was found to be higher at a ratio of 7 males: 1 female (Whiteley, Todd, Carr, & Shattock 2010). The majority of individuals with a diagnosis of classic autism display some intellectual difficulty, as 75% are reported to have an IQ below 70 (Joseph, Tager-Flusberg & Lord 2002). Verbal IQ is believed to be the best indicator of functioning within this population (Happé 1995), however this cannot always be assessed as 50% of children diagnosed with autism are likely to remain mute all their lives (Temple 1997). An illustration (rather than an exhaustive list) of the types of deficits children with autism face include, eye contact (Charman, 2003; Clifford, Young, & Williamson, 2007), gaze direction detection (Riby & Doherty 2009; Webster & Potter, 2008), attention shifting (Courchesne, *et al.* 1994), perceiving identity (Boucher, Lewis, & Collis, 1998) emotion recognition (Hobson, Ouston, & Lee, 1988a, Hobson, Ouston, & Lee, 1989) sharing, turn-taking, and verbal initiations (Shabani, *et al.,* 2002; Spradlin & Brady 1999). All these impairments were highlighted due to their high impact on everyday social functioning and communication. These socio-communicative impairments involve face attention and processing and will be discussed in the next chapter (Chapter 3 – Face Perception) in more detail.

Asperger Syndrome

The DSM IV and the ICD 10 define Asperger syndrome as a separate disorder acknowledging the heterogeneity of symptoms (Klin, Pauls, Schultz, & Volkmar 2005).

Asperger syndrome (AS) is typically diagnosed later in the child's development than Autism. This is normally while the child is attending school with the average age of diagnosis being made at 11 years old. (Mandell, Novak, & Zubritsky 2005; Foster & King 2003). Gender ratios observed in AS were reported by Wing (1981) as 9 males: 1 female, however recent studies report the ratio as being as high as 12 males: 1 female (Whiteley, Todd, Carr, and Shattock 2010) showing that Asperger syndrome is even rarer in female populations in comparison to classic Autism. Higher IQ is observed in Asperger's in comparison to classic autism populations. This is proposed to be caused by superior verbal abilities within this sub-type (Manjiviona and Prior 1999).

The DSM IV and ICD-10 diagnosis of Asperger's syndrome is similar to the diagnosis of autism however it is distinguishable from the classic Autism criteria in the following ways. There is no clinically significant delay in cognitive development (including speech acquisition) or age appropriate self adaptive behaviour (excluding social interaction). This lack of cognitive delay that is present in AS causes the late diagnosis of this disorder.

PDD-NOS

In the DSM IV the disorder classified as 'pervasive developmental disorder not otherwise specified' (PDD-NOS; APA 2000) differs from classic Autism because onset of the impairment is observed at or after the age of 3 years or symptomology may be atypical. Criteria are basically the same for autism however it is not necessary to meet the criteria for number of areas of abnormality. The same disorder is listed in the ICD 10 however it is under the title 'Atypical Autism' (WHO 1993). Children diagnosed with PDD-NOS in comparison with autism show more imaginative play, and non-verbal communication is less impaired (Buitelaar, van der Gaag, Klin, & Volkmar

1999). In comparison to Asperger's Syndrome, PDD-NOS show more impairment on theory of mind tasks (Ozonoff, Rogers, and Pennington 1991), and verbal ability (Ghaziuddin & Mountain-Kimchi 2004).

Some clinicians find it useful to view these developmental disorders along a continuum of Autism Spectrum with autism representing the most severe symptoms, PDD- NOS representing the next in severity, followed by Asperger's disorder (Hillman *et al,* 2007). However if an individual displays a variance of symptoms that do not exactly fulfil a diagnostic criteria for one of the sub-types they may be diagnosed using the umbrella term 'autism spectrum disorder' (Lord & Bishop 2009) as opposed to the older term of Pervasive Developmental Disorders (PDDs). This shift in terminology acknowledges that services are appropriate at times for all individuals with an ASD and recognises there may be few distinctions between broader ASDs (Lord & Risi 2000).

The great heterogeneity of symptoms that exist on the spectrum shows the differing level of social functioning that may take place and may also reflect the varying epigenetic factors which increase susceptibility of ASD. These epigenetic causes will be detailed in the next section (see section 2.2). The different symptoms and various causes of the disorder highlights the importance of clearly detailing participants with ASD that take part in research. Findings in one subset of participants with ASD may not accurately represent the whole population. This thesis has been conducted on participants with various classifications of ASD so these differing capabilities within each sub-category may be investigated. Despite the issues involved in the diagnosis of ASD there are still an increasing number of diagnosed cases. This increase is likely to be caused by the heightened awareness of the disorder and better training in local health services.

2.1.2 Prevalence of ASD

The prevalence of Autism was first reported in an epidemiological survey of Autism as being 4 per 10,000 children (Lotter 1966). One more recent study showed rates of classic Autism to be around 10 per 10,000, considerably higher than 30 years ago (Fombonne 2002). This increased prevalence of Autism has been proposed to reflect improved detection and recognition of autism and its variants, (Chakrabarti and Fombonne 2001) alongside the broadening of diagnostic criteria (Fombonne 2002). Examining the prevalence of the variants of Autism shows (PDD-NOS) has a prevalence rate of 15 per 10,000, and Asperger's syndrome (which in several studies is found to be smaller in comparison with Autism), has a prevalence rate at 2-3/10,000. (Fombonne 2003). Showing that the PDD-NOS subtype and Asperger's syndrome is not as prevalent in the population as classic Autism however accumulated together shows a high rate of Autism Spectrum diagnosis in the general population.

Recent studies indicate that the prevalence of ASD, broadly defined may be as high as 1% of the population, (Baird, *et al.* 2006). The different sub-groups that exist within the Autism Spectrum all represent individuals showing the triad of impairments (Wing & Gould 1979) that is specific to the ASD phenotype. Due to the heterogeneity of ASD and the various manifestations of the triad of impairments the differing diagnostic criteria for the sub-groups exists for those who do not fulfil the full criteria for one sub-group or fall out-with the age of symptom onset. For example, a classic autism diagnosis requires children's' symptoms to be present prior to 3 years old unlike PDD-NOS where this diagnosis can be given when impairment is observed after 3 years old (DSM IV – 2000) allowing children to still receive a diagnosis within the Autism Spectrum. Asperger's syndrome may be diagnosed in a child much older (mainly due to the typical cognitive development that is often observed within this subgroup) with the average age of diagnosis being approximately 11 years old (Mandell *et al.* 2005). No one group classification could exist and be applied to all individuals with ASD and so it is appropriate for these populations to be acknowledged as being part of a sub-group within a spectrum of functioning. This spectrum of functioning shows the Autism sub-group representing the low functioning populations, PDD- NOS representing those with moderate socio-cognitive functioning, followed by Asperger's syndrome who represent high functioning individuals (Hillman *et al.*2007).

Therefore the sub-groups do not only represent different levels of functioning across the spectrum but have separate diagnostic criteria which includes; age of symptom onset, and how debilitating the symptoms/impairments are, such as communication impairments (for example, Ghaziuddin and Mountain-Kimchi 2004). Prevalence rates of these disorders in the population also vary between each sub-group. Both Asperger's syndrome and PDD-NOS show lower prevalence rates compared to classic Autism (Freitag, 2007). Despite having a common characteristic which is the triad of impairments, the differences between the sub-groups may imply different genetic and environmental factors interacting in various ways causing the onset of ASD. These different epigenetic factors may contribute to the heterogeneous manifestation of impaired socio-communicative abilities affecting an individual at varying stages of development. These environmental and genetic influences will be discussed in detail within the next section highlighting possible aetiological theories of ASD.

2.2 Theories of ASD

Some of this research into the aetiology of ASD has highlighted genetic influence (for example, Santangelo and Tsatsanis 2005), lack of connectivity between brain structures (for example, McAlonan, *et al.* 2005) leading to impaired functioning of specific areas of the brain such as the amygdala (for a review see Schultz 2005) which may highlight potential causes of ASD. There are also some psychological theories which aim to try and account for the socio-communicative impairments observed in ASD and the typical autistic phenotype (for example, Baron-Cohen 1995; Kenworthy, Black, Harrison, della Rosa, & Wallace, 2009). In this section the evidence and studies which support these many theories will be examined and discussed.

Epigenetic Factors

The significant role of genetics in the aetiology of ASD is supported by studies which show the increased risk of genetic heritability of classic autism specifically in monozygotic twins. For example, Folstein and Rutter (1977) found the disorder was more common in children who were monozygotic twins (36%) compared to dizygotic twins (0%). This heritable susceptibility of classic autism in monozygotic twins has been found in a further study by Bailey, *et al* (1995) who reported an even higher concordance rate, with 60% more common in monozygotic twins compared to 0% in dizygotic twins. Despite there being a widely acknowledged genetic influence on the aetiology of the ASD, there have been no twin studies conducted just examining the heritability of the sub-groups of ASD such as Asperger's syndrome and PDD-NOS (Freitag 2007). This may be due in part by the low prevalence rates of these subgroups (Fombonne 2003) making association analyses difficult. Therefore heritability rates across the sub-types of ASD remains unconfirmed.

It seems that unlike Rett syndrome there is no single gene that determines the onset of ASD and many genetic loci have been proposed to increase susceptibility of ASD (for example, Herzing, Kim, Cook, & Ledbetter 2001; Santangelo & Tsatsanis 2005; Sutcliffe & Nurmi, 2003). Recently theorists have moved away from single gene theories of ASD and have begun to look at gene and environmental interactions which may instead explain the aetiology of ASD. Epigenetic refers to the heritable changes in gene expression that takes place without changing an individuals' DNA sequence (Wolffe and Matzke 1999). Epigenetic mechanisms such as epimutations and epigenetic polymorphisms are emphasised as the interface of environmental factors and susceptible genes in a disorder, causing defects in gene expression (Peedicayil, 2007). Epigenetics are proposed to play a great role in brain development (Peedicayil 2002), and may therefore greatly influence the onset of certain pervasive developmental disorders.

Despite the increasing interest in the epigenetic factors of ASDs there are no causative influences (either genetic or environmental) that have been reported to differentiate children diagnosed with the different sub-groups i.e. classic Autism, Asperger's syndrome and PDD-NOS (for example, Muhle, Trentacoste & Raplin, 2004). The literature is full of examples where theorists explain the diagnostic differences between the sub-groups of ASD and then explain the possible epigenetic factors as being similar across the whole spectrum, (for example, Landrigan, 2010).

In order to highlight the epigenetic factors contributing to the heterogeneous behaviours of the subtypes that exist across the Autistic spectrum, researchers have been examining specific genetic areas and environmental factors that may be linked to specific behaviour manifestations (Benvenuto, Moavero, Alessandrelli, Manzi & Curatolo, 2009; Hertz-Picciotto, *et al* 2006; Schanen, 2006; Veenstra-VanderWheele & Cook, 2004). This research includes linking susceptible genetic loci to specific behavioural phenotypes reported in ASD (Benvenuto *et al* 2009). Such as epimutations on chromosomes 7 which are associated with language delay in ASD (Alarcon, *et al* 2008), and duplications on chromosome 15 which are proposed to cause motor problems (Shao, Cuccaro, Hauser, Raiford, Menold, Wolpert, 2003). Researchers are also examining how these genetic loci are influenced by contributing environmental factors such as maternal viral infections or maternal stress (for a review see Iwata, Matsuzaki, Takei, Manabe & Mori, 2010). How these environmental factors directly contribute to gene expression and what behaviours they cause are still to be directly linked, therefore research must continue to untangle the many factors involved in genetic susceptibility. This approach of trying to investigate what epigenetic susceptibilities are linked to which behavioural manifestations, links in well with ASD research since diagnosis of the ASD relies on behaviour classification. It seems therefore fitting that epigenetic factors should be examined in such direct ways to highlight what causes these varying behaviours that are present across the ASD. It is still not known which specific genes and environmental influences directly cause ASD however there is a lot of evidence suggesting that a range of different chromosomes interacting with a range of environmental factors causes the impairments associated with the heterogeneous population of ASD (Hertz-Picciotto et al 2006; Schanen, 2006; Veenstra-VanderWheele & Cook, 2004). This research still remains in very early stages and much more work is needed to gain a deeper understanding of the aetiology of ASD.

Psychological theories

There are 3 main cognitive theories which have dominated much of the research surrounding ASD and aim to account for the autistic phenotype. These include Theory of Mind, Executive dysfunction and Central Coherence theory. These psychological theories do not provide an account of what causes ASD but provide an explanation of the behaviours which manifest in ASD and how these behaviours may be linked to a specific impairment. Lewis (2003) proposed that a successful theory which attempts to account for the triad of impairments observed in ASD must fulfil a set of criteria. First the theory must specify a deficit that is universal to all individuals with ASD, second, the deficit and behaviour must be specific to ASD and finally a deficit must causally precede the onset of the behaviours and be present throughout development. Despite these theories being different from each other they all aim to explain the characteristic behaviours of ASD. Due to the observed differences in each cognitive theory, each is better at explaining some characteristics of ASD than other behavioural dimensions. Each theory will be discussed to investigate if Lewis' (2003) criteria are met. The highest significance will be placed on the central coherence theory which is most relevant to this thesis due to its emphasis on perception processing bias which is linked to how attention is allocated by individuals with ASD.

Theory of mind.

Theory of mind is proposed to be a representational understanding of mind. Premack and Woodruff (1978) were the first authors to use the term 'Theory of Mind' in literature and broadly defined it as when an individual attributes a mental state to themselves and others. Wimmer and Perner (1983) devised a task to test when children of typical development possessed a Theory of Mind. This was known as the first-order false belief task. It involved the child being presented with a short story where one character (i.e. Sally) is not present when an object is moved, and therefore Sally doesn't know the object is in a new location. The child being tested is asked where Sally thinks the object is. Research with false-belief tasks have shown that around the beginning of 4 years of age typically developing children show this understanding of their own and other's minds and can pass a false belief task relatively easy (Wellman, Cross & Watson 2001).

A new era of research in ASD began when Baron-Cohen, Leslie and Frith (1985) published a paper examining if children with ASD possess a Theory of Mind. They found that children with ASD failed false-belief tasks in comparison to typically developing children and children with Downs's syndrome. These findings implied that children with ASD were impaired in understanding the minds of others and recognising other's beliefs. This theory became known as the Theory of Mind hypothesis of ASD (Baron-Cohen, Tager-Flusberg & Cohen 1993). An impaired Theory of Mind did not only explain why children with ASD were so impaired during Theory of Mind tasks, it also proposed to explain the wider implications associated with the autistic impairment i.e. the deficits observed in communication, pretend play and social interaction (Baron-Cohen 1988). Communication was thought to be affected by Theory of Mind impairment as during interaction knowing the other persons' 'state of mind' allows us to understand their actions and modify our own behaviours to participate in the communicative act. These initial findings of Theory of Mind ability being impaired in children with ASD have been supported by other studies testing a range of first-order false belief tasks (for example, Leekam & Perner 1991; Swettenham 1996).

However the Theory of Mind hypothesis has received much criticism as even from the earliest study (Baron-Cohen *et al.* 1985) a minority of individuals with ASD passed the classic Theory of mind task implying that a deficit in Theory of Mind is not applicable across the whole population with ASD. To explain why a deficit in Theory of Mind performance is not universal, Baron-Cohen (1989b) proposed that rather than Theory of Mind being impaired, the development of Theory of Mind was instead *delayed* in children with ASD. To investigate this proposal of Theory of Mind delay Baron-Cohen (1989b) carried out the more difficult second-order false belief task which involves the children making inferences about another person's beliefs regarding a third party (I think, he thinks, she thinks). For example, I think that Peter thinks that Joan went to the shop to buy a chocolate bar. Baron-Cohen found that even children who pass the first-order false belief task were unable to pass the more difficult second-order belief tasks. Showing that this more advanced type of metalizing is too difficult for children with ASD due to the delay in theory of mind development.

To further support Baron-Cohen's (1989b) proposal that Theory of Mind is delayed in children with ASD, Happé (1995) found that performance of Theory of Mind was related to verbal ability. Typically developing children with a verbal ability age of 4 years were proposed to show a 50% probability of passing the first-order false belief task. This level of success is not obtained in ASD until they acquire a verbal mental age of 9 years and above (Happé 1995). The higher verbal age which must be met before children with ASD can pass the Theory of Mind task shows the huge delay in successful performance compared to typically developing children. Therefore Happé (1995) reported that the probability of passing a false belief task is predicted by verbal ability which needs to be significantly higher in ASD populations in comparison to typical populations.

It has been proposed that, other socio-communicative skills such as emotion recognition and empathy are also related to Theory of Mind ability. Heerey, Keltner, and Capps (2003) assessed emotion recognition and Theory of Mind in children with ASD (n= 25, 8 – 15 years). They found that the control children recognised self-conscious emotions significantly better than children with ASD ($p = .01$). There was also a significant relationship between Theory of Mind and self-conscious emotion recognition showing that Theory of Mind ability is an important factor in recognising specific emotions such as shame and embarrassment. Impaired emotion recognition in ASD is proposed to contribute to their observed difficulties with empathy and other forms of socio-emotional functioning (Clark, Winkielman & McIntosh 2008). Demurie, De Corel and Roeyers (2011) found that a group of adolescents with ASD (n = 13) were significantly worse at the Theory of Mind task "Reading the mind through the eyes", alongside an empathy accuracy task compared to a group of adolescents typically developing and with ADHD. The authors imply therefore that Theory of Mind skills are closely related to empathy processes. Despite these studies highlighting the links between these socio-communicative skills, nothing can be assumed regarding the direction of causality between Theory of Mind, emotion recognition and empathy as this remains unclear.

The observed relationship of impaired emotion recognition and Theory of Mind ability however links Theory of Mind to the amygdala theory of ASD. Brothers (1990) suggested that the amygdala is part of a 'social brain' that aids the processing of social information such as eye gaze and emotion recognition. The amygdala is believed to process basic facial expressions (Hariri *et al.* 2000) and complex social judgements about faces (Adolphs *et al.* 1994; Le Doux, 1995). The amygdala theory proposes that the amygdala is impaired in individuals with ASD. This may explain why participants with ASD show deficits in emotion recognition (for example, Humphreys *et al.* 2007). Therefore atypical amygdala activation in ASD may not only relate to deficits in emotion recognition but may also be a factor in the delay of Theory of Mind ability.

Baron-Cohen, *et al* (1999) Conducted a study with adults with HFA (n = 6) and compared them to a group of typicals, matched on mean age, handedness, IQ, educational level and socio-economic status. The participants were presented with a 'mind through the eyes task'. It was found that the control group were more accurate in the Theory of Mind task compared to the group with ASD. The typical group were also shown to activate their amygdala during this task unlike the group with ASD who did not show any amygdala activation. The adults with ASD showed instead an increase of activation in the superior temporal gyrus. The role of the amygdala in this study supports Brother's (1990) theory that there are specific neural networks that work on extracting social information from the environment and processing this information. It shows that not only does the amygdala activate typically in typical populations during emotion processing but also during theory of mind task which involves attributing a mental state. The overlap of neural networks involved in emotion processing and Theory of Mind supports the proposal that these two abilities are linked. This may imply that adults and children with ASD possess an atypically functioning amygdala atypically causing impairment in emotional processing and Theory of Mind. However this cannot be stated conclusively and more neurological work must be conducted to establish precise links between the amygdala, Theory of Mind and emotion recognition in ASD.

Despite Baron-Cohen (1989b) modifying the original Theory of Mind hypothesis for ASD, to account for the lack of universality, it still does not fulfil the criteria of a successful cognitive theory of ASD as outlined by Lewis (2003). Theory of Mind hypothesis may explain some of the cognitive impairments presented in ASD however it fails to account for all dimensions of autistic behaviour, including repetitive and restrictive behaviours observed in ASD. The theory also fails to explain why the minority of individuals with ASD who pass the Theory of Mind tasks still show debilitating social and communicative impairments (Happé and Frith 1996). These findings show that Theory of Mind hypothesis cannot fully explain the socio-communicative deficits present in ASD. Research has also shown that Theory of Mind deficits are not only unique to individuals with ASD but have also been observed in blind children (Brown, Hobson, Lee & Stevenson 1997), and children with specific language impairment (Miller 2001). This may be evidence that Theory of Mind impairment observed in ASD is just a consequence of another lower level function that is impaired in the autistic disorder.

A lower level function crucial to the development of Theory of Mind is social perception, including early attention to faces and appropriate use of eye gaze (Tager-Flusberg, Boshart & Baron-Cohen 1998). Cognitive theorists have proposed that theory of mind can only be developed when important developmental milestones are met. These milestones include being able to fixate on a face from birth (Gopnik, Capps & Meltzoff 2000). This skill is important because faces provide evidence of other's internal states and attending to this information is a vital skill during typical development that contributes towards a developing theory of mind (Farroni, Csibra, Simion & Johnson 2002). Therefore the lack of attention to faces specifically the eye area that infants with ASD display (for example, Jones, Carr & Klin 2008) may lead to their delayed development of a Theory of Mind.

Interpreting eye signals is important in developing the capacity to make inferences about other's mental states. Lack of attention to the eye area from an early age would cause an impaired ability to interpret the important communicative cues the eyes can present. Individuals with ASD are often reported to show difficulties in using cues from the eye area of the face to make judgements about beliefs, intentions and desires (Baron-Cohen & Cross, 1992; Baron-Cohen, Campbell, Karmiloff-Smith, Grant & Walker 1993). This shows that lack of attention to this area during early infancy persists through to adulthood.

Eye gaze behaviour may not only contribute to a delayed Theory of Mind but has also been highlighted to affect how information is attended to during Theory of Mind tasks. A study by Ruffman, Garnham and Rideout (2001) found that children with ASD did not use their eye gaze to attend correctly to a scene during a Theory of Mind task that involved a social story about a character's desired hidden object. Children with ASD showed that they were less likely to attend to the correct hidden location compared to children with developmental delay. This eye gaze behaviour was also found to be directly related to the children's level of severity on an autistic scale with those scoring less severe showing better eye gaze shifts. The authors claim that although children with ASD will have a certain amount of social understanding they are unable to use spontaneous strategies such as eye gaze during Theory of Mind tasks and may have to rely on other cognitive routes.

Therefore the Theory of Mind delay observed in ASD may be caused by early atypical attention to faces and eyes. This atypical attention and gaze behaviour may continue throughout development affecting how the individuals with ASD actually perform Theory of Mind tasks. As mentioned above, Theory of Mind also fails to fully explain all aspects of the autistic phenotype showing that a delayed Theory of Mind cannot be the only psychological theory to describe the characteristics of this disorder.

Executive functioning

Another theory which sought to explain the impairments observed in the socio-communicative behaviours of ASD and to also offer insight into why Theory of Mind is impaired in ASD was the Executive dysfunction theory. Executive function refers to persons' higher level cognitive functions and includes a wide range of processes such as, working memory, inhibition, planning, problem-solving and abilities to shift attention. (Baddeley, 1991; Hill, 2004).

The executive dysfunction theory is supported by research which showed that adolescents with high functioning ASD showed more severe impairments in tasks measuring executive function compared to Theory of Mind tasks and emotional understanding (Ozonoff *et al.,* 1991). Executive functions such as attention and behavioural regulation have also been found to be significantly correlated with ASD symptoms, supporting the proposal that Executive dysfunction is related to the behaviours observed in ASD (Kenworthy *et al.,* 2009).

Impairments of Executive functioning (such as planning and attention shifting) may explain some of the socio-communicative problems observed in ASD as well as the repetitive behaviours and deficits in play (Jarrold 1997). For example Turner (1997) explains that the inability to control and regulate attention may cause the individual to become fixated on a specific behaviour and carry it out repeatedly. Executive function also contributes to children participating in school activities. For example abilities to regulate emotional responses, resist impulsive behaviours, and self monitor in general play an important role in successful participation (Zingerevich & LaVesser 2009).

Similar to the Theory of Mind account of ASD, Executive dysfunction is not unique to ASD. ASD is not the only disorder where executive dysfunctions are found. For example patients of many other clinical disorders may fail executive function tasks including, Attention Deficit with Hyperactivity Disorder – ADHD, (Grodzinsky & Diamond 1992; Loge, Staton & Beatty 1990), Schizophrenia (See Elliot & Sahakian 1995, for a review), Williams Syndrome (Tager-Flusberg, Sullivan & Boshart 1997) and obsessive compulsive disorder (Christensen, Kim, Dysken, & Hoover 1992). Therefore since these disorders show an impairment of Executive function yet do not lead to ASD the Executive function alone cannot explain the onset of ASD. The specificity (i.e. the power) of theories explaining the causality of ASD is important as individuals with ASD display a set of definite specific impairments therefore the deficit must be specific to ASD, (Frith & Happé 1994).

An Executive dysfunction may be manifested by difficulty in disengaging from the present (for example, Hughes, Russell & Robbins, 1994). This attention shifting is proposed to enable a person to plan effectively by shifting from one activity and replacing it with a new one. Therefore individuals with ASD may have their attention captured by an object and be unable to shift their attention to a new activity or aspect (Lewis 2003). This may highlight causes of atypical attention allocation across the ASD (for example, Klin, *et al.*, 2002) where adults with ASD were found to fixate on objects instead of socially relevant areas of interest.

The Executive dysfunction theory can explain some features of ASD such as a failure to plan and lack of inhibition (non-specific impairments of ASD) however this theory doesn't offer explanations for all the features associated with ASD such as why individuals with ASD show a local processing bias. There is another psychological theory however which may account for the specific processing style observed in ASD that cannot be explained by Theory of Mind and Executive dysfunction, this is the Weak Central Coherence theory.

Central Coherence

Frith (1989) claimed that typically developing adults and children process information from their environment in a gestalt (global) form. This means that fine (local) details may be missed whilst holistic processing takes place. In contrast global processing is not often utilised by individuals with ASD. Instead they show a bias to process their environment using a more local or featural strategy. Rather than being an impairment, a local processing bias can enhance performance on certain visual tasks (for example, Shah & Frith 1983).

Individuals with ASD are thus hypothesised to show "Weak Central Coherence", which is shown by a processing bias for featural and local information and failure to see information relative to the "big picture" (Happé & Frith 2006). It explains the impairments observed within the ASD population to be caused by an inability to integrate information into a context or "Gestalt". Individuals' with ASD are typically unaffected by context effects evidenced by for example, their superior ability on the embedded figures test (Jolliffe & Baron-Cohen 1999; Shah & Frith 1983). This superior perception of local information has also been observed in the block design test (Shah & Frith 1983). Examples of weak central coherence can be observed when visuo-spatial abilities such as visual grouping are examined. It has been shown that visual grouping is carried out using local grouping strategies compared to gestalt grouping (Brosnan, Scott, Fox & Pye 2004).

Individuals with ASD have also been shown to conduct faster visual searches (O'Riordan, Plaisted, Driver, & Baron-Cohen 2001) showing how their featural strategies can be superior during certain visual tasks. There is also a reduced susceptibility to visual illusions, (Happé 1996; Ishida, Kamio, & Nakamizo 2009; Ropar & Mitchell 1999). Impairment of global perception in ASD is supported by their performance in another visual task known as the Navon task (Navon, 1977). Participants with ASD in a study by Plaisted, Swettenham and Rees, (1999) were presented with the Navon task. The participants were in one condition cued to attend either the local or global information and in the other condition they were allowed to spontaneously attend to the stimuli. Results showed that the participants with ASD only showed global processing when cued to do so, otherwise local information was more attended to, showing that populations with ASD are able to process at global levels however this does not occur naturally. Visuo-spatial strategies may also be indicative of some abilities or functions in ASD, as a study conducted by Walter, Dassonville, and Bochsler (2009) showed that when individuals scored high on the Systemizing Quotient they were less likely to be susceptible to certain visual illusions such as the Ponzo and Poggendorff illusion. The correlation between these two variables is interesting as it has been proposed that eye gaze behaviour/strategies may also be indicative of functioning (for example, Klin *et al.* 2002; Speer, Cook, McMahon & Clark, 2007; Riby and Hancock 2009a), however this will be examined in more detail in the following experimental chapters (Chapter 5 and Chapter 6).

Weak Central Coherence may also offer an explanation of how individuals with ASD attend to faces as there is evidence that they may attend to featural aspects of a face rather than holistic information, or even different features from the features attended to by typically developed individuals. For example Langdell (1978) found that young children with ASD were better at recognising familiar faces by the lower features which was different from children developing typically who were better at recognising upper features. There was also evidence that inverting the face stimulus had no effect on face recognition in children with ASD (showing a lack of configural processing in the older children with ASD). This study will be examined more in Chapter 6 alongside other familiar face processing studies. Not all studies support the Weak Central Coherence theory, for example; the earlier findings of a local bias in processing found by Happé (1996) during visual illusions have not been replicated in recent studies, such as Ropar and Mitchell (1999; 2001). Children and adolescents with ASD have also been shown in some studies to be susceptible to the Thatcher illusion in face processing suggesting that they may still attend to global information (Riby, Doherty-Sneddon & Bruce 2009). Again however these discrepancies may be caused by a variation of participant criteria, ages and methodology.

Furthermore the tendency to apply global or local processing to a visual task may be influenced by other factors. Lopez, Donnelly Hadwin and Leekam (2004) found that during a face matching task based on full faces or features of faces, 17 adolescents with ASD did not show a difference between whole face and feature matching when left to spontaneously look without being cued, showing a lack of holistic processing advantage. However when presented with a cue informing them what to base their matching decision on (i.e. Look at the mouth), the cued condition was found to facilitate performance on holistic processing). Therefore despite showing a bias for featural processing they are not without holistic processing abilities and may instinctively rely more on piecemeal processing strategies. This complex face processing evidence will be examined in more detail within the next chapter (Chapter 3).

Weak Central Coherence may explain or account for some of the behaviours associated with ASD but similar to the other psychological theories it cannot account for all the evidence. Each cognitive theory presents benefits and downfalls in their explanations of the autistic phenotype, and fails to fully explain the core triadic symptoms of ASD. Although they all aid in conceptualizing ASD it is unlikely that any of the theories represent mutually exclusive atypicalities (Tonn & Obrzut 2005). Each of the cognitive theories presented here do not fulfil the criteria for a successful theory of ASD as proposed earlier in this section by Lewis (2003). They were unable to specify a universal deficit which could be applied to the whole population of ASD, or present a deficit specific to ASD. Each theory was therefore able to explain some behavioural domains of ASD but not account for them all. As yet no cognitive account can describe and explain every characteristic of the ASD phenotype.

2.3 Discussion

This chapter presented an introduction to the sub-types of ASD. It showed the variation of behaviours which manifest at varying intensities across the spectrum and how these behaviours are observed and aid in the diagnosis of each child's disorder. Evidence was presented showing how a range of chromosomes which impact on different areas of social functioning interact with a range of environmental factors to cause the heterogeneous manifestations of ASD behaviours. It was important to highlight within this chapter the variability of functioning and socio-communicative ability within this population in relation to this thesis. The participant group selected for the following experimental chapters were chosen to represent this range of ability observed across the Autism spectrum.

The cognitive theories proposed to explain the ASD behavioural phenotype were also presented. These highlight the difficulty in accounting for a vast range of behaviours with one cognitive model. This thesis does not want to prove, disprove or inform any cognitive theories. Instead this collection of experiments proposes to use face processing and eye gaze behaviour as a vehicle to highlight atypical attention allocation across the Autism spectrum. By presenting varying face stimuli to participants across the Spectrum, who display a range of social functioning, it is proposed that links between communicative abilities and attention allocation in ASD can be highlighted. The importance of attending to a face for socio-communicative cues and how this aids social interactions will now be discussed in Chapter 3 – Face Perception.

Chapter 3 – Face Perception

3.1 Introduction

In Chapter 2 social deficits and communicative atypicalities across Autism Spectrum Disorder (ASD) were introduced and discussed. This thesis focuses on the face processing and eye gaze atypicalities in ASD and how these influence the socio-communicative impairments associated with this disorder. In order to explore the socio-communicative impairments the importance of attending to faces and encoding their communicative cues will be highlighted within this chapter.

As social beings, humans rely on successful interactions and cohesive relationships to function within their social groups. In order to successfully participate within an interaction, individuals must recognise social cues from others and modify their own behaviours to suit the situation. Important socio-communicative cues can be accessed by attending to the information presented on a person's face. Each individual can quickly scan a face and accurately process key information simultaneously such as identity, attractiveness and emotional expression. By attending quickly to a face, important social evaluations can be made about that person such as familiarity, how they are feeling and what they are thinking.

Much evidence suggests that we are born with an innate attraction to faces, supporting the notion of the face being high in social and evolutionary importance. For example neonates as young as 9 minutes have shown a preference for schematic faces compared to scrambled face patterns (Goren, Sarty & Wu, 1975). This has also been replicated by several other studies which have examined infants, born within an hour (Johnson, Dziurawiec, Ellis & Morton 1991) and infants aged between 12 hours and 5 days (Maurer & Young 1983). All infants showed a significant preference for face-like stimuli. This early attention to faces will be discussed to a greater extent within this chapter. It is mentioned here to emphasise how selective attention to faces is intrinsic and relevant in establishing early bonds and relationships in typically developed infants.

This innate ability to attend to faces and learn about them shows the evolutionary importance of faces within social groups. Attending to faces may be a fundamental survival strategy which is emphasised by primate groups where facial expressions are relied on as a communicative cue to a greater extent compared to humans. Similar to human primates it has been proposed that these facial expressions are used to maintain social relationships and co-ordinate social interactions (Parr, Preuschoft & de Waal, 2002). For example it has been observed that the bared-teeth display in human primates (which is the equivalent of the human smile) is used in chimpanzee groups to increase social affiliation and attraction, (Waller & Dunbar 2005).

As mentioned previously, in order to facilitate the establishment and maintenance of social relationships, social cues from faces must be attended to and understood. In order to use the information from a face efficiently we have to be able to detect a face rapidly and identify the social cues. This enables us to modify and adapt our behaviours during communication so interactions can be carried out successfully and social cohesion is maintained. Research has shown that it takes as little as 130 milliseconds to detect a face presented in a scene, showing how quickly a face attracts attention (Jacques & Rossion 2006). To be able to detect and process the information on a face quickly requires specific neural networks which work on understanding facial cues. The fusiform face area (FFA) or fusiform gyri is reported to become highly activated when detecting the presence of a face (Grill-Spector, Knouf & Kanwisher, 2004) and identifying it (Haxby *et al*. 2000). Having areas of the brain specialised in specifically processing faces highlights the importance of face cues during our day to day social exchanges.

The importance of facial cues is highlighted further by the innate preference of face configurations by newborns, the use of facial expressions in the maintenance of social relationships in primates and brain functional studies showing neural areas specialised in processing face-specific information. However there are populations born with a developmental disorder who show a lack of interest in faces. This developmental disorder is ASD. From an early age it has been reported that individuals with ASD lack an innate social interest (Clifford & Dissanayake, 2009), and are hindered in many aspects of face processing. This includes the detection of faces (Riby & Hancock, 2009a), processing identity (Deruelle, Rondan, Gepner & Tardif 2004), and facial expression of emotion (Clark, Winkelman & McIntosh, 2008), showing that there is not only a lack of basic orientation of attention towards faces but an impaired range of skills important in the interpretation of facial cues. This thesis aims to examine the face processing atypicality and abnormal gaze behaviour in ASD and emphasise the role these impairments play in the wider implications such as communication and learning environments. After the highlighted importance of face information to individuals who live within social groups it is clear how this atypical face perception contributes to the socio-communicative impairments reported in ASD.

To highlight the impairments of face processing present in ASD, the face processing abilities of typical populations must be examined. By investigating face perception in typical adult and child populations we will be able to establish typical encoding of face information and how this aids in social interactions and communicative ability.

3.2 Adult Literature

This section will present research involving adult face perception and attention to facial communicative cues. This will allow us to examine how efficient face processing skills are important for everyday functioning and successful interactions. Determining how faces are attended to and processed by adults will highlight how face perception may be atypical in populations such as ASD.

There is evidence that humans and other non-human primates are 'specialized' in the recognition and processing of faces and facial communication cues. There are several psychological and neuropsychological models which try to explain the typical processes involved in understanding faces. Support for this theory that faces are 'special' for processing is evident in neurological studies which show an area of the brain which activates during face perception. Humans have been proposed to be face 'experts' and have specialized capabilities in dealing with information presented by the face. This proposal is supported by research on an area of the brain which becomes highly activated during the presentation of face stimuli. It is proposed to be a specialized neural "module" and is called the Fusiform Face Area (FFA) or Fusiform Gyrus (FG). Kanwisher, McDermott and Chun (1997) found that FFA would become more activated in participants when faces were presented compared to non-face objects (for example, scrambled faces, objects and houses). This has been supported by further studies which show this high FFA activation during the presentation of faces (i.e. Grill-Spector *et al.* 2004; Kanwisher, Yin & Wojciulik, 1999). Activation is reduced in the FFA when a participant is presented with an inverted face, (Kanwisher, Tong & Nakayama, 1998) showing that a face is no longer attended to as a face when it's placed upside down. Damage to this area is also proposed to cause prosopagnosia (Whiteley & Warrington 1977) and impairment in recognizing faces (Damasio, Tranel &

Damasio, 1990). These studies emphasize the importance of faces and how areas of the brain are almost set aside to deal with the cognitive load that faces produce. By having modular neural networks, face information can be processed quickly and efficiently and appropriate communicative acts can be carried out. Morris, Fraser and Wormald (2007) found that even when face stimuli was presented using a 'masking' technique (a technique which makes participants unaware of visual stimuli) the FFA was activated, showing that this process is automatic and can take place even when the person is unaware they have actually seen a face. This again supports the notion that faces are important within human society and need to be processed automatically and spontaneously.

However face specialization is still controversial as there are many supporters of an expertise hypothesis. This claims that prolonged exposure to any set of homogeneous stimuli leads to expertise (for example, faces, birds, cars). Expertise theorists claim that the FFA becomes activated because this area is involved in fine-detail discriminations and is not specific to faces. This has been supported by Gauthier, Skudlarski, Gore & Anderson (2000) who found that bird experts' FFA became highly activated whilst viewing birds. However this significant expertise activation of the FFA is not widely found in other research, (for example, Grill-Spector *et al.,* 2004; Rhodes, Byatt, Michie & Puce, 2004).

A model proposed by Haxby *et al* (2000) showed that the FFA does not work in isolation to process face information. This neural model proposed that there is an extended face processing system (see Figure 3.1). The theorists proposed that the OFA (Occipital Face Area) and the FFA work together to quickly detect a face irrespective of viewpoint and identifies it, whereas the superior temporal sulcus deals with the changeable aspects of a face such as emotional expression and eye gaze (i.e. Communicative face cues).

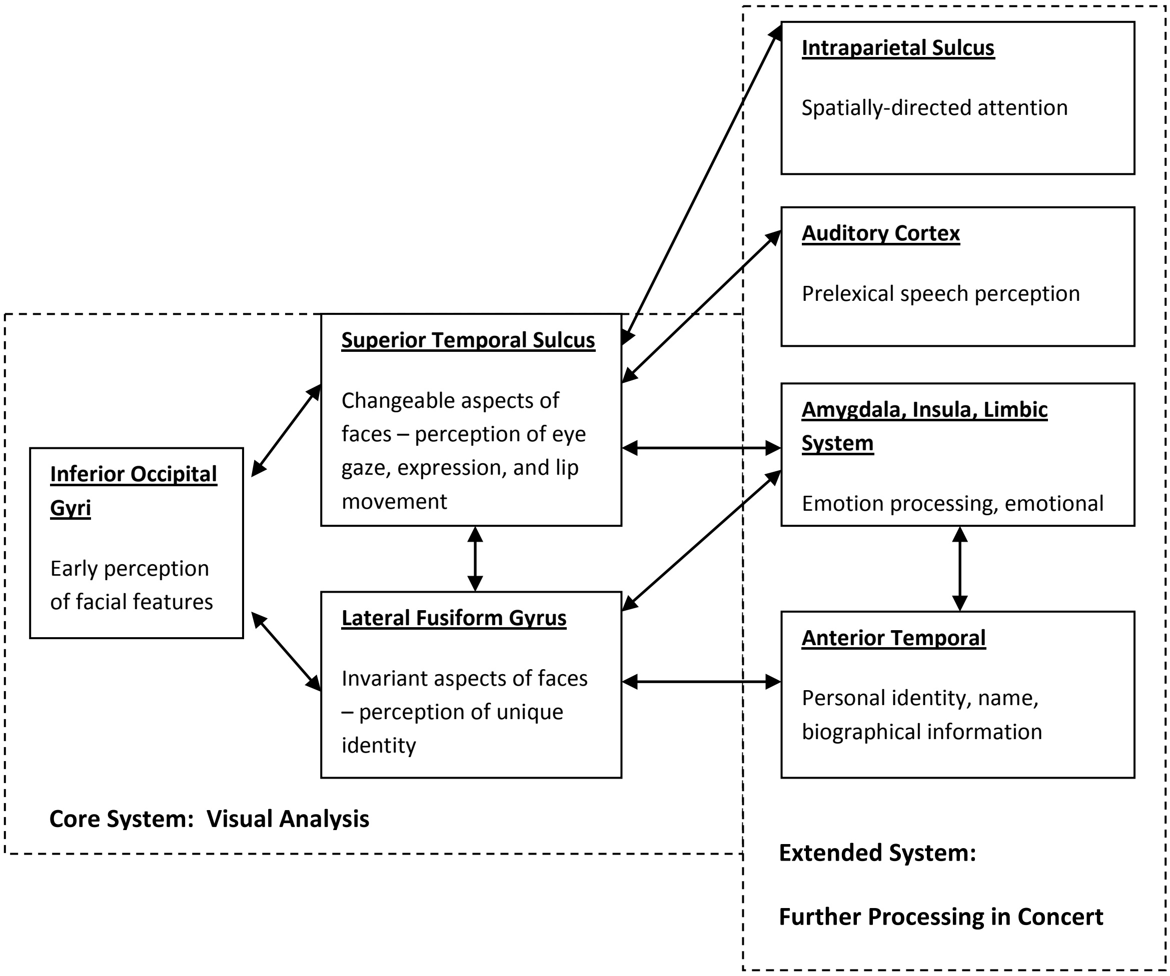


Figure 3.1 Neural Model of Face Perception (Haxby *et al.* 2000)

According to Haxby *et al*'s (2000) model of face processing the STS is part of a core system that deals with the invariant aspects of a face. This core system then feeds into an extended system which deals with processing the variable aspects of a face. This model is particularly relevant for highlighting the issues that may take place during face processing in ASD specifically how facial communicative cues are processed. This will be examined in more detail within a latter section. For this part of the thesis we will examine how this model relates to face recognition, emotion processing and attention to communicative cues in typical populations.

Haxby *et al* (2000) model proposes that emotion and identity are processed independently, which is supported by neurological studies. For example Tranel, Damasio and Damasio (1988) found that patients with specific brain damage were able to recognize emotional expression but were not able to identify persons as familiar. The opposite effect was reported by Young, Newcombe, de Haan, Small and Hay (1993) who found patients with acquired brain damage could judge familiarity but not emotional expression. This double dissociation supports the proposal that these two judgments are processed independently. The evidence that these aspects of faces are processed separately is provided by neuroimaging research. Winston, Henson and Fine-Goulden, (2004) conducted an fMRI and found repetitions of faces with changing identity led to a reduced activation in the fusiform face area and the posterior superior temporal gyrus. Repetitions of faces with changing expression led to a reduced activation in the mid-temporal gyrus.

It can be observed from the above neural model that the amygdala is implicated in part of face processing notably emotion recognition. This can be further supported by neuroimaging studies for example; Habel, *et al.,* 2007) showed that the amygdala became more activated when participants were explicitly asked to judge facial emotions as opposed to the age of a face, showing the importance of this area in emotional processing. The importance of the amygdala has been highlighted in studies done on patients with amygdala damage. Graham, Devinsky and LaBar, (2007) found that participants with amygdala damage were able to identify faces but not successfully categorise emotions.

This supports the proposal that identity and emotion is processed separately and the amygdala is involved in the latter. If this is the case then according to Haxby *et al.'*s (2000) neural model of face processing individuals with ASD may be impaired in both lateral fusiform gyrus (deals with identity) or the STS (deals with emotion recognition) or even both.

The Superior temporal sulcus (STS) has been found to be significantly activated when processing eye gaze information (Perrett, Hietanen, Oram & Benson, 1992). Removal of the STS has also been found to impair gaze perception (Heywood & Cowey 1992) but does not affect performance on other face processing tasks such as face matching tasks (Campbell, Heywood, Cowey, Regard & Landis 1990). A study by Hoffman and Haxby (2000) further showed the specific gaze processing which is carried out in the STS as this area became highly activated when attending to eye gaze direction compared to identifying faces which activated the FFA. This study again shows support that both identity and emotion are independently processed.

This model is important as it shows independent pathways for both processing emotion recognition (facial communicative cue) and identity recognition. Showing that these different types of face information are not processed interdependently. Further research in brain damage shows further evidence that these processes function independently for example, prosopagnosia patients have been shown to recognise emotional expressions but not facial recognition (Lee, Duchaine, Wilson & Nakayama 2010).

The Haxby *et al* (2000) model therefore highlights the important role of several areas of the brain in face recognition and face communicative skills. This model implies that successful social interactions are dependent on both face recognition and interpreting face communicative cues. The amygdala is highlighted in the Haxby *et al*

(2000) model as being particularly important when processing emotional information from a face. The amygdala is proposed to be part of a network of brain areas termed the ‘social brain’ which deals specifically with social information (Brothers, 1990). The Haxby *et al* (2000) model confirms the role of the amygdala in processing socio-emotional cues. This is relevant when addressing possible causes for atypical face processing in ASD as the amygdala has been highlighted to function atypically in ASD (section 2.2). Atypical social perception in ASD may therefore stem from impaired activation of the amygdala (presented in Haxby’s extended face neural networks). There is evidence which shows typical face recognition but reduced accuracy in emotion and eye gaze direction in participants with ASD (for example, Deruelle *et al.,* 2004) implying that they may be impaired in areas of face processing related to social brain networks and general face recognition abilities remain intact. These proposals will be examined in more detail later in the ASD section.

Typical Communicative facial cues

Haxby *et al* (2000) model showed that communicative cues were processed independently of face recognition. These communicative cues include, lip movement, emotional expression and eye gaze. Eye gaze has been observed to have three main functions- sending social signals, opening a channel to receive information and controlling the synchronisation of speech, (Argyle & Cook 1976). It can therefore play an important part in conveying appropriate information during communication. Mutual eye contact is believed to be important in reinforcing relationships and showing affection (Rubin 1970). Eye gaze is also important within interactions as it can be used as a signal of intimacy, similarity and dominance, (Burgoon, Manusov, Mineo & Hale, 1985) and used in deception (Vrij 2002). Understanding eye gaze cues also aids turn taking during interactions (Kleinke 1986) enabling the dialogue to continue smoothly and efficiently.

During spontaneous viewing of faces observers tend to look more at the eye and mouth areas, (Hunnius & Geuze 2004) showing the importance of these areas specifically when processing facial communicative cues. Although the mouth is an area central to the expression of verbal communicative signals, special emphasis is also placed on the eyes. It is believed that eyes provide access to mental states (Baron-Cohen, 1995) and emotional expressions (Lundqvist, Esteves, & Ohman, 1999). Cues presented by the eyes allow us to infer what a communicative partner may be thinking or feeling. This allows us to modify our own behavior to suit the communicative context so mutual exchanges can be made.

One important function that eye gaze provides in face-to-face interaction is joint visual attention. Attending to a person's eye area allows us to follow their eye gaze during conversation if they wish to allocate our attention to something. We are able to observe what has attracted the other persons' attention and also gain insight to their internal mental states. This characteristic of gaze following is linked to the unique morphology of the eye in human primates (Kobayashi & Kohshima, 1997), the pupil standing out against a white background providing information on the viewing direction and the intentions of others. Langton (2000) claims that this sensitivity to other's gaze direction may have intrinsic survival benefits and can be traced to behaviours still observed in primates. These behaviours include gaze following to increase awareness of threat, food sources etc, (Anderson, Sallaberry & Barbier, 1995). The use of eye gaze to establish joint and shared visual attention develops early in life. In turn it is an important mechanism in the development of language, and socio-cognitive skills such as Theory of Mind. Neural structures proposed to be responsible for the detection of eye movements include the STS (Perrett *et al* 1992). Neurons have been found in the STS of monkeys which respond to the gaze direction of other con-specifics. The role of the STS in face processing was highlighted previously in Haxby *et al* (2000) neural face perception model. The STS was shown in Haxby *et al.*'s (2000) model to encode the socio-communicative aspects of a face including lip movement, emotion expression and eye gaze.

Another vital function that faces serve is in communicating emotional states. The ability to quickly recognize emotions is advantageous in social groups. If we are able to quickly observe and recognize the emotion a person is visually displaying on their face then we can judge whether to engage in an interaction or avoid the person. Emotion expressions also convey to us the other person's mental or emotional states, allowing us to understand their behaviours and aid social interactions. Not only do we gain insight into another person's behaviours by understanding their emotional and mental states but this knowledge enables us to monitor and modify our own behaviours to help regulate conversation. These few examples of how face expressions aid social interactions and communication highlights the advantages of processing and encoding emotions quickly and efficiently. Quick processing skills and comprehension of facial cues allow for the regulation of communication and maintenance of social relationships.

Charles Darwin (1872) was the first researcher who wished to examine the universality of facial expressions. He observed that facial expressions could be instantly recognized by adults from different cultural groups "though described in not exactly the same terms," (Darwin 1872, p.14). Darwin has also influenced the last decade of emotion recognition research. One contemporary influential researcher of emotional expression is Paul Ekman. Like Darwin, Ekman was interested in the universality of facial expressions and wished to test if facial expressions varied across cultures. Ekman, Sorenson and Friesen (1969) created stimuli comprising of the 6 basic emotions each one characterized by a distinct pattern of facial muscular movements, including; happiness, anger, disgust, fear, sadness and surprise. These stimuli were shown to different cultures (including Japan, USA, Chile, Argentina and Brazil). Participants from each country were asked to judge what emotion the face was displaying. All cultures showed high accuracy in recognizing the facial emotions with no significant differences of accuracy between the cultures. This shows how facial expressions must be both decoded and encoded similarly by different societies.

However not all aspects of facial expressions are innate and recognized easily by other cultures. For example Ekman and Friesen (1971) presented an emotional scenario to an isolated tribal group in New Guinea and then showed three images of faces, each expressing a different emotion. The participants had to choose the face that reflected the emotional content of the story. They found that happiness was easily recognized alongside sadness, anger and disgust. However the participants would frequently confuse fear and surprise and were correct on only 43% of the trials involving the emotion fear. This shows that the tribe's comprehension of the emotion fear was not similar to western cultures, as these images had over 70% inter-rater reliability when comparing comprehension across western cultures (Ekman & Friesen 1971). This difficulty may be due to the emotional expression of fear being more susceptible to cultural variation. It has been found that cultural variation affects certain facial configurations during emotional expression such as the use of eyebrows which are only used as a sign of dominance in westernized cultures (Keating, *et al.*, 1981).

Therefore facial expressions are not only innate but are also influenced by cultural learning with some cultures showing variations on face configurations for emotional expression. There are also cultural differences in rules regarding emotional expression in public. These cultural rules on how emotion expression is modulated are known as display rules. Display rules along with specific facial configurations are learned by children as they become socialized into their culture. Children must learn from an early age what emotions are acceptable to express and the facial configurations they must use to express them. As a result there is great cultural variation on how intense emotions are portrayed and what emotions are expressed. For example a small group of aboriginal hunters known as the Chewong in Malaysia are not allowed to express any emotion publically except fear and shyness (Howell 1981). Also Japanese cultures do not like to publically show disgust or intense unhappiness (Friesen 1972). Development of these important display rules in child populations will be examined in section 3.3.

Despite variances between cultures, facial expressions remain an important communicative cue across human social groups. The importance of facial expressions can be observed in even more detail in non-human primates who have been shown to rely on their facial expressions to a greater extent than ourselves. Human primates have the advantage of language whereas non-human primates must rely on their facial expressions to a greater extent to communicate their wants and desires. Humans are proposed to have around ten main emotional expressions (Ekman 1982), however chimpanzees have shown around 20 emotional expressions and use them to aid group stability and manage relationships, (Doherty-Sneddon 2003). To function cohesively in a social group facial expression must be encoded and understood correctly. The quick and efficient processing skills we apply to encode facial communicative cues shows how we have developed advanced cognitive capabilities to deal with this important social information. The development of other face processing skills will now be examined in the next section.

Typical featural vs. holistic Processing styles

Not only are there areas of the brain which are proposed to be specialised for processing face information but also the processing strategies adopted to encode faces seem to be specialised also. Unlike objects which are attended to more featurally, faces are encoded based on configural or holistic strategies. Both configural and holistic processing are normally referred to as configural processing in the literature however Leder and Bruce (2000) caution that there is a distinction between holistic and configural processing despite the distinction being difficult to ascertain. The two processing styles have similar definitions which does not make distinguishing between them easier. Holistic processing is defined as the formation of a face as a whole, which cannot be easily broken down into separate features (Tanaka & Farah 1993) and configural processing is defined as the spatial relationships between the features (Bruce 1988) such as the arrangement of features i.e. eyes above a nose (Diamond & Carey 1986). Both definitions imply that facial features are processed in an interdependent way rather than isolated parts.

The holistic theorists however propose that a face 'template' is used for recognition and spatial arrangements of a face are less important. Evidence of this can be assessed by the composite effect (Young, Hellawell and Hay 1987) which is when two faces are presented with the same top half but different bottom halves. When presented upright it is difficult to see that both faces have the exact same top face halves. Instead of seeing the separate features, the face is processed holistically i.e. as a gestalt. This effect is observed for both famous familiar faces (Young *et al.* 1987) and unfamiliar faces

(Hole, 1994). The Composite Face effect however disappears when the face is inverted or the two halves are misaligned both of which would affect the stimulus being recognised as a face. The composite effect supports the role of holistic processing in face perception however it does not completely rule out the influence of the spatial interrelationship of features in encoding the face as a whole.

Configural processing can be assessed by the face inversion effect (Yin 1969) or the Thatcher illusion (Thompson, 1980). The face inversion effect highlights how faces are more difficult to recognize when presented upside down compared to objects (Yin 1969). Face inversion makes it difficult for typical observers to detect spatial relations and therefore disrupts configural processing, however it has shown to leave featural processing unimpaired which is why non-face objects are not as adversely affected by inversion. The Thatcher illusion (Thompson, 1980) is when the eyes and mouth is inverted with respect to the rest of the face. This atypicality is observed straight away when the face is upright, however when the face is placed upside down this discrepancy is not noticed (Carbon & Leder 2005). This is because the inversion of the face reduces configural processing, specifically the spatial interrelationship between the features and the rest of the face.

In this thesis the evidence that will be examined will be holistic and configural processing as opposed to featural processing (which is the processing style often reported in the ASD literature for example, Celani, Battacchi, & Arcidiacono, 1999). Despite a distinction between holistic and configural face processing being acknowledged, both types of processing will be defined in this thesis as the formation of facial features as a whole where features are processed interdependently rather than isolated parts. Featural processing will be defined as a piecemeal strategy where features are processed as separable local elements (for example, Carey & Diamond 1977).

There is much evidence which shows that, in typically developed adults, faces are processed configurally compared to featurally. Tanaka and Farah (1993) have shown that face parts presented in the context of a studied face are more accurately recognized than when presented in isolation or as part of a scrambled face. These results suggest that facial features are not represented in their own but rather as part of a gestalt representation of the face. Second, Tanaka and Sengco (1997) have reported that changing the distance between the eyes of a face disrupts recognition of both the face as a whole and of its other unaltered features. Therefore, changes in the holistic representation of a face can affect recognition of its features. Houses and inverted faces did not produce this effect, suggesting that their features and the configural relationship between them are represented independently and therefore do not form a cohesive whole unlike faces. This holistic advantage is observed only in upright faces and not parts of houses or inverted faces (Tanaka & Farrah 1993). When attending to faces it seems that a different processing strategy is adopted to encode the information presented. This is not observed when attending to any other item or object as observed in the studies above. It seems that when recognising a face we do this better when it is presented as a whole.

A global processing style is not only relied on for face identification, but also emotion recognition. Calder, Young, Keane & Dean (2000) found that emotion recognition was superior for misaligned compared to aligned composite face stimuli where the top half showed one emotion and the bottom half another. This suggested that adults rely on holistic processing strategies when encoding emotional expression from the face. However it may not be as simple as one processing strategy being adopted when recognising emotions and adults may shift between both featural and holistic strategies when encoding emotional expression from a face. Ellison and Massaro (1997) propose that instead of processing emotional expressions holistically, information is encoded from the facial features independently. They found that individual features may be more indicative of specific emotions (for example, a furrowed brow is more likely to be perceived as anger while an upturned mouth implies happiness).

Experiment one of the investigation conducted by Calder, et al (2000) found that when participants were presented with composite faces showing the six basic emotions (the top half showing one emotion and the bottom half another emotion), feature-based cues were relied on also for accurate recognition of specific emotions. For example, viewing the eyes was a better indicator of fear, anger and sadness and viewing the mouth resulted in greater accuracy for judgements of happiness and disgust.

Martin, Slessor, Allen, Phillips and Darling (2011) briefly presented participants (n = 110) with faces showing the six basic emotional expressions (happiness, sadness, anger, disgust, fear and surprise (Ekman 1982). Participants were primed to either process locally or globally using a Navon Letters task (Navon 1977). It was found that emotion recognition was faster and more accurate when primed with a featural (local) processing bias compared to a global (holistic) processing bias. Therefore emotion recognition may benefit more from attention to local information compared to holistic information. The authors proposes that higher accuracy rates during emotion recognition when a local processing strategy is adopted may be caused by successful emotion recognition demanding a more analytical processing style rather than an automatic (holistic) processing style which is observed for identity recognition (Perfect, Weston, Dennis, & Snell, 2008).

It can be concluded from this evidence that faces are identified using specialised global strategies, which allow quick and sufficient identity processing. However important communicative cues from the face such as emotion recognition may be attended to using both a piecemeal strategy (featural processing) and holistic strategy. When emotion expression is not successfully recognised via a global encoding strategy, adults may attend to the individual features which are more indicative of specific emotions. However processing styles that are adopted during emotion recognition are not as well documented as the literature on identity recognition. More research must be conducted to gain a deeper understanding of the similar or different processing styles adopted during emotion and identity recognition. Emotion expression is an important communicative cue which is presented on the face. How these communicative cues are attended to and processed allows us to make social judgements about a face such as how the other person is feeling and whether to engage in an interaction. The ability to comprehend emotions is not only important for social interactions during adulthood but throughout development. Children must learn to attend faces and interpret the communicative cues presented. How this ability develops over time will now be examined in the next section.

3.3 The Typical Development of Face Processing

There is much evidence therefore to show that adults are face 'experts' and at a few seconds glance they can process a range of information about a face including, gender, familiarity and communicative cues such as emotional expression. How this ability develops is often examined to see if this 'expertise' exists from birth. However it has been proposed that this ability develops from birth and children and adults encode faces in qualitatively different ways (Carey & Diamond 1977). In this section how face processing develops will be examined with special emphasis on how communicative facial cues develop.

The Typical Development of Brain activity during Face processing

It has been shown through neuroimaging studies that the size and functioning capabilities of the FFA are still developing in children. With development the FFA has been reported to become more face selective, as primarily only a small area of the right FFA becomes activated by faces. The rest of the extended face processing systems such as the STS and the Occipital Fusiform Gyrus - OFG have been found to remain inactive during the presentation of a face in a group of 5-8 year olds (Scherf, Behrmann, Humphreys & Luna, 2007). The size of the right FFA was also proposed to be important as FFA size was found to correlate with performance on a face recognition task showing that the increase in volume associated with increasing age (from 7 years to adulthood) leads to an increase in face perception skills (Golarai, *et al.,* 2007). These developmental increases in FFA size and face selectivity in children has been replicated in other studies, (for example, Peelen, Glaser, Vuilleumier & Eliez 2009).

The FFA functions differently according to developmental stage. Aylward, *et al* (2005) found no significant difference in brain activation in FFA of younger participants (8-10 years) when viewing houses vs. faces showing that the FFA was not face selective at this age. In contrast older children (12-14 year olds) showed stronger activation in the right FFA in response to faces although it was still not at an adult level. Younger children were also found to have activated inferior temporal gyrus when viewing a face. This is similar to individuals with ASD which will be detailed in section 3.4 who have been proposed to show an immature face processing system.

These qualitative changes which take place in the brain, specifically the FFA, may also support the behavioural studies which show that expertise in face processing also develops during childhood allowing for changes in processing strategies to take place (i.e. Featural to configural), (Carey & Diamond 1977; Mondloch, Le grand & Maurer 2002). These changes in the FFA however may be caused by a child's increasing exposure to faces. Therefore more specialised networks develop to deal with face information. The latter would imply that for the FFA to become appropriately activated in later life then faces must be attended to during development. This may have implications for individuals with ASD as we know they do not naturally orient to faces which may influence FFA development.

Gathers, Bhatt, Corbly, Farley and Joseph (2004) found that all participants (both adult and child populations) showed face-preferential activation in the ventral processing stream, but adults and children aged 9-11 years showed face-preferential activation in the classically defined fusiform face area, whereas children aged 5-8 years showed this activation in the posterior ventral processing stream. Mckone, Crookes and Kanwisher (2009) found that qualitative aspects of adult face recognition measured behaviourally are present very early in development (by 4 years of age), yet functional magnetic resonance imaging and event-related potential evidence shows very late maturity of face-selective neural responses (with the fusiform face area increasing substantially in volume between age 7 years and adulthood).

The FFA is not the only area of the brain which develops as age increases; the amygdala also shows qualitative changes in activation during development. It was found that amygdala activation for angry faces increased with age in children aged between 3.5 and 8.5 years. Children also showed higher amygdala activation when viewing happy faces compared to angry faces an effect not found in the adult group

(Todd, Evans, Morris, Lewis and Taylor 2010). Therefore specific emotions may cause the amygdala to activate differently during development. It has also been proposed that fearful faces are perceived differently by the amygdala in children compared to adults, as one study has found children (aged 11 years) showed reduced amygdala activation when viewing fearful faces compared to an adult group (Thomas, *et al*., 2001). These differences of amygdala activation between child and adult populations may be caused by the child's lack of experience with these types of faces. This may explain why there are different developmental trajectories found for distinct emotions (Durand, Gallay & Seigneuric, 2007).

Some of this research implies that a level of experience with faces is needed to fine tune emotion recognition (Thomas, De Bellis, Graham & LaBar, 2007), or help further develop specialised networks such as the FFA and amygdala. Individuals with ASD however, have been shown not to attend to faces in the same way as their typically developed counterparts (for example, Klin e*t al.* 2002; Riby & Hancock 2008). Therefore this exposure and attention to faces which is required so face processing skills can develop may be missed, causing the atypical face perception often reported in this population; this will be examined further in section 3.4.

Communicative facial cues in Typical Development

The social significance and importance of attending to a face in human primates is best shown by examining neonates' behavior. Johnson *et al.* (1991) found that babies as young as one hour old showed a preference for face-like stimuli compared to non-face stimuli. This face preference is found to continue in older neonates between 12 hours and 5 days old, (Maurer & Young 1983). Many more studies have found this early drive in babies to seek out and direct their gaze at faces from birth (for example, Macchi Cassia, Turati, & Simion, 2004; Turati, Valenza, Leo, & Simion, 2005; Valenza, Simion, Cassia, & Umilta, 1996), especially at the mother's face (Burnham, 1993). Newborns, some younger than 5 days old, were shown to prefer faces with open eyes and direct gaze (Farroni *et al.* 2002; Farroni, Menon, & Johnson, 2006), showing that even at this young age faces which show mutual eye contact are attended to preferentially. This ability to seek out faces and selectively attend to them allows the early establishment of social and emotional reciprocity that is fundamental to development of social and emotional relationships. Actively seeking out a face especially when eye gaze is direct aids a crucial developmental milestone; eye contact.

An infant making eye contact is perceived by adults as the baby wishing to communicate and interact (Bates, Benigni, Bretherton, Camaioni, & Volterra, 1979). From an early age (around 2 months) infants show a preference to attend to the eye area specifically when looking at a face (Maurer & Salapatek 1976). Face recognition tasks show that this preference for the eye area continues throughout development. Children are reported to recognise eyes more than any other isolated feature in familiar faces showing how much attention typically developing children pay to this area of the face (Ge, *et al.,* 2008; Hay & Cox 2000). Attending to the eyes and maintaining mutual gaze is a critical milestone for the later development of important socio-communicative skills. It is crucial to make eye contact so many other important developments can be made for example gaze following, joint attention, and communication cues.

Evidence of the ability to process emotional expression (another important socio-communicative cue) from early infancy is also reported. Bornstein and Arterberry (2003) looked at emotion processing in infants aged 5 months. They conducted a study using the habituation paradigm with stimuli containing faces showing fear and happiness. The infants showed sensitivity to any changes in these expressions showing support that even at this early developmental stage emotion processing abilities are present. Peltola, Leppanen and Hietanen (2008) showed that infants aged 7 months were able to discriminate between faces showing fear and happiness by looking longer at the faces showing fear.

There are differing developmental trajectories in successfully recognising the distinct emotions. The proposal of differing developmental trajectories for emotions specifically negative emotions have been supported by several other studies (Durand, *et al.*, 2007; Gao & Maurer 2009; Thomas *et al*. 2007). Gao and Maurer (2009) examined the ability to comprehend happiness, and fear in children (n = 24 in each age group) aged 5, 7 or 10 years old and adults. They manipulated intensity of emotions by creating faces which morphed from a neutral state to express an emotion. Children as young as five were found to be as accurate as adults at recognising happiness even during low intensities. This shows that the ability to recognise happiness is present from an early age in children. When shown a face expressing fear children did not show the same accuracy levels as adults except the group of children aged 10 years. Abilities to recognise negative emotions quickly and accurately continue to be finely tuned during development through to adulthood (Thomas *et al.* 2007). Durand *et al.* 2007 found that by age 5 children could recognise happiness and sadness efficiently with little improvement over the years. Children were reported to be processing fear just as well as adults by 7 years, 9 years for anger, and 11 years for disgust.

It has been proposed that these differing trajectories for understanding specific emotions may be influenced by a child's exposure to emotional experiences. For example it has been found that children who have experienced physical abuse are more accurate at recognising anger compared to children who haven't experienced physical abuse (Pollak & Sinha, 2002).

Emotion expression and comprehension is not only influenced by the child's experiences but also social learning. Children have to learn about what emotions are acceptable to be expressed in public and to what intensity. These cultural norms of emotional expression are known as display rules. Display rules vary across cultures for example; in high contact cultures such as Italy it is socially acceptable to show intense unhappiness in public. However in non-contact cultures such as Japan, intense expression of unhappiness is deemed unacceptable and disrespectful (Doherty-Sneddon, 2003).

To investigate the development of display rules in children, Saarni (1984) applied a disappointment paradigm to school children (n = 45) aged between 6-12 years. Children were given an undesirable gift (example, a young infant's toy) and observed to see if they would employ display rules and try to mask disappointment. Six year olds showed negative emotions openly unlike older children who did not show as much negative emotion despite showing heightened arousal (for example, evident by lip biting). It was not until 10-11 years of age that children (especially girls) were able to hide their negativity and exhibit positive behaviour such as smiling. The gender difference is proposed to be caused by girls socialising faster than boys (Doherty-Sneddon, 2003). This therefore shows that as children get older they understand the display rules that exist in their culture and as part of their socialisation they regulate their emotional expressions.

This evidence suggests that some emotional expressions are innate and can be produced in the first few years of life. These expressions continue to be fine tuned by social learning and experience. Attending to other's faces and learning display rules is important for the child's developing social cognition. Their knowledge of facial expressions allows them to adapt to cultural norms and engage in social interactions. This may highlight why children with ASD do not understand facial expressions as they lack the innate interest to orient towards faces (Clifford & Dissanayake 2009). Reduced attention to faces may hinder successful understanding of facial configurations, leading to impairments within socio-cognitive development. This atypical emotion recognition in ASD will be examined in section 3.4. In order to attend faces and encode emotional expression efficient processing strategies must be employed by young populations. The next section will examine the perceptual strategies employed during face and emotion processing by typically developing children.

Typical Development of Featural vs. holistic Processing styles

For important social cues children attend to familiar faces to learn about their environment or understand novel situations (Baldwin & Moses, 1996). Children may therefore rely on recognizing a face before attending to the emotional expression that faces may show. The processing strategies that children adopt to encode identity and emotion expression will be examined within this section. It was initially proposed that during the development of face expertise in children an 'encoding switch' would take place during a specific stage in a child's life where they would switch from using a featural processing style for face recognition to a more holistic processing style (Carey and Diamond, 1977). This model of face processing development proposes that children are not as good as adults at processing identity from a face mainly because they do not encode them as efficiently. Carey and Diamond (1977) proposed that children lacked the extensive experience with faces in order to process them holistically (adult like) and instead processed them more in a 'piecemeal' fashion. This has been supported in many other studies which show young children less than 8 years old do not show the inversion effect suggesting that a more featural processing strategy must be used (Carey and Diamond 1977; Schwarzer 2000).

The encoding switch theory of face processing therefore proposes that children up until a specific stage in development will encode faces featurally then adopt a more holistic style which will extend into adulthood. In a study by Mondloch *et al* (2002) it was found that children aged between 6 and 8 were less impaired by the inversion effect during a face matching task compared to adults and 10 year old children. This showed that they are more likely to use a featural processing style unlike the older children and adults. The 6-8 year olds were just as accurate as adults and children of 10 years during the external contour and featural sets, again supporting further the contention that they were processing the faces more featurally. This development of facial skills from featural to holistic is also supported by neurological research which was discussed in the previous section.

The encoding switch theory of processing styles in development still remains controversial. Especially since recent research has highlighted that holistic face processing styles may be used by children in early infancy. To show that infants do use holistic processing, infants at 7 months were shown composite faces which consisted of internal features of one familiar face and external features of another familiar face. When this composite was presented to the infants it was treated as novel. If the infant was processing faces featurally they would recognise the face, however accepting the face as novel suggests they are globally processing the face information, (Cohen & Cashon 2001).

Holistic processing is best shown with the composite effect using chimeric faces. This is where the top half of a face is aligned with the bottom half of another face. As mentioned above, typical adults were impaired when instructed to attend to and identify the top half of the face (Young *et al.* 1987). This is because holistic processing prevents them from only attending to the features in the top half and ignoring the whole gestalt or context of the face. The chimeric face effect has also been observed in 6-year-old children showing holistic processing to be present before the age of 8 years old, (Carey & Diamond, 1994). Also similar to adults, 6-year-old children have been reported to recognise facial features better when they are presented within the context of a whole face during the learning stage compared to being presented in isolation. Therefore like adults, children also show a whole-over-part advantage, (Tanaka, Kay, Grinnell, Stansfield & Szechter, 1998).

As proposed in section 3.2, adults may sometimes rely more on local processing strategy instead of a holistic strategy when recognising emotions on a face (for example, Ellison & Massaro 1997). This may show that holistic perception styles are not always optimal for processing information from the face and adults may switch between holistic and featural styles depending on the face information they require. Despite perceptual style being well documented in child populations for identity recognition, there are comparatively few investigations of processing strategies used by children to determine emotion. Durand, *et al.* (2007) used face inversion and composite face manipulations in children (n = 100) aged 5, 7, 9 or 11 years old and adults (n = 26). They found that all children were affected by inversion and the composite effect showing a reliance on configural processing during emotion recognition. There was also different developmental projectories for each emotion, with happiness and sadness being recognised easiest across all age groups. Children were recognising fear similar to adults by 7 years old, anger was recognised similar to adults at 9 years old and disgust was not accurately processed until 11 years old. This may imply that children do not shift between configural and featural processing for accurate recognition of emotional expression however more research is needed to highlight strategies adopted by children during emotional recognition tasks.

Therefore there still remain inconsistencies in the literature regarding the processing style children adopt during face perception. However research does show the important role face information plays during development. Children must from a young age attend to a face and understand or learn the communicative cues to become successfully socialised within their culture.

3.4 Face Processing in ASD

The socio-communicative impairments observed in ASD have been proposed to stem from abnormal face perception and atypical gaze behavior during early infancy (Hobson, Outson & Lee, 1988). Recent research has focused on these lower-level processing abilities to examine if differences do exist in the way individuals with ASD encode faces and the processing styles they adopt. Neurological studies also show that areas of the brain associated with face perception are impaired in ASD and may influence some of the atypical face processing that is reported across this developmental disorder.

Brain activity during face processing in ASD

Pierce, Muller, Ambrose, Allen and Courchesne (2001) found atypically weak or no activation in the fusiform gyrus in adults with ASD during the presentation of face stimuli. There was also significantly reduced activation in the IOG, STS and amygdala. Neuroimaging studies have further replicated these findings, showing that the FFA, amygdala, IOG and STS are consistently hypoactivated during the presentation of face stimuli in individuals with ASD, (Humphreys, Hasson, Avidan, Minshew & Behrmann 2008; Pelphrey, Morris, McCarthy & LaBar, 2007). All these areas are implicated in Haxby *et al.* (2000) neural face perception model and are highlighted as being significantly important in the encoding of faces, specifically the socio-communicative cues. Face processing systems are reported as showing reduced activation even in younger populations with ASD. Corbett *et al.* (2009) asked children with ASD to perform an emotion matching task and found reduced activation of both the amygdala and the FFA. However it has been implicated that the FFA and amygdala areas function typically in ASD when they are presented with personally familiar faces (Pierce, Haist, Sedaghat & Courchesne, 2004).

It has been proposed that atypical face perception in ASD may be caused by a tendency to process faces similar to objects, as observed by their enhanced local processing bias, (Mottron, Dawson, Soulieres, Hubert & Burack, 2006). Schultz, *et al* (2000) found that during face processing an ASD group showed less activation in the right FFA and more activation in the right inferior temporal gyrus (ITG –object processing area) which may imply that adults with ASD were perceiving faces similar to objects. Hubl, *et al* (2003) also found less activation in the FFA in participants with ASD when attending to faces, but more activation in the medial occipital gyrus (an area also involved in object processing). This activation of object processing systems has also present in young typically developing children (Aylward *et al*. 2005) which may suggest that this lack of specialised processing in the FFA is due to an immature processing system. Individuals with ASD are therefore using the more feature-based strategies that are more typical of non-face object perception and may explain why they tend to use a featural processing strategy when attending to faces.

Communicative facial cues in Autism Spectrum Disorder

Early home video analysis of individuals with ASD show that quality of eye contact (for example appropriate duration) made during early infancy is associated with social functioning levels in later life (Clifford & Dissanayake, 2009). This finding further highlights the importance of attention to faces, specifically the eye area during early development. Home video analysis has also shown that children with ASD engage in significantly less eye contact compared to children of typical development and developmental delay, (Clifford, *et al.,* 2007) showing that they are not drawn to this important area of social significance similar to their typically developing counterparts. Research has also reported that infants with ASD attend to faces for shorter durations compared to typically developing children or children with developmental delay (Swettenham, *et al.,* 1998; Volkmar and Mayes 1990).

Disinterest in the eye region was found to be exaggerated in children with ASD when eye contact is direct (Buitelaar, 1995; Volkmar & Mayes, 1990). This lack of mutual eye gaze has been further supported by eye tracking studies. Jones, Carr & Klin (2008) found that 2 year old children with ASD showed diminished gaze to the eye area of faces when they were shown pictures of an actress playing the role of the caregiver. Fixation on the eye region correlated with level of social impairment in later life with less eye region fixation predicting greater social disability (assessed by using the ADOS). This finding has also been found previously in research that shows time spent looking at the eye region in populations with ASD is significantly correlated with level of functioning, (Speer, Cook, McMahon & Clark, 2007). These findings suggest that a greater impairment in mutual eye gaze during early development may cause a greater impairment in social functioning during adult life. This reported lack of interest in people, faces and eye area is common in populations with ASD.

Swettenham, *et al* (1998) also reported that infants with ASD looked significantly longer at objects than 2 comparison groups. This preference for inanimate objects is identified in other studies (Baron-Cohen, *et al.,* 1996; Trepagnier, Sebrechts, & Peterson, 2002). Hirstein, Iverson, and Ramachandran (2001) examined the autonomic responses in children with ASD after being presented with object and face stimuli. The production of autonomic responses is proposed to be produced by the amygdala and includes responses such as sweating of palms and pupil dilation (Lang, Tuovinen & Valleala, 1964). When stimulated the amygdala produces skin conductance responses-SCRs (Mangina & Beuzeron-Mangina 1996). Hirstein *et al* (2001) measured SCRs of children with ASD (n = 25, age = 7.7 years) when presented with faces and objects, unlike typically developing children and adults (n = 25) who showed increased SCRs to faces, the children with ASD did not show any SCR difference when presented with cup or person showing they reacted similarly for both.

The lack of attending to faces in ASD may also affect the perception of emotional expression (Gross, 2004; Pelphrey, *et al.*, 2002; Teunisse & de Gelder, 2003). Researchers have reported that individuals with ASD have difficulty recognizing emotional expressions in others (Celani *et al.* 1999; Clark *et al.* 2008; Davies, Bishop, Manstead & Tantam, 1994; Hobson, Outson & Lee 1989). Hobson, Ouston and Lee, (1988a, 1988b) tested the ability of children with ASD to identify facial expression of emotion and match this with a person videotaped with gestures, and vocalizations. The results showed that these children had difficulty in correctly recognizing emotional expressions and therefore matching them appropriately.

Some theorists propose that it is recognition of specific emotions that is impaired in ASD. A case study of Asperger syndrome reported relatively impaired recognition of distinct emotions (anger and disgust) in facial expressions (Ellis & Leafhead, 1996). This impairment in specific emotions has also been observed in a study by Wallace, Coleman & Bailey (2008) where adults with ASD were found to be significantly worse at recognising fear, disgust and sadness. Humphreys, Minshew, Leonard & Behrmann (2007) showed high functioning adults with ASD (n = 20, age = 24 years) a set of face stimuli showing the 6 basic emotions, anger, disgust, happiness, fear, sadness and surprise. They found the participants with ASD were impaired at recognising fear compared to the control group (n = 20, age = 28 years). They were also impaired at recognising disgust but to a lesser extent.

This impairment in fear recognition may support the amygdala theory of ASD. Ashwin, Baron-Cohen, Wheelwright, O'Riordan, & Bullmore (2007) found adults with High Functioning ASD showed reduced activation in the amygdala during perception of fearful faces, compared to their controls. Children with ASD have also been reported to look less at faces displaying the fear expression (Sigman, Kasari, Kwon, & Yirmlya, 1992). This shows that impaired recognition of emotions in ASD may be limited to specific emotions. Again this may show an immature emotional recognition system as it was discussed above how distinct emotions have differing developmental trajectories, (Durand *et al.* 2007). Immature emotion recognition systems may be influenced by the lack of attending to faces during infancy in ASD populations, causing social brain systems such as the amygdala not to become fine tuned for dealing with emotion expression information. Not attending to faces during development would also hinder learning of specific facial configurations for emotions which not only impairs emotional recognition but as detailed earlier in section 3.3 successful socialisation within cultures.

Alternatively it may be that these emotions are ones which involve interpreting cues from the eyes. Calder *et al.* (2000) found that recognition of specific emotions were more reliant on understanding emotional expression from the eyes. These emotions included fear, anger and sadness. As discussed earlier, individuals with ASD are particularly impaired during fear recognition (Humphreys *et al*. 2007). This may imply that impaired emotion recognition is influenced by lack of attention to the eye area as children with ASD develop. By not attending to the eyes children with ASD do not learn the different eye configurations for specific emotions. One such example is provided by Gross (2004) who found that children with ASD attended more to lower features of the face when making emotional judgments and were less reliant on the eye area. This reliance on the lower features of faces such as the mouth area has been found when populations with ASD are making socio-emotional judgments of a face (Borman-Kischkel, Vilsmeier & Baude, 1995; Celani *et al.* 1999).

Further support which shows impaired comprehension of socio-communicative cues from the eye area in ASD comes from a study conducted by Baron-Cohen, Wheelwright, and Jolliffe (1997). They found that higher-order social/mental states, which were signalled primarily by the eyes (for example, states such as "flirtatiousness"), were not recognized normally by adults with high-functioning ASD. However, the adults with ASD were readily able to recognize the facial expressions of other basic emotions such as happiness.

It is clear that individuals with ASD are not born with the ‘innate’ social interest to attend to faces, specifically eye areas. This may explain some of the wider implications of socio-communicative impairments observed across this spectrum. Therefore populations with ASD do not attend to relevant areas of faces and have also been shown to adopt atypical processing strategies when encoding face structures. How these strategies differ from typical populations will be detailed in the next section.

Featural vs. holistic processing style in Autism Spectrum Disorder

Early studies examining face perception skills in ASD showed that this population adopted a more featural processing strategy. For example, when presented with photographs of faces that could be categorized on the basis of type of hat (feature-based) or facial expression (configuration-based), typically developing children preferred sorting by expression unlike children with ASD who preferred sorting by type of hat (Weeks & Hobson, 1987). This local processing bias has been found in further studies. For example, Celani *et al.* (1999) found that children with ASD (n = 10, age 12.7 years) were impaired in a task of face matching; when feature based strategies were made more difficult (the face stimuli were presented at separate times rather than concurrently). The authors claimed that this showed impairment in holistic processing of faces in ASD. Individuals with ASD are also proposed to be less sensitive to the face inversion effect because they use more feature-based strategies when processing faces, (for example, Hobson *et al.* 1988a; Langdell, 1978). Tantam, Monaghan, Nicholson, & Stirling (1989) found that individuals with ASD could recognize upside down faces just as well as upright faces showing that they were not susceptible to impaired configural processing.

It seems that during the processing of faces participants with ASD do not use information from the context of the face. Teunisse and de Gelder (2003) found that participants with ASD were able to recognise face halves in aligned or mis-aligned composite faces showing less gestalt processing and more of a piece-meal strategy.

Joseph and Tanaka (2003) found that control children were better at recognising a facial feature when it had been presented during the encoding stage within the context of a face. However children with ASD only showed this whole face advantage when identifying the mouth area and showed severe impairment in recognising the eyes. This is also consistent with eye tracking results which show that adults with ASD fixate more on the mouth area (Klin *et al*. 2002) and significantly less on the eye area (Riby and Hancock 2008; 2009a). This evidence seems to imply that individuals with ASD rely on a featural processing bias when attending to faces however research shows that global processing is not completely lacking within the ASD population.

Nishimura, Rutherford and Maurer (2008) found evidence of holistic processing of faces in high functioning adults with ASD. The adults showed normal holistic processing (shown by the composite face effect) normal disruption of face processing caused by inverted faces suggesting less featural processing of faces was taking place. Children with ASD have also been shown in some studies to be susceptible to the Thatcher illusion in face processing suggesting that they may still attend to global information. (Riby, Doherty-Sneddon & Bruce 2009; Rouse, Donnelly, Hadwin & Brown, 2004). These findings have been proposed to support the enhanced perceptual functioning model which states that perception in ASD is influenced by locally orientated processes and are not impaired entirely in global processing strategies (Mottron, Dawson, Soulieres, Hubert & Burack 2006).

Therefore, these inconsistent results may imply that rather than impaired holistic face processing, featural face processing is simply enhanced in ASD. This may explain why similar studies can yield such distinct results. For example, Falck-Ytter (2008) found that children with ASD looked at the same features in both upright and inverted faces showing that the children with ASD were using featural processing strategies.

However van der Geest, Kemner, Camfferman, Verbaten and van Engeland (2002a) found that when faces were inverted children with ASD looked less at the face and eye areas (showing they were sensitive to the inversion effect) and therefore do have global processing skills, however the authors propose that this gestalt processing ability may not be as advanced as their typically developed counterparts. Therefore individuals with ASD may have global processing abilities but are more inclined to use a featural processing strategy when attending to faces.

It has been shown that child and adult populations with ASD apply a featural processing bias during identification of a face which may imply that they can attend to emotional expressions analytically similar to typical adults (for example, Calder *et al.* 2000). Featural processing of emotional expressions has been reported to cause higher accuracy during emotion recognition tasks (Martin *et al.* 2011). Despite individuals with ASD showing featural processing bias (for example, Falck-Ytter, 2008) they are still impaired in emotion recognition tasks (for example, Deruelle *et al.* 2004; Gross, 2005). This impaired ability to recognise emotional expression in the face may not be caused by their reliance on featural processing but by a lack of attention to the eye area as they develop (for example, Clifford & Dissanayake, 2009). This impaired ability to see the social significance of the eye area causes the children with ASD not to learn important eye configurations which are used during emotional displays. This lack of learning may cause the impaired comprehension of emotions often reported in research in individuals with ASD (Deruelle *et al*. 2004; Gross, 2004; 2005).

A study which may support the role of reduced attention to the eye area in emotion recognition in ASD populations was conducted by Pelphrey, Sasson, Reznick, Paul, Goldman, & Piven (2002) who presented high-functioning adults with ASD (n = 5) with faces showing the six basic emotions (anger, disgust, happy, sad, fear and surprise). During the emotion naming task, the adults with ASD were found to be impaired in fear recognition and a trend towards impaired anger recognition. Fear is an emotion which has been proposed to be mainly indicated by the eye area (Calder *et al.* 2000; Ellison & Massaro, 1997) as well as anger (Calder *et al.* 2000). Eye-tracking applications were used to record the eye gaze behaviour of the ASD group. The results showed that during emotion recognition, the ASD group looked significantly less at the eye area compared to the control group. This shows how lack of attention to the eye area may be linked to the impaired recognition of specific emotions in ASD.

Therefore the evidence shows that the processing style of individuals with ASD is not so clear cut. Inconsistent findings may imply a local *bias* in their processing style rather than an impaired global processing strategy. Despite a local processing bias being reported as increasing emotion recognition accuracy, children and adults with ASD still show impaired emotion comprehension skills. This impairment of emotion recognition may be caused by lack of attention to the eye area during development in populations with ASD. Lack of attention to the eye area may mean that areas of the brain (such as the amygdala) do not become fine-tuned to deal with social information from the eyes. The deficit in understanding communicative cues from the eyes may have wider implications on the socio-communicative impairments associated with ASD.

3.5 Conclusions

By examining typical development of face processing abilities and how humans become face 'experts' by adulthood this chapter has emphasised the importance of attending to facial cues. However research shows that populations with ASD are impaired in many aspects of face perception. They fail to make appropriate eye contact (for example, Volkmar & Mayes, 1990) and show impaired emotion recognition (for example, Clark *et al.* 2008). There is even neuroimaging evidence which shows neural networks do not process facial cues typically in populations with ASD. Together the behavioural and neuroimaging results show that participants with ASD do not attend to face cues appropriately which means relevant information available for processing is reduced. As highlighted above faces are important in many aspects of communication. If these facial cues are missed or not understood then there will be wider implications on the socio-communicative abilities of individuals with ASD. This has already been observed in studies which show eye gaze behaviour as being indicative of social competence or functioning (Jones *et al.* 2008; Riby & Hancock, 2009b). This thesis aims to investigate the wider implications of this atypical face perception and gaze behaviour specifically how they attend to faces for communicative cues. Atypical attention to important parts of a face could have implications on how faces are attended to during interactions and communicative systems used by children with ASD. If the child with ASD is not attending to important information then they will fail to utilise the system and use it efficiently. The following experimental chapters will examine how children with ASD attend to faces which they encounter during social interactions and their learning environment.

Chapter 4 –Eye Tracking Methodology

4.1 Introduction

This chapter provides the justification of using the methodology employed within this thesis specifically eye-tracking. It will explain how eye-tracking can reveal visual strategies when individuals examine social scenes. These strategies can highlight how attention is allocated on a scene or face and therefore highlights what information is available for processing. Eye-tracking can allow us to examine the visual allocation of attention in populations with ASD who have been shown to have atypical gaze behaviour. This technique can be informative about the visual scanning strategies adopted by this population and how they attend to their social environment. Eye-tracking techniques have been used in this thesis as a vehicle to highlight atypical attention allocation to faces across the Autism Spectrum. Examining the gaze behaviour of children with ASD and how they attend to communicative cues presented on faces may allow us to gain a deeper understanding of their socio-communicative impairments. Before considering key eye tracking literature it is helpful first to consider central concepts associated with how humans select their attentional focus.

4.2 General Selection of Attention

The brain has limited sensory and information-processing systems which are constantly bombarded with information. Therefore it is crucial to select and focus on particular aspects of the environment while ignoring others (Broadbent, 1958). We use eye movements to attend to the social environment and select the information we wish to process. These overt shifts of attention and eye fixations are used to orient to specific information which helps us understand our external world.

As proposed in the previous chapter faces are important in human interactions and have been proposed to be so significant that specific brain areas are involved in dealing with face information (Kanwisher, McDermot & Chun, 1997). Behavioural evidence has also supported this, showing that we selectively attend to faces compared to objects when presented simultaneously (Borrmann, Boutet & Chaudhuri, 2003), or presented together in a complex scene (Ro, Russell & Lavie, 2001). It has been reported that faces can be particularly distracting during a task even when the faces are irrelevant and participants are experiencing high perceptual load (Lavie, Ro & Russell, 2003). This shows how it is difficult to ignore faces due to their potential to show new information or convey social cues. This quick orientation to socio-communicative information is present from an early age and important in social and emotional development.

Selective attention in typical development

Intrinsic interest in social stimuli highlights its' important role in a child's socio-emotional and cognitive development and has been observed in many studies conducted on young populations. For example, it was found that 8-10 month old typical children oriented to their name being called 75% of the time during a retrospective study of home videotapes, showing a high response rate when social stimuli was presented (Werner, Dawson, Osterling & Dinno, 2000). High visual attention on social information has been found also, with infants as young as one hour showing a bias to orient toward faces (Farroni *et al.* 2006; Johnson *et al.* 1991; Macchi *et al.* 2004; Maurer & Salapatek, 1976).

Faces therefore do attract visual attention quickly and are able to maintain it for long periods of time; however it is the eye area of a face that achieves most of this selective attention. Farroni *et al.* (2002) found that, from birth, human infants prefer to look at faces that engage them in mutual gaze compared to faces that are averted and that, from an early age, healthy babies show enhanced neural processing of direct gaze. Newborns also show preferences to look at faces with eyes opened again showing from an early age they orient quickly to the eye area of a face (Farroni *et al.* 2002; Farroni *et al.* 2006).

This selective attention allocation to social stimuli such as faces continues throughout development. For example, Kikuchi, Senju, Tojo, Osanai, and Hasegawa (2009) found that typically developed children (n = 22) when presented with pictures of natural scenes depicting both people and objects were able to quickly detect changes in the face of the people or the objects quicker compared to the background. Changes to the heads were detected faster in comparison to objects, showing that the people in the image attracted most attention in children.

Not only does the face draw the attention of children but the communicative cues the face presents can also cause the child to adapt and modify their own behaviours. When this takes place more social responses are observed in infants to aid continued interaction with caregivers. However the faces natural ability to draw attention seems to be impaired in populations with ASD which may shed light on their impaired social skills and communicative ability.

Selective attention in ASD

Maestro, *et al* (2005) found that during the first 6 months of life (looking at home videos) typically developed children showed more social visual attention (i.e. orienting toward people, smiling at people) compared to children later diagnosed with ASD. The 2 groups were not significantly different when comparing non-social attention (i.e.

orienting toward objects or smiling at objects). This atypical social attention was continued in infants with ASD even when familiar individuals' faces were presented showing that familiarity did not reduce atypical attention allocation (Maestro *et al.* 2005).

Home video analyses of children's first year lends further support to these studies of early selective attention during development in children with ASD. These studies show that infants later diagnosed with ASD look at others less frequently than infants later diagnosed with general learning difficulties (Osterling, Dawson, & Munson, 2002) or typically developing infants (Osterling & Dawson, 1994; Osterling *et al.* 2002).

Not only have individuals with ASD been reported to show lack of visual attention to people specifically faces, they have been reported to show a higher interest in objects. Swettenham, et al (1998) found using video analysis that infants later diagnosed with ASD spent less time orienting and directing attention at a persons' face. Instead they looked for longer time durations at objects (i.e. a teddy bear), compared to children with developmental delays or typically developing children. These results indicate an abnormality in selectively attending to social information in ASD, present from as young as 20 months.

<u>4.3 Eye-tracking</u>

Therefore our gaze behaviour and selective attention can reveal what we are feeling, thinking or perceiving. Eye-tracking techniques can therefore be used to take advantage of this behaviour and provide us with insight of momentary cognitive and social processes. Due to the eye-tracking technology being non-invasive it is now favoured in assessing automatic processing behaviours in children specifically atypical populations such as ASD. Despite being unobtrusive it still supplies us with accurate measurements of where an individual is looking on an image and for how long.

Eye-tracker technology measures many types of eye movements including saccades, smooth pursuits and eye-movements during scene/face perception. Saccades are ballistic (pre-determined) eye movements which can be both voluntary and reflexive. These rapid eye movements work to position the central fovea (part of the retina specialized for detailed visual processing) to a new location within the environment, and typically coincides with an overt shift of attention allocation (Duchowski, 2007). Many measures can be extracted from saccades including peak velocity, amplitude and durations (Karatekin, 2007). Smooth pursuit eye movements are used to track small objects that move slowly and smoothly (Fukushima, 2003). These non-ballistic (not pre-determined) movements match gaze velocity to target velocity to keep the object within foveal vision at all times. Despite being different visual systems, smooth pursuit and saccadic eye movements share similar neural substrates. They have also been reported to work together so when the pursuit system fails to foveate the object continuously, saccades are used to catch up or anticipate the object's next location (Karatekin, 2007). These are just a few examples to illustrate the range of eye gaze movements and how they are used to attend to the environment. This thesis is interested specifically in eye movements during face and scene perception to highlight how selective attention is allocated in atypical development.

Recording eye movements during face and scene perception can provide us with evidence of what information may be attended to and available for processing, during more naturalistic contexts. It has been proposed that we make 3-4 saccades a second during scene perception and pause (fixate) between them to take in information to the fovea (Karatekin, 2007). Fixation duration shows us where people are selectively attending and how long this attention is maintained and will be examined in the present thesis. The main measures used in studies of face and social scene perception include, fixation, location and sequencing of fixations (Karatekin, 2007). This thesis will be reporting eye-tracking measures including, time to first fixation, number of fixations and lengths of fixations on specific locations selected within the images or social scenes (i.e. faces, eyes, mouth). This is similar to eye-tracking measures used previously with children and adults with ASD during face and social scene perception (Klin *et al.* 2002; Pelphrey *et al*. 2002; Speer *et al.* 2007; Riby & Hancock, 2008; 2009b) so results presented here may be compared to previous literature.

4.4 Eye-tracking to scenes and people

Gliga, Elsabbagh, Andravizou, and Johnson, (2009) presented 6 month old typically developing infants with a complex visual scene showing both faces and objects. Using eye-tracker methodology they found that despite the presence of objects the infants directed their first saccade to the face. Showing that allocation of selective attention to the face is present in early infancy. This quick orientation to social stimulus such as the face continues throughout development into childhood, as it was shown in one study that typically developing children were able to *spontaneously* fixate on hidden faces within a scene (Riby & Hancock, 2009a).

Riby and Hancock (2009a) wanted to investigate if faces would grab the attention of children with moderate to severe ASD (n = 24) as quickly as typically developed children. They found children with ASD took significantly longer to locate hidden faces within scenes compared to their typically developing counterparts. This shows that faces fail to stand out and attract attention from individuals with ASD as much as typically developed children.

Not only do faces fail to initially capture attention in ASD but they also fail to maintain this attention (for example Nakano, *et al.,* 2010). Klin *et al.* (2002) recorded the eye gaze behaviour of adolescents with high-functioning ASD (n = 15) whilst viewing short dynamic video extracts showing emotionally intense interactions from Edward Albee's '*Who's Afraid of Virginia Woolf?*' When watching this black-and-white movie participants with ASD exhibited different visual fixations to those of a typically developing comparison group. Rather than fixating on socially salient information (for example, actors' faces and body movements), participants with ASD tended to look at irrelevant inanimate objects within the scene. The ASD group were found to fixate for a longer proportion of time on the mouth, body and object regions significantly more compared to the control group. The ASD group also fixated on the highly relevant eye area of the characters significantly less compared to the typical matches. This study highlighted that not only were faces atypically attended to by participants with ASD but also socially salient internal features specifically the eyes.

Lack of attention to the eyes has been proposed to contribute to some of the socio-cognitive impairments observed in ASD and has been reported in numerous eye tracking studies (Boraston , Corden, Miles, Skuse & Blakemore, 2008; Dalton *et al.* 2005; Pelphrey *et al.* 2002; Riby & Hancock, 2008; Speer *et al.* 2007). This impaired attention and lack of typical scanning strategies observed in ASD may provide insight into the nature of the cognitive processes and socio-communicative impairments observed in ASD. However before important implications of this research can be drawn inconsistencies in the literature has to be addressed.

It has been proposed that atypical eye gaze behaviour in ASD is highly dependent on stimuli type and design. For example some theorists have proposed that atypical attention to social scenes can be improved in ASD, when stimulus is static, and has reduced ecological validity (Speer *et al.* 2007; van der Geest, Kemner, Camfferman, Verbaten & van Engeland 2002b). Differences in stimuli type are among some of the inconsistencies in the eye-tracking literature relevant to this thesis. The differences in stimuli type, and level of functioning within participant populations had to be considered when designing the methods involved in experimental Chapters 5, 6 and 7.

Recently, as mentioned above, literature has shown an increase in the use of eye-tracking methodology to investigate the visual strategies in populations with ASD when attending to scenes (Klin *et al.* 2002; Speer *et al*. 2007; Riby & Hancock, 2008; 2009b). This work is important in understanding the underlying mechanisms in attention allocation and how this may extend understanding of the autistic social phenotype. However it is difficult to clearly compare the results or conclusions from the studies due to the variation of population with ASD; stimuli; and ability tests conducted. These will now be addressed.

Level of functioning and attention to social stimuli

Eye-tracking studies on populations with ASD have shown a great variance in the participants' level of functioning. Due to the heterogeneity present within the autistic phenotype, each individual with ASD will not function in the same way, showing a huge range of cognitive and communicative capabilities (for a review see Chapter 2). This variance may extend to some of the lower-level processing such as visual attention and eye gaze behaviour.

Klin *et al.* (2002) found that high functioning adolescents and adults with ASD (n = 15) looked less at the eye area of dynamic social scenes and more at the mouth (this was proposed to be caused by their high verbal IQ). Higher fixation time on the mouth region was associated with high levels of social ability (calculated using the VABS-E –

Vineland Adaption Behaviour Scales) and lower levels of autistic social impairment (assessed by the ADOS – Autism Diagnostic Observation Schedule). High fixation time on objects was associated with lower social ability scores and high autistic social impairment.

Norbury, *et al* (2009) conducted research on a moderate to high functioning group of adolescents and found similar associations between mouth fixation time and social ability as Klin *et al*. (2002). The ASD group in Norbury *et al.* (2009) experiment was further categorised as being with impaired (n = 14) or typical language ability (n = 14). They were shown video clips displaying typical interactions and events. The authors reported associations between fixation duration and communicative competence (assessed by VABS-II – Vineland Adaptive Behaviour Scale II) across both language sub-groups. Increased fixation time to the eyes were associated with lower communicative scores, increased fixation to the mouth was associated with higher communicative ability. These results would imply that eye gaze behaviours and visual attention to scenes may be indicative of autistic severity.

Speer *et al.* (2007) found that in high functioning children and adolescents with ASD (n = 12), eye region fixation and body region could predict social competence as assessed by the SRS (Social Responsiveness Scale: Constantino & Gruber, 2005). The less fixation time spent on the eye region predicted less social responsiveness.

Riby and Hancock (2009a) conducted a study on a group of children (n = 20) with moderate to severe ASD, there was a relationship between the childrens' performance on this task and their level of functioning on the spectrum. The higher the score on the CARS (Childhood Autism Rating Scale: Schopler, Reichler & Renner, 1988), the less time participants spent fixating on the embedded face. This shows that children with a higher level of autistic impairment showed fewer fixations on faces. Face fixation durations were found to be indicative of functioning on the autism spectrum (as assessed by the CARS) in other studies (Riby & Hancock, 2008; Riby & Hancock, 2009b).

Within this body of research none of the studies discussed above included a high variation of ASD sub-types. The studies either concentrated on moderate to severe ASD or High functioning ASD. As explained before if gaze behaviour is indicative of socio-cognitive abilities then it is important to include the range of sub-types of ASD in one study. Another striking inconsistency is the actual ability tests used to ascertain the participants social and cognitive skills. These tests are then used to predict visual attention and eye gaze behaviour. It is therefore difficult to compare populations with ASD across studies (i.e. in terms of impairment and ability) because these have been assessed using different scales.

This thesis therefore aimed to enrol participants who display a variation of autistic severity and social ability. This was believed to best represent the heterogeneity of the autism spectrum. The visual attention and eye gaze behaviour of participants with classic autism was examined alongside the social attention of participants diagnosed with High Functioning Autism and Asperger's Syndrome. This is particularly relevant for this thesis as it intends to highlight any atypicality in visual attention to important information in children's classroom aids and images. Due to similar classroom aids being implemented in the classrooms across the autism spectrum regardless of individual diagnosis, any variations in eye gaze behaviour or scanning strategies can have implications.

Due to the sample being *children* with ASD the CARS (Childhood Autism Rating Scale: Schopler, Reichler, & Rocher-Renner, 1988) was used to ascertain participants' abilities and severity. These ability scores were then used to examine any relationships with eye gaze behaviour and visual attention during the course of 2 experiments conducted on children. This will also allow for basic comparisons with other literature on child participants as there has been extensive research using this scale on this type of sample (Riby & Hancock 2008; 2009a; 2009b; Riby & Doherty, 2009). There were further inconsistencies within the literature including stimulus type which had to be considered before designing the methodology.

Impact of ecological validity and complexity

The main body of research on participants with ASD reports similar atypical visual attention to the face and specifically eye area within a scene (Klin *et al.* 2002; Pelphrey *et al.* 2002; Speer *et al*. 2007; Riby & Hancock 2008; 2009b). However there are some theorists who proposed that stimulus type may be manipulated to reduce this atypical eye gaze behaviour (For reviews see Ames & Fletcher-Watson, 2010; Boraston & Blakemore, 2007). This can have huge implications for learning materials and communicative aids. If certain image and stimuli types reduce atypical gaze behaviour then improvements in learning and home environments can be made so all information displayed can be communicated to the individuals with ASD appropriately. Detailed below are some examples of the different stimuli presented to populations with ASD. These examples have been selected as being most relevant to this thesis and the stimuli that will be presented in the following chapters.

As explained above Klin *et al.* (2002) examined how high functioning adolescents and adults with ASD (n = 15) attended to realistic dynamic images displaying intense social situations. Participants with ASD looked significantly less at the eye region and significantly more at the mouth, body and object regions of the dynamic scenes. Avoidance of the eye area was also observed in stimuli of static images showing a single person displaying an emotion (Pelphrey *et al*. 2002), and typical static social scenes for example, a bride and groom on their wedding day (Riby & Hancock, 2008).

Van der Geest *et al.* (2002b) conducted a study with 16 high functioning children on the autistic spectrum. They were presented with cartoon-like stimuli which was pictures with little human like figures placed in scenes which including a farm or house. The images were very unrealistic and resemble child drawings. He found that the children with ASD spent the same amount of time as the typical groups viewing the images and spent the same amount of time and number of fixations on the human-like figures. Time to first fixation and fixation duration of first fixation was also similar in both groups.

Speer *et al.* 2007 presented images and video clips to high functioning children (n = 12) and adolescents with ASD. These were either moving images showing one person or 2 or more people engaged in an interaction (images and video clips were taken from the same film as Klin *et al.* 2002) or static images showing one person or again two or more persons engaged in an interaction that weren't already included in the dynamic condition. The only differences to be found in the study were during the social dynamic condition where it was found the individuals with ASD spent significantly less time fixating on the eye area of the participants and more time looking at the body, compared to their controlled matches.

These results would imply that atypical eye gaze behaviour may be dependent on the stimuli type presented. However a recent study by Riby & Hancock (2009b) was conducted to resolve the discrepancy between the results presented by Klin *et al*. (2002) and van der Geest *et al.* (2002b). In the present study Riby and Hancock compared less realistic cartoon images (both static and dynamic) with realistic human images (both dynamic and static). For the cartoon images they used stimuli from the cartoon animation '*The Adventures of TinTin*'©. They found that for all types of stimuli children with moderate to severe ASD (n = 20) spent a significantly smaller proportion of their time fixating on the face region than both the control groups (visuo-spatial ability matches and chronological age matches). Participants with ASD spent a smaller proportion of time than both comparison groups in fixating on the eye region when viewing cartoon pictures and human movies. Therefore the atypical visual attention persisted across all stimulus types regardless of the ecological validity or movement of the stimuli.

One hypothesis to explain the inconsistent results reported across the autism spectrum literature is that attention to communicative cues in individuals with ASD is only impaired when the stimulus is sufficiently realistic or complex (Ames & Fletcher-Watson, 2010). This thesis sets to extend on the latest study carried out by Riby and Hancock (2009b) within a more applied context by examining selective attention to cartoon-like pictures used as communicative aids by populations with ASD. If the atypical eye gaze behaviour persists despite a reduction of ecological validity then this may affect where the children with ASD are allocating attention on these important images. Important information may be missed if they are unable to allocate attention to salient parts of the image. Pictures are particularly important as educational groups are now creating communication strategies for individuals with ASD, using pictures as an actual alternative communicative system.

4.5 Conclusions

This thesis examines if atypical eye gaze behaviour and impaired visual attention allocation affects the successful scanning of images used as communicative aids with populations on the autism spectrum. As proposed above eye-tracking has been established within populations with ASD to provide accurate accounts of eye gaze behaviour. They have already been successful in highlighting atypical attention to salient information (Klin *et al.* 2002; Pelphrey *et al.* 2002; Riby & Hancock 2008; 2009). This thesis will now examine children with ASD's selective attention allocation to communicative cues using eye tracking methodology.

The experiments presented here examine how children with ASD fixate on images showing reduced ecological validity and varying social complexity. As proposed by Ames and Fletcher-Watson, (2010) while information is presented in the real world with varying complexity and in multiple sensory modalities, it is only by separating these components that we can distinguish effects of perceptual processing styles from social attention atypicalities in ASD.

In Chapter 5, children's attention to materials used within the classroom environment will be examined, PECS and Boardmaker. This will include cartoon-like images similar to the images used in Riby and Hancock's (2009b) study. Due to their findings that atypical gaze behaviour in children with ASD persisted regardless of ecological validity, it is predicted that children with ASD will show reduced fixation of the eye and face areas presented within their picture communication systems, compared to their typical matches. These picture systems also present different levels of ecological validity. The Boardmaker images are less realistic and therefore present a greater level of reduced ecological validity compared to the more realistic PECS images. It was predicted that the children with ASD would fixate longer on the faces and eye areas of the less realistic Boardmaker images compared to the PECS images. Chapter 6 will present images showing an isolated familiar, unfamiliar person and the child's own image to children across the autism spectrum. It is proposed based on a previous study investigating the influence of familiarity on gaze behaviour conducted by Sterling, Dawson, Webb, Murias, Munson, Panagiotides *et al.* (2008) that children with ASD will still attend to the eye area less compared to their typically developed counterparts but will show no difference in fixation to the mouth area. Previous research has also reported reduced attention to unfamiliar faces by populations with ASD (Klin *et al* 2002; Riby & Hancock 2008). This may be caused by unfamiliar faces being too arousing to individuals with ASD (Hutt & Ounstead 1966) unlike familiar and self faces which the children encounter daily. Therefore it is predicted that children with ASD will fixate less on unfamiliar faces compared to self and familiar faces. Finally, Chapter 7 will examine selective attention allocation to simple/complex images in children with ASD. These images will show varying numbers of people and objects. It is predicted based on previous literature (Klin *et al*. 2002) that the children will selectively allocate more attention to the non-socially salient areas such as the objects compared to the people. It is also proposed that similar to Speer *et al.* (2007) findings that children with ASD will show reduced atypical attention during stimuli of less complexity (such as 1 person 1 object and 2 person 1 object). It is predicted that the children with ASD will fixate less on the face AOIs during the highly complex scenes (4 person 4 object) as reduced attention to the face area during the presentation of static complex scenes has been reported in previous literature (Riby & Hancock, 2008).

There will be a great variation of functioning across the Autism Spectrum presented in the participant sample within this thesis, so that a better representation of the actual population of ASD can be represented in these eye-tracking studies. It is proposed that similar to previous research (Riby & Hancock, 2009a; 2009b; Speer *et al.* 2007) regardless of stimulus type, individuals with severe autistic impairment will show significantly reduced attention to eye areas of a face compared to higher functioning children with ASD. This research wishes to extend existing eye-tracking literature by examining atypical selective attention allocation in children with ASD when attending to communicative cues presented in social scenes and faces. It is proposed that by examining the gaze behaviour in ASD that a greater understanding of perceptual processing and socio-communicative attention across the Autistic Spectrum will be gained.

Chapter 5 - An Eye-tracking Study of Attention to Communication Aids

This chapter will examine how children with ASD attend to Picture Communication Systems. These systems are used extensively by schools and residential houses to communicate information to children and adults with ASD and to allow people with ASD to communicate with others. The pictures show cartoon-like faces, and objects. Some of these images are used to inform the individuals with ASD about their daily routine or timetable such as Boardmaker (BM) Picture Communication Symbols (PCS). Other picture symbols are used as an alternative communicative strategy such as Picture Exchange Communication Systems (PECS). These PECS images are exchanged by individuals with ASD for desired items (such as snacks, favourite toys) or activities (such as softplay).

For both these picture systems to work effectively and communicate information to the individual or be used as a communicative tool, the child or adult with ASD must attend to appropriate areas on the image. As reported in Chapter 3 children and adolescents across the autistic spectrum do not attend to faces typically (Klin *et al.* 2002; Pelphrey *et al.* 2002; Riby & Hancock, 2008; 2009a; Speer *et al.* 2007). The literature shows that for some populations with ASD effective use of these picture systems can be achieved and are reported to improve communicative abilities (for example, Charlop-Christy, Carpenter, Le, LeBlanc & Kellet, 2002). However some studies such as Tincani (2004) show children with ASD are not all able to comprehend and use picture systems efficiently. These differences may be caused by how the children with ASD are attending to the images. Those who are able to allocate attention to the faces or objects for a sufficient amount of time may understand what the images represent and use the system effectively. Poor communicative ability and general lack of understanding may also cause the impaired use of picture communication systems. This chapter will therefore examine if level of functioning impacts on how these images are attended to and potentially understood. By examining how attention is allocated to these images, ways may be found to improve the system to become more accessible to individuals across the autism spectrum with various levels of functioning.

The picture systems (PECS and BM) present cartoon-like images of objects and faces. However the BM images are less realistic and therefore show less ecological validity compared to the more realistic PECS images. Images of reduced ecological validity may affect how children with ASD allocate attention. A previous study by van der Geest *et al.* (2002b) found that presenting images of child-like drawings of people and objects to children with ASD reduced atypical eye gaze behaviour. The reduced ecological validity presented within the BM images may therefore reduce atypical attention allocation to faces by children with ASD compared to the more realistic PECS images. Therefore it is predicted that children with ASD will attend to the BM faces for longer compared to the PECS faces.

Using eye-tracking methodology we will examine how children with ASD attend to these picture symbols. We are interested in 2 key issues: i) whether reduction of ecological validity affects eye gaze behaviour in children with ASD and ii) if level of functioning impacts on how these picture symbols are fixated on. If level of functioning affects eye gaze behaviour as reported in previous literature (Klin *et al.* 2002; Riby & Hancock, 2009a), then this may influence attention to important areas of the images and which children across the autism spectrum may benefit best from this alternative communication type.

5.1 Introduction

Recent studies indicate that the prevalence of ASD may be as high as 1% (Baird *et al.* 2006). The economic cost of ASD is substantial, with the average UK cost of special school provision (including the provision of communication aids) being estimated as around £11,000 per child per annum (Jarbink & Knapp, 2001). Many children require interventions, particularly for communication difficulties, since a high proportion of individuals with ASD remain without functional speech (Charlop & Haymes, 1994; Volkmar, Lord, Bailey, Schultz, & Klin, 2004). Many problem behaviours are proposed to be caused due to impaired communicative abilities. Research has shown direct links between improved communicative ability and less disruptive behaviours (Carr & Durand, 1985; Durand & Carr, 1991; Hagopian, Fisher, Sullivan, Acquisto, & LeBlanc, 1998).

Communicative Aids

Interventions have been developed to focus on alternative communication strategies for children who do not develop speech known as Augmentative and Alternative Communication (AAC) systems. AAC systems are used by individuals with disabilities to replace or aid communications skills (Ganz & Simpson, 2004). There are two types of AAC techniques: aided and unaided. Aided communication involves devices that are external to the individuals that use them, for example Picture communication symbols (PCS) and voice output communication aids (VOCAs). Unaided communication includes manual signs and gestures and does not require any equipment (Mirenda, 2003).

Sign language is just one example of unaided communication which is taught to children with ASD. Sign language has been reported to be successfully learned by children with ASD and that the communicative system promotes speech acquisition. Layton (1988) examined the affect of sign language on communicative behaviours such as word utterances in children with moderate to severe ASD (n = 60). He found that all children were able to successfully use sign language and they produced more word utterances after training. This improvement in vocalizations was emphasized more in the children who had shown high vocal imitation abilities before treatment. Studies have shown that non-verbal children with ASD are able to learn and use around 10- 20 signs (for example, Barrera, Lobato-Barrera & Sulzer-Azaroff 1980; Benaroya, Wesley, Ogilvie, Klein & Clarke 1979). This limited amount of expressive signs would limit children's vocabulary and communicative ability. In comparison children who are typically developing will begin to show expressive vocabulary sizes of approximately 50-100 words by 18 – 20 months (Patterson 2002). Bates and Goodman (1997) propose that large expressive vocabulary sizes are needed to reach a "critical" mass which will influence the onset of word combinations and the beginning of children's functional speech and communicative capabilities. This emphasizes the importance of a large repertoire of words or expressive symbols needed to help develop functional communication. Therefore 20 signs in comparison do not allow for the children to learn an efficient language system and leaves them limited in their communicative capabilities. This would suggest that sign language is not a successful system which could aid communication in children across the autism spectrum. Motor abilities in children with ASD also affect the successful learning of sign language. This is problematic for children with ASD as a small proportion of the population show impaired motor co-ordination (for example, Wing, 1996). A study by Seal and Bonvillian (1997) found in a group of children and adolescents with ASD (n = 14, mean age = 13years 8 months) that fine motor age was significantly correlated with sign vocabulary size and sign formation accuracy. The influence motor ability and co-ordination has on the successful acquisition of sign language may highlight why after intensive training with signs a significant number of children with ASD are reported to only acquire the successful use of a few signs (Layton & Watson, 1995).

Another type of alternative communication system used by individuals with ASD is Voice output communication Aids (VOCAs). These are portable electronic devices which produce digitalized speech output. An individual uses a hand or finger to select a symbol from the VOCAs display which then activates a message (Mirenda, 2003). Literature is more limited on the success of VOCAs with children with ASD compared to sign language and Picture systems. Brady (2000) conducted a case study on a 5 year old girl with ASD who was shown how to conduct requesting behaviours with a VOCA. The girl was reported to show an increase in speech comprehension following successful use of the VOCA for requesting. Schepis, Reid, Behrmann and Sutton (1998) taught children with ASD (n = 4) aged between 3 and 5 years who had little to no functional speech, to interact with classroom staff using VOCAs. All four children were shown to respond to questions, make requests and make social comments (for example “thank you”) the children’s vocabulary sizes varied between 4-8 messages such as “I’d like a drink please,” “yes”, “no” and “I need to use the bathroom.”. The authors report that the majority of VOCA interactions observed in the children were spontaneous. Despite the limited literature documenting the success of VOCA, it is still not widely applied across the autism spectrum. The main issues acknowledged with the VOCA systems involve the cost (which can be considerably high) and vocabulary is also limited to what the device can store to memory (Iacono, & Duncum, 1995). There may also be issues regarding the communicative impairments observed in children with ASD and the use of VOCAs as they rely on the children attending to and understanding the voice output commands that the device creates. This can be problematic for children with ASD due to their auditory deficits which make it difficult for them to attend to speech and understand the meanings of auditory output (Schopler, Mesibov, & Hearsey, 1995). Therefore systems which emphasize visual stimuli, which do not require complex skills for comprehension or efficient use, are recommended for populations with ASD (Hodgon, 1995).

According to the NAS school database, over half of all ASD specific schools and units in the UK claim to use picture communication systems to enhance pupils' communication skills (National Autistic Society, 2005), showing that the picture systems are accessed and utilized by most special units and schools. Due to the communicative impairments observed in children with ASD which include for example production of speech, understanding communicative intent, auditory input, and gesture use, systems such as VOCA and sign language may demand too many advanced skills (i.e. gestural, linguistic and symbolic skills) to be used efficiently. Therefore Picture communication systems may offer a more concrete representation that the children with ASD are able to comprehend and use.

Picture Communication Symbols

Visual images which present symbols or pictures depicting actions or objects (for example, snack time, play, and worksheet) are used as communicative aids for children who are impaired in language but also to convey information to children with ASD regarding their environment and daily routine. These visual strategies use images such as BM, to produce visual timetables and rule reminders (such as "wash hands in the bathroom"). Visual prompts such as BM were introduced due to reports of impaired attention and comprehension of linguistic input in children with ASD (Hodgon, 1995).

Therefore picture symbols were proposed to aid communicative understanding in children with ASD. Visual schedules and prompts have been reported to reduce disruptive behaviours (Dooley, Wilczenski & Torem, 2001) and improve task engagement (Masey & Wheeler, 2000). Children on the autistic spectrum show more comprehension via the picture prompts and do not become confused and frustrated with lack of consistent routine (Cohen & Volkmar, 1997) as they are able to refer to their visual schedules throughout the day.

Bryan and Gast (2000) conducted a study on children with ASD (n = 4) with ages ranging between 7 years 4 months and 8 years 11 months. Each student was presented with a picture schedule and their behaviour was video recorded. They found that using visual activity schedules children with ASD were able to engage in tasks more and transition between tasks was easier transitions between tasks has been reported previously to be problematic for children with ASD (Cohen & Volkmar, 1997). This increase in task activity was linked to the visual aids being presented to the child. Bryan and Gast (2000) also reported that the visual schedule encouraged children to interact with each other as the children would point out if the others were not adhering to their visual schedule. However basic visual prompts do not improve the children's abilities to express their needs and how they are feeling to others unlike the Picture Exchange Communication System (PECS; Bondy & Frost, 1994).

Picture Exchange Communication System or PECS is an alternative communication method which aims to teach *spontaneous* socio-communicative skills using symbols or pictures depicting actions or objects with a small descriptive word at the top (for example, softplay, eat, snack). PECS images can be used similarly to the BM images to make up visual schedules or rule reminders. However PECS expands previous visual strategies to promote *initiations* in communication in children with ASD by utilising a behavioural paradigm. Therefore PECS differs from other visual systems by increasing the capacity for the production of communication rather than only comprehension of communication. Therefore potentially providing the children with ASD with the ability to express themselves or communicate their wants and desires to others. The PECS symbols are paired with an 'I want' image when the child is requesting an item or activity of interest. The child partners their 'I want' strip with a symbol representing what they desire. The child must then exchange his or her symbol for the requested item (Bondy & Frost, 1994, 1998) which is unique to the PECS system. Receipt of the requested item reinforces the communicative behaviour, i.e. producing a symbol. The PECS system is appealing for speech therapists because it does not require others to be familiar with the system (unlike sign language) and the initiator does not require complex motor movements (Siegel, 2000; Yamall, 2000). PECS also has a relatively low cost and is portable and suitable for use in many settings making it advantageous within an educational or home setting (Frost & Bondy, 1994). The appeal of PECS is increased by case reports that show the system can be taught in a relatively short time period (Bondy & Frost, 1993). The system also makes use of functional communicative responses that promote interactions between the child and the environment as it requires the child to approach a listener and initiate interaction (Frost & Bondy, 1994).

The Picture Exchange Communication System (PECS) is proposed to be different from Picture Communication Symbols (PCS) such as BM. The BM images are used to create picture timetables or manual communication boards where children point to the item they want or activity they wish to do. PECS is proposed to not only aid in communication but help to develop it, by encouraging independent use of the symbols for communication. As children with ASD must actively seek out partners and exchange their symbols for desired items (Bondy & Frost, 1994). Children who received PECS training showed an increase in initiations, and picture/symbol use. Picture use varies between children with one case study detailing one child's PEC image repertoire as including 100 images (Bondy & Frost, 1994). However on average children or adolescents with ASD are able to learn approximately 71 images (Bondy, 1989) which is much higher than the sign items learned by children with ASD which were reported to not increase over 20 (for example Barrera *et al.* 1980). Failure to initiate communicative interactions is a cardinal feature of young children with ASD (Mundy, 2003). Therefore even modest improvements may enhance social development.

Several studies have reported that PECS can increase non-verbal communication in children with ASD; some children are also described as acquiring spoken language (Charlop-Christy, Carpenter, Le, LeBlanc, & Kellet 2002; Ganz and Simpson, 2004; Kravits, Kamps, Kemmerer, & Potucek, 2002). One study conducted by Ganz and Simpson (2004) trained children with ASD (n = 3) aged between 3 and 7 years old on how to use PECS as a communication aid for approximately one week. Each child was selected so they had no prior experience with the PECS system. They found that after PECS training the children were able to use the system successfully as a communication aid and showed increased word utterances of speech. All participants had begun the PECS trial with either no spoken language or one word utterances and at the end of the trial were reported to speak in three – four word utterances.

In a study by Charlop-Christy *et al.* (2002) it was found that children with ASD (n = 3) were able to master PECS use quickly after brief periods of training. They observed an increase in mean length of word utterances from the children showing no words and this increasing to an average two word utterances. There was also an increase of initiations and requests which increased from an average of 5.6 behaviours recorded before PECS training to 31 across the three children. When socio-communicative behaviours increased, problem behaviours were reported to decrease. The children were having less disruptions (such as making grabs) during sessions which were taking place approximately 5.6 times each 10-15 minute session and reduced to 0.9 after PECS training which the authors claimed was caused by their increased communicative abilities.

However other studies have claimed the PECS system does not increase vocalizations or word utterances, but do report various changes in communicative behavior i.e. communication initiations, requesting actions or increased symbol use (Ganz, Simpson & Corbin-Newsome, 2008; Howlin, Gordon, Pasco, Wade, & Charman 2007; Yoder & Stone, 2006). Some studies have reported that a minority of children with ASD are unable to use the PECS system efficiently as a communication aid (Tincani 2004; Yoder & Stone 2006). For example Ganz *et al.* (2008) taught the PECS system to 3 children with ASD aged between 3 and 5 years old. The children, similar to the previous studies mentioned, had no previous experience with PECS and showed limited functional speech. After training only two of the three children were able to use PECS efficiently i.e. mastering the first phase of PECS training. To pass this phase the children had to show independent exchanges using the PECS images (exchanging an image for a desired item) 80% of the 10 trials conducted each session (across 3 consecutive sessions). The authors claim that the child not learning how to master the first phase of PECS may be caused by the child not showing appropriate comprehension of the images presented within the PECS system. This lack of comprehension may involve the children not allocating attention to relevant areas of the image and therefore not understanding what the image represents. This may imply that the picture system images (including BM and PECS) may require improving in order to be used appropriately by more children with ASD. By examining how children with ASD visually scan the images and allocate attention may highlight ways to improve the image presentation and increase image comprehension.

Attention to images with reduced ecological validity

Some of the images used within PECS and BM include cartoon faces denoting hygiene behaviours, functional actions, and emotions. Images also include objects that represent the children's wants and desires. Results which show how some children are unable to effectively learn to use PECS (for example, Ganz *et al.* 2008; Tincani, 2004) may imply that objects and faces presented within the images are not attended to appropriately. This disparity in the PECS literature of the systems success may be caused by atypical gaze behavior when attending to the images by children with ASD.

It has been observed that individuals across the autism spectrum when presented with realistic stimuli fixate longer on objects and allocate attention less on face areas (Klin *et al.* 2002). However one study conducted by van der Geest *et al.* (2002b) found that individuals with ASD did not show atypical gaze patterns while viewing less realistic stimuli. The children with ASD fixated similarly compared to their typical matches on people and objects presented within the images. The images used by van der Geest *et al.* (2002b) had resembled child-like drawings which may have caused the atypical gaze behaviour to be reduced. Riby and Hancock (2009b) also presented stimuli of reduced ecological validity to children with ASD, however these were considerably more realistic compared to van der Geest *et al.* (2002b) stimuli. Riby and Hancock (2009b) found that children with ASD fixated less on the faces of the cartoon characters compared to the typically developing children. The cartoon-like figures shown in the images presented by Riby and Hancock (2009b) are similar to the figures presented in the PECS system. This may imply that despite a reduction of ecological validity it may not be sufficiently reduced enough causing the persons shown in the PECS images to be attended to atypically by children with ASD. Despite van der Geest *et al.* (2002b) showing that neutral objects were also attended to typically by children with ASD.

This may have been caused by the ecological validity being significantly reduced in these images. The images presented within the PECS are more realistic which may cause atypical attention to the objects also similar to the increased fixation on objects during real image presentation (Klin *et al.* 2002). Atypical gazing when ecological validity is not sufficiently reduced may contribute to the lack of consistency within the results of Picture communication use across the autistic spectrum. Children with ASD may not be able to comprehend the images appropriately if they are fixating too long on the images showing objects and not fixating long enough on the images showing faces.

This chapter aims to clarify the strengths and potential weaknesses within the Picture Exchange Communication System (PECS) symbols (Pictures used with the permission of Pyramid Educational Consultants UK Ltd) and BM images (The Picture Communication Symbols ©1981-2009 by DynaVox Mayer-Johnson. All Rights Reserved Worldwide. Used with permission) in relation to the gaze-pattern phenotype of ASD. Using eye tracker technology, fixation lengths and patterns on both the PECS and BM images and specifically where children with ASD are allocating attention within the images will be examined.

5.2 Experiment 1, 2 & 3

The following experiments investigated how the Picture Exchange Communication System (PECS) symbols and BM images were attended to using eye-tracking methodology. Experiment 1 compared how children with ASD attend to PECS and BM images showing objects and faces (PECS face, PECS object, BM face, BM object) compared to typically developing children matched on; verbal mental ability (VA), visuo-spatial ability or Non-verbal Ability (NVA) and chronological age (CA). Experiment 2 examined attention to faces of reduced ecological validity presenting emotional expressions across the groups (ASD, CA, VA & NVA). Attention to faces according to emotion, symbol type and group membership was examined to highlight if atypical gaze behaviour persisted across all emotion types. Experiment 3 investigated level of functioning within the ASD population and how this affects attention to faces from different symbol types and emotional expressions

.5.2.1 Experiment 1

This experiment extended the current face recognition literature by using eye-tracking technology to investigate how attention is allocated in typical and atypical populations when attending picture communication symbols. This study was novel as to the authors' knowledge no other studies have examined the eye gaze behaviour of children with ASD as they fixate on their communicative images. It was predicted that the participants with ASD would fixate less on the face AOIs regardless of picture symbol type (BM and PECS) compared to their typically developing matches. This prediction was based on previous research which found atypical attention to the face area by children with ASD compared to their typical matches despite viewing images with reduced ecological validity (Riby & Hancock, 2009b). However other research by van der Geest *et al* (2002b) reported that atypical gaze behaviour in children with ASD was reduced when attending to people presented in images which showed a great reduction of ecological validity. This may suggest that when images are significantly reduced in ecological validity and appear less realistic, children with ASD may fixate on faces typically. Based on these findings it was predicted that the children with ASD would fixate longer on the face area while attending the less realistic BM images compared to the more realistic PECS images. It was also proposed that the children with ASD would fixate longer on the object areas across symbol types compared to the typical groups since previous research showed that non-socially salient items and objects are fixated on for longer periods of time by populations with ASD (Klin *et al.* 2002).

Method

Participants

Twenty one children with ASD were recruited from special units attached to three mainstream schools, and one specialist ASD school (see Table 5.1). Participants ranged between 9 years 7 months and 16 years 5 months (mean = 13 years 7 months; SD = 2 years 5 months). Verbal ability age was assessed using the British Picture Vocabulary Scale, second edition (BPVS II - Dunn, Dunn, Whetton & Burley, 1997) and provided a mean verbal mental age (VA) for the group of 7 years 3 months (ranging from 3 years 7 months to 15 years 2 months). Non-verbal ability was assessed by the Raven's Coloured Progressive Matrices (RCPM – Raven, Court & Raven, 1990) giving a mean score of 27 (ranging from 11 to 35; max score possible 36). All the children with ASD reported in this chapter also took part in all the experiments detailed in Chapter 6.

Table 5.1

Participant details for children with ASD and their typically developing comparison groups

Group	N	Gender Ratio males:females	CA[i]	VA[ii]	NVA[iii]
ASD	21	20:1	13y 7m (30)	74 (27)	27 (7)
CA	21	15:6	13y 6m (24)	113 (19)	32 (6)
VA	21	14:7	8y 4m (28)	75 (23)	22 (7)
NVA	21	18:3	10y 4m (24)	98 (22)	27 (5)

I Chronological age provided in years and full months. Standard deviation provided in full months in parenthesis.
Ii Verbal ability is calculated using the mean raw score from the British Picture Vocabulary Scale standard deviation in parenthesis.
iii Nonverbal ability is provided as mean scores on the Ravens Coloured Progressive Matrices task (max. score 36) standard deviation in parenthesis.

The children with ASD were matched to three typically developing comparison children using individual matching criteria. Chronological age matched group had a mean chronological age 13 years 6 months (t (40) = .150, p = .96). The VMA group was matched to the participants with ASD for verbal ability age using the BPVS II had a mean verbal mental age of 7 years 4 months (t(40) = -.079, p=.973). The group matched for nonverbal ability (Visuo-spatial ability) had a mean RCPM score of 27 (t (40) = .090, p=.766). The typically developing matched children (who took part in all the experiments detailed in both Chapters 5 and 6) were recruited from mainstream schools with ASD units attached. These children were therefore accustomed to the picture symbols being used throughout their schools to convey information.

All participants with ASD had previously been diagnosed by clinicians as being on the autistic spectrum. The Childhood Autism Rating Scale (CARS; Schopler *et al.*

1988) 9 children as mild-moderately autistic and 7 children as severely autistic. The remaining 5 children scored over 90 on the Asperger Syndrome Diagnostic Scale (ASDS; Myles *et al.* 2001). A score over 90 on this scale indicates the presence of Asperger Syndrome. The Social Communication Questionnaire (SCQ; Rutter *et al.* 2003) was conducted, with 19 children obtaining a score over 15 (a score of 15 or over implies the presence of ASD or PDD-NOS). The remaining two children showed a score of 13 and 11 which may imply these children have higher socio-communicative ability compared to the other children in the ASD group.

Design and Procedure

Stimuli

Images from the PECS and BM systems were selected showing objects or faces (see Appendix A). The object images showed one or several objects, the face images were showing cartoon like people (head and shoulders) doing actions such as brushing teeth and shaving. The images selected were based on the pictures already used in the classroom to communicate to the children their timetable, rules or be used to request items and objects. Prior to testing, the researcher examined the symbol use across 4 separate schools (3 mainstream schools with specialist ASD units attached and 1 residential specialist ASD school). Symbols from both the PECS and BM systems that were used the most consistently across these schools were selected and presented as stimuli. The person and object images represented activities, desired objects and daily hygiene behaviours.

Images were also selected that could easily be followed up by the teachers in the classroom. For example, swimming was not chosen as the child may expect to go swimming after being shown the picture which represents this activity.

These picture symbols tend to be small (as part of a portable timetable etc) and are typically 144 x 144 pixels (5.08 cm). These were increased in size to 400% which measures 576 x 576 pixels (20.32cm), using Adobe Photoshop CS (Adobe, San Jose, California, USA) so that the tracker could be more efficiently used.

The PECS pictures (n=10) and BM images (n=10) were shown in separate trial blocks as part of a battery of eye-tracking assessments. Each picture was presented for 3 seconds (in randomised order within the trial blocks) and separated with a blank screen showing a fixation point in the middle for 1 second. Participants were told ‘please look at the pictures while they are on the screen’, and no further instruction was provided.

Apparatus

The research used a Tobii 1750 eye-tracker (Tobii Technology, Stockholm, Sweden), using ClearView 1.5.10 (Tobii Technology) for the presentation of stimuli and recording eye movements. The eye-tracker was controlled via a Dell Inspiron 6400 (Dell, Round Rock, Texas, USA) laptop computer. The system is portable and was moved to the testing location of each individual. The system is also completely non-invasive, with no need to constrain the head or body and little indication that eye movements are tracked. The Tobii 1750 system tracks both eyes to a rated accuracy of 0.5 degrees, sampled at 50 Hz and was calibrated for each participant using a 5-point infant calibration of each eye.

ClearView 1.5.10 provides a ‘definition tool’ to identify areas of interest (AOI) for analyses. For all images, AOI were designated to faces and objects. The face AOI was marked with the polygon definition tool covering the face region with a hairline boundary (see Figure 5.1). AOI for the objects was defined using polygon definition tools also to mark the outline of the object or objects presented together.

i)

ii)

Figure 5.1 An example of the stimuli with the areas of interest (AOI) outlined. (i) The PECS images depicting a face and objects, (ii) BM images showing a face and selection of objects.

To ensure accuracy of gaze recordings for each AOI, a programme was designed using Matlab (Mathworks, Natick, Massachusetts, USA). This ensured calibration was consistent across all stimuli (as calibration is only checked via the Tobii software at the beginning of the trial).

Design

This study employed a mixed design with between-subject factor of Group (ASD, CA, VA, NVA) and within-subject factor being Symbol Type (2 levels: BM; PECS) and the AOI (2 levels: face or object).

Procedure

Participants were tested individually at home or at school. As well as the stimuli presented here participants viewed realistic images containing familiar and unfamiliar faces (see Chapter 6). The whole session (battery of eye-tracking assessments) lasted 10-12 min with each trial block being presented for 2-3 min. Participants were seated approximately 50 cm from the eye-tracking screen with the experimenter sat to one side to control the computer but not interfere with viewing behaviour. The participant was told that they would see different types of pictures during the session and the first eye-tracking task involved calibration of the eye-tracker.

For this purpose, the participant followed a bouncing cat around the screen to five locations. All participants in this experiment were able to comply with task demands and be calibrated successfully so no removal of participants from the study was necessary. Following calibration, participants viewed the stimuli (the PECS trial block and the BM trial block) as part of a battery of eye-tracking assessments. All trial blocks were presented in a random order to participants. Once all the conditions were complete the experimenter debriefed the participant.

Results

Task engagement Fixation Duration

Task engagement time was calculated by examining total fixation time spent looking at the image. It was found that group had a significant effect on total fixation time (task engagement) $F(3, 83) = 11.260$, $p<.001$. The ASD group engaged in the task significantly less compared to the CA and NVA group. Post-hoc bonferroni shows that the ASD group (m=37970ms) engaged significantly less than the CA group (m = 48716ms) ($p< .000$) and the NVA group (m = 49190ms) ($p<.000$). There was no significant difference between the ASD group and the VA (m= 38828ms) ($p = .740$). The VA group also engaged in task significantly less compared to the CA group ($p<.001$) and the NVA group ($p<.001$). Therefore proportional data must be used for the rest of this analysis.

Proportion of mean total fixation time and time to first fixation will be presented within the thesis. The relevant analysis is presented which includes the significant and non-significant effects related to investigating the hypotheses. This will be applied across all experimental chapters and the results in full will be included in the appendices. The full analysis from the present chapter is included in Appendix B.

Proportion of mean total task fixation time.

The proportions of mean task fixation time spent on the areas of interest (faces and objects) were examined to highlight how long the children were allocating their attention on the object and face areas. The PECS images were examined separately from BM images to highlight the different or similar ways attention was allocated to the two symbol types which present different levels of ecological validity within their images.

A mixed 4x2x2 ANOVA was carried out with between-subject factor Group (ASD, CA, VA, NVA) and within-subject factor being Symbol Type (2 levels: BM; PECS) and the AOI (2 levels: face or object). Only the relevant analyses will be presented within the thesis for the additional analyses of factors see Appendix B. There was no significant main effect of Symbol Type $F(1,80) = .032$, $p = .858$, $\eta^2_p = .000$. There was no significant interaction between Group and Symbol Type $F(3, 80) = 1.697$, $p = .174$, $\eta^2_p = .060$.

Table 5.2

Proportion of mean task fixation time spent looking at objects and face AOIs in Boardmaker (BM) and PECS images (SD in parenthesis)

	FACE AOI		OBJECT AOI	
Group	PECS	BM	PECS	BM
ASD	.241 (.084)	.093 (.059)	.119 (.110)	.185 (.168)
CA	.250 (.069)	.119 (.035)	.062 (.052)	.181 (.064)
VA	.290 (.100)	.132 (.102)	.038 (.046)	.252 (.133)
NVA	.243 (.075)	.143 (.086)	.080 (.053)	.235 (.212)

All Groups including the ASD group fixated longer on the face AOIs (m = .189) compared to object AOIs (m = .144). $F(1,80) = 28.388$, $p < .001$, $\eta^2_p = .262$ showing that the ASD group fixated typically on the faces presented within the images (see Table 5.2). Group membership did not impact on time spent fixating on the AOIs F (3,80) = 2.015, p =.119, η^2_p = .070. Symbol type was shown to influence what AOI was attended to AOI F (1, 80) = 163.759, p < .001, η^2_p = .672. To investigate this significant interaction post-hoc paired samples t-tests were carried out. It was found that participants fixated longer on the face AOI during the PECS condition (m = .256) compared to the face AOI during BM images (m = .122) t(83) = 10.790, p < .001. This may be due to the faces presented on the PECS images being more realistic than the BM images, and may imply that the PECS symbols attracted longer fixation durations from the groups compared to the BM images. Figure 5.2 shows that the PECS faces were fixated on longer than any other area of interest. Symbol type continued to affect how long the object AOI was fixated on with the children looking longer at the objects within the BM condition (m = .213) compared to the object AOI in the PECS condition (m = .075) t (83) = 6.819, p < .001. The PECS object pictures were much more complex than the BM images at times which may have caused the children to fixate less on the image.

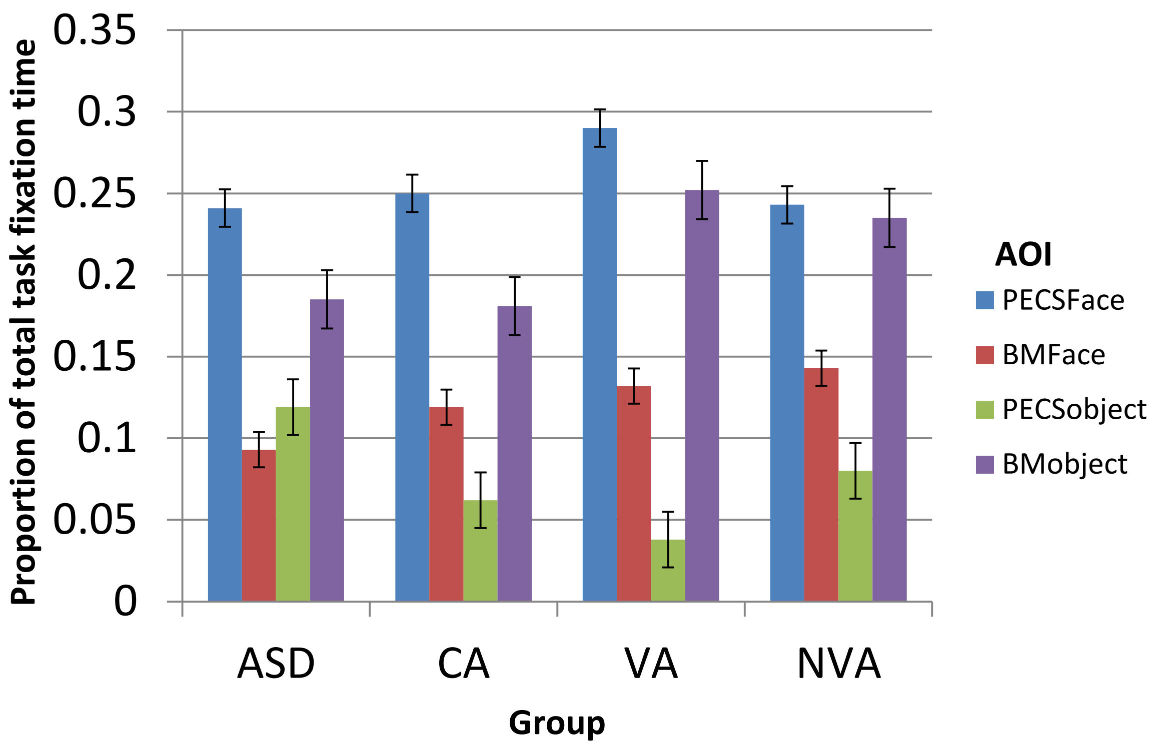


Figure 5.2 How attention was allocated to the face and object AOIs in PECS and BM images across groups.

There was a trend that Symbol type and Group membership affected how long object and faces were fixated on $F(3, 80) = 2.597$, $p = .058$, $\eta^2_p = .089$. To investigate this trend one way ANOVAs were carried out between groups for each AOI. The Groups fixated similarly on the face AOI during the PECS condition. However Group membership affected how the PECS object AOI was fixated on $F(3, 80) = 4.931$, $p < .01$. Post-hoc bonferroni showed that the ASD group ($m = .119$) looked longer compared to the CA group ($m = .062$) $p < .05$, VA group ($m = .038$) $p < .001$. There was also a trend towards the ASD group fixating longer on the PECS object AOI compared to NVA group ($m = .080$) $p = .077$. The children all fixated similarly on the BM images including the face AOIs $F(3,80) = 1.703$, $p = .173$, and the object AOIs also $F(3,80) = 1.132$, $p = .341$. There were no differences between fixation proportion across all stimuli types and AOIs between groups F (3,80) = .993, p= .400, η^2_p = .036. Therefore the PECS object AOI attracted the attention of the ASD more compared to the typically developing groups. The ASD group however fixated similarly on the face AOIs in the PECS images and BM images compared to the typically developing groups.

Time Taken to Fixate

Time taken to fixate was examined to show which areas of the picture symbols were selected for attention first by the children. Time taken to fixate will also highlight if symbol type or group membership affected which AOIs were fixated on the quickest.

Table 5.3

Time taken to fixate on objects and face AOIs in Boardmaker (BM) and Picture Exchange Communication (PECS) images (SD in parenthesis)

	FACE AOI		OBJECT AOI	
Group	PECS	BM	PECS	BM
ASD	594.0 (251.5)	895.6 (621.5)	525.9 (199.7)	816.8 (458.8)
CA	660.3 (238.6)	905.1 (368.7)	548.8 (201.8)	670.1 (382.8)
VA	736.2 (333.7)	1050.6(505.0)	539.2 (267.5)	785.6 (317.3)
NVA	663.3 (306.6)	934.3 (378.9)	532.1 (203.6)	661.0 (299.1)

A mixed 4x2x2 ANOVA was carried out with between factors being Groups (ASD, CA, VA, NVA) and within subject factors being Symbol type (BM and PECS) and the AOI (face and object). The children were shown to fixate quicker on the PECS AOIs (m = 599.9 ms) compared to BM AOIs (m = 839.9ms) F (1, 80) = 34.471, p < .001, η^2_p

= .301, which can be clearly seen in Table 5.3 and Figure 5.3. Group membership did not affect time taken to fixate on the different symbol types F (3,80) = .481, p = .696, η^2_p = .018.

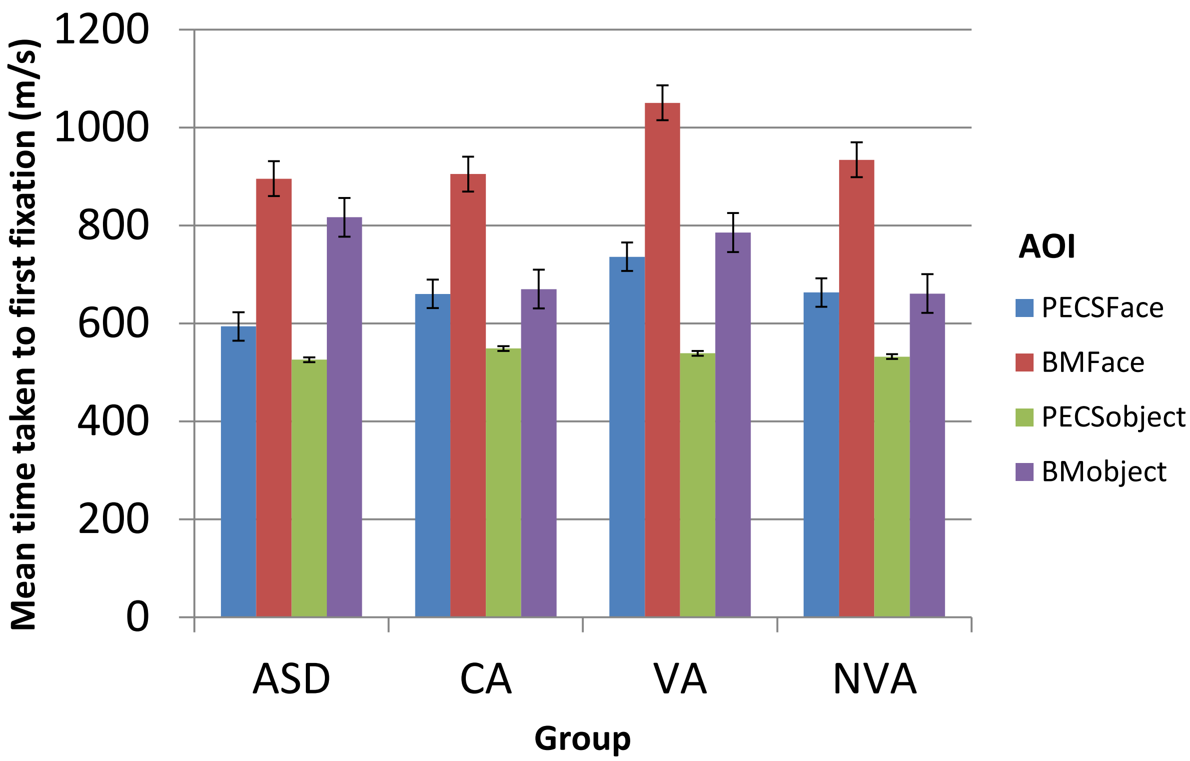


Figure 5.3 Mean time taken to fixate on face and object AOIs in Picture Exchange Communication (PECS) and Boardmaker (BM) images across groups.

The participants fixated significantly quicker on the object AOIs (m = 634.9ms) compared to the face AOIs (m = 804.9ms) F (1,80) = 26.131, p < .001 η^2_p = .246, which can be clearly seen in the Figure 5.3. This may show that when ecological validity is reduced in images objects attract attention quicker compared to face AOIs. Group membership did not influence time taken to fixate on the face and object AOIs F (3, 80) = 1.062, p = .370, η^2_p = .038.

No significant interaction took place between Symbol type and AOI, Symbol type therefore did not affect how quickly AOIs were attended to, $F(1,80) = 1.875$, $p = .175$, $\eta^2_p = .023$. Group membership and symbol type did not impact on how quickly objects and faces were allocated for attention $F(3, 80) = .223$, $P = .880$, $\eta^2_p = .008$. There was no differences between Groups on time taken to fixate on the AOIs across the symbol types $F(3,80) = .707$, $p = .551$, $\eta^2_p = .026$.

Discussion

This study extended the current face recognition literature by using eye-tracking technology to investigate how attention is allocated in typical and atypical populations when attending picture communication symbols. It was predicted that the participants with ASD would look less at the face AOI regardless of picture symbol type (Boardmaker and PECS) compared to their typically developing counterparts, however the results do not support this. The ASD group were found to fixate for a similar amount of time on the face AOI compared to their typically developing matches. All groups including the ASD group fixated longer on the face AOIs across the stimuli types compared to the object AOIs. This does not support predictions made at the beginning of the experiment which were based on previous research which reported increased fixation on objects and reduced fixations on faces in a population with ASD (Klin *et al.* 2002).

The prediction made at the beginning of the study which proposed that the children with ASD would fixate longer on the face area while attending the BM images compared to the PECS images was not supported. PECS faces were attended to for longer compared to the BM faces by all the groups including the ASD group. This is not consistent with previous research conducted by van der Geest *et al* (2002b) who reported that children with ASD's atypical attention to faces was reduced when ecological validity was reduced. It seems that cartoon-like faces which presented increased ecological validity maintained children with ASD's attention for longer compared to images of reduced ecological validity. This may suggest that when ecological validity is too reduced (as seen in BM images), faces may not maintain the attention of children with ASD. However if ecological validity is sufficiently reduced allowing the faces to retain some realistic qualities such as detailed eyebrow configurations (as seen in PECS images), then attention to faces is maintained for longer. These results may have implications on how picture symbols are designed and suggests that if ecological validity is reduced to a great extent, the image may not attract children with ASD's attention for long durations.

However the prediction that children with ASD would fixate longer on object AOIs compared to their typical matches was partly supported. The group with ASD fixated longer on the PECS object AOI compared to all other groups. This supports previous research which shows that children with ASD maintain attention for longer at non-social objects compared to typically developing children (for example, Swettenham *et al.* 1998). They may have attended the PECS longer than the other groups due to the high complexity and detail in some of the PECS images. Presenting many items within an image may cause higher mean fixation duration in ASD populations compared to typical populations, which may be due to the increased complexity of the images. A higher number of objects may maintain attention allocation of the children with ASD as previous literature reports that they do fixate longer on objects compared to typically developed counterparts (Klin *et al*. 2002). How complexity influences attention allocation in children with ASD will be examined in more detail in Chapter 7.

These results may imply that faces (with overall reduced ecological validity) are attended to by children with ASD similar to their typically developing counterparts. Therefore reduced ecological validity may reduce the atypical gaze behaviour which is often reported in children with ASD (Speer *et al.* 2007; Pelphrey *et al.* 2002). This is similar to results reported by van der Geest *et al.* (2002b) who found that children with ASD were able to fixate on the faces of cartoon-like figures similar to typically developing children because of their reduced realism. This finding is inconsistent with Riby & Hancock (2009b) who found that atypical attention allocation to faces persisted across stimuli type regardless of ecological validity.

This may be due to the different level of functioning in the children with ASD who were recruited in Riby & Hancock (2009b) study and the participants with ASD in the present study. In the current study, the ASD group may have looked longer at the face AOIs due to the inclusion of high functioning participants (which are higher functioning compared to the children with ASD included in the Riby & Hancock 2009b study). Previous literature has suggested that level of functioning is related to fixation time spent looking at faces (Riby & Hancock 2009a; 2009b). Including high functioning children with ASD in the sample may have caused these results to show high fixation durations on face AOIs unlike Riby and Hancock (2009b) who included low to moderate functioning children with ASD and found reduced fixation on face AOIs. How level of functioning may impact on attention allocation to these images will be examined in Experiment 3 of this chapter. The results reported in this study are encouraging for picture symbol use across the autism spectrum since children with ASD are fixating typically on the faces within their picture images. These results so far suggest that they are attending to the faces presented long enough to encode the relevant information.

Therefore this experiment showed that children with ASD were able to fixate on faces presented within their picture communication symbols similarly to typically developing children. This may be due to the high functioning children with ASD included in this study, therefore how level of functioning affects attention allocation to these images will be examined in Experiment 3.

5.2.2 Experiment 2

Experiment 2 builds upon Experiment 1 by examining attention allocation to picture symbols denoting emotional expressions. Children with ASD are asked to select emotional images to tell the teachers and caregivers how they are feeling that day. Attending to appropriate areas of these images (for example mouth and eyes) may enable the child to understand what emotion the picture represents as previous literature has shown attending to the eye and mouth areas aids social judgements of a face including emotion recognition (for example, Pelphrey *et al.* 2002). As previously reported adults and children with ASD show reduced attention to the eye area of faces (for example, Norbury *et al.* 2009; Speer *et al.* 2007). The predictions made for this study are based on previous research which has reported atypical attention to faces specifically the eye area in ASD populations when trying to recognise emotions (Hernandez *et al.* 2008; Pelphrey *et al.* 2002). This lack of attention on the eye area may influence the impaired recognition of facial expressions observed in populations with ASD (for example, Deruelle *et al.* 2004). It is therefore predicted that the ASD group will fixate significantly less on the eye area of faces showing emotional expressions compared to the typical groups.

Perlphrey *et al.* (2002) also found that fixation on the mouth area was not significantly different between the group with ASD and the typically developed matches while attending faces showing emotion. Therefore it is predicted that there will be no significant differences of fixation time on the mouth area of the faces showing emotional expression between the children with ASD and the typically developing groups.

The final prediction for this study is based on previous research by van der Geest *et al* (2002b) who reported that children with ASD showed reduced atypical allocation of attention to people presented in images of significantly reduced ecological validity. This was different from Riby and Hancock (2009b) who found that children with ASD still did not fixate typically on persons presented in images of reduced ecological validity. However the images used by Riby and Hancock were significantly more realistic compared to the images used by van der Geest *et al* (2002b). Based on these findings it was predicted that the children with ASD would fixate longer on the eye area while attending the BM images which show lower ecological validity compared to the PECS images which show higher ecological validity. This study is novel compared to existing literature which has examined how populations with ASD attend to faces showing emotional expression. The present experiment extends previous research of emotion recognition in ASD, by exploring how attention is allocated to cartoon-like faces expressing emotion that are presented within their communicative systems.

Method

Participants

Participants were the same as those recruited for Experiment 1 and are therefore not detailed in this section (see section 5.2.1).

Design and Procedure

Stimuli

Images from the PECS and BM systems were selected showing faces expressing emotions (see Appendix C). Similar to Experiment 1, the researcher examined the symbols across 4 separate schools (3 mainstream schools with specialist ASD unit and 1 residential specialist ASD school) before testing commenced. Symbols from both the PECS and BM systems that were used the most consistently across these schools were selected and presented as stimuli. The PECS images show a head, torso and arms expressing a range of emotions including afraid, angry, happy, sad, and tired. The BM images showed the same emotions however these images mainly consisted of a floating head, except for two images which showed arms and hands to add emphasis to emotion. A symbol showing 'sore' was also selected from BM and the symbol 'sick' from the picture exchange communication system was selected as the closest image for comparison. The 'sore' and 'sick' images are particularly important as the children must attend to them and use the pictures effectively to alert caregivers of illness. These images were selected because they were observed to be consistently used within learning and home environments of the children with ASD included in the present experiment. They were also highlighted by speech and language therapists to be particularly important in conveying how the children are feeling during day to day activities. The PECS emotion images were presented randomly within one trial block and the BM emotion images were presented randomly in another separate trial block. These trial blocks were presented to the children in a random order as part of a battery of eye-tracking assessments.

Apparatus

The apparatus was the same as used for Experiment 1 and are therefore not detailed in this section (see section 5.2.1) except for how the areas of interest (AOI) were defined which will be detailed below.

i)

ii)

Figure 5.4 An example of (i) PECS images depicting emotions, (ii) BM images showing a selection of emotions both with areas of interest (AOI) outlined.

ClearView 1.5.10 was used to identify areas of interest (AOI) for analyses. For all images, AOI were designated to eyes and mouths since these are the areas of the face important during the recognition of emotion (Martin, *et al.*, 2011). AOI for the eyes and mouth were defined using rectangular definition tools to mark regions covering these features (see Figure 5.4).

Design

This study employed a mixed design with between-subject factor of Group (ASD, CA, VA, NVA) and within subject factors being Symbol type (PECS and BM) and AOI (eye or mouth).

Procedure

The procedure was the same as used for Experiment 1 and is therefore not detailed in this section (see section 5.2.1).

Results

Proportion of mean fixation time

Attention allocation to the eye and mouth areas of the face can be highlighted by examining proportion of mean face fixation time spent on the eye and mouth AOIs. This will show where on the face the groups fixated on the longest and if they attended to the relevant areas of these faces showing emotional expression.

Table 5.4

Proportion of mean task fixation time spent looking at eye and mouth AOIs in Boardmaker (BM) and PECS images (SD in parenthesis)

	EYE AOI		MOUTH AOI	
Group	PECS	BM	PECS	BM
ASD	.260 (.124)	.430 (.159)	.087 (.035)	.159 (.068)
CA	.320 (.173)	.517 (.138)	.159 (.052)	.202 (.094)
VA	.276 (.121)	.392 (.201)	.146 (.074)	.277 (.162)
NVA	.346 (.226)	.513 (.286)	.173 (.092)	.172 (.082)

A 4x2x2 mixed ANOVA was carried out with between factors being Groups (ASD, CA, VA, NVA) and within subject factors being Symbol type (PECS and BM) and AOI (eye or mouth). Only the relevant analyses which are most related to the proposed hypotheses will be presented within the thesis, for additional analyses of factors see Appendix B.

The children were found to fixate significantly less on the PECS AOIs (m = .221) compared to the BM AOIs (m = .333) $F(1,80) = 52.862$, $p < .001$, $\eta^2_p = .398$ (see Table 5.4). Group membership did not impact on time spent fixating on the different Symbol types $F(3,80) = .386$, $p = .764$, $\eta^2_p = .014$. All groups including the ASD group fixated for a longer proportion of time on the eye AOIs (m = .382) across the images compared to mouth AOIs (m = .172) $F(1,80) = 58.538$, $p < .001$, $\eta^2_p = .423$. Group membership did not impact on how long the AOIs were fixated on $F(3, 80) = 1.191$, $p = .318$, $\eta^2_p = .043$ (see Figure 5.5).

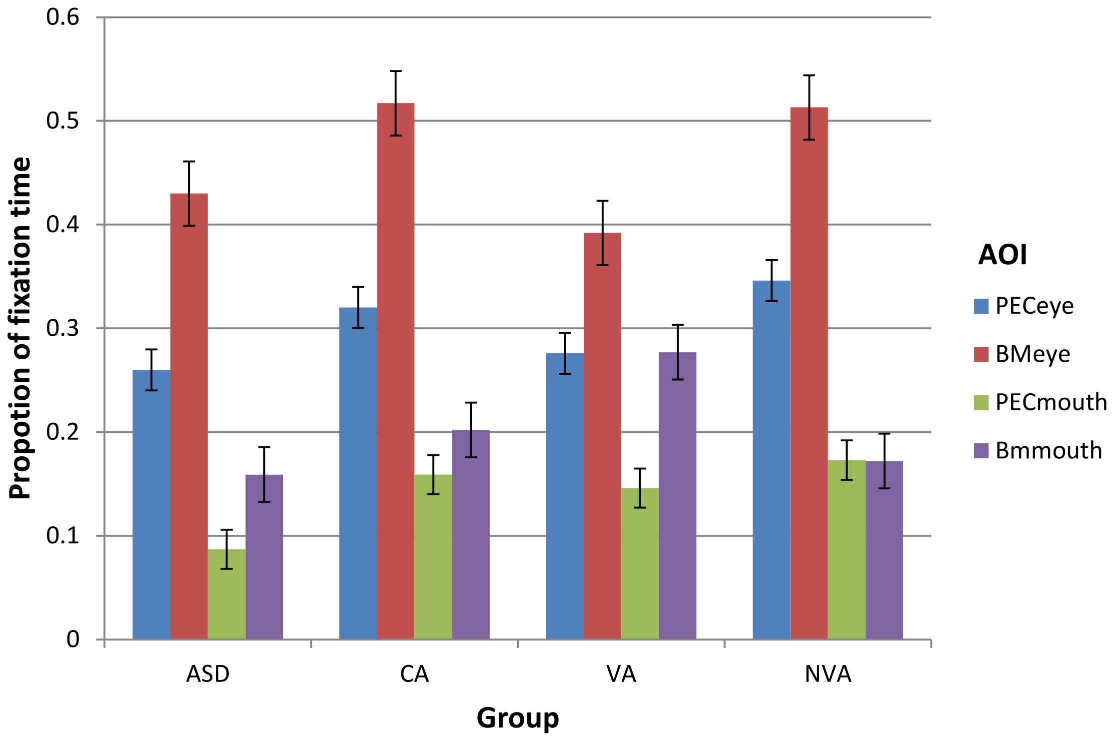


Figure 5.5 The groups mean fixation duration on faces showing emotion across the symbol types

Symbol type impacted on which AOIs were fixated on F (1,80) = 6.924, $p < .01$, $\eta^2_p = .080$. This significant interaction was investigated by looking at each AOI (eye and mouth) and comparing the Symbol type. The children fixated longer on the BM eye AOI (m = .463) compared to the PECS eye AOI (m = .301) t (83) = 5.994, $p < .001$. The participants also looked significantly longer on the BM mouth AOI (m = .202) compared to the PECS mouth (m = .142) t (83) = 2.798, $p < .01$. There was no significant interaction between Symbol type, AOI and Group F (3,80) = 1.158, p = .331, $\eta^2_p = .042$.

There was a trend towards a significant effect of Group F (3,80) = 2.533, p = .063, $\eta^2_p = .087$ however post-hoc bonferroni showed there were no significant differences between the groups, (ASD = .234; CA = .299, VA = .272, NVA = .301), ASD – CA, p = .128; ASD – VA, p = 1.00; ASD – NVA, p = .110.

Time to First Fixation

Time to fixate on the eye and mouth areas was also examined to highlight if the eye and mouth attracted the attention of the ASD group differently compared to the typically developing groups.

Table 5.5

Time taken to fixate on eye and mouth AOIs in Boardmaker (BM) and Picture Exchange Communication (PECS) images (SD in parenthesis)

	EYE AOI		MOUTH AOI	
Group	PECS	BM	PECS	BM
ASD	387.5 (231.2)	266.6 (143.5)	184.9 (121.8)	308.2 (236.9)
CA	458.5 (218.4)	338.7 (168.2)	312.7 (146.8)	330.5 (189.5)
VA	513.3 (321.5)	275.8 (105.7)	253.8 (221.5)	487.2 (287.3)
NVA	582.3 (324.3)	256.2 (134.6)	446.1 (200.9)	383.2 (231.0)

A 4x6x2x2 mixed ANOVA was carried out with between factors being Groups (ASD, CA, VA, NVA) and within subject factors being Symbol type (PECS and BM) and AOI (eye or mouth). Only the relevant analyses will be presented within the thesis; for the additional analyses of factors see Appendix B. There was a trend for the children to take a longer time to fixate on the PECS AOIs (m = 392.3ms) compared to the BM AOIs (m = 339.1ms) $F (1, 80) = 3.115$, $p = .081$, $\eta^2_p = .038$ (see Table 5.5).

Group membership impacted on time taken to fixate on the different Symbol types F (3, 80) = 2.781, $p < .05$, $\eta^2_p = .096$. To investigate this significant interaction between subjects ANOVAs were conducted for each Symbol type. For PECS condition there was a significant effect of Group F (3, 80) = 2.383, p = .075. Post-hoc bonferroni showed there were no significant differences between groups CA (m = 385.2ms) and VA (m = 414.5ms) however there was a trend towards the NVA group (m = 514.7ms) taking significantly longer time to fixate on the PECS images compared to the ASD group (m = 286.4ms) p = .058. For the board maker stimuli there was no significant effect across Groups F (3,80) = .497, p = .685.

The children did not show different amounts of time to fixate on the AOIs F (1, 80) = 1.275, p = .262, $\eta^2_p = .016$. Group membership did not impact on time taken to fixate on the AOIs F (3,80) = .212, p = .888, $\eta^2_p = .008$ (see Figure 5.6).

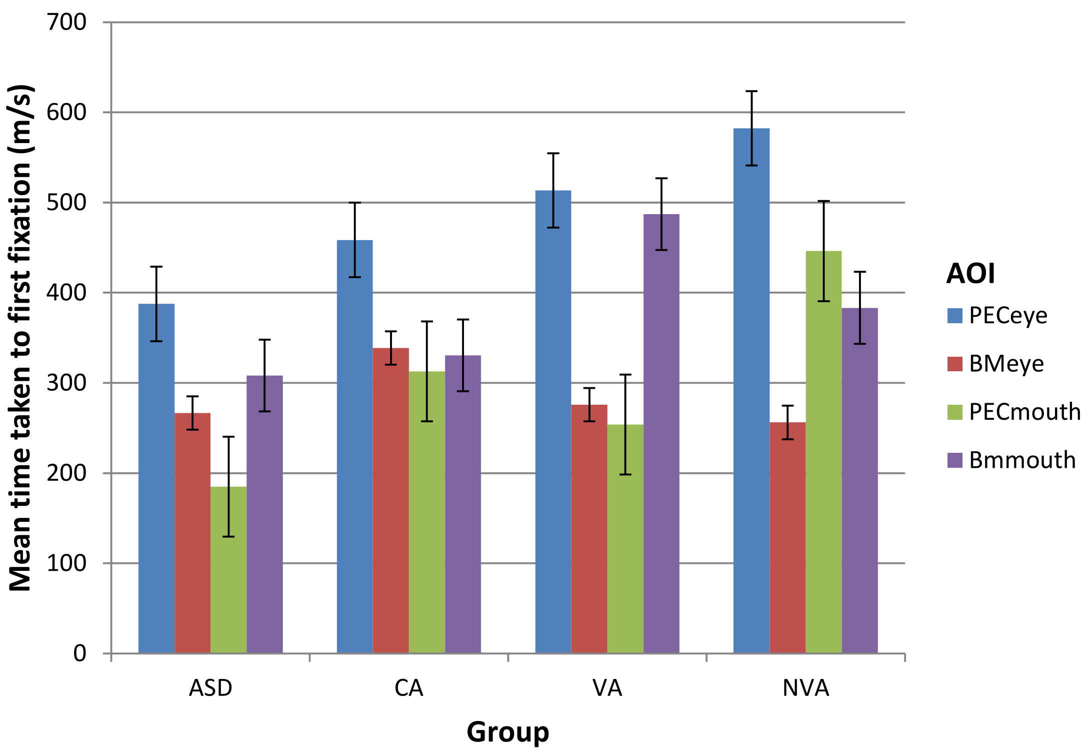


Figure 5.6 Time to first fixation on eye and mouth AOIs of faces showing emotion across the groups

Symbol type impacted which AOIs were fixated on quickest by the children $F(1,80) = 17.930$, $p < .001$, $\eta^2_p = .185$. This significant interaction was investigated by looking at each AOI and comparing the stimuli type using paired samples t-tests. The participants took significantly longer to fixate on the PECS eye AOI (m = 496.2ms) compared to the BM eye AOI (m = 288.3ms) $t(83) = 4.624$, $p < .001$. There was also a trend towards significance for the children to fixate quicker on the PECS mouth (m = 304.0ms) compared to the BM mouth (m = 392.1ms) $t(83) = 1.846$, $p = .068$. There was no significant interaction between Symbol type, AOI and Group $F(3, 80) = .955$, $p = .418$, $\eta^2_p = .035$. There was no significant effect of Group $F(3, 80) = 1.207$, $p = .313$, $\eta^2_p = .044$.

Discussion

All groups fixated on the AOIs similarly. There was no significant difference of fixation time on the eye area between the ASD group and the typically developing group showing that the children with ASD did not avoid fixating on the eye AOI. All the groups including the ASD group fixated significantly longer on the eye AOIs compared to the mouth AOIs across all emotion types, showing that the eye area of a face expressing emotion maintains the attention of the children with ASD similarly compared to the typically developing children. This does not support the prediction made at the beginning of the experiment which proposed, based on previous research (Pelphrey *et al.* 2002) that children with ASD would show reduced fixation on the eye area of faces showing emotion compared to typically developing children. In this study the children with ASD fixated similarly to their typically developed counterparts. This may be due to the stimuli being less ecologically valid in the present study. Previous experiments which have found reduced fixation on the eye area of emotional faces in populations with ASD have used stimulus depicting real faces (for example, Hernandez *et al.* 2008; Pelphrey *et al.* 2002).

These results are also inconsistent with previous research which reported reduced fixation on the eye area of faces by children with ASD when attending images of reduced ecological validity (Riby & Hancock 2009b). The different results reported by Riby & Hancock's (2009b) study and the present study may be caused by differences of complexity. The images presented by Riby & Hancock showed cartoon-like figures with detailed backgrounds unlike the images shown in the present study which displayed isolated cartoon-like figures with white backgrounds. Reduced attention to the eye area during Riby & Hancock's study may have been caused by the children with ASD fixating on details presented within the complex background therefore reducing time spent fixating on the eyes. Therefore the children with ASD may attend the eye area of these faces expressing emotion similarly to their typically developed counterparts due to the reduced ecological validity and reduced complexity of these images.

It was also proposed that the ASD group would fixate similarly on the mouth AOI compared to the typically developing groups. This was supported as the ASD group fixated similarly compared to the typically developing groups on the mouth AOI across all stimulus and emotion conditions. This supports Pelphrey *et al.* (2002) study which also found no differences of the time spent fixating on the mouth AOI between the ASD group and the typically developing group. Therefore the typical fixation duration spent on the mouth AOI of faces observed in ASD continues even when the ecological validity of faces showing emotional expression is reduced.

It was predicted that the children with ASD would fixate longer on the eye area while attending the less realistic BM images which show low ecological validity compared to the PECS images which show higher ecological validity. The results presented in this study supported this prediction as all groups including the ASD group fixated significantly longer at the BM images compared to the PECS images showing emotion. This is consistent with previous research by van der Geest *et al* (2002b) who reported that children with ASD allocated attention to people typically when they were presented in images of significantly reduced ecological validity. This shows that the AOIs were fixated on more in the less realistic images. These results may have been caused by the mouth and eye formations of the BM images which were more exaggerated an emphasized compared to the PECS images. The PECS images displayed more natural looking facial configurations, similar to realistic faces. The emphasis of specific facial configurations (such as a severely down-turned open mouth or widened eyes) to display the emotion in the BM images may have maintained the children's attention for longer.

The children with ASD fixated on the eye area of the picture communication symbols similarly compared to their typically developing peers. These results are again encouraging for the application of picture symbols in children across the spectrum. This research does not highlight how the children with ASD are processing the information and comprehending the communicative cues conveyed in the images. However what this experiment does show is what information is being attended to within the images and therefore what information is *available* to be processed. Future research must be conducted to examine if the children with ASD understand what emotions the cartoon-like images are displaying, alongside eye-tracking methodology which would highlight if attention allocation is linked to the comprehension of emotion.

5.2.3 Experiment 3

This experiment extends the current ASD literature by investigating the level of functioning in ASD and how it affects attention allocation to their communicative aids. Attention to faces has already been reported to be indicative of level of functioning across the Autism Spectrum (for example, Riby & Hancock, 2009a), eye area (Speer *et al.,* 2007) and mouth (Klin *et al.,* 2002). A study by Riby and Hancock (2009b) examined how level of functioning influenced attention to figures of reduced ecological validity (i.e. cartoon figures). They found that higher scores on the CARS (lower functioning on the ASD spectrum) were associated with lower fixation duration on the cartoon faces. This may have implications on how children with ASD attend to their communication symbols as these are similar to the figures used by Riby and Hancock (2009b). These systems are mostly used as an alternative communicative strategy by lower functioning children (Bondy & Frost, 1994). However if the lower functioning children are not attending to the cartoon faces within their picture symbols then they may miss relevant information and fail to use the symbols effectively. It is predicted based on Riby and Hancock's (2009b) findings that the lower functioning children with ASD in the present study will fixate less on the faces within these images and high functioning children with ASD will show longer fixations on the face. It was also predicted, based on Klin *et al.* (2002) results which showed high fixation on objects was related to low social communicative ability, that the lower functioning children with ASD would fixate longer on the object AOIs.

Method

Participants

Twenty nine children with ASD were recruited from special units attached to three mainstream schools, one specialist ASD school and one residential specialist ASD school (see Table 5.6). Participants ages ranged between 9 years 7 months and 16 years 8 months (mean = 14 years 8 months; SD = 2 years 3 months).

Table 5.6

Participants with ASD and details of their autistic characteristics and socio-communicative abilities

	N	Gender ratio males:females	CA[iv]	SCQ[v]	CARS[vi]
ASD	29	27: 2	14y 8m (28)	23 (6)	37 (8)

[iv] Chronological age is provided in years and full months, standard deviation is provided in parenthesis.
[v] Communicative ability is provided as a score on the Social Communication Questionnaire, standard deviation is in parenthesis.
[vi] Level of functioning on the Autism spectrum is provided as a score on the Childhood Autism Rating Scale.

Twenty one of the children had already taken part in Experiments 1 and 2, a further 8 children with ASD had been recruited but were not high functioning enough to be compared to typically developing children. Despite this they were recruited for Experiment 3 since this is an investigation of how level of functioning relates to eye gaze behaviour. These participants similar to the existing children in the ASD group had previously been diagnosed by clinicians as being on the autistic spectrum. By including the children with low functioning ASD, the Childhood Autism Rating Scale (CARS; Schopler *et al.* 1988) now scored 10 children as mild-moderately autistic and

14 children as severely autistic. The remaining 5 children scored over 90 on the Asperger Syndrome Diagnostic Scale (ASDS; Myles *et al.* 2001). A score over 90 on this scale indicates the presence of Asperger Syndrome. The Social Communication Questionnaire (SCQ; Rutter, *et al.* 2003) was also conducted to assess communicative ability in the children and scored 27 participants over 15 (a score over 15 implies the presence of ASD or PDD-NOS).

Design and Procedure

Task stimuli and the procedure were the same as used for Experiment 1 and are therefore not detailed in this section (see section 5.2.1). Due to the involvement of low functioning participants with ASD more verbal instructions were provided because these children had no reading ability.

Results

Mean proportion of fixation time.

Mean proportion of task fixation time was selected for correlation analysis to examine if attention to the object and face AOIs was significantly related to level of functioning across the autism spectrum. Examining fixation time may highlight how long the object and face AOIs maintained the children with ASD's attention.

Table 5.7

Correlations between CARS, SCQ and proportion of mean task fixation time

	FACE AOI		OBJECT AOI	
	BM	PECS	BM	PECS
CARS	.009	.031	.272	.133
SCQ	-.065	.003	.240	.057

There were no significant correlations between the CARS or SCQ scores and fixation duration on the face and object AOI s in the picture symbols (see Table 5.7). Showing that level of functioning did not impact on how these cartoon-like images were attended to.

Time taken to first fixation.

Time taken to fixate on the AOIs was examined to see if this was indicative of functioning level of the children with ASD. How quickly the face or object AOIs attracted the attention of the children with ASD may vary according to the level of their social functioning.

Table 5.8

Correlations between CARS, SCQ and mean time taken to first fixation

	FACE AOI		OBJECT AOI	
	BM	PECS	BM	PECS
CARS	.024	-.318	-.005	.068
SCQ	-.109	-.300	.102	.070

Again there were no significant correlations between the CARS or SCQ and eye gaze behaviour (see Table 5.8) during the presentation of their picture symbols. These results may imply that level of functioning does not influence time taken to fixate on AOIs within the images.

Discussion

No significant correlations were observed between the CARS or SCQ with eye gaze behaviour during presentation of their communicative symbols. This may imply that level of functioning does not affect how attention is allocated to picture symbols across the ASD. The results here are not consistent with predictions made which proposed that level of functioning would be significantly correlated with attention to the face areas of these images. Therefore there is no relationship between autistic impairment and eye gaze behaviours during fixation on their picture symbols.

These results are inconsistent with Riby and Hancock (2009b) who found that low functioning children with ASD fixated less on face areas even in images of reduced ecological validity. The results in the present study being inconsistent with Riby and Hancock (2009b) findings may be due to the different stimuli used. Some of the stimuli from Riby and Hancock (2009b) presented more than one character within a static image so presented a social scene to the children with ASD. The picture symbols presented here showed a single person at any time depicting an action. Therefore children with ASD may show a reduction of atypical gaze behaviour when the social element of the image is reduced. Level of functioning may therefore only be indicative of attention allocation in children with ASD when the stimulus contains a social element. When there is no social scene children with ASD may be able to fixate typically and attend the important information presented within the images. Speer *et al.* (2007) also found that dynamic scenes which presented social interactions were significantly correlated with a social responsiveness score. When social ability decreased so did fixation duration to the eye area. This may also highlight how presenting social scenes impacts on the attention allocation in children with ASD.

The findings in the present study also did not support the prediction that lower functioning children would fixate longer on the object AOIs similar to Klin *et al.* (2002). This difference again may be related to the type of stimuli used as Klin *et al.* (2002) presented dynamic social scenes showing real people engaged in interactions. These scenes not only presented a varying number of people but also a varying number of objects presented on the screen. The high amounts of social interaction presented in this stimulus may have caused individuals with ASD to fixate longer on the objects presented within the scenes. Individuals with severe autistic impairment may lack the motivation to attend social stimuli such as faces during social interactions and therefore instead fixate on something they are interested in such as objects. This increased preference for attending objects compared to typically developing children has been documented even in young populations with ASD (for example, Swettenham *et al.* 1998).

In order to investigate how social variations of an image impacts on gaze behaviour in children with ASD, the number of persons included in social scenes must be manipulated and presented to children with ASD alongside varying numbers of objects. Examining how they fixate on these scenes will highlight if an increased social element does affect eye gaze behaviour in populations with ASD and leads to increase fixation on objects. This issue of how social and item complexity affects attention allocation in children with ASD will be examined in Chapter 7.

The results from this experiment however are encouraging for the Picture Communication systems (such as Picture Exchange Communication and Boardmaker) since the findings seem to imply that high functioning children with ASD attend the symbols similarly to low functioning children with ASD. It is particularly important that children with severe autistic impairment are able to fixate on these symbols and not show reduced fixation which previous studies may have implied (Riby & Hancock, 2009b). Especially since it is lower functioning children with ASD who show impaired speech and communicative abilities (DSM-IV, 1994; APA, 2000) and therefore depend more on these alternative communicative strategies such as picture symbols.

5.3 General Discussion

This chapter extended the current face recognition literature by using eye-tracking technology to investigate how attention is allocated in populations with ASD when attending picture communication symbols. The evidence presented seems to imply that reduced ecological validity may reduce atypical gaze behaviour in children with ASD. Similar to typically developing counterparts the children with ASD fixated longer on face AOIs compared to the object AOIs. This is inconsistent with previous literature which found reduced face fixation and increased object fixation in adults with ASD compared to typical adults (Klin *et al.* 2002). The results in the present study may be different from Klin *et al.* (2002) findings due to the stimuli in the present study showing isolated cartoon-like figures. Klin *et al.* (2002) stimuli showed dynamic scenes with real people engaged in social interaction. Therefore reduced social element and ecological validity of the stimuli presented in this study may have caused the ASD group to fixate typically on the face area. However reduced ecological validity does not explain the inconsistencies which exist between this study and Riby and Hancock (2009b). Riby and Hancock (2009b) showed that atypical gaze behaviour still persisted in children with ASD despite the presentation of cartoon images. Riby and Hancock (2009b) images however sometimes depicted more than one person engaged in social interaction which may have caused children with ASD to fixate less on the eye and face areas compared to the typically developing groups. Therefore the results in this chapter may be inconsistent with Riby and Hancock (2009b) and show reduced atypical eye gaze behaviour in children with ASD because there is no social interaction present within these images. The reason for this high attention duration on the face areas may be caused by the stimuli in the present study only showing one person.

Children with ASD were also found in the present study to fixate on the eye area of faces similarly to typically developing counterparts showing that the eye area is not aversive to children with ASD which has previously been proposed (Hutt & Ounstead 1966). This is inconsistent with Pelphrey *et al.* (2002) who reported reduced eye area fixation in adults with ASD during emotion recognition of real faces. The results presented in the present study being different to the results reported by Pelphrey *et al.* (2002) cannot be explained due to complexity or social element of the images. Both stimulus sets presented faces showing emotional expression. The inconsistency of these results may be influenced by the children with ASD fixating on the eye area due to the reduced ecological validity of the face showing emotional expression. This may suggest that emotional expressions on the face can be attended to appropriately by populations with ASD if ecological validity is reduced.

However reduced ecological validity may not be the only factor which impacted on the typical gaze behaviour observed in the children with ASD in the present study. Research conducted by Riby and Hancock (2009b) showed that children with ASD fixated less on the eye area during images of reduced ecological validity compared to their typically developing counterparts. However Riby and Hancock (2009b) presented complex images of reduced ecological validity. This complexity included the presentation of numerous characters and detailed backgrounds. This increased detail within the images may have caused the children with ASD to fixate less on the eye regions of the cartoon-like figures and instead fixate on the background area. Therefore the typical gaze behaviour in the present study may have been caused by presenting isolated figures with reduced ecological validity. The reduction of both complexity and ecological validity may have caused the reduced atypical gaze behaviour in the present chapter. To investigate these factors further, attention to isolated real figures will be examined in Chapter 6, and complexity levels which impact on gaze behaviour in children with ASD will be investigated in Chapter 7.

The different symbol types also attracted different attention from the groups across experiments. The children were observed during one experiment to fixate longer on the PECS faces denoting hygiene behaviours compared to the BM faces. This may have been caused by the PECS images being more realistic and therefore attracting attention longer compared to the more cartoon-like BM images. However during another experiment which presented the picture symbols showing emotional expressions, the children fixated for longer on the eye and mouth areas of the less realistic BM images compared to the PECS images. This may have been due to the exaggeration of facial configurations of the BM pictures compared to the more realistic facial configurations of the PECS pictures. More exaggerated facial configurations such as a down-turned mouth or widened eyes may inform the viewer more about what emotional expression the face represents. These results imply that different levels of ecological validity impacts on how attention is allocated and maintained on images conveying different information. This suggests that specific visual information may benefit from being presented in images showing specific levels of ecological validity for example, more realistic images (PECS) may better convey hygiene behaviours and less realistic images (BM) may better convey emotional expressions. However further research is required to examine if different types of information are attended to and comprehended more efficiently when presented with different levels of ecological validity.

Findings presented here seem to be positive regarding the use of picture symbols in low functioning populations with ASD since, over half of all ASD specific schools and units in the UK claim to use picture communication systems to enhance pupils' communication skills (National Autistic Society, 2005). Based on previous research (Riby and Hancock, 2009b) it had been predicted that lower functioning children with ASD may not attend to these images as well as children with ASD who are higher functioning. However, both high functioning and low functioning children with ASD were attending to the object and face areas similarly. There were also no significant correlations which may imply that level of functioning did not influence how attention was allocated to these images. If children across the spectrum are able to attend appropriately to the images then they are able to access the information these symbols attempt to portray. However the ability to then process this information and use the picture systems effectively may explain the inconsistencies of success rate in the use of picture symbols (for example, Tincani, 2004). So despite this study showing that the children with ASD allocate attention to these symbols similar to their typically developing counterparts, and therefore have the relevant information at their disposal, they may not be processing the information appropriately. More research must be conducted on the children's picture communication aids to examine what processing stage may affect the comprehension of these symbols.

Therefore this chapter has presented experiments which found evidence of typical eye gaze behaviour in children with ASD. The children were able to allocate attention to faces and eye areas similar to typically developing children. There are many inconsistencies between this study and other studies which have reported atypical fixation on eye areas and faces (Klin *et al.* 2002; Riby & Hancock, 2009b). These discrepancies may be caused by stimuli used in the previous studies presenting social situations or reduced ecological validity. The following chapters will examine factors which may further influence attention allocation in children with ASD. Chapter 6 will present isolated familiar and unfamiliar persons alongside the child's own image to examine if familiarity reduces atypical eye gaze behaviour across the autism spectrum. Chapter 7 will investigate how social and item complexity affects attention allocation in children with ASD. Each chapter will focus on how varying factors such as complexity and familiarity impacts on how children with ASD attend to faces for communicative cues. Any results which show how atypical gaze behaviour can be reduced across the autistic population can have huge implications for the use of communicative images and how learning environments are managed.

Limitations and Future Directions

Future research is needed to highlight if the typical gaze behaviour reported in this chapter is influenced by the reduction of ecological validity or social influence. Studies must be conducted using cartoon-like figures of varying ecological validity and presenting them either engaged in social interaction or isolated. This would highlight what factors influence what gaze behaviours in children with ASD. Any significant results could have wide implications on how communicative visual aids such as BM and PECS are designed and presented. It was not highlighted by the present study if the typical allocation of attention was related to increased comprehension of the images and what they represent. Therefore future studies could involve a comprehension task asking the children what the images show or what emotions are presented to examine if there are any correlations between specific gaze behaviours and comprehending what the images show.

Chapter 6 – The Effect of Familiarity and Attention to Faces

6.1 Introduction

The main aim of this thesis is to use eye-tracking methods to explore attention to faces for communicative cues in ASD. Chapter 5 explored how children with ASD attended to the Picture Communication System, which presents images of reduced ecological validity. However, in many classrooms for pupils with ASD, realistic images are also used (alongside these cartoon-like images) to convey information. For example, in a school for pupils with ASD included in this chapter, these real pictures show teachers, care-workers and the children and are used to denote the child's work space or allocated care-worker for that day. As previously mentioned in Chapter 3, children across the autism spectrum attend to faces atypically, however, up to this point in the current thesis we do not know whether they attend to familiar faces in a typical / atypical style and whether they are attended to in the same way as unfamiliar faces. Furthermore, we ask for the first time how images of the child's own face are attended to (the 'self' category). Therefore, this chapter will explore how gaze patterns are affected by the familiarity of an image (personally unfamiliar, personally familiar and the self image).

As mentioned in Chapter 3, there are atypicalities in the ability of individuals with ASD to identify faces (for example, Deruelle, *et al.* 2004) which may imply that recognition of a face may be difficult for individuals with ASD. Using eye-tracking we will explore how children with ASD attend to familiar and unfamiliar faces alongside images of themselves. We are interested in two key issues. i) Any atypicalities of gaze behaviour / patterns when individuals with ASD attend to faces across the three categories of familiarity compared to typically developing individuals and ii) the effect of gaze direction (direct / averted) in relation to these familiarity categories. For example, faces with eye gaze directed towards a viewer (direct gaze) have been suggested to cause heightened arousal and anxiety for individuals with ASD (for example, Hutt & Ounstead, 1966). In such cases we might predict reduced attention to the eyes by individuals with an ASD (for example, as reported in various studies Klin *et al.* 2002; Perlphrey *et al.* 2002). However, we do not know if this 'aversion' to direct eye contact remains for faces that are personally familiar to the individual with ASD.

While previous research has examined the role of familiarity in attention patterns to faces, there is a lack of existing literature comparing attention to self images versus faces of different levels of familiarity using eye tracking methods. Recent neurological studies show that a persons' own face is processed by specific neural networks (for example, Uddin, Kaplan, Molnar-Szakacs, Zaidel & Iacoboni, 2005). This may have implications for how a familiar face is attended to compared to a self face. Attention allocation to self faces may highlight the development of self concept in children of typical development alongside children with ASD; for example, the latter are proposed to have an impaired concept of 'self' linked to impaired theory of mind (Frith & Happé, 1994).

6.1.1 Processing Familiar and Unfamiliar Faces.

Adult Literature

Faces portray many communicative cues. One of the first cues to be processed is the identity of the face (for example, Haxby *et al.* 2000). Judging familiarity allows us to decide whether to engage in, or avoid, an interaction. Therefore, categorising the familiarity of a face is crucial to our social interactions. There is much evidence that suggests there are differences in the way that familiar and unfamiliar faces are processed (Hole & Bourne, 2010). Familiar faces have been proposed to be over-learned especially personal familiar faces which have been attended to for long periods of time, at different angles showing various facial expressions. This over-learning causes a highly flexible representation of that face to be formed within our mind (Tong & Nakayama, 1999). Once this internal representation has been established, familiar faces can be recognised quickly even from low quality images (Burton, Wilson, Cowan & Bruce, 1999) or when they have been adapted slightly such as the addition of facial hair (Carbon, 2008). Unfamiliar face recognition however does not have a robust representation in the beholders' mind (due to lack of experience with the face) and as a consequence unfamiliar face recognition has been reported to be extremely error –prone (for a review see Hancock, Bruce & Burton, 2000).

The proposal that familiar faces have a robust mental representation has been supported by neurological studies which show the brain reacts differently to faces of varying degrees of familiarity. As proposed in the previous chapter (see Chapter 3 – Face Perception) the fusiform gyrus or fusiform face area (FFA; Kanwisher *et al.* 1997) responds to faces more than any other class of stimulus (Haxby, *et al.*, 1994; Kanwisher *et al.* 1997). The fusiform gyrus has also been proposed to be involved in discriminating between familiar and unfamiliar faces, (Henson, Shallice & Dolan, 2000; Rossion, Caldara, Seghier, Schuller, Lazeyras & Mayer, 2003). The right fusiform area has been reported to be more sensitive to repetitions of familiar faces compared to repetitions of unfamiliar faces, which also supports the implication of a more robust cortical representation for familiar faces within the brain's neural networks (Eger, Schweinberger, Dolan & Henson, 2005).

When we encounter a face for the first time or have only encountered the face a few times, there is a reliance on the face's external features for recognition, such as the hair.

However, with increasing familiarity with a face this reliance shifts to processing of internal features (Buttle & Raymond, 2003; Nachson, Moscovitch, & Umiltá, 1995; Young, Hay, McWeeny, Flude, & Ellis, 1985). The reason why processing strategies change with increased familiarity may be influenced by the benefits of efficient processing of familiar and in particular highly familiar face stimuli (for example, Ellis, Shepherd & Davies,1979). Tong and Nakayama (1999) suggest that familiar faces require less cognitive and attentional resources to process and that familiar faces are processed faster than unfamiliar faces, aiding social encounters and encoding more communicative cues. The reliance on internal features for quick processing of familiar faces may be influenced by the many encounters we have with familiar faces in various settings. During these encounters external features may change such as hairstyle or hair colour. We therefore pay more attention to the internal features as these remain constant during these social encounters. Due to the attention shifted to the internal features it has been proposed that the mechanism for faster and more efficient encoding is due to the internal features being configurally processed. Campbell, Walker and Baron-Cohen (1995) proposed that this internal processing requires a "finer grain of spatial resolution" (Campbell *et al.* 1995) and that the ability to encode faces using this finer spatial resolution develops with age and experience with faces.

Buttle and Raymond (2003) demonstrated that changes to faces were detected faster when the faces involved were highly familiar face (such as a famous face). In a typical adult population (n = 47) they conducted a change detection task where Face pairs (which included variations of unfamiliar and familiar faces) were presented on a screen followed by a scrambled face mask when the face pair appeared again one face was changed to a different face of the same gender and the other face remained the same. Participants had to detect which face had changed and where this change was located (left or right visual field). Participants were shown to detect changes better when the faces changed were familiar (famous). However this reported higher accuracy of familiar face changes was reduced when the faces were inverted (disrupting configural processing), suggesting that the participants relied on configural information (i.e. the relationship between the inner parts) of a face to process and recognise familiar faces. This reliance on internal features for familiar face recognition is consistent with previous research (for example, Clutterbuck & Johnston 2002; Young *et al.* 1985).

Particularly relevant to the current chapter, is a recent eye-tracking study which showed qualitative differences in face scanning dependant on face familiarity for typical adults. Heisz and Shore (2008) conducted an eye-tracking experiment where faces were repeatedly exposed to a group of adult females (n = 11) until the faces became ‘familiar’. They found that scanning patterns changed as a function of familiarity. Fixation count on the face decreased during increased exposure which the authors proposed indicated fewer fixations are needed for identification of a familiar face. It was also reported that when faces became more familiar these fewer fixations were allocated to the eye area and less fixations were made on the nose, mouth and cheek regions. Therefore when faces are unfamiliar many more areas of the face are explored and attended to. Regardless of familiarity it was found that the eye region was viewed for longest and more often due to the social significance of this area during interactions. The findings reported by Heisz and Shore (2008) imply that the familiar and highly familiar ‘self’ faces shown in the present study may be attended to differently compared to the unfamiliar faces. We may therefore predict that the children in this study will fixate more often across more areas of interest on unfamiliar faces and fewer fixations will be made on familiar faces.

Developmental literature

From as young as 12 hours to 4 days old a neonate shows a preference to look at their mother's face compared to a strangers face (for example, Bushnell, Sai & Mullin, 1989; Pascalis, de Schonen, Morton, Deruelle & Fabre-Grenet, 1995; Walton, Bower & Bower, 1992). This suggests an early preference for familiar faces and those of the primary caregiver. This preference may be intrinsic to the child's socio-emotional development.

An example of these changes can be observed in a study by (Carver, *et al.*, 2003). Brain activity of young infants when looking at familiar (mother's faces) and the faces of strangers were examined and recorded. Three groups of infants (n = 14 in each group) at different ages and therefore differing stages of development; 1)18 - 24 month olds, 2) 24 – 45 month olds and 3) 45 – 54 month olds, were presented with faces of a familiar person (mother) and a stranger while their brain electrical activity was recorded (ERPs). Children's responses to familiar and unfamiliar faces varied as a function of age. The younger group of children showed greater amplitude in ERP responses of the Nc (associated with attention to salient stimuli and recognition memory) and P400 Components (related to face processing) to their mother's face compared to stranger's face. This was unlike the older infant group (45 – 54 months) who showed greater Nc and P400 amplitude during the presentation of the stranger's face. The authors proposed that this difference in activity may be linked to how the infants are allocating attentional resources during their socio-emotional development. For example, they propose that the younger children's brain is more active when looking at their main caregiver because they must learn all they can about this important face, which will be conducive in socio-cognitive development for example, augmenting relationships, social referencing and gaze following. This greater ERP amplitude may also be related to the importance of the mother's face and the formation of the early attachment relationship between the main caregiver and child. During this time the child may often experience anxiety on being separated from their main caregiver. Despite the mother's face continuing to be an important stimulus, by 4 years of age children are forming relationships outside the main caregiver relationship (i.e. school friends and teachers). Therefore change in ERP may reflect these different stages of attachment. At 4 years old the children will have established all they need about the main caregiver's face and their stage of socio-emotional development now relies on learning more about their environment. Therefore, different socio-emotional needs may imply how attention is allocated to stranger and familiar faces. This may have important implications for populations with impaired socio-emotional development, impaired attachments or those lacking an intrinsic interest in faces. This could result in atypical attention allocation, and the delayed reaching of important developmental milestones.

The time course of development in children may not only influence the allocation of attention to familiar and unfamiliar faces but also the processing styles adopted for each. It was first proposed by theorists that children process both familiar and unfamiliar faces similarly by relying on the external features (Hole & Bourne, 2010). This is unlike adult processing styles which show an internal bias for only familiar faces (for example, Bruce, *et al.*, 1999; Young *et al.* 1985). Then at around 7 years of age there is a qualitative switch which takes place during development, when internal face parts are relied on to a greater extent than external face parts in the recognition of familiar faces, (Bonner & Burton, 2004). However the exact age this 'switch' is proposed to take place is very controversial with some researchers proposing the shift to take place at an older age of 10-11 years old (Campbell & Tuck 1995) other authors proposing this shift takes place at a much younger such as 4 years old (i.e. Ge *et al.,* 2008).

The age at which reliance on external features is replaced with an internal features bias was investigated by Bonner and Burton (2004). Children aged 7 to 8 years old (n = 46) and 10 to 11 year old (n = 38) children. They were given a face matching task of personally familiar peers (i.e. Fellow classmates) and unfamiliar (school children from another school). With familiar faces both age groups were more accurate at matching faces by their internal features and unfamiliar faces with external features showing that reliance on internal features for familiar face recognition is present in children as young as 7 years old. There were improvements in recognising familiar faces as children got older as there were differences between the 2 age groups with the 7 to 8 year olds could only recognise 52% of their classmates using internal features and 10 to 11 year olds were able to recognise 77%.

However this internal feature bias during familiar face recognition may occur earlier in development than first proposed by Bonner & Burton (2004). Wilson, Blades and Pascalis (2007) also looked at developmental trends however this time in face recognition and not face matching. They found that all groups (5-6, 7-8, and 10-11) were more accurate with identifying personally familiar adult faces with internal features. Showing that even in children as young as five years old the internal feature advantage for familiar faces is manifested. However, this is not the case for unfamiliar faces, which are recognised better by their outer face parts throughout development into adulthood (Hancock, Bruce, & Burton, 2000; Want, Pascalis, Coleman & Blades, 2003). The varying results reported in face processing studies may be due to methodological issues such as cropping or blurring of stimuli, differences in actual size of the face area shown or differences in experimental procedures used such as face matching paradigms compared to face recognition tasks. However, despite these variations no research has reported internal features being most useful for recognising unfamiliar faces, showing that an internal feature advantage is only observed for familiar faces.

Therefore, behavioural data suggests that we adopt different strategies for familiar and unfamiliar faces, certainly from late childhood and into adulthood and perhaps younger (for example, Ge *et al*. 2008). The next section will consider behavioural data for individuals with ASD.

ASD literature

Recently, researchers have been investigating the processing strategies for familiar and unfamiliar faces adopted by individuals with ASD in comparison to their typically developing counterparts. Atypical attention towards faces has been reported particularly, a lack of attention to the eye area (for example, Riby & Hancock 2009a, 2009b; Tinbergen & Tinbergen, 1972). However, the role familiarity in any atypicality of attention to faces has only recently attracted attention.

Langdell (1978) was the first researcher to examine familiar face processing by children with ASD. He split a sample of children diagnosed with ASD (n = 20) into two groups, younger children with ASD (n = 10; mean age = 9.8 years) and older children with ASD (n = 10; mean age = 14.1 years). Each ASD group was matched to two groups of typically developing children, one group based on chronological age (CA) and the other typically developing group matched on mental ability (MA). Two groups of children with atypical development were also recruited to match the participants with ASD based on both CA and MA. All participants were shown 10 photographs of faces (9 showing familiar peers and 1 showing the child themselves).

The child was asked to identify the faces that were presented with different areas of the face masked. Faces were masked to either show the upper features, lower features, isolated features and the whole face presented upright and inverted. The younger children with ASD showed significantly higher accuracy of recognising familiar peers based on the lower facial features compared to the matched typical and atypical groups of children. The older children with ASD showed similar ability compared to younger children with ASD to recognise faces based on lower face and similar performance compared to the control groups for accurate recognition based on upper face parts. This implied that the older ASD group were able to recognise a face equally well based on upper regions and lower regions of the faces. These results may suggest that processing style changes in children with ASD as they get older.

Wilson *et al.* (2007) conducted a face recognition task involving children with ASD (n = 17, mean age = 8.6yrs) being asked to recognise a familiar staff member based on whole, inner and outer face parts. The ASD group showed the same pattern of performance compared to their typically developing matched group. Familiar faces were recognised with the typical inner face part bias compared to outer face parts. Showing evidence that typical face processing strategies may be present during familiar face perception within a population with ASD.

Evidence from the Wilson *et al.* (2007) study therefore suggests that children with ASD may show the typical internal bias when recognising familiar faces. Unfamiliar face recognition was investigated by Rondan, Gepner and Deruelle (2003), who asked children with ASD (n = 14, m = 10.1 yrs) to match unfamiliar faces based on outer features (hairline, ears and chin) and inner face parts (eye, nose and mouth). The typically developing groups matched by chronological age and verbal mental age, showed the typical advantage when matching unfamiliar faces using outer face parts.

However, the group with ASD did not show any difference in matching abilities between the outer and inner face parts. This seems to show that despite evidence that a typical processing bias may be applied during familiar face perception (Wilson *et al.* 2007) the external parts bias for unfamiliar face matching is atypical (Rondan *et al.* 2003). This may imply that children with ASD do not adopt the different strategies that are typical for processing familiar and unfamiliar faces. Children with ASD may use the same internal processing styles for recognising both familiar and unfamiliar faces. Unlike typically developing children who would use inner face parts when recognising familiar faces and an outer face parts bias when processing unfamiliar faces.

As proposed previously eye-tracking can be used alongside behavioural studies to allow us to make inferences about the underlying cognitive processes involved in face perception (Karatekin, 2007). One such eye-tracking study examined eye gaze behaviour whilst high functioning adults with ASD (n = 17) attended to familiar and unfamiliar faces (Sterling *et al*. 2008). The high functioning adults with ASD (n = 17) and typically developed adults that were matched based on chronological age and IQ, were allowed to spontaneously attend to images of both familiar and unfamiliar faces. Both ASD and typical groups looked longer and fixated more on the eyes and mouth of unfamiliar faces compared to familiar faces which may imply a visual strategy used to identify faces. Across all stimulus types the group with ASD fixated for less time on the eye area compared to their typical counterparts, showing that atypical attention to the eye area persisted across familiar and unfamiliar faces.

Recently more research has been examining a person's own face and it has been proposed that no face is more familiar than a person's own self-image (Tong &Nakayama, 1999). To the authors knowledge there is no existing eye-tracking literature which examines children with ASD looking at familiar and unfamiliar faces in relation to self-faces. Self recognition is proposed to be an important milestone in achieving a meta-representation of self (Butterworth, 1992). Self cognition and awareness is linked to the theory of others, as you apply self knowledge to the understanding of other people during social interactions (Carruthers and Smith, 1996).

6.1.2 How the self may relate to the processing of other faces

Much research has investigated how self concept develops and is involved in social cognition. This chapter is interested in how attention to self faces compares to personally familiar and unfamiliar 'other' faces. How we allocate attention to our own faces may be linked to our self awareness or concept of self . Self recognition and how we attend to our own reflection is proposed to be the first milestone of self awareness (Lewis, 1995). Therefore attending to self faces may aid development of self awareness and gaining understanding of others. How our own face is attended to compared to the faces of others will be investigated in both typical populations and atypical populations.

Adult Literature

"I know that I exist, the question is, what is this 'I' that I know?" Descartes (1641/1985).

All human beings possess a concept of self (Keenan, Wheeler, Gallup & Pascual-Leone, 2000). A fully developed self concept or meta-representation is known as the idea of "me" or one's own mental state. This involves the knowledge of the recursive relation "I know that I know" (Lewis & Ramsay, 2004), and is different from the "I know" relation which is present in younger ages (Lewis, 1995). The basic self concept i.e. "I know", that first appears in infancy will be discussed in the next section.

The self concept established by adulthood is connected with the ability to understand and attend to others (Sanefuji & Ohgami, 2011) and is therefore deeply embedded in social behaviour and social cognition (Brewer, 1991). An example of how the self-concept may influence social cognition and understanding is the "simulation theory of mind" (Carruthers & Smith, 1996). This theory proposes that understanding others is gained from an intact self representation because representation of others is 'anchored' in our own self representation (Birch & Bloom, 2007). Using the self-other connection a person can infer and understand another's actions by drawing on their own knowledge. This theory highlights the importance of an intact self meta-representation before a functional Theory of Mind can develop (Frith & Happé, 1999). This link between the development of self and Theory of mind will be discussed in more detail in the next section.

Studies on typically developing individuals have found that attention is selectively allocated to stimuli that is highly self-descriptive and that this stimuli is processed preferentially (Bargh, 1982; Kuiper & Rogers, 1979). Our own face has been proposed to be an example of this preferential attention and processing. Our own faces seem to have a robust cognitive representation within our minds, similar to familiar faces, allowing us to recognise ourselves quickly from any angle. For example, Tong and Nakayama (1999) found that adult participants were quicker at detecting their own face when it was presented amongst unfamiliar distracter faces. This own face advantage continued even when participants face were presented in novel angles and views. There is mounting evidence that the capacity for self-recognition is distinct from familiar face recognition. This distinction is highlighted by neurological studies showing brain networks specifically involved in own-face processing are independent from familiar face processing networks (Keenen *et al.* 2000; Uddin *et al.* 2005).

For example, Platek, *et al* (2006) presented participants (n = 12, mean age = 19.36 yrs) with their own face, a personally familiar face and unfamiliar face. They then examined what areas were activated for each type of face presentation. They found that during self-face presentation activation was observed in the right superior frontal gyrus, inferior parietal lobes, left middle temporal gyrus and medial frontal lobes. The latter has also been found to be active during Theory of Mind tasks (i.e. Fletcher, *et al* 1995; Gallagher, *et al.*, 2000) again supporting a link between self representation and the theory of others. However, a consensus regarding the specific neural substrates of self-face recognition has not yet been achieved, and is still under much debate and ongoing investigation.

Therefore, self information may be processed and attended to preferentially. This self interest and how it contributes to a developing self concept will be examined in the next section.

Developmental literature

Some areas of self development, specifically the important ability of self recognition, occur during the first year of life (see Butterworth, 1992; Lewis, 1995). A way to test self-recognition is to conduct the mirror self-recognition task. The mirror self-recognition task was devised by Gallup (1970) to test self-awareness in chimpanzees. It involves covertly marking a child's face with a spot of rouge and then presenting them with a mirror. An intact representation of self is ascribed to any child who touches the rouge upon seeing their reflection. Typically developing children pass this task at approximately 18 months of age (Anderson, 1983; Courage, Edison, & Howe, 2004; Lewis & Ramsey, 2004.) A self meta-representation (a more robust mental idea of "me") is proposed to emerge when the child is around 2.5 years old

(Lewis, 1992; Lewis & Brooks-Gunn, 1979). The self meta-representation that develops in children includes the ability to empathise with others (Bischof-Kohler 1994), alongside high self-awareness and self-reflective emotions (Lewis, Sullivan, Stranger & Weiss, 1989). This is interesting as these abilities have also been linked to Theory of Mind (for example Heerey *et al.* 2003) supporting the notion that a self representation in children may be a developmental milestone for Theory of Mind (Carruthers & Smith, 1996). See Chapter 2 for more details of Theory of mind milestones during development.

Lewis and Ramsay (2004) also found within a sample of typically developing children (n = 66) that pretend play and personal pronoun use are abilities which stem from a self meta-representation. This is because Pretend play is proposed to involve an ability to understand both others and one's own mental states (Piaget, 1951/1962) and the successful use of personal pronouns need an understanding of "me" and "you" (Hobson, 1990). It was found that these behaviours were fully manifested when the children were around 2 years old.

Again children have been shown, similar to adults (for example, Devue, Laloyaux, Feyers, Theeuwes & Bredart, 2009), to allocate a lot of attention to their own face. Sanefuji and Ohgami (2011) showed typically developing children (n= 16, mean age = 4.6 years) their own image alongside images of other similar aged peers. The typically developing children showed preferential attention to their own image and attended to their own face for a longer period of time compared to the screen which presented an unknown peer.

Also noted from several studies is as typically developing children get older they show more self-conscious behaviours when they perceive their own face (for example, Lewis *et al.* 1989; Sanefuji & Ohgami, 2011). This again further supports the notion that as the self-concept develops, a deeper understanding of other's also emerges i.e. a theory of mind- (Frith & Happé, 1999). Possessing a Theory of Mind allows us to understand that others will have evaluations and opinions of us (Tager-Flusberg, 1999), which causes self-conscious emotions to manifest such as embarrassment and shame (for example, Heerey *et al.* 2003).

This section presented evidence that some socio-cognitive ability is anchored in a developing self concept. This may imply that individuals with ASD who show socio-communicative impairments may have a delayed self awareness. This will be explored in the next section.

ASD Literature

As proposed earlier, the self is connected with the ability to understand and attend to others (Sanefuji & Ohgami, 2011). Individuals with ASD may be unable to reflect on their own mental states as well as make judgements of others leading to the social impairments observed in the spectrum (Frith & Happé,1999). Using the self-other connection a person can infer and understand another's actions by drawing on their own knowledge. Impairments in self referential processing has led to researchers proposing an 'absent-self' hypothesis (Frith & Happé, 1999; Frith, 2003) which may be related to the impaired theory of mind often reported in ASD (for example, Baron-Cohen, *et al.* 1999; Leekam & Perner, 1991). The absent-self theory proposes that a higher order of self-awareness may be impaired in ASD and not actually completely absent as the term would suggest.

A simple concept of self may exist in children with ASD as they have been shown to achieve mirror self-recognition at a mental age of 18 months (for example, Dawson &

Mckissick 1984; Neuman & Hill 1978; Spiker & Ricks 1984) similar to their typically developing counterparts. Mainly the child's verbal ability was seen as intrinsic to the development of self recognition, as Spiker and Ricks (1984) found that communicative abilities in children with ASD affected their performance in the mirror self-recognition task. Those with impaired verbal ability showed less self recognition. Despite evidence of self recognition, children with ASD show an impaired ability to use personal pronouns to differentiate between themselves and others (for example, Lee, Hobson & Chiat 1994). Also, criteria according to the DSM IV for diagnosing an ASD is impaired pretend play. So if personal pronoun use, and pretend play are all intrinsic to the development of a meta-representation of the self (Lewis & Ramsay 2004) this would imply a more complex self concept is delayed or impaired in ASD.

Possessing a self meta-representation also includes the ability to empathise with others (Bischof-Kohler 1994) and understanding self-reflective emotions (Lewis, *et al.* 1989). This may explain the impaired reflecting ability with their own false beliefs (Baron-Cohen, 1989a) and the high presence of alexithymia (Bird *et al.* 2010; Fitzgerald, Angstadt, Jelsone, Nathan & Phan, 2006; Silani, *et al.,* 2008) in individuals with ASD. Lombardo, Chakrabarti, Bullmore, Sadek, and Pasco (2010) also found that during mentalizing tasks based on the 'self' or the Queen, areas of the brain were not typically activated in adults with ASD. There were specific disruptions in the neural networks involved in the processing of self-information. The middle cingulate cortex that is typically involved in self processing (for example, Moran, Macrae, Heatherton, Wyland & Kelley, 2006) responds more to the mentalizing of others in ASD. The areas involved in activating during 'other' information processing were similar in both ASD and controls. The deficit was specific in the neural networks which are preferentially activated during self information processing, supporting the absent-self theory in ASD.

However simple face recognition studies have shown that not all self processing atypically activates the brain in ASD. Uddin, *et al.*, (2008) conducted an fMRI study on children with ASD while they were exposed to their own face morphing into a gender-matched face of another. The children were found to activate the right Inferior Frontal Gyrus less than typically developing children during the viewing of other people's faces, however when viewing morphs containing more of their own faces this area was activated similarly in both groups. Showing that the children with ASD were able to perceive their own face similarly to TD children.

How children with ASD look and attend to their own faces in comparison to others was investigated by Sanefuji & Ohgami (2011). Children with ASD (n = 16) mean age 4.6 years, were exposed to a set of monitors where one displayed an image of the child's own face and another which displayed a peer's face (peers' faces were controlled so they were the same age as the participant). Children with ASD showed preferential looking at their own image compared to peers. This implies that children with ASD are able to recognise their own image and that their own face captures their attention. Therefore the other self-referential difficulties observed across the autism spectrum may lie in the higher level cognitive meta-representations of the self. This study however does not detail how attention was allocated to the self face by both atypical and typical populations. Atypical scanning of the faces and lack of attention to social cues from their own face may be related to the impaired self reflective skills observed across ASD (Frith & Happé, 1999).

6.2 Experiments 4, & 5

The following experiments investigated how familiar, unfamiliar and self-faces were attended to using eye-tracking methodology. Experiment 4 investigated attention to averted and direct gaze according to familiarity (familiar, unfamiliar and self-face) and group (ASD, CA, VA & NVA). How children with ASD attended to these faces compared to typically developing children matched on; verbal mental ability (VA), visuo-spatial ability or Non-verbal Ability (NVA) and chronological age (CA) was investigated. Experiment 5 examined levels of functioning within the ASD population and how this affected attention to faces with differing familiarity.

6.2.1 Experiment 4

This experiment will examine attention to averted and direct gaze according to familiarity and group membership. Previous research has reported atypical attention to faces specifically the eye area in ASD populations (for example, Klin *et al.* 2002; Langdell, 1978). It has been proposed that the eye region causes anxiety and arousal in ASD (Hutt & Ounstead, 1966) and the atypical attention allocated to the eye region in ASD is used as an arousal management strategy (Hutt & Ounstead, 1966; Richer & Coss, 1976; Spezio, Adolphs & Hurley, 2006). Real images observed by the researcher across the ASD schools showed children and staff with direct and averted gaze. Direct eye gaze may heighten arousal in children with ASD (Hutt & Ountead, 1966) causing the children to attend to these images atypically. It is therefore predicted that atypical attention will be increased during gaze directed conditions due to the heightened arousal caused by direct gaze in ASD.

This experiment extends the current face recognition literature by using eye-tracking technology to investigate how attention is allocated in typical and atypical populations when looking at faces of varying familiarity including their own faces. It was predicted that the participants with ASD would look less at the eye AOI regardless of face type (familiar, unfamiliar or self). This prediction is based on previous research which found atypical attention to the eye area during viewing of both unfamiliar (for example, Klin *et al.* 2002; Riby & Hancock, 2008) and familiar faces (Sterling *et al.* 2008). It was further predicted that this atypical attention to faces will persist regardless of familiarity in the ASD group compared to their typically developing counterparts. It was proposed that this impaired attention to the eye area would also be present during exposure to the child's self image due to the evidence of impaired self-referential ability observed across the Autism spectrum (Lewis *et al.* 1989; Bird *et al.* 2010). Previous findings showed increased gazing on this region by individuals with ASD (Klin *et al.* 2002), therefore it was predicted that the ASD group would fixate for longer on the mouth AOIs compared to the eye AOIs. Research has also reported that populations with ASD show reduced fixation to unfamiliar faces (Klin *et al* 2002; Pelphrey *et al* 2002; Riby & Hancock 2008). This may be caused by unfamiliar faces being more arousing to children with ASD (Hutt & Ounstead 1966) unlike familiar and self faces which they encounter daily. Therefore it was proposed that children with ASD would fixate less on unfamiliar faces compared to familiar and self faces.

Method

Participants

Twenty one children with ASD were recruited from special units attached to three mainstream schools, and one specialist ASD school (see Table 6.1). Participants ranged between 9 years 7 months and 16 years 5 months (mean = 13 years 7 months; SD = 2 years 5 months). Verbal ability age was assessed using the British Picture

Vocabulary Scale, second edition (BPVS II - Dunn, Dunn, Whetton, and Burley, 1997) and provided a mean verbal mental age (VA) for the group of 7 years 3 months (ranging from 3 years 7 months to 15 years 2 months). Non-verbal ability was assessed by the Raven's Coloured Progressive Matrices (RCPM – Raven, Court & Raven, 1990) giving a mean score of 27 (ranging from 11 to 35; max score possible 36). All these participants with ASD had taken part also in the experiments detailed in Chapter 5. It was ensured that all children had studied at their schools for at least one year so they were all familiar with the staff.

Table 6.1

Participant details for children with ASD and their typically developing comparison groups

Group	N	Gender Ratio males:females	CA[vii]	VA[viii]	NVA[ix]
ASD	21	20:1	13y 7m (30)	74 (27)	27 (7)
CA	21	15:6	13y 6m (24)	113 (19)	32 (6)
VA	21	14:7	8y 4m (28)	75 (23)	22 (7)
NVA	21	18:3	10y 4m (24)	98 (22)	27 (5)

vii Chronological age provided in years and full months. Standard deviation provided in full months in parenthesis.
viii Verbal ability is calculated using the mean raw score from the British Picture Vocabulary Scale standard deviation in parenthesis.
ix Nonverbal ability is provided as mean scores on the Ravens Coloured Progressive Matrices task (max. score 36) standard deviation in parenthesis.

All participants had previously been diagnosed by clinicians as being on the Autistic spectrum. The Childhood Autism Rating Scale (CARS; Schopler, Reichler, & Rocher-Renner, 1988) rated 9 children as mild-moderately autistic and 7 children as severely autistic. The remaining 5 children scored over 90 on the Asperger Syndrome Diagnostic Scale (ASDS; Myles, Bock, & Simpson, 2001). A score over 90 on this scale indicates the presence of Asperger Syndrome. The Social Communication Questionnaire (SCQ; Rutter, Bailey, Berument, Lord & Pickles, 2003) was conducted, with 19 children obtaining a score over 15 (a score of 15 or over implies the presence of ASD or PDD-NOS). The remaining two children showed a score of 13 and 11 which may imply these children have higher socio-communicative ability compared to the other children in the ASD group.

The children with ASD were matched to three typically developing comparison children using individual matching criteria. Chronological age matched group had a mean chronological age 13 years 6 months ($t(40) = .150$, $p = .96$). The VMA group was matched to the participants with ASD for verbal ability age using the BPVS II had a mean verbal mental age of 7 years 4 months ($t(40) = -.079$, $p=.973$). The group matched for nonverbal ability (Visuo-spatial ability) had a mean RCPM score of 27 ($t(40) = .090$, $p=.766$). All the typically developing groups detailed in this chapter had also taken part in Experiments 1 and 2 described in Chapter 5.

Design and Procedure

Stimuli

Pictures of a familiar adult male and female both looking directly and averting at a 90° angle (full-view and side-view) were taken for each child. This consisted of the head and shoulders of teachers, care-workers, support staff etc. An unfamiliar adult male and female (full-view and side-view) were also assigned to each child. These images were mainly selected from pictures taken as familiar for other children recruited from other schools. The child's own picture was taken in the same style again showing direct and averted face angles. Images were taken using a camera, prior to testing by the researcher. The images were based on the pictures already used in the classroom to communicate to the child their support workers and timetable. The angles of faces presented within these images varied considerably across the 4 schools (3 mainstream schools with an ASD unit and 1 residential school). The researcher observed real images in the children's timetables showing direct facing persons and other images showing only a person's profile.

Images were taken using a Panasonic camera and edited in Adobe Photoshop CS (Adobe, San Jose, California, USA) to ensure size and pixels were consistent. The size of each real image was made to 650 pixels wide x 488 pixels height, w 9.17cm x h 6.89cm.

All these pictures (n=10) were shown randomly within the same trial block. The trial block was then presented randomly alongside other trial blocks as part of a battery of eye-tracking assessments (these other trial blocks are shown in Chapter 5). Each image was presented for 3 seconds and separated with a blank screen showing a fixation point in the middle for 1 second. Participants were told 'please look at the pictures while they are on the screen', and no further instruction was provided.

Apparatus

The research used a Tobii 1750 eye-tracker (Tobii Technology, Stockholm, Sweden), using ClearView 1.5.10 (Tobii Technology) for the presentation of stimuli and recording eye movements. The eye-tracker was controlled via a Dell Inspiron 6400 (Dell, Round Rock, Texas, USA) laptop computer. The system is portable and was moved to the testing location of each individual. The system is also completely non-invasive, with no need to constrain the head or body and little indication that eye movements are tracked. The Tobii 1750 system tracks both eyes to a rated accuracy of 0.5 degrees, sampled at 50 Hz and was calibrated for each participant using a 5-point infant calibration of each eye.

ClearView 1.5.10 provides a ‘definition tool’ to identify areas of interest (AOI) for analyses. For all images, AOI were designated to eyes and mouth. AOI for the eyes and mouth were defined using rectangular definition tools to mark regions covering these features (please see Figure 6.1).

i)

ii)

iii)

Figure 6.1 An example of (i) a familiar/unfamiliar male face, (ii) a familiar/unfamiliar female face and (iii) a child's own image with areas of interest (AOI).

To ensure accuracy of gaze recordings for each AOI, a bespoke programme was designed using Matlab (Mathworks, Natick, Massachusetts, USA). This ensured calibration was consistent across all stimuli (as calibration is only checked via the Tobii software at the beginning of the trial).

Design

This study employed a mixed design with between-subject factor of Group (ASD, CA, VA, NVA) and within subject factors being Familiarity of faces (familiar, unfamiliar, self) and the AOI (eye or mouth).

Procedure

Participants were tested individually at home or at school. As well as the stimuli presented here participants viewed PECS and BM images containing cartoon-like figures (see Chapter 5). The whole session lasted 10-12 min with each trial block being presented for 2-3 min. Participants were seated approximately 50 cm from the eye-tracking screen with the experimenter sat to one side to control the computer but not interfere with viewing behaviour. The participant was told that they would see different types of pictures during the session and the first eye-tracking task involved calibration of the eye-tracker.

For this purpose, the participant followed a bouncing cat around the screen to five locations. All participants in this experiment were able to comply with task demands and be calibrated successfully so no removal of participants from the study was necessary. Following calibration, participants viewed the trial block as part of a battery of eye-tracking assessments. All trial blocks were presented in a random order to participants. Once all the conditions were complete the experimenter debriefed the participant.

Results

Fixation Duration

For fixation duration there was no overall difference in the time spent engaging in task $F(3,80) = 1.800$, $p = .154$, $MSE = 131.48$, showing that the ASD group (m = 6345.71ms MSE = 318.64) engaged in task similarly compared to their typically developing counterparts, CA (m = 7176.1ms, MSE = 203.48), VA (m = 6888.76ms, MSE = 246.02) and NVA (m = 6704.81ms, MSE = 255.67). However, because proportion of fixation time was used previously the same will be applied to the analyses in this chapter to maintain consistency.

Proportion of mean fixation time

Proportion of mean fixation time was examined to highlight which area of interest (eyes or mouth) maintained attention for longest from the children.

Table 6.2

Proportion of mean face fixation time looking at familiar unfamiliar and self, AOIs (eye & mouth) across groups

EYE AOI

	fam		unfam		self	
Group	D	A	D	A	D	A
ASD	.649 (.310)	.404 (.334)	.578 (.289)	.430 (.216)	.407 (.350)	.470 (.385)
CA	.347 (.246)	.274 (.285)	.461 (.285)	.326 (.325)	.420 (.326)	.268 (.364)
VA	.395 (.323)	.311 (.285)	.585 (.504)	.385 (.292)	.402 (.352)	.259 (.337)
NVA	.420 (.336)	.339 (.311)	.436 (.324)	.319 (.323)	.369 (.391)	.326 (.390)

MOUTH AOI

	fam		unfam		self	
Group	D	A	D	A	D	A
ASD	.092 (.133)	.123 (.217)	.078 (.096)	.034 (.093)	.122 (.235)	.064 (.227)
CA	.179 (.220)	.134 (.159)	.135 (.156)	.130 (.168)	.094 (.140)	.011 (.029)
VA	.164 (.150)	.214 (.257)	.104 (.142)	.093 (.125)	.252 (.336)	.170 (.257)
NVA	.128 (.161)	.134 (.194)	.245 (.330)	.076 (.135)	.136 (.182)	.089 (.210)

A mixed 4x3x2x2 ANOVA was carried out with between factors being Groups (ASD, CA, VA, NVA) and within subject factors being Familiarity of faces (familiar, unfamiliar, self), Gaze (direct and averted) and AOI (eye or mouth). The results and trends most relevant for investigating the hypotheses proposed at the beginning of the experiment are detailed within the chapter, for the full analysis please see Appendix D. There was a trend of Familiarity impacting on how long images were fixated on F (2,

159) = 2.359, $p = .089$, $\eta^2_p = .029$. To investigate this trend towards significance paired samples t-tests were carried out. All children fixated for significantly longer on the unfamiliar AOIs (m = .276) compared to the self AOIs (m = .243) t (83) = 2.010, $p < .05$.

All participants looked for a longer proportion of mean face fixation time at the face AOIs which were direct (m = .300) compared to the AOIs which were averted (m = .225) F (1, 80) = 31.014, $p < .001$, $\eta^2_p = .279$. This shows that the children fixated longer on a face that was direct compared to averted, this can be shown in Figure 6.2. Therefore a direct face maintains attention longer than a face turned away from the observer.

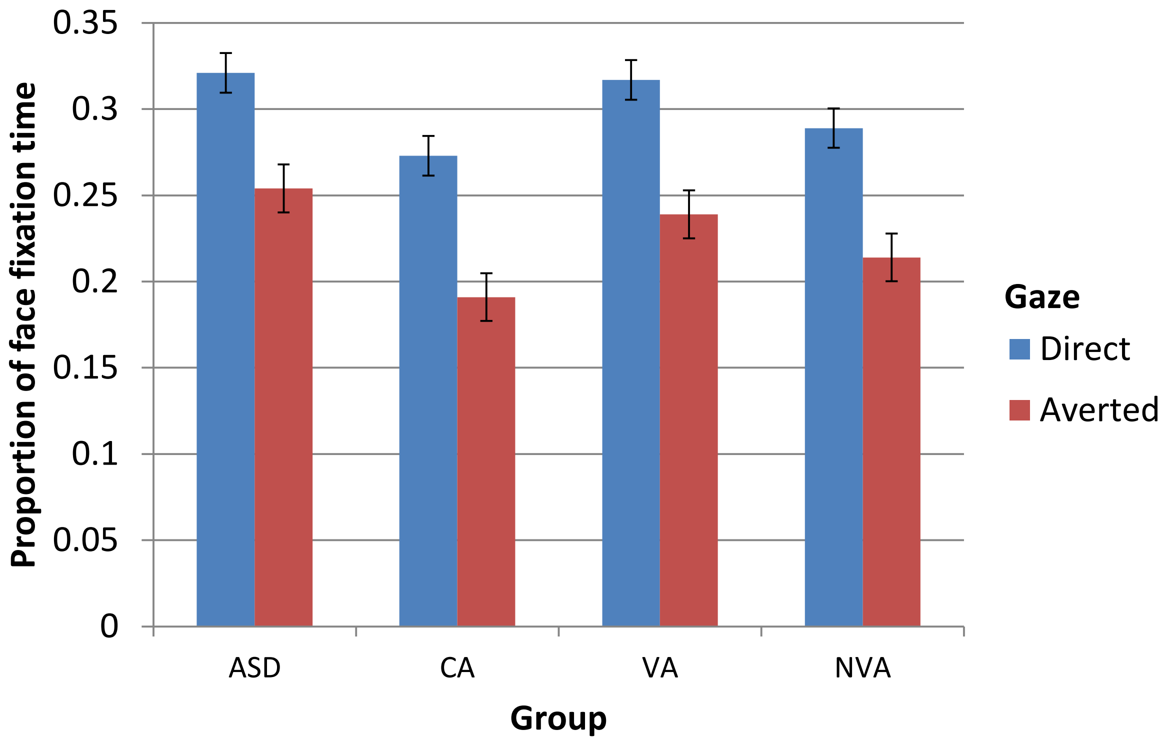


Figure 6.2 Mean face fixation for direct and averted faces across groups

The children fixated longer on the eye AOI (m = .400) compared to the mouth AOI (m = .125)F (1, 80) = 72.727, $p < .001$, $\eta^2_p = .476$. Group membership did not impact on attention allocated to AOIs showing that the ASD group fixated on the AOIs similarly compared to typically developing children $F(3,80) = 1.897$, $p = .137$, $\eta^2_p = .066$. The ASD group fixated similarly compared to typically developing groups on the faces across familiarity and gaze conditions $F(6, 148) = 1.509$, $p = .184$, $\eta^2_p = .054$.

Familiarity was observed to impact on how long the eye and mouth AOIs were fixated on $F(2, 155) = 3.288$, $p < .05$, $\eta^2_p = .039$. In order to investigate this significant interaction paired samples t-tests were carried out for each AOI (eye and mouth). There was a trend towards a significant difference between familiar eye (m = .392) and unfamiliar eye (m = .440) showing that there was a trend for groups to look longer at the unfamiliar eye compared to familiar $t(83) = 1.742$, $p = .085$. There was a significant difference between unfamiliar eye and self eye (m = .368) fixation time $t(83) = 2.396$, $p < .05$ showing that all groups fixated on the unfamiliar eye longer than the eye region of their own face. There was a trend for groups to look longer at the familiar mouth (m = .146) compared to unfamiliar mouth (m = .112) $t(83) = 1.957$, $p = .054$. This was similar for familiar mouth (m = .146) and self mouth (m = .117) where it can be observed there was a trend towards a significant difference, $t(83) = 1.682$, $p = .086$ implying that there was an overall tendency for the children to look more at the familiar mouth than the self mouth.

Group membership also impacted on how long the eye and mouth areas were fixated during Familiarity $F(6, 155) = 2.566$, $p < .05$, $\eta^2_p = .088$. To investigate this interaction one-way ANOVAs were carried out between Groups (ASD, CA, VA, NVA) for each AOI. A one-way ANOVA was carried out between the Groups for familiar eye AOI and a significant effect was observed $F(3,80) = 2.720$, $p < .05$. Post-hoc bonferroni found that there was no significant differences between any of the groups however there was a trend towards significant difference between ASD group and CA group ($p = .053$) showing the ASD group fixated longer on the familiar eye AOI compared to the CA group. No significant effects of group were found across the unfamiliar eye AOI and self eye AOI.

A one way ANOVA was carried out for self mouth AOI $F(3,80) = 2.793$, $p < .05$. Post-hoc bonferroni showed there was a significant difference between the CA group (for group means please see table above) and the VA group ($p < .05$) showing that the CA group looked significantly less at the self mouth AOI compared to the VA group. There was no significant effects of group were found across the unfamiliar and familiar mouth AOIs (please see Appendix D).

Gaze direction impacted on how long the AOIs were fixated on $F(1, 80) = 6.055$, $p < .05$, $\eta^2_p = .070$. Paired samples t-tests showed that the groups all fixated for a longer proportion of time on the eye AOI when gaze was direct ($m = .456$) compared to when gaze was averted ($m = .345$) $t(83) = 4.530$, $p < .001$ (see Table 6.2) again showing that the eye region attracted more attention when the eyes were directed towards the viewer. This was similar to what was found with the mouth AOI as for direct faces ($m = .144$) the mouth AOI was fixated on significantly longer than the mouth of averted faces ($m = .106$), $t(83) = 2.842$, $p < .01$ supporting the earlier results which showed that direct areas of interests were fixated on longer than regions of an averted face. Group membership did not impact on time spent fixating on eye and mouth AOIs during the familiarity and gaze conditions $F(6, 148) = 1.069$, $p = .382$, $\eta^2_p = .039$.

Time to First Fixation

Time to first fixation was examined to highlight how long the children took to fixate on the relevant areas such as eye and mouth. This would highlight the areas of faces which captured attention quicker.

A mixed 4x3x2x2 ANOVA was carried out with between factors being Groups (ASD, CA, VA, NVA) and within subject factors being Familiarity of faces (familiar, unfamiliar, self), Gaze (direct and averted) and AOI (eye or mouth). Only significant effects and trends relevant for the exploration of the thesis will be highlighted within the chapter. For full analysis see Appendix D. Familiarity impacted on time taken to fixate on the images $F(2,151) = 7.117$, $p < .001$, $\eta^2_p = .082$. To investigate this significant effect, paired samples t-tests were carried out comparing familiarity conditions. All groups fixated quicker on self AOIs (m = 495.7ms) compared to familiar AOIs, $t(83) = 2.379$, $p < .05$. The groups continued to fixate quicker on their self face AOIs compared to unfamiliar AOIs $t(83) = 3.908$, $p < .001$. Showing that their own face captured the children's attention quicker than any other face type.

Group membership impacted on time taken to fixate during the Familiarity conditions $F(6, 151) = 2.005$, $p = .073$, $\eta^2_p = .070$. To investigate this significant interaction repeated measures ANOVAs were carried out for each group to examine the effect of familiarity condition in each group. There was a significant effect of Familiarity across the CA group $F(2,37) = 5.529$, $p < .01$, $\eta^2_p = .217$. Paired samples t-tests showed that the CA group fixated significantly quicker on their own face AOIs (m = 407.31ms) compared to familiar AOIs (m = 725.8ms) $t(20) = 2.352$, $p < .05$ and compared to unfamiliar AOIs (m = 792.4ms) $t(20) = 3.663$, $p < .01$. A similar effect was observed for Familiarity in the VA group $F(2,39) = 5.514$, $p < .01$, $\eta^2_p = .216$. Paired samples t-tests showed that the VA group fixated quicker on their own face AOIs (m = 456.1ms) compared to unfamiliar face AOIs (m = 819.6ms) $t(20) = 3.503$, $p < .01$. This showed that most typically developing groups were quicker to fixate on their own images compared to any other familiarity type.

Gaze also impacted on time taken to fixate on the images, showing that time to fixate on the AOIs was significantly longer for faces when gaze was directed to the front (m = 713.8 ms) compared to the faces with averted gaze (m = 506.7 ms) $F(1,80) = 19.691$, $p < .001$, $\eta^2_p = .198$. Showing that averted faces attracted attention quicker, this can be observed in Table 6.3. This may be due to children being drawn to an averted face to examine where the face is directing attention and may be preparing to engage in gaze following.

Table 6.3

Time to first fixation on AOI according to gaze and familiarity condition (SD in parenthesis)

EYE AOI

	fam		unfam		self	
Group	D	A	D	A	D	A
ASD	655.4 (748.0)	541.3 (581.4)	383.5 (277.1)	569.0 (504.6)	700.9 (828.9)	717.1(894.6)
CA	970.6 (800.5)	423.6 (426.9)	920.6 (643.7)	708.1 (777.0)	598.1 (693.2)	400.5(630.1)
VA	593.2 (489.7)	588.5 (732.6)	540.1 (388.7)	842.1 (713.5)	608.1 (739.3)	303.5(510.4)
NVA	780.3 (619.0)	619.6 (729.3)	606.7 (469.9)	948.5 (852.5)	549.5 (671.2)	661.1(912.0)

MOUTH AOI

	fam		unfam		self	
Group	D	A	D	A	D	A
ASD	410.6 (581.6)	422.8 (619.5)	680.1 (891.3)	195.7 (515.5)	536.1 (400.1)	47.1 (54.0)
CA	937.2 (956.7)	571.7 (779.9)	1016.0 (879.7)	524.9 (689.3)	422.3 (727.6)	208.3 (138.6)
VA	839.9 (861.7)	575.5 (650.7)	1246.1 (957.1)	649.9 (939.0)	709.2 (613.3)	203.3 (285.4)
NVA	799.1 (899.0)	500.7 (771.3)	772.0 (861.0)	526.3 (908.4)	855.9 (771.9)	410.5 (904.5)

Group membership did not impact on time taken to fixate on the AOIs, showing that groups oriented to the AOIs similarly F (3,80) = 1.449, p = .235, η^2_p = .052 (see Figure 6.3). Group membership also did not impact on time taken to fixate on the faces across the Familiarity and Gaze conditions F (6, 158) = .938, p = .469, η^2_p = .034. Groups did not influence time taken to fixate on the AOIs during the Familiarity conditions F (6, 152) = .744, p = .609, η^2_p = .027.

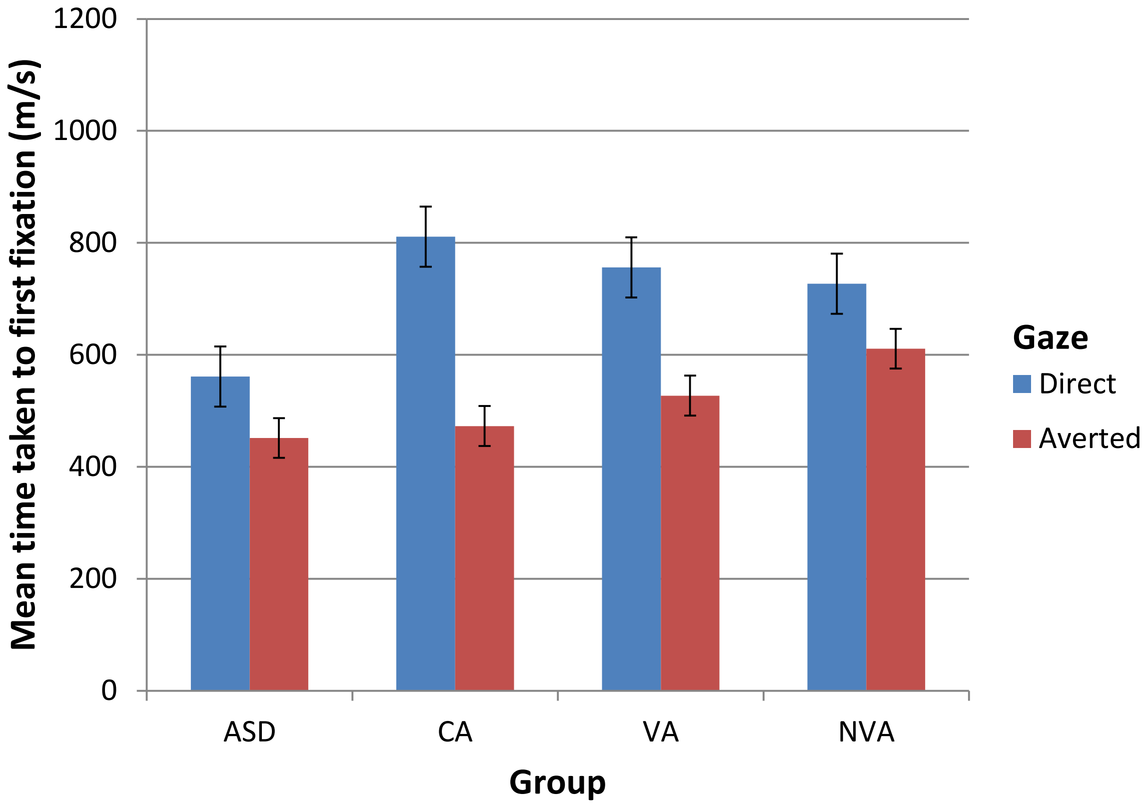


Figure 6.3 Time taken for groups to fixate on direct and averted face AOIs

Gaze impacted on time taken to fixate on the AOIs F (1,80) = 11.932, p < .001, η^2_p = .130. To investigate this interaction paired samples t-tests were carried out, showing that there was a significant difference between time taken to fixate on the mouth AOI when it was direct (m = 768.7ms) and averted (m = 403.1ms) $t(83) = 5.028$, $p < .001$ showing that the children took longer time to fixate on the mouth AOI when the gaze of the face was direct and were quicker to fixate on the mouth AOI when the face was averted. This can be observed in the Figure 6.4.

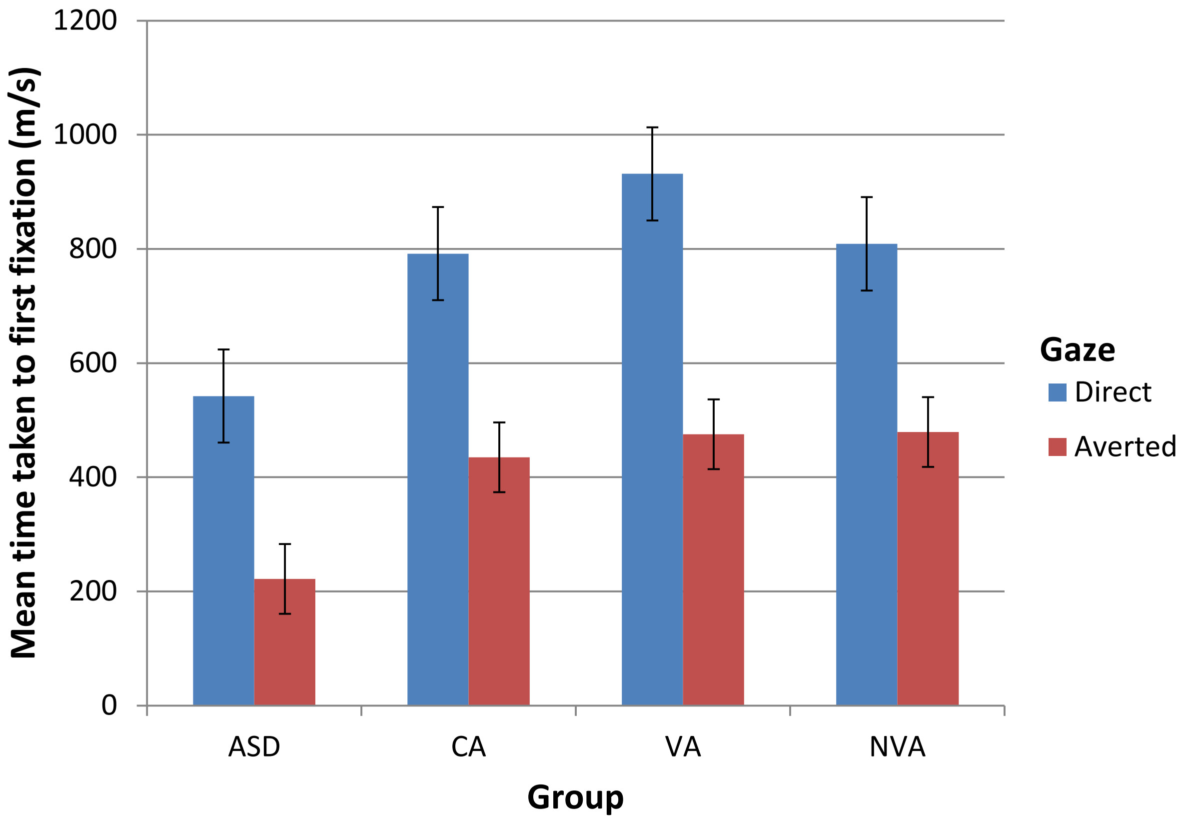


Figure 6.4 Mean time taken for groups to fixate on the mouth AOI

There was a significant interaction between Familiarity, Gaze and AOI $F(2, 158) = 3.532$, $p < .05$, $\eta^2_p = .042$. To investigate this interaction between factors paired samples t-tests were carried out for each AOI (eye and mouth) examining familiarity and gaze. There was a significant difference observed between time taken to fixate on the eye AOI of a familiar face when the face was direct (m = 749.9ms) compared to when the face was averted (m = 543.3ms), showing that the children took less time to fixate on the eye AOI when the face was averted t (83) = 2.365, $p < .05$. There was a trend towards a significant difference observed for unfamiliar faces showing there was a slightly longer time to fixate on the eye AOI when gaze was averted (m = 766.9ms) compared to when gaze was direct (m = 612.7ms), t (83) = 1.685, p = .086. Therefore Familiarity influenced how attention was allocated to the eye area during Gaze (direct & averted) conditions. For familiar faces time to fixate on eye area was less when it was averted. This may be caused by the child relying on the eye area of a familiar face for social signals for example, gaze following, social referencing. This was not observed for the unfamiliar eye area which the children fixated on quicker when it was directly facing which may be influenced by the children trying to identify the face (see Figure 6.5).

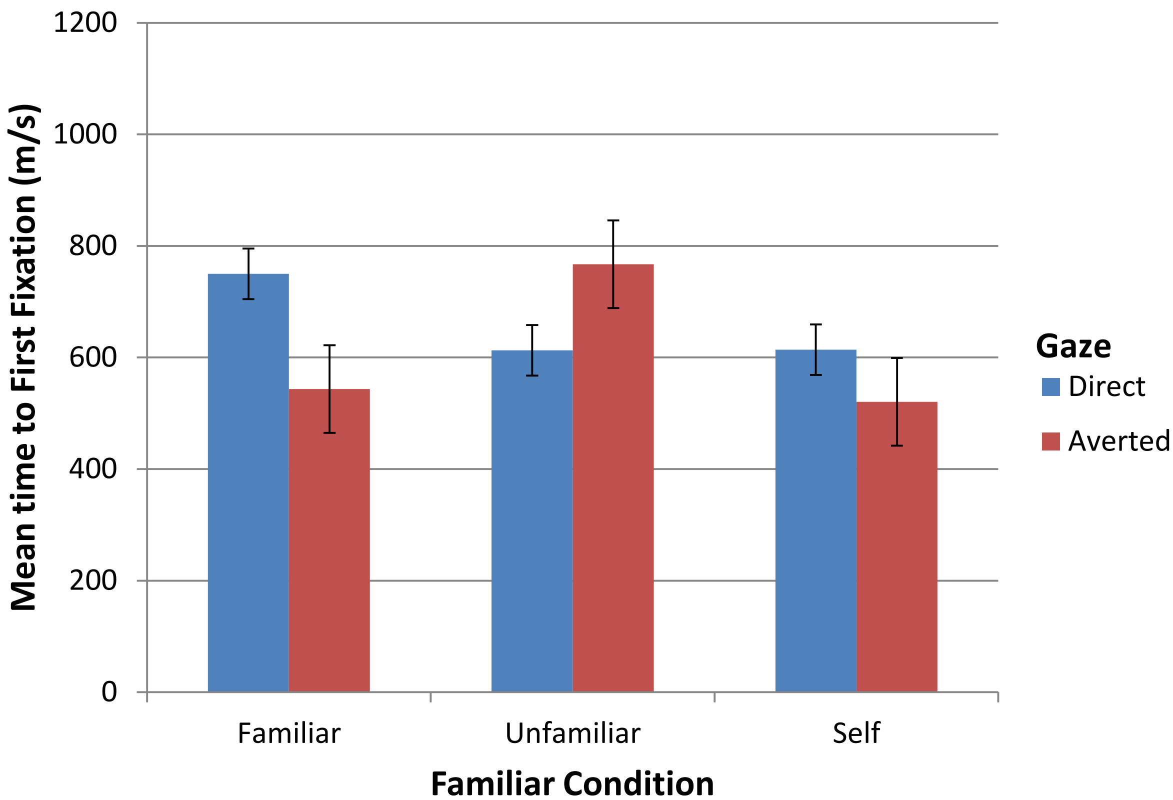


Figure 6.5 Mean time to first fixation on the eye AOI during averted and direct gaze across familiarity condition

For the mouth AOI, it was observed that the participants took longer to fixate on the mouth AOI of familiar faces which were gazing directly (m = 746.7ms) compared to when faces were averted (m = 517.7ms) t (83) = 2.099, p < .05. The mouth AOI was fixated on quicker when the face was unfamiliar and averted (m = 474.2ms) compared to when gaze was direct (928.6ms), t (83) = 3.404, p < .001.

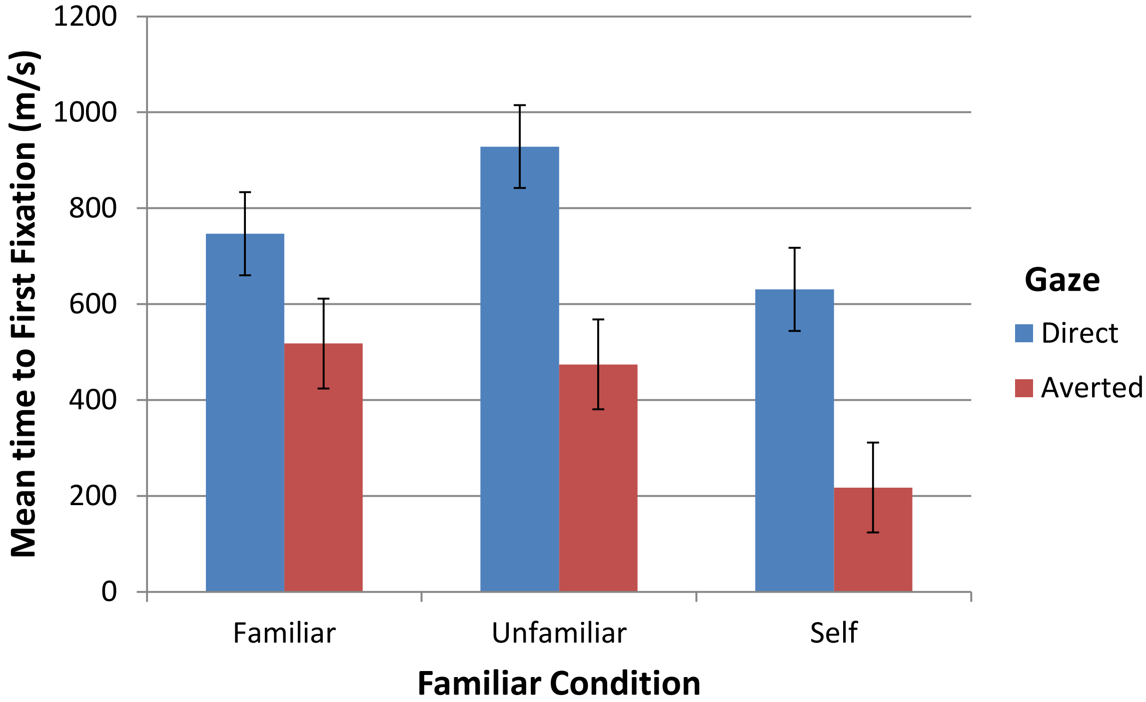


Figure 6.6 Time taken to fixate on the mouth AOI during averted and direct gaze across familiarity conditions

The children also fixated quicker on the mouth AOI of self faces with averted gaze (m = 217.31ms) compared to the self faces gazing direct (m = 630.86ms) t (83) = 3.694, p < .001. This shows that for mouth AOI all groups took longer to fixate on the mouth when the face was direct compared to the averted face which can be observed clearly from Figure 6.6.

Discussion

This experiment highlighted how attention was allocated to averted and direct gazing faces according to familiarity and group membership in children with ASD. It was predicted that atypical attention to faces would persist regardless of familiarity in the ASD group and that this atypical attention will be increased during gaze directed conditions due to the heightened arousal caused by direct gaze in ASD - as it has been proposed that the eye region causes anxiety and arousal in ASD (Hutt & Ounstead, 1966). However all groups including the ASD group, fixated on the direct facing eye and mouth regions for a longer time compared to the averted face regions. These findings also show that a face specifically the eye area is not aversive to children with ASD. This may suggest that eyes do not cause the proposed high anxiety or arousal in ASD (Richer & Coss, 1976; Spezio *et al.* 2006). Instead individuals with ASD may not fully understand the social relevance of the eye area and do not instinctively allocate their attention to this region. Longer selective attention allocation to direct gazing faces may be caused by this face type providing more socio-communicative cues, as information can be retrieved from the clearly seen eye and mouth regions.

This study was therefore inconsistent with Hernandez *et al* (2008) who showed that attention to the eye area in a high functioning ASD group was not influenced by gaze direction unlike the present study which found that fixation duration made by children with ASD was longer on the eye region of direct gazing faces. However Hernandez *et al.* (2008) found that the ASD group fixated less on the eye region compared to their typically developing matches which is not found in the present study. Level of functioning of participants with ASD could not have influenced the results of Hernandez *et al.* (2008) study compared to the present study as both recruited participants with less severe autistic impairment. The differences in gaze behaviour may have been caused by the high number of images presented by Hernandez *et al.* (2008) to the ASD population which may have resulted in attention to the eye area being reduced in the participants.

Therefore direct face AOIs were fixated on for longer durations showing that attention was maintained for a higher proportion of fixation time. However it is averted faces (specifically the averted mouth AOIs) which were fixated on quickest showing that averted face areas captured the children's attention quicker. The mouth area may have been attended to quicker in the averted faces because there was a restricted view of the eye area. Lack of socio-communicative cues from the eyes may cause children to rely and fixate more on the mouth area for social information.

For familiar persons there was less time taken to fixate on the eye area of an averted face compared to direct. This may be influenced by the use of faces during gaze following and social referencing. Quick fixation to the averted eye area may be caused by our intrinsic desire to locate what others are fixating on i.e. gaze following. The ability to be drawn to another's eye gaze is important for social living in primate populations (Anderson, Sallaberry & Barbier, 1995) as having your attention drawn to a group members gaze direction may highlight a food source or threat. Gaze following (when presented with a head turned) is observed in children as young as 3-6 months (Scaife & Bruner, 1975) and is an important milestone in socio-cognitive development. This intrinsic interest in following another's attention may have caused the children in this study to fixate on the averted faces quicker compared to the direct faces. A familiar face may be relied on more for social cues and information about the environment, such as social referencing during novel situations. Therefore if children are presented with a familiar face looking away they may allocate attention to the eye area to interpret where the person is looking. This was not the case for unfamiliar faces which showed a trend for the eye area to be fixated on quicker when it was direct compared to averted. This result must be interpreted with caution due to it only being a trend however this may imply that the groups were trying to identify this face and therefore fixated quicker on the eye region during direct gaze conditions. The unfamiliar face may not be associated with the high social relevance such as familiar faces which may explain why the children did not fixate more on this face type during averted conditions. There were no significant differences between the self eye areas during averted and direct conditions. This may show that this face is not relied on for social cues (similar to the familiar face) but is not perceived as completely unfamiliar and has to be identified (similar to gaze behaviour observed during unfamiliar trials).

These results showed that the ASD group attended to the eye area of the face similarly compared to the typically developing groups. This does not support the prediction based on previous research which proposed the atypical attention allocated to the eye region in ASD is used as an arousal management strategy (Hutt & Ounstead, 1966; Richer & Coss, 1976; Spezio *et al.* 2006). This study shows that the ASD group similarly to typically developing matches looked longer at the direct gazing eye region compared to averted eye region, which is not consistent with Hernandez *et al.* (2008) who found attention to eye area was not influenced by gaze direction. The ASD group fixating for a longer time on the eye area when gaze is direct suggests that the participants with ASD do not find this area aversive. This may imply that instead of an aversion to the eye area in individuals across the autism spectrum it is instead a lack of recognising this area as being important in conveying socio-communicative cues.

This experiment extended the current face recognition literature by using eye-tracking technology to highlight how attention is allocated in typical and atypical populations when looking at faces of varying familiarity including their own faces. It was predicted that the participants with ASD would look less at the eye AOI regardless of face type (familiar, unfamiliar or self), based on previous research which found atypical attention to the eye area during viewing of both unfamiliar (for example, Klin *et al.* 2002; Riby & Hancock, 2008) and familiar faces (Sterling *et al.* 2008). However the children with ASD in the present study fixated similarly on the eye area across the faces of different familiarity compared to their typically developing counterparts. This is not consistent with previous literature which found that adults with ASD fixated less on the eye region across familiar and unfamiliar faces compared to typical adults (Sterling *et al*. 2008). The differences between this study and Sterling *et al*. (2008) include the age of populations where Sterling *et al.* (2008) population involved *adults* with high functioning ASD (unlike the present study which has examined children with ASD). Both participant groups involved individuals who were high functioning on the autism spectrum, therefore differences in results between these two studies cannot be explained by the inclusion of individuals with less severe autistic impairment. The stimuli presentation in Sterling *et al*. (2008) study differed from the present study. The images in Sterling *et al*. (2008) experiment were presented 10 times each at time periods of 8 seconds whereas the present study only presented the images once at 3 seconds. This may suggest that atypical eye gaze behaviour reported in ASD populations when attending to stimuli may be influenced by how long the stimuli is presented for. When faces are presented for longer periods of time, the ability to maintain attention to relevant areas of the face may be reduced in populations with ASD, however initial eye gaze behaviour may be typical. This would suggest that atypicalities may only arise when a face is presented for long periods and implies that discrepancies across the literature may be related to methodological differences such as how long stimuli is presented.

It was also proposed at the beginning of the study that the ASD group would fixate for longer on the mouth AOIs based on previous research which showed increased gazing on this region by individuals with ASD (Klin *et al.* 2002). Again there were no significant differences of fixation time spent on the mouth area between the children with ASD and their typically developing counterparts. This showed that the ASD group were not fixating more on the mouth area compared to the typically developing groups. This is inconsistent with previous research which has reported increase fixation on the mouth area in high functioning adults with ASD (Klin *et al.* 2002). The differences found between Klin *et al.'s* (2002) results and the findings in the present study may be related again to stimuli type. The images shown in the current study lacked any social interaction and presented only isolated figures. Klin *et al.'s* (2002) stimuli showed dynamic images involving human actors displaying intense social interactions. The individuals with ASD may have attended the mouth AOI in Klin *et al.* (2002) study for longer to encode important communicative cues from the mouth region that they could not understand from the eyes. This shows that the adults with ASD may have relied more on the mouth area for social information compared to the eye area. Therefore increased mouth fixation may be a visual strategy adopted by individuals with ASD to encode and process socio-communicative cues.

All groups including the ASD group fixated for a longer fixation time on the eye area compared to the mouth area. This attention allocation to the eye region is similar to Sterling *et al.* (2008) who reported that both typical adults and adults with ASD fixated longer on the eyes compared to the mouth. The similarities between what

Sterling *et al.* (2008) found and this study may be caused by the inclusion of higher functioning individuals with ASD. This will be investigated more by the next experiment which will examine level of functioning and attention to the eye AOI. This may imply that the eye area which is an important source of information during interactions (i.e. Argyle & Cooke, 1976) can receive the appropriate attention from high functioning individuals with ASD, and may account for their high communicative abilities. These findings may also imply that the eye area is not a region which causes arousal in individuals across the autism spectrum which has previously been implied (Hutt & Ounstead, 1966). However it may also be that the stimuli presented in this study similar, to the images presented in Sterling *et al*. (2008) study, only showed faces. Therefore, there was also a lack of competitive information such as other people or objects presented on the image. Showing only an isolated figure may have reduced the atypical gaze behaviour which has been observed in children and adolescents with ASD (Speer *et al*. 2007). Complex images, presenting many people and items within a scene may influence the atypical attention allocation observed across the Autism Spectrum. Previous research which has examined gaze behaviour in children and adults with ASD during viewing of social scenes has reported atypical attention to the face area specifically the eye region (for example, Klin *et al.* 2002; Riby & Hancock, 2008; 2009b). How image complexity impacts on what areas of an image are selected for attention in children with ASD will be examined within this thesis in Chapter 7.

It was proposed that children with ASD would fixate less on unfamiliar faces compared to familiar and self faces. This was not supported by the results as there was a trend for all children (including the children with ASD) to fixate longer on the unfamiliar face AOIs compared to the self AOIs. This is not consistent with previous research which shows children with ASD show reduced fixation to unfamiliar faces

(Klin *et al* 2002; Riby & Hancock 2008). However the results are consistent with Sterling *et al* (2008) who reported that adults with ASD fixated significantly longer on unfamiliar faces compared to familiar faces. This increased fixation on unfamiliar faces may be caused by the children trying to identify the face or learn the new face they are being exposed to. These results show that unfamiliar faces are not arousing to children with ASD (Hutt & Ounstead 1966) and that unfamiliar faces are able to maintain attention for longer compared to the self faces.

This experiment wanted to extend the existing eye-tracking literature which examined attention to familiar and unfamiliar faces by examining how 'self' faces are also selectively attended to. There was an observed trend for all groups to fixate for less time on their own face compared to both familiar and unfamiliar faces. Fewer fixations on their own face may be due to high levels of self conscious emotions which are related to seeing your own image (for example, Sanefuji & Ohgami, 2011). Lewis *et al.* (1989) noted from several studies that as typically developing children grow older they show more self-conscious behaviours when they perceive their own face, therefore less attention to their own face observed in this study may be a strategy to manage self-conscious emotions. These findings are inconsistent with Sanefuji and Ohgami (2011) who found that children fixated longer on their own faces. The results of Sanefuji and Ohgami's (2011) study may have been influenced by the child's own image being presented at the same time as a same aged peer. In the present study each image showed an isolated person of varying familiarity on their own, therefore children may have fixated more on the unfamiliar and familiar faces in the present study because these 'other' faces (familiar and unfamiliar) are not competing for attention with their own face (self). This was a trend and not a significant effect so caution must be taken during interpretation. There was also a trend for the typically developing groups to fixate on their own image quickest and not the ASD group. This may indicate that the self face does not capture attention in children with ASD as observed in typical populations, again however caution must be warranted with this interpretation. Therefore the typically developing children's own faces seem to attract attention very quickly but do not maintain this attention allocation for long. This is consistent with previous literature (Tong & Nakayama, 1999) which showed how self faces capture attention quicker than any other faces. This may suggest that specialised neural networks are involved in detecting and processing our own faces (for example Keenen *et al.* 2000; Uddin *et al.* 2005) and that attention allocation is not maintained on our own faces because of more efficient and specialised processing. However much more research is needed to examine how a child's own face is encoded and if it is processed differently compared to other face types.

The children with ASD attended their own faces similarly compared to the matched control groups. They were found to fixate typically on both the eye and mouth areas of their own faces. This is consistent with Sanefuji and Ohgami's (2011) study which reported that children with ASD showed typical preferential attention to their own faces when presented alongside a same aged peer. These results suggest that children with ASD may have developed a basic concept of self, similar to their typical counterparts. Evidence of impaired self-referential ability in populations with ASD may therefore be linked to an impaired meta-representation of self, rather than a basic self awareness such as self-recognition and attending visual self information. An impaired meta-representation of self would impair the ability of applying self knowledge to the understanding of other's beliefs, desires and cognitive states. Further research is needed to investigate how children with ASD comprehend self-knowledge and if they are able to use this information to understand social situations or other's behaviours during social interactions.

Therefore no significant differences of attention to eye and mouth regions between groups were observed, showing that the ASD group fixated for similar amounts of time on the eye and mouth area compared to the typical groups. This is not consistent with the predictions made at the beginning of this study which proposed atypical attention to the eyes and mouth would persist across face types in the ASD group. This finding therefore doesn't support many other eye-tracking studies which report reduced attention to the eye region in populations with ASD (Pelphrey *et al.* 2002; Riby & Hancock 2008, 2009; Speer *et al.* 2007) and increased attention to the mouth region (Klin *et al.* 2002). This increased fixation on the eye area may be caused by the inclusion of higher functioning children with ASD. Research has already shown that gaze behaviour and selective attention to faces are associated with level of functioning across populations with ASD (for example, Norbury *et al.* 2009; Speer *et al.* 2007). The next experiment will be conducted to examine if attention allocation to faces is related to level of functioning which may highlight why the results in this study are inconsistent with previous literature.

6.2.2 Experiment 5

This experiment extends the current ASD literature by investigating the level of functioning in ASD and how it affects attention allocation to faces differing in familiarity. There have already been a number of studies which show evidence that attention allocation to the face is related to socio-communicative abilities across the spectrum of ASD (for example, Klin *et al.* 2002; Norbury *et al.* 2009; Riby & Hancock, 2008). This is conducted by using a participant group representative of the true heterogeneous nature of the ASD population. A lot of the previous research on attention allocation to faces in ASD participants has focused on using higher functioning participants (for example, Klin *et al.* 2002; Speer *et al.* 2007; Vivanti, Nadig, Ozonoff & Rogers, 2008). This research aims to extend the literature by including a more varied level of functioning within the ASD participants. It is predicted that children who are lower functioning will look less at the eye areas for all face familiarity conditions based on previous findings which reported a significant correlation between level of functioning on the Autism spectrum and fixation time on the eye area (for example, Riby & Hancock 2009a; 2009b; Speer *et al.* 2007).

Method

Participants

Twenty nine children with ASD were recruited from special units attached to three mainstream schools, one specialist ASD school and one residential school (see Table 6.4). Participants ages ranged between 9 years 7 months and 16 years 8 months (mean = 14 years 8 months; SD = 2 years 4 months). All these participants with ASD had taken part in Experiment 3 which is detailed in Chapter 5. It was ensured that all children had studied at their schools for at least one year so they were all familiar with the staff.

Table 6.4

Participants with ASD and details of the autistic characteristics and socio-communicative abilities

	N	Gender ratio males:females	CA[x]	SCQ[xi]	CARS[xii]
ASD	29	27: 2	14y 8m (28)	23 (6)	37 (8)

[x] Chronological age is provided in years and full months, standard deviation is provided in parenthesis.
[xi] Communicative ability is provided as a score on the Social Communication Questionnaire, standard deviation is in parenthesis.
[xii] Level of functioning on the Autism spectrum is provided as a score on the Childhood Autism Rating Scale.

Twenty one of the children had already taken part in Experiment 4 (and all the experiments in Chapter 5), a further 8 children with ASD had been recruited but were not high functioning enough to be compared to typically developing children. Despite this they were recruited for Experiment 5, since this is an investigation of how level of functioning relates to eye gaze behaviour. These participants similar to the existing children in the ASD group had previously been diagnosed by clinicians as being on the autistic spectrum. By including the children with low functioning ASD, the Childhood Autism Rating Scale (CARS; Schopler *et al.* 1988) now scored 10 children as mild-moderately autistic and 14 children as severely autistic. The remaining 5 children scored over 90 on the Asperger Syndrome Diagnostic Scale (ASDS; Myles *et al.* 2001). A score over 90 on this scale indicates the presence of Asperger Syndrome. The Social Communication Questionnaire (SCQ; Rutter *et al.* 2003) was also conducted to assess communicative ability in the children and scored 27 participants over 15 (a score over 15 implies the presence of ASD or PDD-NOS).

Design and Procedure

Task stimuli and the procedure were the same as used for Experiment 4 and are therefore not detailed in this section (see section 6.2.1). Due to the involvement of low functioning participants with ASD more verbal instructions were provided because these children had no reading ability.

Results

Proportion of mean face fixation time

Correlations were conducted examining fixation duration with social and communicative scales which measure socio-cognitive abilities in the children with ASD. This can highlight if fixation duration to faces is associated with level of functioning across the autism spectrum.

Table 6.5

Correlations between CARS, SCQ and mean face fixation time correlations

	EYE AOI			MOUTH AOI		
	fam	unfam	self	fam	unfam	self
CARS	-.242	-.343	-.316	-.220	-.192	-.079
SCQ	-.386*	-.510**	-.452*	-.081	-.131	.012

* = correlation is significant at the 0.05 level (p < 0.025 after the application of a Bonferroni correction for multiple comparisons).

** = correlation is significant at the 0.01 level (p <0 .005 after the application of a Bonferroni correction for multiple comparisons).

There are no significant correlations between CARS scores and proportion of mean face fixation time which does not support previous studies which have found such correlations (i.e. Riby & Hancock, 2008). However, there are significant negative correlations between the SCQ scores and all eye AOI across the familiarity conditions (see Table 6.5). This shows low level of socio-communicative ability (high scores on the SCQ) is related to spending a low proportion of fixation time looking at the eye AOI across all familiarity conditions. High scores on the SCQ (scores ≥ 15 implies presence of ASD) having a significant relationship with proportion time spent looking at the eyes shows that socio-communicative abilities are related to attention allocation of this area.

Time to First Fixation

Time taken to fixate on the eye and mouth AOIs was examined to show if time taken to fixate on the AOIs of a face were indicative of level of functioning across the autism spectrum.

Table 6.6

Correlations between CARS, SCQ and mean time to first fixation

	EYE AOI			MOUTH AOI		
	fam	unfam	self	fam	unfam	self
CARS	-.249	-.081	-.340	-.206	-.053	-.008
SCQ	-.290	-.095	-.228	-.211	-.094	-.082

There were no significant correlations between the CARS scores or SCQ scores and AOIs across familiarity (see Table 6.6). This may imply that level of social functioning or level of autistic impairment is not related to how faces attract attention despite there being a relationship between fixation time and socio-communicative ability.

Discussion

There were no correlations observed between the CARS scores and fixation time which is inconsistent with Riby and Hancock (2009a, 2009b). This may be caused by the different levels of functioning in the participant groups of the present study and Riby and Hancock (2009a, 2009b). The participant sample in the present study had a varying level of social functioning including the recruitment of high functioning children with ASD whereas the participant sample in Riby and Hancock's consisted of children with moderate to severe ASD.

For the present study the SCQ scale showed more significant relationships with how the eye area is attended to across familiarity types. Higher SCQ was significantly related to proportion of fixation time spent looking at the eye area of familiar, unfamiliar and self faces. This shows that low social ability was significantly correlated with low eye area fixation. Again this result is consistent with previous literature such as Speer *et al.* (2007) who found eye region fixation predicted social ability with those who fixated on the eye less showing less social responsiveness. This is consistent with Spiker and Ricks (1984) who found that high verbal ability in children with ASD predicted performance on a self recognition task. The present study has also showed that socio-communicative ability predicts attention to self eye area. This may imply that high attention allocation to their own and other faces aids social ability.

There was no significant correlation observed for mouth AOI which is inconsistent with Klin *et al.* (2002) and Norbury *et al.* (2009). Both of these researchers found high fixation on the mouth was related with better communicative capabilities (calculated social competence scale from the VABS - Vineland Adaption Behaviour Scales). Lack of correlations found with the mouth area may be caused by the scales used to measure ability. This shows how different social scales may be representative of attention allocation to different areas of a face. Scores on the Vineland show a significant relationship with attention to the mouth area (for example, Klin *et al.* 2002; Norbury *et al.* 2009) and social ability scores (as conducted in the present study) show a high correlation with fixation to the eye region.

The results observed in this experiment supports the predictions made regarding lower functioning on the autism spectrum will predict fixation on the eye area regardless of face familiarity. This is consistent with previous literature which has shown that atypical gaze behaviour and face perception is associated with the socio-communicative impairments observed in ASD (Riby & Hancock 2009a, 2009b; Speer *et al.* 2007). It shows that eye gaze behaviour is indicative of social functioning across the autism spectrum. The findings also propose that familiarity does not reduce the atypical allocation of attention to the eye region of faces.

This has implications on how participants are selected to represent the autistic population in research. When comparing findings of eye gaze behaviour, attention must be paid to the level of functioning represented in the participant samples as this will impact greatly on the fixation results. Future research should consider including participants of varying ability to better represent the heterogeneity observed across the population of Autistic spectrum disorder.

6.3 General Discussion

This chapter presented experiments which were novel in that they presented a self, familiar and unfamiliar face paradigm to a group of children with ASD. This paradigm has not to the author's knowledge, been applied to individuals across the Autism Spectrum. This section will now summarise the main conclusions from the experiments presented in this chapter.

All the experiments presented showed the children with ASD attended to faces similarly to their typically developing counterparts. The children with ASD fixated for similar amounts of time to the eye and mouth region regardless of familiarity and gaze direction compared to their controlled matches. These results therefore show that the eye area of faces are not arousing for individuals across the Autism spectrum and may show that populations with ASD are able to attend to this area. However the results presented in this chapter do not highlight if children with ASD are able to attend to the eye area during relevant times during a social interaction. Not attending the eye area at appropriate times during an interaction may cause important socio-communicative cues to be missed.

This chapter suggests that familiarity does play a role in how attention is allocated and which area of the face is attended to. When the face is familiar the results presented here suggest that children fixate longer on the mouth area and fixate longer on the eye area when the face is unfamiliar. This may imply that when a face has to be identified children attend to the eye area for recognition and when the face is known attention is allocated to the mouth area for the encoding of socio-communicative cues. Similar to Heisz and Shore (2008) this would seem to suggest that as a face becomes familiar qualitative changes are observed in how we visually scan that face and what areas are selected for attention. This change in how faces are attended to based on their familiarity is observed in both typical and atypical development. Therefore this suggests that children with ASD change how they fixate on a face based on how familiar that face is. This implies that they are able to perceive a familiar face and identify it before changing visual strategies to attend to relevant socio-communicative information.

The children's own image was not fixated on for longer or showed that self impacted on a specific area which was selected for attention as observed for familiar and unfamiliar faces. Instead the typically developing children's own faces seemed to attract attention quicker. This effect was not observed in the ASD population who did not show that their own face captured their attention. However children with ASD were able to fixate typically on their own faces, showing similar fixations to their eye and mouth areas compared to their typical matches. This may indicate that children with ASD are able to recognise themselves and attend to visual self information similar to typically developing children.

However it is worth emphasising that the children presented in this sample included high functioning children with ASD which may have influenced the reduced atypical attention allocation to the face. As shown level of social functioning across the autism spectrum may impact on how long the eye area is fixated on despite familiarity. Therefore if only low functioning children with ASD had been recruited we may have observed less attention to the eye area in the atypical group compared to the typically developing children. This also shows that children with severe autistic impairment will continue to look less at the eyes despite varying familiarity compared to children who show less severe impairments. This again shows the importance of paying attention to level of functioning presented in the participant groups of individuals with ASD when comparing results to previous literature.

Limitations and Future Directions

The children with ASD presented in this chapter may have also shown typical allocation of attention to faces because of the stimuli presented. The stimuli consisted of images showing isolated figures with no other objects or people presented within the scene. Therefore there was a lack of competitive information such as other people or items which may have influenced the reduced atypical gaze behaviour observed in the participants with ASD. Presenting numerous persons and objects within an image may explain why previous studies have reported atypical fixation on faces (for example, Riby & Hancock 2008, 2009b). Reducing the number of objects or people presented within the scenes may therefore help increase typical gaze behaviour. Making a scene more or less complex may impact how attention is allocated on the scene by children with ASD and will now be examined in Chapter 7.

Chapter 7 – Image complexity: Competition between faces and objects

7.1 Introduction

As proposed in Chapter 4, certain stimulus types may increase or reduce atypical eye gaze behaviour observed in individuals with ASD (for a review see Ames & Fletcher-Watson, 2010). This can have implications for the development of learning materials and communicative aids, as well as highlight how attention may be allocated when individuals with ASD attend to their social world. This could also account for the large discrepancies that exist concerning the typicality or atypicality of social attention reported in the current literature which will be detailed below (for example, the difference between van der Geest *et al.* 2002b and Klin *et al.* 2002).

Complexity of social scenes

As explained in previous chapters Klin *et al.* (2002) examined how high functioning adolescents and adults with ASD (n = 15) attended to realistic dynamic images displaying intense social situations. Participants with ASD looked significantly less at the eye region and significantly more at the mouth, body and object regions of the dynamic scenes. Speer *et al*. (2007) proposed that the results reported by Klin *et al*. (2002) may have been caused by the stimuli being dynamic and displaying an intense social interaction. Speer *et al.* (2007) therefore presented images and video clips to high functioning children (n = 12) and adolescents with ASD. These were either moving images showing one person (isolated dynamic), or groups of people (social dynamic) engaged in an interaction (images and video clips were taken from the same film as Klin *et al*. 2002). They also presented static images showing one person (isolated static), or groups of people engaged in an interaction (social static) that weren't already included in the dynamic condition. The ASD group were reported to fixate similarly to their typical matches in most of the conditions including social static, isolated static and isolated dynamic. The only significant difference between the ASD and typical matched group reported in this study was for the social dynamic condition. The results showed that the individuals with ASD spent significantly less time fixating on the eye area of the faces and more time looking at the body, compared to their controlled matches in this specific condition. Therefore Speer *et al*. (2007) concluded that atypical attention allocation in ASD may only be observed when stimuli are complex and moving. They proposed that presenting static images or reducing the number of people shown in the pictures would reduce the atypical allocation of attention to images across the autism spectrum.

However static images showing individuals engaging in social interactions were presented along with movies in a recent study by Riby and Hancock (2009b). Riby and Hancock (2009b) found that for all types of stimuli children with moderate to severe ASD (n = 20) spent a significantly smaller proportion of their time fixating on the face region than both the control groups (visuo-spatial ability matches and chronological age matches). Participants with ASD spent a smaller proportion of time than both comparison groups fixating on the eye region when viewing the socially complex movies. However the reduced attention to faces across all stimuli types implies that atypical visual attention persists regardless of the movement of stimuli. Atypical attention to the eyes by higher functioning adults with ASD has also been reported even when the images consisted of only static isolated faces (Pelphrey *et al.* 2002; Sterling *et al.* 2008), supporting Riby and Hancock (2009b) findings that atypical gaze behaviour in ASD persists across stimuli types.

One hypothesis to explain these inconsistent results reported across the autism spectrum literature is that attention to communicative cues in individuals with ASD is only impaired when the stimulus is *sufficiently* realistic or complex (Ames & Fletcher-Watson, 2010). This experiment sets to extend on the latest studies carried out by Speer *et al.* (2007) and Riby and Hancock (2009b) by presenting stimuli showing various numbers of people (social complexity) and various numbers of objects (object complexity) to examine how complexity affects attention allocation in children with ASD and if one type of complexity increases atypical attention allocation in this population. Important information may be missed if they are unable to allocate attention to salient parts of the image. Findings here may also highlight how children with ASD are allocating attention when exploring their social world.

Task relevant processing and attention

This study also adds to the previous experiments detailed earlier by controlling image complexity and including a behavioural task. Karatekin (2007) proposes that fixation duration increases along with a decrease of saccadic amplitude when task difficulty and perceptual processing increases. This means that when more fine-grained information must be attended to and processed we tend to gaze longer at relevant parts of an image. The perceptual load of the task has also been proposed to affect selective attention allocation (Lavie, 1995). Lavie (1995) proposes that when perceptual load is low then distracters (and therefore irrelevant areas of the image) are processed, however when perceptual load is high, only relevant information is attended to. This therefore implies that task engagement will affect how selective attention is allocated within images compared to spontaneous gazing which has already been examined in this thesis.

As mentioned previously in the thesis, individuals with ASD show atypical gaze behaviour during spontaneous looking at people and social scenes (Klin *et al.* 2002; Riby & Hancock 2008, 2009b) A recent study conducted by Remington, Swettenham, Campbell and Coleman (2009) examined how perceptual load affected how attention was allocated by adults with ASD (n = 14) compared to their typically developed counterparts by giving them a visual search task. Participants had to do a task where target letters were presented with distracter letters. The results showed that despite there being no significant differences in accuracy rates between the two groups, the adults with ASD showed an increased interference effect (i.e. processing the distracter letters). This implies that items in peripheral vision were being processed by the adults with ASD (causing the interference effect) compared to the control group. These results suggested that the group with ASD show a larger perceptual capacity allowing them to process more perceptual information (including processing both target information alongside information presented in the periphery visual space) compared to typically developed adults. This increased perceptual capacity may highlight why individuals with ASD show superior visual search abilities (for example, O' Riordan & Plaisted, 2001).

Bar-Haim, Shulman, Lamy and Reuveni (2006) conducted a study which examined attention allocation to faces during a probe detection task. They presented target probes near the eye and mouth areas of faces and asked high functioning children with ASD (n = 12) to respond when the probes were present as fast as they could. They were also given a short memory task at the end where they were asked to identify 8 faces that were presented with 8 new faces. The children with ASD fixated more to the eye region compared to the mouth similar to typically developing children. This was indicated by quicker reaction times when target probes were presented nearer the eyes compared to the mouth regions. The memory task showed that children with ASD showed similar accuracy rates compared to the control group. The authors proposed that this increased attention to the eye area may be caused by the involvement of a task or the recruitment of higher functioning children with ASD.

However typical attention to faces in ASD during tasks is also observed when the stimuli represents social complexity. Fletcher-Watson, Leekam, Findlay and Stanton (2008) showed pairs of realistic scenes (some which showed social interactions) to 36 adolescents and adults with ASD. The image pairs were presented one after the other and were either identical or different in one detail. The participants were asked whether there was a change present or not. Some of these included object changes (for example, spectacles) or changes in eye gaze. Both groups showed quicker response times to eye gaze over spectacle changes. The authors imply that this quick attention to the eye area in typical populations is caused by the social significance of eye gaze direction. However the ASD group attending to this area may not reflect them recognising the social significance of the eyes but may be simply attending to all areas of the image to detect changes, implying that attention to eye area was increased due to the introduction of a task. Also the inclusion of adults with ASD who are very high functioning may have increased this reported allocation of attention to the eye area as previous studies have already shown that high attention to this area is related to higher functioning across the autism spectrum (for example, Speer *et al.* 2002).

Volkmar, Lord, Bailey, Schultz, and Klin (2004) suggested that individuals with ASD may show the same gaze behaviour as typically developed groups when engaged in tasks that are not embedded within a social context. Pelphrey *et al.* (2002) showed faces displaying different emotional expressions to a group of high functioning adults with ASD (n = 5). They presented two experiments were one allowed the participants just to look at images of face expressions. The second study required the participants to attend to the faces and identify the emotion therefore giving the participants a task to do. For both studies it was found that the adults with ASD looked significantly less at the eye area compared to the typically developed matched group. Showing that atypical gaze behaviour in ASD persisted despite a task being undertaken. However the task did cause some qualitative differences in eye gaze behaviour of the two groups. During the task phase the adults showed fewer fixations compared to spontaneous looking. This may imply that because they have a task to do, they are not exploring the face as much during the task phase as they did during spontaneous looking. This may be due to the groups controlling their perceptual load and are therefore more focused on attending to the relevant areas of the face to deal with the task in hand.

Discrepancies in attention allocation may be caused by typically developing children understanding that the eye area holds social significant information however children with ASD may only attend the eye area if the area is task relevant. These tasks here however may all show typical attention during tasks because of the high-functioning children and adults with ASD being recruited. It has already been observed that level of functioning impacts how realistic images are attended to (i.e. Klin *et al.* 2002; Riby & Hancock 2009a, 2009b; Speer *et al.* 2007). ASD populations that are able to engage in tasks are also mainly high functioning individuals as it can be problematic to maintain attention in individuals with more severe autistic impairment.

Therefore this chapter will extend on previous eye-tracking studies by presenting two experiments (Experiment 6 and 7) which specifically manipulate item and social complexity separately and examines how this affects attention allocation in children with ASD and those without ASD. These experiments will also be conducted differently from the previous experiments presented in this thesis by examining gaze behaviour during task completion. The results can then be compared to previous chapters to explore differences between spontaneous attention allocation and task driven attention allocation.

7.2 Experiments 6 and 7

The following experiments investigated how images of varying social and item complexity were attended to using eye-tracking methodology and involving a task. Experiment 6 was conducted on a student population to ensure methodology was accurate at examining attention allocation on images of varying complexity. Experiment 7 then investigated how children with ASD attended to faces and objects presented on images of varying social and item complexities (1 person 1 object, 1 person 4 object, 2 person 1 object, 2 person 4 object, 4 person 1 object, 4 person 4 object) compared to typically developing children matched on; verbal mental ability (VA), visuo-spatial ability or Non-verbal Ability (NVA) and chronological age (CA).

Attention to faces and objects according to level of complexity, and group membership will be examined. Performance by the ASD group will highlight if there is atypical allocation of attention to the face and object AOIs when presented in complex images (for example 4 person 4 object condition) compared to simplistic images (for example 1 person 1 object condition).

7.2.1 Experiment 6

This experiment was a pilot study with students from the University of Stirling. This pilot study aimed to highlight how long each stage would take and if the task of remembering the faces or objects were of similar difficulty. This would imply that any differences found in Experiment 7 between faces and objects being remembered in ASD populations may be more linked to their socio-communicative impairments rather than the faces being more difficult to identify compared to objects. It was also to examine if the different complexity conditions did present sufficiently varied levels of complexity to induce different gaze patterns.

It was predicted that because of the attention faces demand when presented in visual scenes (for example, Ro, Russell & Lavie, 2001; Theeuwes & Van der Stigchel, 2006) that despite varying object complexity the typical population will fixate longer on the faces. It was also proposed that there will be no differences in task accuracy of remembering faces or objects because despite processing these differently, typical adults are able to show high accuracy in remembering both objects and faces (Bruce & Humphreys, 1994; Bruce & Young, 1986).

<u>Method</u>

<u>*Participants*</u>

Participants were twenty five students studying Psychology at the University of Stirling. The ages ranged from 18 years 3 months to 21 years 4 months (mean = 19 years 2 months; SD = 3 years 9 months). The participants' scores ranged from 6 - 30 on the Autism Spectrum Quotient (AQ; Baron-Cohen, Wheelwright, Skinner, Martin &

Clubley, 2001) scale. A score of 32 and over indicates the presence of an ASD therefore no participant showed evidence of having this developmental disorder.

Design and Procedure

Stimuli

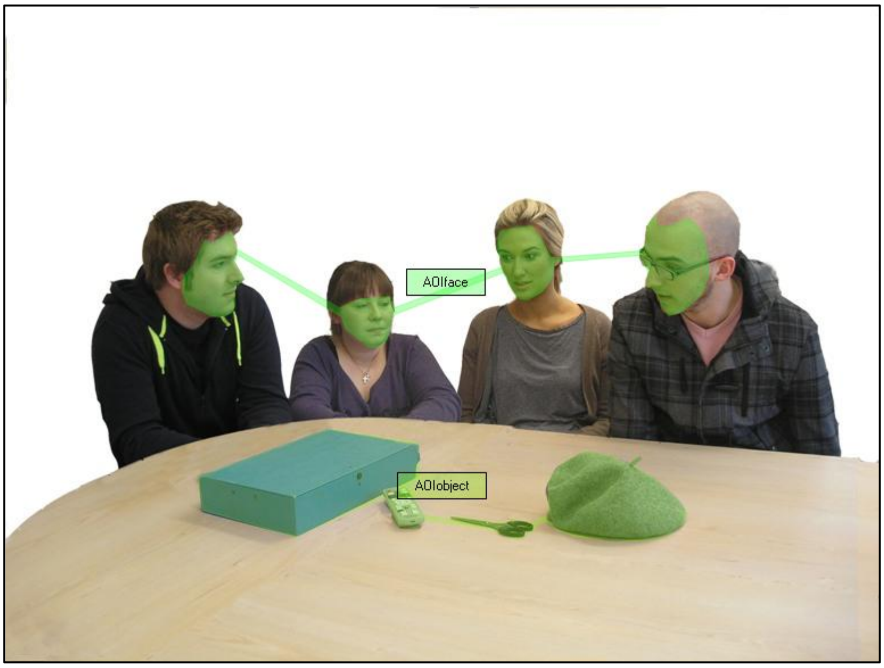
Photos were taken using an Olympus digital camera C55Z, set up in a lab on a tripod. Each image presented people round a table with various objects placed on the table (see Appendix E). The 1, 2 and 4 people were presented alongside 1 and 4 objects. Images were edited in Adobe Photoshop CS (Adobe, San Jose, California, USA) removing the background of the scene so it appeared pure white. The images were then resized to 768 x 576 pixels, w27.09cm x h20.32cm and uploaded to the eye-tracker.

The images presented for the memory task included face regions from the stimuli alongside other similar shaped face regions. An object was also presented on an A4 sheet of paper with a matched object (i.e. same object with different pattern or same object with differing colours). The choice sheets for each condition are shown in Appendix E. Both the faces and objects were increased in size to 1417 x 2126 pixels, w9.12cm x h13.68cm using Adobe Photoshop CS (Adobe, San Jose, California, USA).

Apparatus

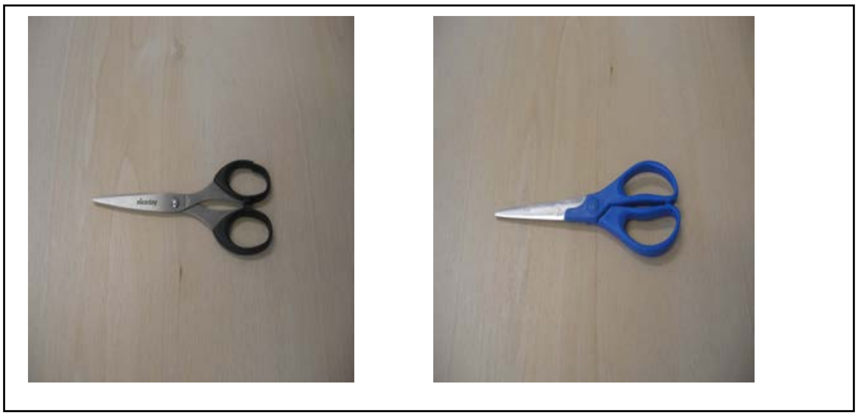
The research used a Tobii 1750 eye-tracker (Tobii Technology, Stockholm, Sweden), using ClearView 1.5.10 (Tobii Technology) for the presentation of stimuli and recording eye movements. The eye-tracker was controlled via a Dell Inspiron 6400 (Dell, Round Rock, Texas, USA) laptop computer. The system is portable and was moved to the testing location of each individual. The system is also completely non-invasive, with no need to constrain the head or body and little indication that eye movements are tracked. The Tobii 1750 system tracks both eyes to a rated accuracy of 0.5 degrees, sampled at 50 Hz and was calibrated for each participant using a 5-point infant calibration of each eye.

ClearView 1.5.10 provides a 'definition tool' to identify areas of interest (AOI) for analyses. For all images, AOI were designated round all the faces (with a hairline boundary) and all the objects in each condition (see Figure 7.1). AOI for the faces and objects were defined using polygon definition tools to mark the outline of these regions.



i)

ii)



iii)

Figure 7.1 Stimuli showing the i) 4 person 4 object condition presented on the eye-tracker with areas of interest (AOI) outlined, ii) the choice sheet showing 2 faces, iii) choice sheet showing 2 objects

Design

This study employed a within-subject design, within-subject factors include Complexity (6 levels: 1 person 1 object, 1 person 4 object, 2 person 1 object, 2 person 4 object. 4 person 1 object, 4 person 4 object), and the AOI (2 levels: face or object).

Procedure

Participants were tested in an experimental booth at the University of Stirling, and the whole session lasted 8 minutes. They were seated approximately 50 cm from the eye-tracking screen with the experimenter sat to one side to control the computer but not interfere with viewing behaviour. The participant was told that they would see different types of pictures during the session and the eye-tracking task involved calibration of the eye-tracker. For this purpose, the participant followed a bouncing ball around the screen to nine locations. All participants in this experiment were able to comply with task demands and be calibrated successfully so no removal of participants from the study was necessary.

Following calibration, participants viewed an instruction slide which stated ‘please look at the images and try to remember what they show’, no further instruction was provided. All the pictures (n=6) were presented in the same trial block. They were presented for 5 seconds each (in randomised order) and separated with a blank screen showing a fixation point in the middle. After the presentation of each image on the screen participants were randomly presented with a choice of two faces and two objects and asked which ones had been presented previously in the images. These faces and objects were the same for all the participants with one being a face and object presented in the image earlier, partnered with a new similar face and object. After the participant selected a face and object the experimenter then clicked on the mouse to show the next image. Once all the conditions were complete the experimenter debriefed the participant.

Results

Fixation Duration

Fixation duration was examined during the pilot study to highlight if manipulating item and social complexity affected how long face and object AOIs maintained attention.

Table 7.1

Mean total fixation time on the face and object AOIs across conditions (SD in parenthesis)

Face AOI			
1p1o	1p4o	4p1o	4p4o
2406.6 (525.5)	1358.4 (625.7)	1911.0 (369.1)	1298.3(380.7)
Object AOI			
1p1o	1p4o	4p1o	4p4o
915.6 (327.4)	2880.9 (221.4)	486.0 (199.5)	1670.2 (692.8)

1p1o = 1 person 1 object, 1p4o = 1 person 4 object
4p1o = 4 person 1object, 4p4o = 4 person 4 object

A within subjects ANOVA was carried out with within factors being Complexity (1 person 1 object, 1 person 4 object, 2 person 1 object, 2 person 4 object, 4 person 1 object, 4 person 4 object) and the AOIs (face and object). The conditions most relevant to this thesis will be presented within the result section, this includes the conditions of low social complexity low item complexity (1 person 1 object), low social complexity high item complexity (1 person 4 objects) high social complexity low item complexity (4 person 1 object) and high social complexity high item complexity (4 person 4 objects). The full analysis (including the 2 person conditions) is presented within Appendix F. Complexity was shown to impact on how attention was allocated to the images $F(3, 66) = 29.290$, $p < .001$, $\eta^2_p = .560$. The students looked longer at the face and object AOIs during the 1 person conditions (low social complexity). The Complexity conditions fixated on the most was the 1 person 4 object condition (m = 2119.63ms). This was fixated on significantly longer compared to all conditions including the 1 person 1 object condition (m = 1661.1ms) $t(23) = 3.455$, $p < .01$, 4 person 1 object stimuli (m = 1198.5ms) $t(23) = 8.551$, $p < .001$, 4 person 4 object image (m = 1484.3ms) $t(23) = 6.074$, $p < .001$.

The 1 person 1 object condition (low social complexity, low item complexity) was the next Complexity condition to be fixated on most by the students. This was fixated on significantly longer compared to 4 person 1 object image $t(23) = 4.514$, $p < .001$. There was a trend to look significantly longer at the 1 person 1 object condition compared to 4 person 4 object condition $t(23) = 1.802$, $p = .085$. The students fixated least on the 4 person 1 object image (high social complexity low item complexity). This was significantly less compared to the 1 person conditions (see above analyses), 4 person 4 object image $t(23) = 7.055$, $p < .001$. Therefore the participants seemed to fixate longer on the AOIs presented within the 1 person (low social complexity) conditions compared to the 4 person conditions (high social complexity).

AOI did not impact on fixation duration across the conditions $F(1, 23) = 1.121$, $p = .301$, $\eta^2_p = .046$. There was a significant interaction between AOI and Complexity $F(4, 91) = 38.588$, $p < .001$, $\eta^2_p = .627$. To investigate this significant interaction paired samples t-tests were carried out for each Complexity condition to compared fixation duration on each AOI. The participants were shown to fixate significantly longer on the face AOI ($m = 2406.6$ms) compared to the object AOI ($m = 915.6$ms) $t(23) = 6.717$, $p < .001$ during the 1 person 1 object condition (see Table 7.1). Showing that during low social and item complexity the face maintains attention significantly longer compared to the object AOI. In the 1 face 4 object stimuli the participants were shown to fixate significantly longer on the object AOI ($m = 2880.9$ms) compared to the face AOI ($m = 1358.4$ms) $t(23) = 6.645$, $p < .001$, showing that more attention was allocated to the object AOIs when the objects presented on the image were increased. Face AOIs ($m = 1911.2$ms) were fixated on significantly longer compared to object AOIs ($m = 486.3$ms) during the 4 person 1 object condition $t(23) = 12.383$, $p < .001$, which implies attention allocation to faces increases as the number of faces presented within the scene increases. However when the number of faces and the number of objects are equal during the 4 person 4 object (high social complexity and high item complexity) condition, the group showed a trend of looking longer at the object AOI ($m = 1670.2$ms) compared to the face AOI ($m = 1298.3$ms) $t(23) = 1.871$, $p = .074$. Which implies that when many objects and faces are presented within a social scene there is a trend for participants to fixate longer on the object AOIs compared to the face AOIs.

Time to First Fixation

Time to first fixation was an eye-tracking measure examined during this study to highlight how quickly face or object AOIs attracted attention when presented within social scenes of varying complexity.

Table 7.2

Mean time taken to first fixate on the face and object AOIs across conditions (SD in parenthesis)

Face AOI			
1p1o	1p4o	4p1o	4p4o
341.3 (256.4)	533.7 (235.2)	1216.5 (363.3)	1503.5 (650.3)
Object AOI			
1p1o	1p4o	4p1o	4p4o
993.2 (543.0)	789.7 (215.7)	1822.5 (630.5)	1518.7 (529.3)

1p1o = 1 person 1 object, 1p4o = 1 person 4 object
4p1o = 4 person 1object, 4p4o = 4 person 4 object

A within subjects ANOVA was carried out with within factors being stimuli condition (1 person 1 object, 1 person 4 object, 2 person 1 object, 2 person 4 object, 4 person 1 object, 4 person 4 object) and the AOIs (face and object). Complexity impacted on time taken to fixate on the images $F(4, 77) = 13.899$, $p < .001$, $\eta^2_p = .377$. To investigate the significant effect of Complexity paired samples t-tests were carried out comparing conditions. The 1 person 4 object AOIs (m = 660.7ms) were fixated on the quickest. This was significantly quicker compared to the 4 person 1 object condition (m = 1519.5ms) $t(23) = 4.507$, $p < .001$, 4 person 4 object AOIs (m = 1511.1ms) $t(23) = 7.321$, $p < .001$. There was no significant difference between 1 person 1 object (m = 667.3ms) and 1 person 4 object $t(23) = .066$, $p = .948$. The 1 person 1 object condition was fixated on quickest compared to the 4 person 1 object AOIs $t(23) = 4.635$, $p < .001$, and 4 person 4 object image $t(23) = 7.220$, $p < .001$ showing that the conditions which presented 1 person were fixated on quickest compared to the 4 person conditions. The 4 person (high social complexity) conditions were therefore fixated on similarly as there was no significant difference between the 4 person 1 object condition and 4 person 4 object condition t (23) = .048, p = .962.

The participants were quicker to fixate on the face AOIs (m = 828.2 ms) across all Complexity conditions compared to object AOIs (m = 1356.3ms), $F (1,23) = 19.855$, $p < .001$, $\eta^2_p = .463$ (see Table 7.2). Complexity did not impact time taken by participants to fixate on the AOIs $F (4, 75) = 1.774$, $p = .155$, $\eta^2_p = .072$ which implies that complexity does not affect how quickly the object or face AOIs attract attention.

Task Accuracy

A paired samples t –test was carried out to examine if objects were remembered significantly more compared to faces. However there was no significant difference between accuracy in identifying the objects (m = 78%) and the faces (m = 70%) t (23) = 1.460, p = .157.

Discussion

The results therefore show that varying object or social complexity affected which AOIs were attended to for long durations. This is not consistent with the prediction made at the beginning of the study which proposed because of the attention faces demand when presented in visual scenes that the typical population would fixate more on the face AOIs. This is therefore not consistent with previous literature which showed that faces receive more attention when presented among objects (Ro *et al.* 2001; Ro & Friggel, 2007). However time taken to fixate on faces was less compared to objects showing that the participants were quickest at locating faces on the images regardless of complexity. So despite not being attended to across all the conditions for the longest period of time face AOIs were able to attract selective attention significantly quicker compared to objects and supports previous studies which suggest that faces summon quick selective attention to its visual space (Theeuwes & Van der Stigchel, 2006).

Despite fixating on faces quicker compared to objects across all image types the time spent fixating on the faces varied according to the different complexity conditions. It was found that during conditions which increased object complexity and decreased social complexity that objects were fixated were fixated on for longer durations of time. This was the similar for face AOIs, as when more people were presented in the image more time was spent fixating on the faces. Therefore when more people than objects are presented, the face AOIs are fixated on longer and when more objects than people were shown objects were fixated on more.

However, when one person was presented alongside one object the participants fixated longest on the face AOI compared to the object AOI. This shows that the face was attended to preferentially instead of the object during simple scenes (1 person 1 object condition). This does not imply that when the number of persons presented is equal to the number of objects shown, that face AOIs will be attended to more because during the 4 person 4 object condition the students fixated significantly longer on the object AOIs compared to the face AOIs. This may imply that when the image is highly complex objects are attended to for longer fixation lengths compared to faces. This suggests that faces do not always attract attention for longer compared to objects when presented in equal numbers together in a scene.

The longer fixation that was observed on the object AOIs during this 4 person 4 object (high social complexity, high item complexity) condition may be caused by objects and faces being encoded differently by the participants. Objects are proposed to be processed more featurally compared to faces which are processed more holistically (Farah, 1995). If objects are encoded using part-based visual strategies then more attention may be allocated in order to process the fine details presented in the objects. Faces may be fixated on less during this high complex condition because they are processed holistically which may require less fixation time compared to the objects. Attention being maintained for longer on the object AOIs may have been influenced by the type of task being conducted. The task presented here was a basic memory task therefore better encoding of the faces and objects were relied on for successful remembering of the items. It may be that different types of tasks influence attention allocation to social scenes of varying complexity. For example a social judgement task such as distinguishing emotions may cause more attention to the face and eye area by typical populations (for example Pelphrey *et al*. 2002).

The results reported here are also inconsistent with the findings by Klin *et al.* (2002) who found high levels of attention to faces and eye areas in typical adult populations during spontaneous gazing of complex scenes. This may have been caused by the stimuli in Klin *et al.* (2002) study displaying an intense social interaction which may cause typical adults to fixate more on the eyes, due to their understanding of the social significance of the eye area (Fletcher-Watson, *et al.* 2008). Therefore typical adults may attend faces and eyes more than objects in a scene during intense social interactions due to the socio-communicative cues the face and eyes provide during these types of scenes. More attention to the face and eyes may have also been influenced by the allowance of spontaneous gazing showing that the typical participants' natural attention was drawn to areas of high social significance. In the present study the participants were required to perform a memory task which may have impacted on the visual strategies they adopted when scanning the scenes. Increased scanning of the image may have been applied by the participants in order to attend to as much detail as possible within the image and improve their memory of the scene. Interpretation of these results however must be made with caution since the study was conducted on a small population of students as a pilot study. The effects of complexity on how faces are attended to by typical adults must be explored in a larger sample of the typically developed population and by applying a range of tasks which may involve memory, visual searches or social judgements.

It was also proposed that there would be no differences in task accuracy of remembering faces or objects because despite processing these differently, typical adults are able to show high levels of accuracy when remembering both (Bruce & Humphreys, 1994; Bruce & Young, 1986). There was no significant difference found between accurate recognition of objects and faces showing that both items were remembered similarly. This is also encouraging for the methodology which will be applied in Experiment 7. Specifically these results show the task stimuli presented for identification by participants allowed for faces and objects to be successfully recognised. The different patterns of gaze behaviour also observed in this pilot study suggest that different levels of complexities cause different visual strategies and that the stimuli differs enough in complexity to cause qualitative differences in attention allocation. Therefore these variations of complexity can now be successfully applied to child populations across typical and atypical development. If different accuracy levels are observed between recognition of faces and objects during the memory task in the children with ASD then this may be more related to their socio-communicative impairments rather than differences in task difficulty of remembering faces compared to objects. Also we have observed that the variations of complexity presented to an adult population was sufficiently varied enough to cause differences in gaze behaviour.

Therefore if there are no differences of visual strategies caused by the different complexity conditions then it can be assumed that complexity does not influence children's gaze patterns.

7.2.2 Experiment 7

This experiment will examine how children with ASD attended to faces and objects during varying social and item complexities (1 person 1 object, 1 person 4 object, 2 person 1 object, 2 person 4 object, 4 person 1 object, 4 person 4 object) compared to typically developing counterparts. Only the conditions relevant for investigating the hypotheses will be reported within the thesis, this includes 1 person 1 object (low social complexity low item complexity); 1 person 4 object (low social complexity, high item complexity); 4 person 1 object (high social complexity, low item complexity); 4 person 4 object (high social complexity, high item complexity). The full analysis including all conditions is attached in Appendix F. Attention to faces and objects according to level of complexity, and group membership will be investigated. Performance by the ASD group will highlight if there is atypical allocation of attention to the face and object AOIs when presented in complex images (for example 4 person 4 object condition) compared to simplistic images (for example 1 person 1 object condition). It is also proposed that similar to Speer *et al.* (2007) findings that children with ASD will show typical attention during stimuli of less complexity (such as 1 person 1 object and 2 person 1 object). It is predicted that reduced attention to the face by the children with ASD will occur for the highly complex scenes (4 person 4 object) as reduced attention to the face area during the presentation of static complex scenes has been reported in previous literature (Riby & Hancock, 2008). It is also proposed that children with ASD will show higher accuracy rates for remembering objects during the memory task due to previous research reporting impaired recognition of unfamiliar faces in ASD populations (Boucher & Lewis, 1992).

Method

Participants

Twenty children with ASD were recruited from special units attached to three mainstream schools and one specialist school for children with ASD. Participants ranged between 6 years 1 month and 17 years 8 months (mean = 12 years 3 months; SD = 3 years 8 months). Verbal ability age was assessed using the British Picture Vocabulary Scale, second edition (BPVS II – Dunn *et al.* 1997) and provided a mean verbal mental age (VA) for the group of 7 years 6 months (ranging from 3 years 9 months to 16 years). Non-verbal ability was assessed by the Raven's Coloured Progressive Matrices (RCPM – Raven *et al.* 1990) giving a mean score of 24 (ranging from 13 to 31; max score possible 36). Six of the participants with ASD had also taken part in the earlier experiments detailed in Chapters 5 and 6. See Table 7.3 for full details of participants.

Table 7.3

Participant details for children with ASD and their typically developing comparison groups (standard deviation in parenthesis)

Group	N	Gender ratio males:females	CA[xiii]	VA[xiv]	NVA[xv]
ASD	20	17:3	12y 3m (45)	77 (28)	24 (6)
CA	20	15:5	12y 3m (37)	112 (25)	30 (4)
VA	20	12:8	8y 5m (41)	78 (29)	22 (8)
NVA	20	13:7	9y 8m (43)	93 (31)	24 (6)

xiii Chronological age provided in years and full months. Standard deviation provided in full months in parenthesis.
xiv Verbal ability is calculated using the mean raw score from the British Picture Vocabulary Scale standard deviation in parenthesis.
xv Nonverbal ability is provided as mean scores on the Ravens Coloured Progressive Matrices task (max. score 36) standard deviation in parenthesis.

The children with ASD were matched to three typically developing comparison children using individual matching criteria. These typically developing counterparts had not taken part in any of the previous experiments documented in Chapters 5 and 6. Chronological age matched group had a mean chronological age 12 years 3 months ($t(38) = .040$, $p = .969$). The VMA group was matched to the participants with ASD for verbal ability age using the BPVS II had a mean verbal mental age of 7 years 7 months ($t(38) = -.156$, $p=.877$). The group matched for nonverbal ability (Visuo-spatial ability) had a mean RCPM score of 24 ($t(38) = .101$, $p=.920$). See Table 7.3 for full descriptions of the groups involved.

All participants in the ASD group had previously been diagnosed by clinicians as being on the autistic spectrum. The Childhood Autism Rating Scale (CARS; Schopler *et al.* 1988) 6 children as mild-moderately autistic and 6 children as severely autistic. The remaining 8 children scored over 90 on the Asperger Syndrome Diagnostic Scale (ASDS; Myles *et al.* 2001). A score over 90 on this scale indicates the presence of Asperger Syndrome. The Social Communication Questionnaire (SCQ; Rutter *et al.* 2003) was conducted, with all 20 children obtaining a score over 15 (a score of 15 or over implies the presence of ASD or PDD-NOS).

Design and Procedure

Task stimuli and the procedure were the same as used for Experiment 7 and are therefore not detailed in this section (see section 7.2.1). Due to the involvement of typically developing children and children with ASD more verbal instructions were provided because these children had reduced reading ability.

Design

This study employed a mixed design with between-subject factor of Group (ASD, CA, VA, NVA) and within-subject factor being Complexity (6 levels: 1 person 1 object, 1 person 4 object, 2 person 1 object, 2 person 4 object, 4 person 1 object, 4 person 4 object) and the AOI (2 levels: face or object).

Results

Fixation Duration

The ASD group (m = 3387.9ms) engaged in task similarly compared to their typically developing counterparts, CA (m = 3679.9ms), VA (m = 3408.8ms) and NVA (m = 2998.3ms), $F(3,76) = .872$, $p = .459$. This shows that the ASD group (m =

3387.86ms) engaged in task similarly compared to their typically developing counterparts. However proportion of fixation time was previously reported for analysis carried out on the children's data, therefore the same will be applied to the analyses in this chapter to maintain consistency throughout the thesis.

Proportion of fixation time

Proportion of fixation time was selected as an eye-tracking measure to highlight if image complexity impacted on how the object and face AOIs maintained attention.

Table 7.4

Mean proportion of time spent looking at the face and object AOIs for complexity conditions across the groups (standard deviation in parenthesis)

		Face		
Group	1p1o	1p4o	4p1o	4p4o
ASD	.436 (.264)	.274 (.266)	.160 (.190)	.078 (.091)
CA	.352 (.229)	.242 (.183)	.205 (.180)	.075 (.089)
VA	.426 (.288)	.191 (.199)	.200 (.177)	.088 (.086)
NVA	.340 (.236)	.181 (.198)	.146 (.171)	.071 (.076)

		Object		
Group	1p1o	1p4o	4p1o	4p4o
ASD	.160 (.179)	.460 (.311)	.093 (.123)	.228 (.185)
CA	.219 (.159)	.558 (.313)	.085 (.080)	.262 (.196)
VA	.178 (.146)	.435 (.281)	.101 (.095)	.244 (.217)
NVA	.200 (.161)	.438 (.331)	.074 (.093)	.310 (.238)

1p1o = 1 person 1 object, 1p4o = 1 person 4 object
4p1o = 4 person 1object, 4p4o = 4 person 4 object

A mixed 4x6x2 ANOVA was carried out with between factors being Groups (ASD, CA, VA, NVA) and within subject factors being Complexity (1 person 1 object, 1 person 4 object, 2 person 1 object, 2 person 4 object, 4 person 1 object, 4 person 4 object) and the AOIs (face and object). The Complexity conditions most relevant to this thesis will be presented within the result section, this includes the conditions of low social complexity low item complexity (1 person 1 object), low social complexity high item complexity (1 person 4 objects) high social complexity low item complexity (4 person 1 object) and high social complexity high item complexity (4 person 4 objects). The full analysis (including the 2 person conditions) is presented within Appendix F. Complexity impacted on how much time was spent fixating on the images F (4, 312) = 40.279, $p < .001$, $\eta^2_p = .346$, paired samples t-tests were conducted to investigate the significant effect of condition. The children fixated least on the high social complexity images (4 person 1 object and 4 person 4 object). The children however fixated the least proportion of fixation time on the 4 person one object (high social complexity low object complexity) condition AOIs (m = .133), this was significantly less compared to 1 person 1 object condition (m = .289) t (79) = 8.655, $p < .001$, 1 person 4 object condition (m = .347) t (79) = 12.275, $p < .001$, and 4 person 4 object (m = .169) t (79) = 2.632, $p < .01$. The condition to look least at after 4 person 1 object was the 4 person 4 object condition, this was significantly less compared to 1 person 1 object t (79) = 6.021, $p < .001$, 1 person 4 object , t (79) = 10.599, $p < .001$. The Complexity condition which the children fixated more on the most was 1 person 4 object (low social complexity high item complexity) significantly longer compared to the 4 person conditions (see above) and 1 person 1 object t (79) = 2.520, $p < .05$ (see Table 7.4). There was no significant interaction between Complexity and Group F (12, 312) = 1.251, $p = .246$, $\eta^2_p = .047$.

All the children (including the ASD group) fixated significantly less on the face AOIs of the images (m = .197) compared to the object AOIs (m = .273) across the complexity conditions F (1, 76) = 22.395, $p < .001$, $\eta^2_p = .228$. Group membership did not impact on what AOIs were fixated on showing that the ASD group did not attend to the object or faces differently compared to the other groups F (3, 76) = 1.762, $p = .162$, Np2 = .065.

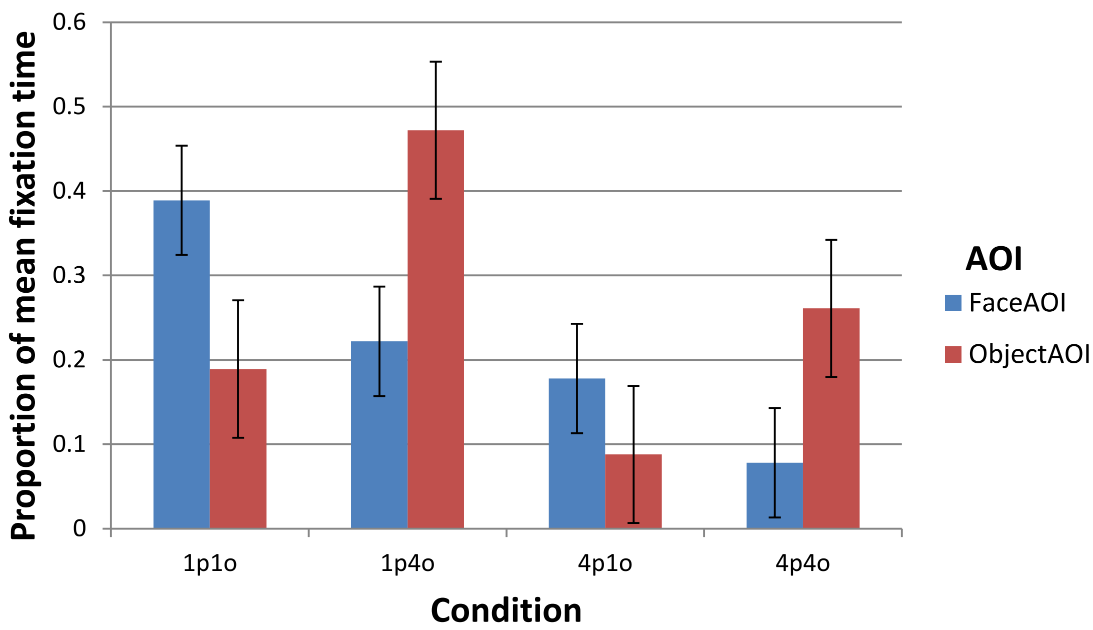


Figure 7.2 Mean proportion of time groups spent looking at the face and object AOIs across the conditions

There was a significant interaction between Complexity and AOI F (4, 276) = 39.302, p < .001, η^2_p = .341. Paired samples t-tests were carried out to investigate this interaction, by comparing the AOIs in each condition. For the 1 person 1 object (low social complexity low item complexity) condition the groups fixated significantly longer on the face AOI (m = .389) compared to the object AOI (m = .189) t (79) = 6.323, p <.001 (see Figure 7.2). As the number of objects increased in the 1 person 4 object (low social complexity high item complexity) image the children fixated significantly longer on the object area (m = .473) compared to the face area (m = .222), t (79) = 5.707, p <.001.

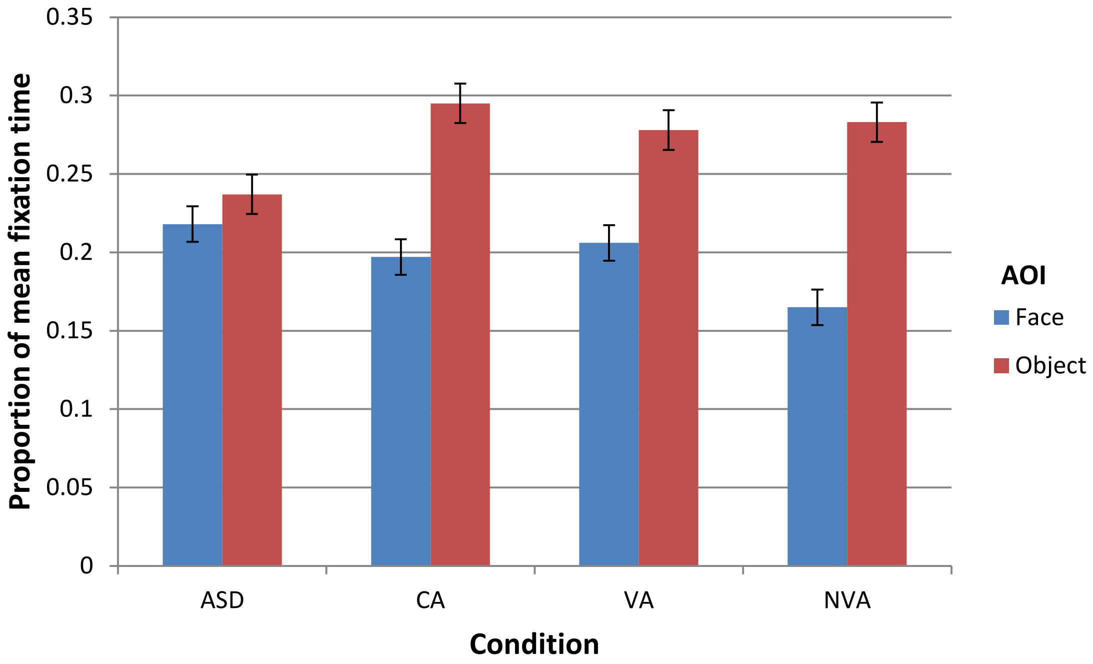


Figure 7.3 Mean proportion of time spent looking at the face and object AOI across the groups.

For the 4 person 1 object (high social complexity, low item complexity) image where the number of persons presented was increased the children fixated on the face AOIs (m = .178) significantly longer compared to the object AOI (m = .088), t (79) = 4.376, p <.001 . However when the number of objects were increased to match the number of persons presented the groups fixated significantly longer on the object AOI (m = .261) compared to the face areas (m = .078), 4 person 4 object t (79) = 7.057, p < .001.

Group membership did not impact on how the AOIs were attended to during each condition showing that the ASD group again fixated similarly on the object and face AOIs during each Complexity condition F (11, 276) = .984, p = .461, η^2_p = .037 (see Figure 7.3). There was no significant effect of Group F (3,76) = .252, p = .860, η^2_p = .010.

Time taken to first fixation

Time taken to fixate on the object and face AOIs across complexity conditions was examined to highlight if the ASD group took different lengths of time compared to their typically developing counterparts to fixate on the object and face AOI.

Table 7.5

Mean time taken to first fixation on the face and object AOIs for complexity conditions across the groups (standard deviation in parenthesis)

	Face			
Group	1p1o	1p4o	4p1o	4p4o
ASD	1094.3 (924.7)	806.2 (628.9)	1143.7 (893.3)	605.0 (600.4)
CA	245.2 (235.3)	621.9 (516.2)	1170.4 (748.8)	99.3 (851.3)
VA	646.6 (573.1)	198.5 (217.4)	1084.2 (680.7)	898.7 (595.5)
NVA	319.0 (315.8)	469.7 (306.3)	906.3 (670.1)	1107.5 (902.3)

	Object			
Group	1p1o	1p4o	4p1o	4p4o
ASD	1354.3 (709.2)	954.3 (809.8)	963.5 (794.2)	1408.1 (989.9)
CA	1076.7 (803.5)	1179.4 (948.2)	1007.1 (887.3)	1140.4 (992.9)
VA	833.2 (815.7)	954.0 (801.1)	1169.9 (739.6)	1047.7 (834.0)
NVA	848.4 (780.9)	992.3 (851.0)	725.7 (737.2)	1166.2 (775.7)

1p1o = 1 person 1 object, 1p4o = 1 person 4 object
4p1o = 4 person 1object, 4p4o = 4 person 4 object

A mixed 4x6x2 ANOVA was carried out with between factors being Groups (ASD, CA, VA, NVA) and within subject factors being Complexity (1 person 1 object, 1 person 4 object, 2 person 1 object, 2 person 4 object, 4 person 1 object, 4 person 4 object) and the AOIs (face and object). The Complexity conditions most relevant to this thesis will be presented within the result section, this includes the conditions of low social complexity low item complexity (1 person 1 object), low social complexity high item complexity (1 person 4 objects) high social complexity low item complexity (4 person 1 object) and high social complexity high item complexity (4 person 4 objects). The full analysis (including the 2 person conditions) is presented within Appendix F. Complexity did not impact on time taken to fixate on the images $F(4, 282) = 1.826$, $p = .129$, $\eta^2_p = .023$. Group membership did not impact on time taken to fixate across the images of different Complexity $F(11, 282) = 1.597$, $p = .098$, $\eta^2_p = .059$.

All the children fixated quickest on the face AOI (m = 795.7ms) across all the Complexity conditions compared to the object AOI (m = 1064.3ms) $F(1, 76) = 6.923$, $p < .01$, $\eta^2_p = .083$, similar to the adult participants in Experiment 6 (see Table 7.5). Group membership did not impact on time taken to fixate on the face and object AOIs across Complexity conditions showing that the ASD group took similar amount of time to fixate on the faces and objects compared to the typically developing groups $F(3,76) = .127$, $p = .944$, $\eta^2_p = .005$. Complexity did not impact on time taken to fixate on the face and object AOIs in the images $F(3, 234) = 1.985$, $p = .115$, $\eta^2_p = .025$. Group membership did not impact on time taken to fixate on the AOIs within each condition, therefore the ASD group took similar time to fixate on the face and objects in each condition as their typical matches $F(9, 234) = .806$, $p = .614$, $\eta^2_p = .031$. There was no differences observed between the groups $F(3,76) = 1.060$, $p = .371$, $\eta^2_p = .040$.

Task Accuracy

A mixed 4x2 ANOVA was carried out with within factors being the Recognised Items (object and face) and the between factors being the groups (ASD. CA, VA,NVA). There was a significant effect of Recognised Item $F(1, 338) = 18.353$, $p < .001$, $\eta^2_p = .195$ showing that objects (m = 74.56%) were remembered more than faces (m = 62.11%). Critically, there was no significant interaction between Recognised Item and Group, therefore the Groups remembered faces and object AOIs similarly $F(3,76) = .980$, $p = .407$, $\eta^2_p = .037$. There was no significant effect of Group membership $F(3,76) = .619$, $p = .605$, $\eta^2_p = .024$.

Discussion

There was no significant effect of group showing that the children with ASD fixated similarly to their typically developing counterparts across all complexity conditions similar to findings reported by Speer *et al.* (2007). The ASD group did continue to fixate on the face AOIs similar to their typically developing counterparts across all conditions which does not support the previous prediction that reduced attention to the face by children with ASD would occur for the highly complex scenes – when there is more competition from other non-social information. This is inconsistent with previous literature which has found reduced attention to faces in children with ASD (Riby & Hancock, 2008). The difference between this study and the study conducted by Riby and Hancock (2008) is the level of functioning of the ASD participants. The children in Riby and Hancock (2008) study had moderate to severe ASD. This study not only included children with severe ASD but also recruited children with high functioning ASD. This critical difference may explain why the group of children in the present Experiment performed typically across all conditions of complexity. Riby and

Hancock (2008) results may have also have differed from the present study because Riby and Hancock (2008) only required their participants to spontaneously attend to images unlike the present study where allocation of attention to the images was influenced by a memory task.

Complexity of the images affected fixation duration to objects or faces across all the groups. During the 1 person 1 object condition the children fixated significantly longer on the face AOI compared to the object AOI. This shows that they *preferentially* attended to the face compared to the object. These findings support suggestions that children (mainly typically developing children) attend faces preferentially and this may be due to their social significance and the socio-communicative cues they convey (for example, Kikuchi *et al.* 2009). However the children show longer fixations on the object AOIs across all the other stimuli conditions (except the 4 person 1 object condition where they again fixated longer on the face AOI - this would have been caused by more face AOIs being present during this condition compared to object AOIs). When the number of persons and objects presented are the same (i.e. 4 person 4 object condition) the children are shown to fixate for longer on the object AOI. This may show that objects are being attended to for longer by the children so that fine grained information can be encoded to allow for more featural processing and aid accuracy during the memory task.

Despite the object AOIs being fixated on for longest across the conditions the face AOIs were fixated on the quickest regardless of complexity. This supports previous literature which show faces are almost fixated spontaneously by children who are typically developing (Riby & Hancock, 2009a).

It was proposed that children with ASD would show higher accuracy rates for remembering objects during the memory task due to previous research reporting impaired memory of unfamiliar faces in ASD populations (Hauk, Fein, Maltby, Waterhouse & Feinstein, 1998). This was supported as children with ASD performed similarly to their typically developing counterparts and remembered objects significantly more compared to faces. It shows that all groups of children when shown the same images, attended to and extracted similar information which was later retrieved from memory. This further supports the eye-tracking analysis as it implies that the children with ASD attended to the same information presented on an image as typically developing children while engaged in a task. Children may not show high accuracy rates during face recognition due to a lack of face expertise. During development the children may become more expert in recognising faces as they get older due to high and increased exposure to faces during their everyday social encounters.

If the children had been allowed to gaze at the image spontaneously then increased fixation on the faces compared to objects may have occurred which is often observed in typical child populations (for example Riby & Hancock, 2008). The children with ASD showing similar visual strategies compared to their typically matched counterparts may imply that giving children across the autism spectrum a task to conduct may reduce atypical attention. This may explain why children with ASD have been reported as attending to the eye area during studies which require the children to conduct tasks (for example, Fletcher-Watson *et al.* 2008; Bar-Haim *et al*. 2006). Atypical gaze behaviour may be highlighted in populations with ASD during spontaneous attention allocation where they do not naturally attend to social salient areas of an image (for example Klin *et al.* 2002; Riby & Hancock, 2008, 2009b).

The type of task undertaken by populations with ASD may also impact on how they attend to areas of an image. As reported previously Pelphrey *et al*. (2002) found during a social judgement task adults with ASD fixated less on relevant areas of a face compared to a control group. Volkmar *et al.* (2004) suggested that individuals with ASD may show the same gaze behaviour as typical populations when engaged in tasks that are not embedded within a social context. The present study may extend this proposal by showing that even tasks undertaken during viewing of a social scene can cause typical attention in children with ASD and atypical attention allocation in this population may be more related to tasks which require socio-communicative judgements. To examine this, attention to complex social scenes by children during variations of tasks or spontaneous gazing must be carried out. This would highlight the qualitative ways gaze behaviour changes to deal with perceptual load during task engagement in children.

Therefore the children with ASD in this study fixated similarly as their typically developing counterparts during attention to stimuli of varying complexity. This is consistent with Speer *et al.* (2007) who found that children with ASD attended static images of varying complexity similarly to their control matches and that atypical gaze behaviour was only observed during dynamic and complex stimuli. Speer et al had also recruited high functioning children and adolescents with ASD which may explain why the results reported in this study are consistent with the present findings.

7.3 General Discussion

Complexity of the images affected fixation duration to objects or faces in both adult and child populations. Showing that how many items or persons presented on a scene does impact on how participants allocate attention to an image. It was also shown that the object AOI was attended by both adult and child populations for longer during the conditions of high complexity. This may show that objects maintain attention for longer so that fine grained information can be encoded to aid in memory retrieval during task. Despite the object AOIs being fixated on for longer across most of the complexity conditions, the face AOIs were fixated on the *quickest*. This supports previous studies which show faces are almost fixated spontaneously by children who are typically developing (Riby & Hancock, 2009a) and adults (Theeuwes & Van der Stigchel, 2006).

The children with ASD fixated similarly compared to their typically developing counterparts across all complexity conditions. This typical gaze behaviour observed in the ASD group may have been caused by them undertaking a memory task. This is similar to previous studies which have found children with ASD fixate similarly compared to matched counterparts during a visual task (Bar-Haim, *et al*. 2006) even when that task requires attention to a social scene (Fletcher-Watson *et al.* 2008). If the task had been a social judgement task different visual strategies by the children with ASD may have been adopted such as less attention to relevant parts of the faces as reported by Pelphrey *et al.* (2002). Therefore requiring the children with ASD to attend to areas of social significance of a scene or face may be more successful in highlighting atypical visual strategies across this population. The children with ASD may have also shown reduced atypical gaze behaviour because of the inclusion of high functioning populations with ASD similar to other experiments which have examined task driven attention allocation (for example, Fletcher-Watson *et al.* 2008). This may also explain the inconsistencies with the typical gaze behaviour to faces by the ASD group presented in this chapter and Riby and Hancock (2008) findings which found reduced attention allocation to the face area in children with ASD who were moderate to low functioning.

The eye-tracking data which highlighted attention was allocated to relevant areas similarly by the children with ASD and typically developing children was also supported by the memory task results which showed accuracy rates were similar also. The groups remembering similar items implies that they were attending and encoding similar information about the image.

The most important findings from this study highlighted how complexity affected the ASD group similarly compared to the typically developing children. Critically, children with ASD showed similar visual strategies compared to the typically developing children. This has possible implications for the use of images for communicating information to populations with ASD. This may imply that complexity does affect how the children with ASD attend to faces presented on images but only in the same way as seen in typical development. Including many objects on the scene may impact on how long faces are attended to and how often. Therefore if images are meant to communicate important social information then images should present people with no objects. By only presenting relevant persons objects will not distract the populations with ASD and more attention will be allocated to the face areas within the images.

Limitations and future directions

Future studies must examine how different types of tasks impact gaze behaviours across populations with ASD. It may be beneficial to include tasks involving visual search strategies, memory and social judgements alongside spontaneous looking to highlight qualitative differences these tasks cause in gaze behaviours. Comparing how different tasks influence attention allocation may explain the discrepancies shown in the literature (for example Pelphrey *et al*. 2002; Bar-Haim *et al.* 2006).

Chapter 8 – Evaluation and General Discussion

8.1 Communicative Face Skills

This thesis introduced the importance of attending to faces and fixating on the relevant areas of a face for socio-communicative cues in ASD. The relevant literature surrounding ASD was presented along with the many subtypes which occur within the spectrum. In addition literature was presented which showed the relevance of face processing in this developmental disorder. The benefits of applying eye-tracking methodology were outlined, explaining the advantages of using this technology to provide ecologically valid measures of attention allocation in children with ASD. Other methodological issues were also outlined that were relevant for consideration before the experiments were designed and carried out.

This thesis used eye-tracking explorations to highlight how attention is allocated to communicative cues presented on faces by children with ASD to enhance our understanding of the socio-communicative impairments which are observed across this disorder. The importance of attending to faces and understanding the communicative cues conveyed allows for successful identification of the face, social judgements, and insight to mental states all of which are integral to establishing and maintaining social relationships which was highlighted at the beginning of the thesis. The ability to attend to the eye area which provides insight to other's cognitive states, desires and wants was highlighted as being particularly important in understanding facial communicative cues. By emphasising the literature which reported how faces are attended to by adults and children who are typically developed allowed us to understand how children with ASD may be impaired in their attention allocation.

This thesis highlights how children with ASD continue to attend to the face despite variations of stimuli type which have already been examined within the literature. Specific emphasis was placed on the recruitment of children with ASD who showed a wide range of functioning capabilities to gain more realistic results which represents the heterogeneous population of ASD. This chapter examines the evidence from the three experimental chapters. First the eye-tracking findings are summarised to highlight the interesting attention allocation by children with ASD and how these findings may relate to their communicative impairments. How this research can impact wider aspects of ASD and how future studies required to enhance the understanding of this pervasive developmental disorder are also presented here.

8.2 Summary of Findings

This section summarises the main findings from the experimental chapters and considers how the evidence relates to the main story of the thesis.

How ecological validity impacts on face attention

Communicative aids used by populations with ASD were outlined within Chapter 5, including sign language, Voice Output Communication Aids (VOCAs) and Picture Communication Systems. Despite the picture systems showing more success and efficiency compared to the other aids, the system is still not comprehended by some children with ASD. This impaired understanding was proposed to be caused by a lack of image comprehension (Ganz, Kaylor, Bourgeois & Hadden, 2008). Images used within the picture systems present persons and objects of reduced ecological validity. It had been proposed by previous research that despite reducing ecological validity of images, atypical attention allocation to relevant areas of an image in children with ASD persisted (Riby & Hancock, 2009b). This impaired attention to relevant areas of the image including face and eye areas may explain impaired comprehension of the picture communication symbols. Not attending to the relevant areas of the symbols implies that an impaired understanding of what the image represents may occur. Therefore further investigation was required to highlight if children with ASD were able to allocate attention to the relevant areas of their picture communicative symbols. It was also important to examine level of functioning present in the children with ASD and if this impacted on attention allocation across the images. Therefore Chapter 5 investigated if children with ASD were attending to relevant areas of the picture communication symbols showing actions, emotions and objects from two different systems; BM and PECS, which presented different levels of ecological validity. Areas of particular interest included the face, and eye areas of these images.

Results of Chapter 5 showed that the children with ASD evidenced similar attention allocation compared to their typically developing counterparts. The ASD group were observed to orient to the face and eye areas presented within these images similarly compared to the typical groups again highlighting that the relevant areas maintained the attention of the children with ASD. The results presented here were consistent with van der Geest *et al* (2002b) who found that by presenting children with ASD pictures of reduced ecological validity atypical allocation of attention to people was reduced. However Riby and Hancock, (2009b) reported that children with ASD showed atypical face fixation on stimuli despite reduced ecological validity which is inconsistent with the findings presented here. The main relevant differences between the study presented here and Riby and Hancock (2009b) experiment involved the participants with ASD and their level of functioning. In the present study high functioning children were involved which may have caused an increased fixation on the face regions as opposed to the participants enrolled in Riby and Hancock (2009b) study which included children with ASD who were low to moderate functioning.

However there was a main effect of group during viewing of the emotions which showed children with ASD were attending less at the relevant areas across these images. Therefore despite attention across symbol type and AOI being typical their overall attention was not. This would mean that the children with ASD may not have been attending to the images in general as long as their typical counterparts. This lack of attention may lead to a reduced understanding of what the emotion images show. There may have been a main effect of group during the viewing of these images because they all consisted of faces showing emotion so special attention had to be allocated to the facial configurations on the faces. Impaired attention has been reported in adults with ASD when attending real faces showing emotion (Pelphrey et al 2002). The findings presented within this thesis may suggest that the atypical attention to faces showing emotion in populations with ASD is not reduced when ecological validity is reduced. Further research may be needed to examine children with ASD's qualitative gaze behaviour when attending to real and cartoon-like faces showing emotion which would highlight if reduced ecological validity does impact on gaze behaviour during emotion perception.

Previous research has proposed that attention to faces is indicative of level of functioning in children with ASD (Norbury *et al*. 2009; Riby & Hancock, 2009a; Speer *et al*. 2007) with higher functioning children with ASD showing longer fixations on faces, eyes and mouth areas. Therefore level of functioning was examined in Chapter 5 to highlight if this impacted on time spent fixating or time taken to fixate on areas of the images mainly objects and faces. There were no significant correlations suggesting that level of functioning did not impact on attention allocation to the picture communication symbols. This is again inconsistent with Riby and Hancock (2009b) who found that low functioning children with ASD fixated less on face areas even in images of reduced ecological validity. Further investigation of stimulus type then showed that the images used by Riby and Hancock (2009b) at times were socially complex and showed many persons engaged in social interaction. This was different from the stimuli used in the present study which presented isolated persons depicting actions or emotions. This warranted further investigation which was conducted during Chapter 7 and will be detailed later in this section.

Interestingly, the different symbol types impacted on the gaze behaviour by the children. The groups were observed to fixate longer on the PECS faces compared to the BM faces and they also fixated on the BM objects longer than the PECS objects. The main difference between these symbol types was ecological validity. The PECS symbols were more realistic compared to the BM symbols. This may have caused the children to attend to the faces shown within the PECS system longer since the faces presented within this system are more similar to the real faces they encounter daily. The longer fixation on the BM objects may have been caused by the images being really simplistic and they did not show much detail. This was unlike the PECS object images which at times were very complex. The lack of detail presented within the BM symbols might have caused the children not to understand or recognise what the objects were during a quick fixation. Therefore in order to solve the ambiguity of the BM images the children may have attended them for longer. During attention allocation to the emotion symbols all groups attended to the BM eyes and mouth for a longer time compared to the PECS areas. Therefore despite the PECS images being more realistic and attended to for longer in the previous study, when conveying emotions the children fixated longer on the less realistic BM images. This may have been caused by the BM images showing faces with exaggerated facial expressions such as an extremely down-turned mouth for ‘sad’ expression. These exaggerated facial expressions may have maintained the children’s attention for longer. The differences of attention allocation within these different symbol types may have implications on how symbols are designed and how ecological validity may impact on what areas of an image are attended to. Further investigation on how ecological validity influences attention to faces is warranted to highlight how sufficiently realistic or cartoon-like faces must be to receive attention to the relevant areas. For example, more cartoon-like faces may be more appropriate to convey emotional facial expressions because they maintain a child’s attention for longer.

In summary, overall attention to face and eye areas presented within picture communication systems such as PECS and BM seem mainly typical in children with ASD. This is particularly encouraging for the use of visual aids such as picture communication systems to help the communicative abilities within this population. It shows that children with ASD who show varied levels of functioning are able to attend typically to both the faces and eyes which are presented in their picture symbols. Attending to faces presented within the picture symbols is important for understanding what the symbols may represent such as emotions or actions. Therefore attention to the face and facial configurations for communicative cues are important for efficient comprehension of what the images are showing. This exploration of gaze behaviour to communicative aids by children with ASD has successfully highlighted typical attention to relevant socially salient areas of the images. This suggests that children with ASD who do not learn to efficiently use the picture systems may be impaired in a more conceptual understanding of the images rather than perceptual processing. Some children with ASD may have difficulties in understanding what the images represent despite attending to the relevant areas of an image. This impaired understanding of picture symbols may be more emphasised in lower functioning populations who generally show more deficits in communicative ability. Therefore further research is needed to examine if children with ASD understand what the picture symbols represent and if this comprehension is associated with level of functioning across the autism spectrum.

Typical attention to familiar, unfamiliar and 'self' faces

The next aspect of how faces were attended to by children with ASD that was investigated, was the role familiarity played. Chapter 6 applied a familiar, unfamiliar and self paradigm to examine if children with ASD would attend typically to more familiar faces. The most interesting line of investigation presented in this chapter was how children with ASD would attend to their own faces and if attention to the self faces would be different compared to typically developing children. Previous literature has reported populations with ASD show impaired self-referential ability (for example, Lee *et al.* 1994) which is proposed to be linked to an impaired self awareness (Lewis, 1995). A deficient self-awareness and self-referential ability in populations with ASD may be associated with reduced attention to their own faces. Most research which has been conducted on face processing presented unfamiliar faces to adults and children with ASD (for example Pelphrey *et al.* 2002; Speer *et al.* 2007; Riby & Hancock, 2008). The atypical attention often reported within this population may be reduced when attending familiar faces due to increased exposure which is required for a face to become familiar. Previous research had found that high functioning adults with ASD attended familiar faces atypically and continued to show reduced eye fixation compared to their typically developed counterparts (Sterling *et al.* 2008).

By examining attention to familiar, unfamiliar and self faces in Chapter 6 it was shown that the children with ASD attended typically to the faces regardless of familiarity. They were shown to fixate similarly on the eye and mouth regions across the familiarity conditions as well as the self condition similar to their typically developing counterparts. They also showed longer fixation duration on the eye area compared to the mouth area similar to their matched control groups. This was inconsistent compared to Sterling *et al.* (2008) findings that adults with ASD fixated less on the eyes compared to their controlled matches. Despite both studies recruiting high functioning populations with ASD, the main differences between the present study and Sterling *et al.* (2008) include age of sample (the present study examined children with ASD and Sterling *et al.* (2008) was conducted on an adult population) and presentation time of stimuli. Sterling *et al.* (2008) had presented his stimuli approximately 10 times each at time periods of 8 seconds, whereas the present study only presented the images once at 3 seconds. This may imply that populations with ASD are unable to maintain this attention to the eye area and this may be why atypical gaze behaviour is observed when stimuli is presented for longer periods of time. The findings presented in Chapter 6 may suggest that individuals with ASD show typical gaze behaviour during initial allocation of attention.

Level of functioning was also examined in Chapter 6 to highlight if it was associated with attention to the eye and mouth areas of familiar, unfamiliar and self faces. It was found that level of functioning assessed by scores on the Social Communicative Questionnaire – SCQ (which indicated low socio-communicative ability if score was high) was associated with fixation to the eye areas in familiar, unfamiliar and self faces.

Low fixation duration on the eye areas across familiarity types was indicative of low socio-communicative ability. Not only does this support previous proposals that atypical gaze behaviour is associated with socio-communicative impairments in ASD (Hobson *et al.* 1998) it also proposes that the increased eye fixation reported within this chapter may have been caused by the recruitment of children with ASD who are high functioning and therefore more likely to fixate on the eye region for longer. The important implications of these findings on participant recruitment for future studies will be considered in section 8.3.

Mutual eye gaze does not cause aversive gaze behaviour

Another domain of face communicative skills examined in Chapter 6 was attention to the eye area of a face that showed direct gaze (mutual eye contact) or averted gaze. Authors have previously suggested that mutual eye gaze causes anxiety and arousal in populations with ASD (Hutt & Ounstead, 1966) and the atypical attention allocated to the eye region is used as an arousal management strategy (Richer & Coss, 1976; Spezio *et al.* 2006). Therefore the familiar, unfamiliar and self faces were presented to be either direct gazing or showing averted gaze. It was predicted, based on the proposed increased arousal mutual gaze causes within this population (Hutt & Ounstead, 1966) that the children with ASD would fixate less on the eye region of direct gazing faces compared to faces showing averted gaze.

The children with ASD were observed to fixate for longer durations on the direct gazing eye regions compared to the averted eye regions similar to their typically developing matches. This was inconsistent with a study conducted on an adult population with ASD who were high functioning which reported that gaze direction did not impact on fixation duration to the eye region (Hernandez *et al.* 2008). The findings presented within this chapter showed that similar to typically developing children the eye region of direct gazing faces maintained attention for longer in children with ASD compared to averted faces. Hernandez *et al*. (2008) also reported that the ASD group fixated significantly less compared to their typical matches across the direct and averted eye regions which is again not supported by the current study as the children with ASD fixated typically on the eye areas.

The results presented in Chapter 6 suggest that the eye area is not an aversive region to children with ASD. Research which claims a lack of attention to the eye area during real social interactions (for example, Volkmar & Mayes, 1990) may instead be caused by the individuals with ASD failing to see the social significance of this area during an interaction. Due to this impaired natural instinct to attend to this socially salient area at appropriate times during social interactions may impact on their comprehension of the communicative cues this area conveys.

Typical gaze behaviour during complex scenes

The previous studies had also only examined children with ASD's gaze behaviour when looking at stimulus which presented isolated persons. Therefore the typical fixation on the face region by the children with ASD may have been caused by the images only presenting one person therefore not showing any levels of complexity. This chapter wanted to examine how increasing the complexity of an image (both socially and non-socially) impacted on gaze behaviour. Klin *et al*. (2002) presented complex dynamic images to high functioning adults with ASD and reported the ASD group spent less time fixating on the face and eye regions compared to their typically developed counterparts. Riby and Hancock (2008) also found that attention was not allocated typically to the face area by moderate and severe functioning children with

ASD during the viewing of complex social scenes. Therefore this chapter examined how sufficiently complex an image had to become to influence atypical attention allocation in children with ASD.

The children with ASD fixated similarly compared to their typically developing matches on both object and face areas across all complexity conditions. This showed that increasing item or social complexity did not impact on how attention was allocated by children with ASD any differently compared to the typical groups. This is similar to what Speer *et al.* (2007) reported, as the high functioning children and adolescents with ASD in Speer *et al.'s* (2007) study fixated typically on static images of varying complexity. The findings presented in this chapter were however inconsistent with the results reported by Riby and Hancock (2008) who found that the low to moderate functioning children with ASD fixated less on the face area of a complex social scene compared to their typically developing matches. The results presented here may have been different to those reported by Riby and Hancock (2008) due to participant differences as the participants involved in Riby and Hancock's (2008) study were children with moderate to severe ASD, unlike the participants recruited in the present study which included high functioning children with ASD and may have caused the increased attention to the face area of the images.

There was a shift of attention observed in the children when complexity of the image increased. An increase of complexity caused attention to be allocated to objects for longer, and when images showed reduced complexity, faces were fixated on for longer. This suggests that a face bias shifts to an object bias when complexity of an image increases. These attention shifts may have implications on the use of images presented as communicative aids to children with ASD. It shows that to place emphasis on faces, the images they are presented within must be less complex. This shift of attention may reflect less time is needed to attend to faces to process and encode information due to the use of configural processing strategies which allow for the quick encoding of faces. This processing style is not applied to encoding information from objects. Objects tend to be processed in a more piece-meal strategy (Tanaka & Farrah 1993) and therefore may require longer periods of attention by the children.

The results presented within this thesis suggest that regardless of complexity children with ASD are able to attend typically to faces. This shows that presenting non-socially relevant items in an image does not distract the children with ASD any more than typically developing children. These findings may suggest that children with ASD are able to attend typically to faces they encounter during real social world experiences which tend to be naturally complex.

Task driven attention allocation

In order to examine more factors which may impact on how children with ASD allocate attention, Chapter 7 was conducted differently compared to the previous chapters. Task driven attention allocation was examined instead of spontaneous allocation of attention to highlight if conducting a task would impact on the way children with ASD fixated on the images. During the presentation of complex images the children were asked to remember what items and persons were presented. After the image was shown they were given a short memory task which examined how well they remembered objects and faces from the stimuli.

Task accuracy was consistent with gaze behaviour data as it showed the children with ASD were able to remember similar numbers of items compared to the typically developing groups. All groups showed higher accuracy when remembering objects which was reflected by increased fixation on the object AOIs compared to face AOIs during image presentation. This showed that the ASD group allocated attention similarly compared to the typically developing groups to the same areas of the images to encode information for the memory task. The results presented in this chapter suggest that children with ASD employed typical visual strategies to attend to an image during a memory task. Atypical gaze behaviour in the children with ASD may have been reduced because they were conducting a task, which is consistent with previous literature. For example reduced atypical gaze behaviour in populations with ASD has been reported while they conducted target probe tasks and visual scene tasks (Fletcher-Watson *et al*. 2008; Bar-Haim *et al.* 2006). Differences may have been highlighted between the children with ASD and typically developing groups during viewing of complex images if they had been allowed to spontaneously attend to the images. This may also explain why the children with ASD in the present thesis attended typically to faces and is inconsistent with previous research which has reported reduced fixation to faces presented within complex images when populations with ASD are allowed to spontaneously allocate attention (for example, Klin *et al*. 2002; Riby & Hancock, 2008).

Further research is required to examine how different tasks may impact on attention allocation to images by children with ASD. For example a task which requires social judgements to be made may be more difficult for children with ASD who are often reported to be impaired in such tasks (Baron-Cohen *et al*. 1997). Social judgement tasks may also highlight differences in where children with ASD allocate attention and what areas of the image they believe to be relevant compared to typically developing children. This would also provide a reliable way to examine how children with ASD allocate attention when they are trying to make sense of their real social world.

8.3 Implications

This section will examine how the results presented within this thesis feeds into the wider knowledge of ASD. This includes how eye-tracking methodology provides insights into how children with ASD attend to facial communicative cues. We must consider how this research has enhanced our understanding of how children with ASD allocate attention and how this is associated with their overall socio-cognitive impairments.

Attending to faces for communicative cues

It was proposed in Chapter 3, that infants with ASD were impaired in allocating attention to the face from a young age (Volkmar & Mayes, 1990). It was specifically noted that infants with ASD showed impaired attention to the eye regions of faces and would often fixate on this area significantly less compared to their typically developing matches. Eye-tracking methodology highlights that this atypical attention to the eye area persists throughout development into adult populations with ASD (for example Klin *et al*. 2002; Riby & Hancock, 2009b). Lack of attention to the face and specifically socially salient areas such as the eyes may influence the socio-communicative impairments observed in ASD such as impaired language skills, comprehension of emotional expression and joint attention. Attending to faces often during social encounters allows children to learn the social signals faces convey. Not attending to the face from an early age will mean that important face skills will not be developed.

However this thesis shows that children with ASD are able to attend to face, eye and mouth areas for similar amounts of time compared to their typically developing counterparts (Chapter 6 & Chapter 7). The time taken by children with ASD to fixate on faces was also similar to the typical group which suggests that faces are able to capture attention in ASD. This also implies that faces are not completely aversive to children with ASD as previously proposed (Hutt & Ounstead, 1966) and they are able to attend to relevant features such as the eye region. However the results presented in this thesis do not highlight if children with ASD attend to the eye area during appropriate times of an interaction. Previous studies have proposed that populations with ASD do not fixate on the eye region at appropriate times and that this gaze behaviour may contribute to the socio-communicative impairments observed in ASD (Kasari, et al, 1990). Therefore despite children with ASD being able to attend to the eye area for typical fixation durations, if the eyes are not fixated on during appropriate times, communicative cues may continue to be missed and not learned.

The stimuli presented to the children within this thesis was only shown for small periods of time (three and five seconds). This may imply that initial gaze behaviour is typical in children with ASD and they are able to fixate initially on relevant areas of the face. It would be interesting to examine using eye-tracker methodology if this attention to the eye area continued if the faces were presented for longer periods of time and if this attention is applied appropriately during longer durations of social interactions.

This chapter also highlighted how faces capture attention when presented within a complex social scene. As social beings we naturally orient towards faces and by quickly attending to a face important social judgements can be made about others including identity, cognitive states, wants and desires. Faces are shown to capture attention quickly in both adult (Ro *et al.* 2001) and child populations (Riby & Hancock, 2009a). Chapter 7 in the present thesis also shows that faces capture attention of children with ASD. It was observed that children with ASD alongside typically developing groups took less time to fixate on faces across all complexity conditions.

This shows that despite the face appearing alongside non-social items such as objects, children with ASD are able to quickly allocate attention to a face presented within an image. This suggests that when faces are competing for attention compared to objects, children with ASD are able to fixate quickest on a face and therefore be able to attend to the relevant facial communicative cues.

In summary, the current thesis shows that children with ASD are able to fixate quickly on a face even when it is presented within complex scenes. This shows they are able to attend to the relevant areas of social scenes and relevant information is available for processing.

Level of functioning in ASD

Participant characteristics in populations with ASD were highlighted by this thesis to be important when interpreting eye-tracking results. Level of functioning within ASD has been shown to be related to fixation duration spent on the face (Riby & Hancock, 2009b) and eye regions (Speer *et al.* 2007). The results presented in this thesis were consistent with these results showing that low social ability was associated with low fixation time spent on the eye areas (Chapter 6). This has implications on how results are compared with previous ASD literature. Most eye-tracking studies focus on specific populations of ASD such as high functioning only or moderate to severe functioning only. This means that the eye-tracking experiments which were conducted on higher functioning children or adults with ASD may have reported a reduction of atypical attention on socially salient features of the face which would not be consistent with the gaze behaviour reported in a study which recruited moderate to severe functioning populations with ASD. This thesis therefore highlights the caution that must be taken when comparing results with previous literature, participant's level of functioning must be taken into consideration. Most of the inconsistent eye-tracking literature which has examined attention to faces (Klin *et al*. 2002; Norbury *et al*. 2009; Riby & Hancock, 2009b; Speer *et al*. 2007) may have been greatly influenced by participant's level of functioning.

Visual Communicative Aids

Not only did this thesis examine how attention may be allocated by children with ASD to actual faces they encounter in the real social world but how they fixate on faces presented within their communicative aids. It was shown in Chapter 5 how picture communication systems can be used successfully by children with ASD both as a system which conveys information (such as a timetable) and as an alternative system for spoken language (Charlop-Christy *et al*. 2002; Ganz & Simpson, 2004). However not all children with ASD were shown to be able to use this system effectively (Ganz *et al*. 2008). Some authors proposed that the children with ASD who weren't able to use the system appropriately may not have been able to comprehend what the images were representing. It was proposed by this thesis that lack of image comprehension may have been the result of the children not attending to relevant areas of the images. However this was not the case as the present thesis showed children with ASD were able to fixate similarly compared to typically developing children on the picture symbols. They showed similar fixation durations during both face symbols and object symbols. This is encouraging for picture systems as it shows children with ASD are able to fixate on the relevant areas of the image and the relevant information is available for encoding. It also shows that the children are not fixating for significantly longer periods of time on the images which show objects despite previous research which proposed populations with ASD show a preference for objects (Trepagnier *et al*. 2002). This may suggest that children who are unable to efficiently use picture systems may be impaired during a higher level processing stage or conceptual understanding of the images rather than impaired perceptual processing. This suggests that children with ASD may be attending to the relevant areas of the images but are not able to understand what the images represent and symbolize.

The children with ASD who were included in the present thesis had visual communication systems which included realistic images of themselves, teachers and support workers. These real images were presented within the children's timetables to show who they would work with daily. In Chapter 6 we examined how children with ASD fixated on faces which were familiar or unfamiliar and their own face. It was shown that the children with ASD fixated on the faces and relevant facial features such as the eyes across all familiarity types for similar fixation lengths as the typically developing groups. This shows that they are able to attend to these realistic images appropriately and the relevant information is available for processing identity etc. However it was also shown within Chapter 6 that attention to these realistic images was significantly associated with level of functioning. The more severe children with ASD were shown to fixate on the eye region less. This may impact on the relevant information available for lower functioning children to process and influence their ability to successfully identify the faces. The results presented in this chapter suggests that using realistic images within a timetable for children with ASD may only benefit the higher functioning children as they will be able to appropriately attend to these images.

Attending to the 'self' in ASD

This thesis showed that children with ASD attended to their own image similarly compared to typically developing children. They were able to fixate on the eye area for a similar amount of time compared to the typical groups also. However most of the typically developing groups took significantly less time to fixate on their own images compared to familiar and unfamiliar faces. This shows that their own face captured their attention quicker than other faces similar to previous studies which found similar effects in adult populations (Tong & Nakayama, 1999). This was not observed in the children with ASD who took similar amounts of time to fixate on familiar, unfamiliar and self faces. Despite this children with ASD were able to fixate typically on their own image. The ASD group attended the eye and mouth areas of their own faces similarly compared to typical matches. This may suggest that a basic self concept is present in children with ASD and that the reported impaired self-referential ability observed in this population may be caused by a meta-representation of self. Therefore children with ASD may be able to attend to visual self-information but not self-referential mental states. Impairments in self awareness mean that self knowledge cannot be applied to others to understand their beliefs, desires and cognitive states. More research is needed to examine if children with ASD are able to use any self information to comprehend social encounters and other people's behaviours.

8.4 Future Directions for Research

The research presented within this thesis could be extended to further examine how children with ASD attend to faces for communicative cues and how this is associated with their many socio-communicative impairments. There is technology which could increase ecological validity of selective attention in children with ASD and could investigate further how this population attends to their actual social environment. The initial considerations emphasize how the research presented in this thesis could be extended.

Chapter 7 showed how during a task children with ASD fixated on a complex image showing faces and objects similarly compared to typically developing groups. The task accuracy results reflected how selective attention was allocated with longer fixations on the object AOIs leading to increased recall of the objects. Future research could examine the impact of different tasks on how children with ASD fixate on images. An interesting avenue would be to include a social judgment task for the children with ASD to carry out while recording their gaze behaviour. It has already been reported that populations with ASD show impaired accuracy during social judgment tasks (Baron-Cohen *et al.* 1997). This impaired accuracy during social tasks may be caused by not attending to appropriate areas of faces and therefore reducing the amount of relevant information that is available for processing. Examining gaze behaviour during a social task could further highlight the visual strategies adopted by children with ASD when trying to extract social information specifically from the face and enhance our understanding of their socio-communicative impairments.

It has been shown by this thesis that children with ASD are able to allocate attention typically to familiar, unfamiliar and self faces (Chapter 6). However it would be interesting to examine the qualitative changes which may take place in gaze behaviour as a function of familiarity in children with ASD. Typically developing adults have been shown to change how they scan and attend to faces as a face becomes more familiar (Heisz & Shore, 2008). This thesis has shown that visual strategies used by children with ASD whilst attending familiar, unfamiliar and self faces were similar to typically developing children. Therefore it would be interesting to examine if changes in qualitative gaze behaviour in children with ASD would be similar compared to typical groups as they attend faces which are becoming more familiar. To examine this, novel faces would have to be presented several times to children with ASD and typical matches until the face has become sufficiently familiar. During these exposures eye-tracking data will highlight how the visual strategies change according to changes of familiarity. This would allow researchers to gain an understanding of how gaze behaviour develops and changes during familiar face processing in children with ASD. It may also highlight if they are able to adapt visual strategies depending on the type of faces they encounter for example familiar or unfamiliar.

An interesting endeavor for future investigations would be to examine how children with ASD attend to their real social environment. Screen eye-trackers which record gaze behaviour as the populations with ASD examine images or film extracts have high ecological validity but do not reliably represent the socio-cognitive load real social encounters demand. Mobile eye-trackers could be used by the children with ASD as they engage in a range of real social interactions. This would provide invaluable insight into how children with ASD attend to faces for communicative cues during social encounters while they deal with conversational demands and arousal. Mobile eye-tracking methods could be also used to examine how children with ASD attend to their learning environments and classrooms. This would inform teachers how to design or decorate learning environments to reduce distraction or increase attention to relevant learning stimuli such as their picture symbols. The use of mobile eye-trackers to highlight how children with ASD explore their social environment would greatly enhance our understanding of their social abilities and how they selectively allocate attention.

8.5 Conclusions

Therefore the results presented within this thesis have implications for the design of visual communication aids. Children with ASD showed an overall reduced attention to picture symbols despite the pattern of attention allocation across the symbol types and areas of interest being generally typical. This may imply that children with ASD are still not fixating as much as their typically developing counterparts. Symbol type also impacted on attention in children with ASD, with PECS faces being fixated on for longer when they were denoting hygiene behaviours. Unlike the other study which showed BM faces were attended to longer when they showed emotions. This may be caused by different levels of ecological validity being more efficient at communicating certain information types. For example less realistic BM images may be more informative when conveying emotional expressions. Image complexity should also be considered carefully when designing images. There was an observed switch from face to object bias which occurred when images became more complex. Therefore if information on the face is particularly important and needs to be conveyed efficiently, then the face must be presented within an image of low complexity so children will attend to the face for longer periods of time and be more likely to encode this information.

To conclude this thesis extends our understanding of how children with ASD attend to faces for socio-communicative cues. The present studies showed that children with ASD are able to fixate on faces and attend to relevant areas such as the eyes. This thesis also highlighted that faces are able to capture the attention of children with ASD similar to typically developing children. However when interpreting these results it must be remembered that the participant group presented within this thesis represented the actual population of ASD and showed a varied range of functioning. The results highlighted that level of functioning is associated with how children with ASD attend to faces, showing that lower functioning children fixate on faces less. Therefore the current thesis provides more understanding of how children with ASD fixate on faces for communicative cues and how this is indicative of their overall socio-communicative abilities.

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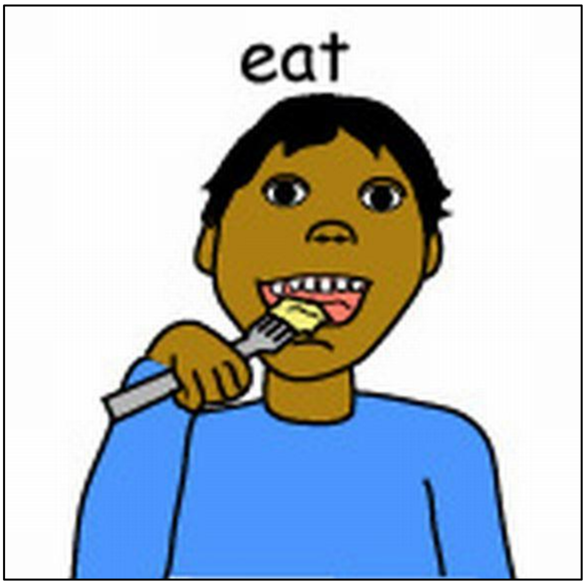
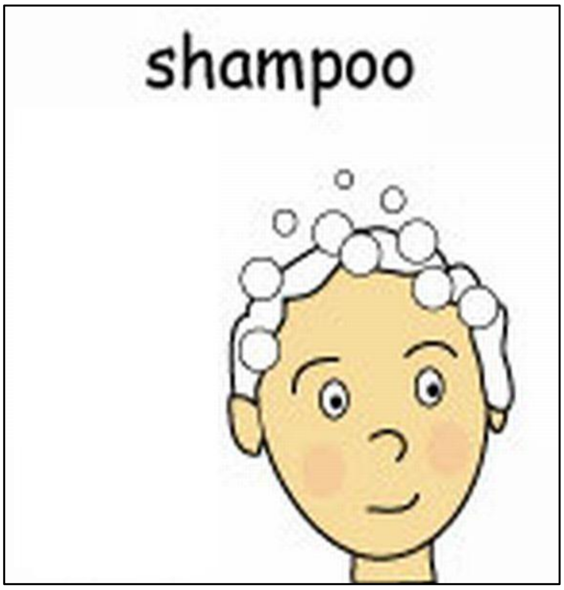
Appendix A

Images presented in Experiment 1 and 3

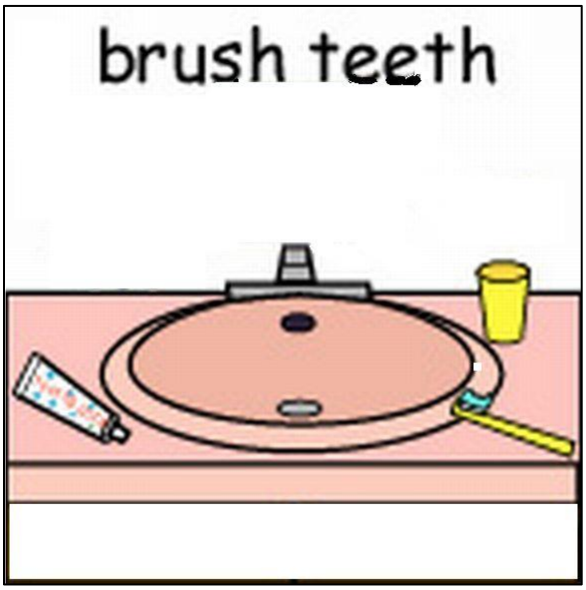
PECS images with faces

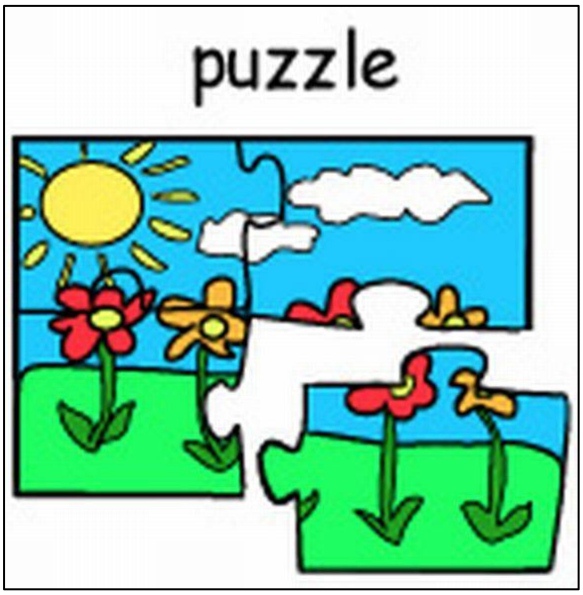





shave

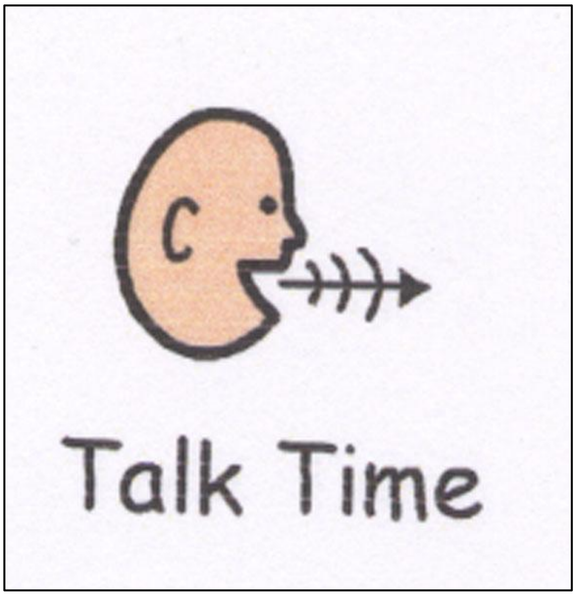
PECS images with objects

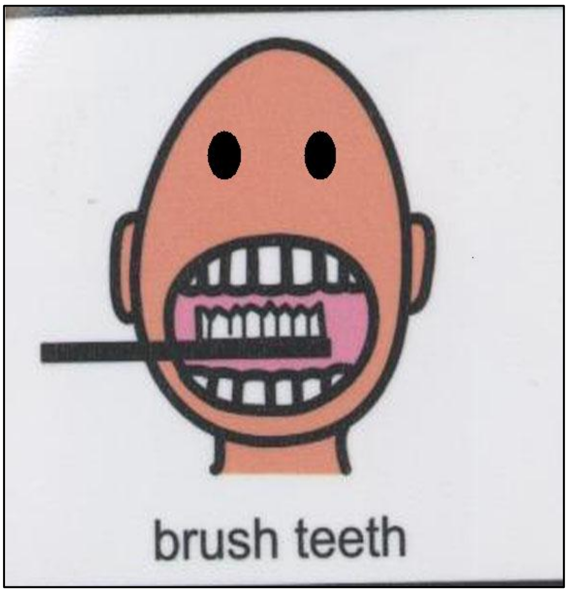


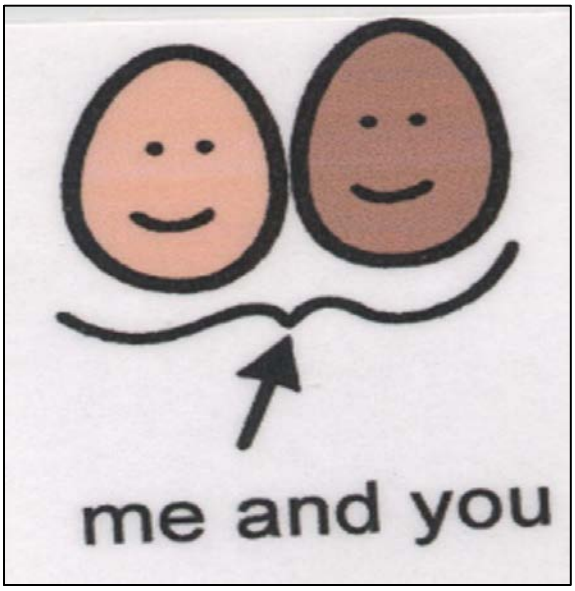


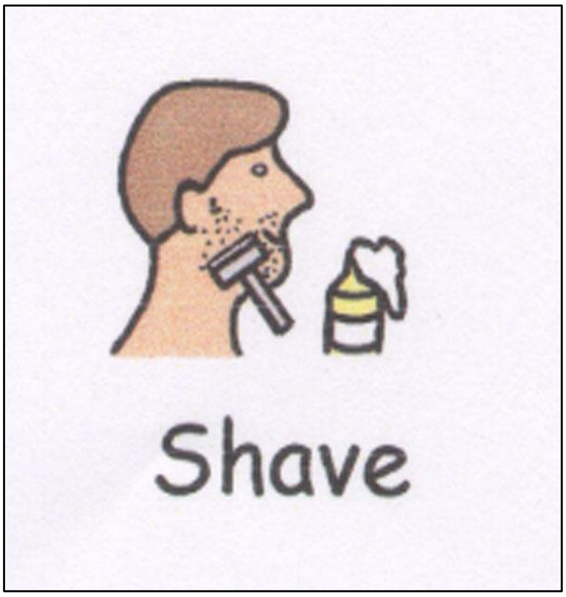

spelling
alligator
balloon
character

BM images with faces

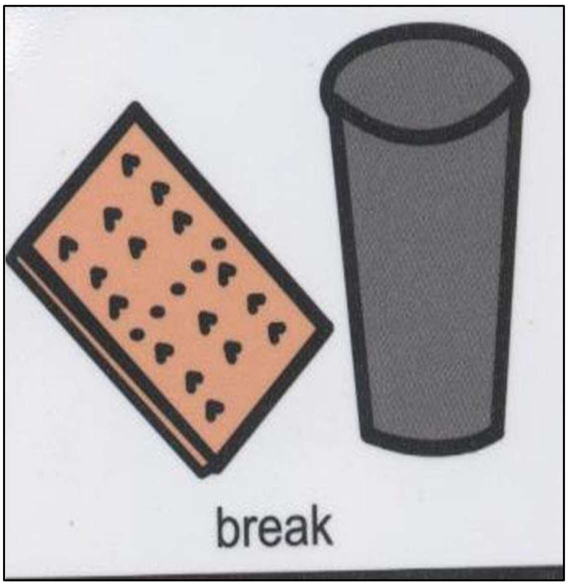


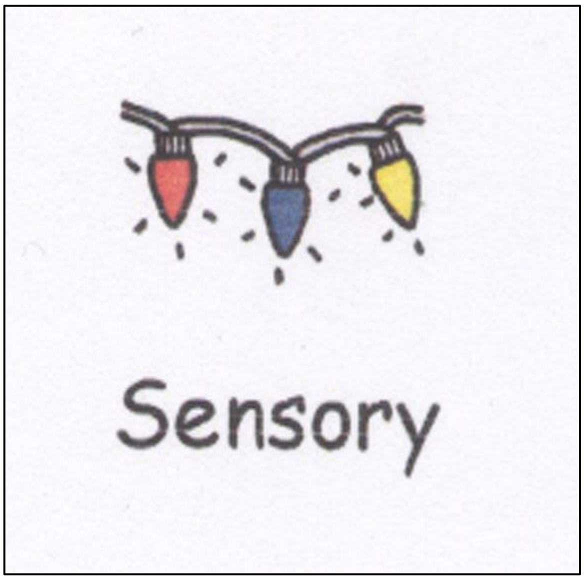


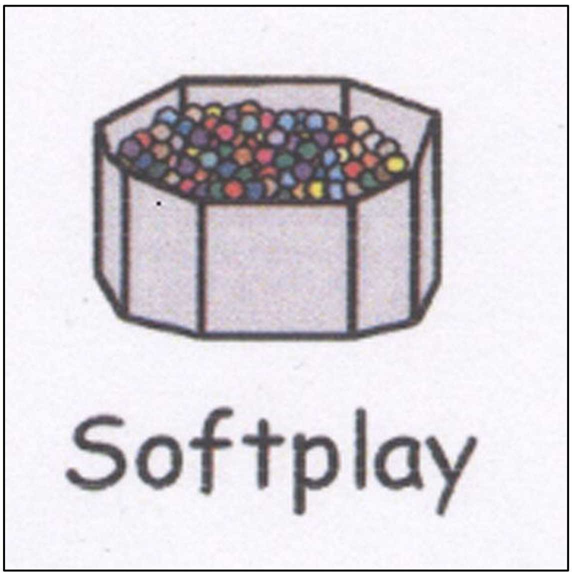


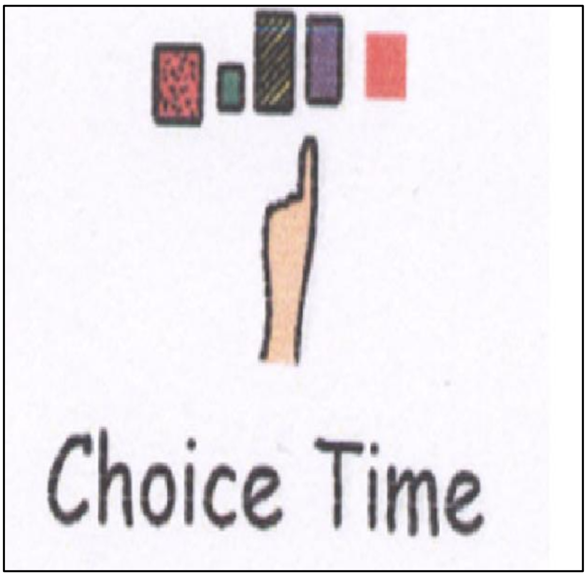

Shave

BM images with objects










Cooking

Appendix B

Chapter 5 – Full Analysis of Results

.**5.2.1 Experiment 1**

Proportion of mean total task fixation time.

The proportions of mean task fixation time spent on the areas of interest (faces and objects) were examined to highlight how long the children were allocating their attention on the object and face areas. The PECS images were examined separately from BM images to highlight the different or similar ways attention was allocated to the two symbol types which present different levels of ecological validity within their images.

A mixed 4x2x2 ANOVA was carried out with between-subject factor Group (ASD, CA, VA, NVA) and within-subject factor being Symbol Type (2 levels: BM; PECS) and the AOI (2 levels: face or object). There was no significant main effect of Symbol Type $F(1, 80) = .032$, $p = .858$, $\eta^2_p = .000$. There was no significant interaction between Group and Symbol Type $F(3, 80) = 1.697$, $p = .174$, $\eta^2_p = .060$.

All children including the ASD group fixated longer on the face AOIs (m = .189) compared to object AOIs (m = .144), $F(1, 80) = 28.388$, $p <= .001$, $\eta^2_p = .262$. Group membership did not impact on time spent fixating on the AOIs $F(3, 80) = 2.015$, $P =.119$, $\eta^2_p = .070$. Symbol type was shown to influence what AOI was attended to AOI $F(1, 80) = 163.759$, $p <= .000$, $\eta^2_p = .672$. To investigate this significant interaction post-hoc paired samples t-tests were carried out. It was found that participants fixated longer on the face AOI during the PECS condition (m = .256) compared to the face AOI during BM images (m = .122) $t(83) = 10.790$, $p < = .001$. This may be due to the faces presented on the PECS images being more realistic than the BM images, and may imply that the PECS symbols attracted longer fixation durations from the groups compared to the BM images. Symbol type continued to affect how long the object AOI was fixated on with the children looking longer at the objects within the BM condition (m = .213) compared to the object AOI in the PECS condition (m = .075) $t(83) = 6.819$, $p <= .001$. The PECS object pictures were much more complex than the BM images at times which may have caused the children to fixate less on these images.

There was a trend that Symbol type and Group membership affected how long object and faces were fixated on $F(3, 80) = 2.597$, $p = .058$, $\eta^2_p = .089$. To investigate this trend one way ANOVAs were carried out between groups for each AOI. The groups fixated similarly on the face AOI during the PECS condition. However group membership affected how the PECS object AOI was fixated on $F(3, 80) = 4.931$, $p < .01$. Post-hoc bonferroni showed that the ASD group (m = .119) looked longer compared to the CA group (m = .062) $p <= .05$, VA group (m = .038) $p <= .001$. There was also a trend towards the ASD group fixating longer on the PECS object AOI compared to NVA group (m = .080) $p = .077$. The groups all fixated similarly on the BM images including the face AOIs $F(3, 80) = 1.703$, $p = .173$, and the object AOIs also $F(3, 80) = 1.132$, $p = .341$. There were no differences of general fixation proportion across the Groups $F(3, 80) = .993$, $p = .400$, $\eta^2_p = .036$. Therefore the PECS object AOI attracted the attention of the ASD more compared to the typically developing groups. The ASD group fixated similarly on the face AOIs in the PECS images and BM images compared to the typically developing groups.

Time Taken to Fixate

Time taken to fixate was examined to show which areas of the picture symbols were selected for attention first by the children. Time taken to fixate will also highlight if symbol type or group membership affected which AOIs were fixated on the quickest.

A mixed 4x2x2 ANOVA was carried out with between factors being Groups (ASD, CA, VA, NVA) and within subject factors being Symbol type (BM and PECS) and the AOI (face and object). The participants were shown to fixate quicker on the PECS AOIs (m = 599.9 ms) compared to BM AOIs (m = 839.9 ms) $F(1, 80) = 34.471$, $p <= .001$, $\eta^2_p = .301$. Group membership did not affect time taken to fixate on the different symbol types $F(3, 80) = .481$, $p = .696$, $\eta^2_p = .018$.

The children fixated significantly quicker on the object AOIs (m = 634.9ms) compared to the face AOIs (m = 804.9ms) $F(1, 80) = 26.131$, $p <= .001$ $\eta^2_p = .246$. This may show that when ecological validity is reduced in images objects attract attention quicker compared to face AOIs. Group membership did not influence time taken to fixate on the face and object AOIs $F(3, 80) = 1.062$, $p = .370$, $\eta^2_p = .038$.

No significant interaction took place between Symbol type and AOI Symbol type did not affect how quickly AOIs were attended to, $F(1,80) = 1.875$, $p = .175$, $\eta^2_p = .023$. Group membership and Symbol type did not impact on how quickly objects and faces were allocated for attention $F(3, 80) = .223$, $p = .880$, $\eta^2_p = .008$. There was no differences of time taken to fixate on the images $F(3, 80) = .707$, $p = .551$, $\eta^2_p = .026$.

<u>Number of Fixations</u>

Number of fixations made by the groups on the object and face AOIs across the symbol types was another eye-tracking measure examined. Higher number of fixations on the AOIs may imply that the faces or object areas are being explored by the children.

Number of fixation measures can be examined alongside fixation duration data to highlight visual strategies that may be adopted by the different groups during viewing of the images (such as high number of low duration fixations may suggest more exploratory scanning).

A mixed 4x2x2 ANOVA was carried out with between factors being Groups (ASD, CA, VA, NVA) and within subject factors being Symbol type (BM and PECS) and the AOI (face and object). All children fixated more times on the PECS AOIs (m = 4.36) compared to the BM AOIs (m = 2.56) $F (1, 80) = 144.800$, $p <= .001$, $\eta^2_p = .644$. Group membership did not affect number of fixations on symbol types $F (3, 80) = .139$, $p = .936$, $\eta^2_p = .005$.

The children fixated significantly more on the face AOI (m = 2.70) compared to the object AOIs (m = 4.21) $F (1, 80) = 219.155$, $p <= .001$, $\eta^2_p = .733$. Group membership did not affect how many times the face and object AOIs were fixated on $F (3, 80) = 1.944$, $p = .129$, $\eta^2_p = .068$.

Symbol type influenced what AOI was fixated on a high amount of times $F (1, 80) = 5.876$, $p <= .05$, $\eta^2_p = .068$. Paired samples t-tests show that the PECS face AOI (m = 3.49) was fixated on significantly more on the BM face AOI (m = 1.91), $t (83) = 9.155$, $p <= .001$. The children continued to fixate more times on the PECS AOIs by showing a higher number of fixations on the PECS object AOI (m = 5.23) compared to BM object AOI (m = 3.20) $t (83) = 11.415$, $p <=.001$. Group membership and symbol type did not influence what AOIs were fixated on $F (3, 80) = .356$, $p = .785$, $\eta^2_p = .013$.

Group membership influenced how many times the images were fixated on $F (3, 80) = 3.061$, $p <= .033$, $\eta^2_p = .103$. Post-hoc bonferroni showed that the only significant difference was between the ASD group (m = 3.01) and the CA group (m = 3.79) p <=

.05, there was no significant differences between any other groups VA (m = 3.36) and NVA (m = 3.68). This showed that the ASD group did fixate less times on the images compared to the CA group.

5.2.2 Experiment 2

Proportion of mean fixation time

Attention allocation to the eye and mouth areas of the face can be highlighted by examining proportion of mean face fixation time spent on the eye and mouth AOIs. This will show where on the face the groups fixated on the longest and if they attended to the relevant areas of these faces showing emotional expression.

A 4x2x2 mixed ANOVA was carried out with between factors being Groups (ASD, CA, VA, NVA) and within subject factors being Symbol type (PECS and BM) and AOI (eye or mouth). The children were found to fixate significantly less on the PECS AOIs (m = .221) compared to the BM AOIs (m = .333), $F (1, 80) = 52.862, p <= .001, \eta^2_p = .398$. Group membership did not impact on time spent fixating on the different Symbol types $F (3, 80) = .386, p = .764, \eta^2_p = .014$.

All the children fixated for a longer proportion of time on the eye AOIs (m = .382) across the images compared to mouth AOIs (m = .172) $F (1, 80) = 58.538, p < .001, \eta^2_p = .423$. Group membership did not impact on how long the AOIs were fixated on $F (3, 80) = 1.191, p = .318, \eta^2_p = .043$.

Symbol type impacted on which AOIs were fixated on $F (1, 80) = 6.924, p <.01, \eta^2_p = .080$. This significant interaction was investigated by looking at each AOI (eye and mouth) and comparing the stimuli type. The children fixated longer on the BM eye AOI (m = .463) compared to the PECS eye AOI (m = .301) $t (83) = 5.994, p < .001$.

The groups also looked significantly longer on the BM mouth AOI (m = .202) compared to the PECSs mouth (m = .142) t (83) = 2.798, $p < .01$. There was no significant interaction between Symbol type, AOI and Group F (3, 80) = 1.158, p = .331, $\eta^2_p = .042$. There was a trend towards a significant effect of Group F (3, 80) = 2.533, p = .063, $\eta^2_p = .087$ however post-hoc bonferroni however showed there were no significant differences between the groups, (ASD = .234; CA = .299, VA = .272, NVA = .301), ASD – CA, p = .128; ASD – VA, p = 1.00; ASD – NVA, p = .110.

<u>Time to First Fixation</u>

Time to fixate on the eye and mouth areas was also examined to highlight if the eye and mouth attracted the attention of the ASD group differently compared to the typically developing groups.

A 4x2x2 mixed ANOVA was carried out with between factors being Groups (ASD, CA, VA, NVA) and within subject factors being Symbol type (PECS and BM) and AOI (eye or mouth). There was a trend for children to take a longer time to fixate on the PECS AOIs (m = 392.3ms) compared to the BM AOIs (m = 339.1ms) F (1, 80) = 3.115, p = .081, $\eta^2_p = .038$. Group membership impacted on time taken to fixate on the different symbol types F (3, 80) = 2.781, $p <.05$, $\eta^2_p = .096$. To investigate this significant interaction between subjects ANOVAs were conducted for each Symbol type. For PECS condition there was a significant effect of Group F (3, 80) = 2.383, p = .075. Post-hoc bonferroni showed there were no significant differences between groups CA (m = 385.2ms) and VA (m = 414.5ms) however there was a trend towards the NVA group (m = 514.7ms) taking significantly longer time to fixate on the PECS images compared to the ASD group (m = 286.4ms) $p = .058$. For the board maker stimuli there was no significant effect across groups $F(3, 80) = .497$, $p = .685$.

The children took similar amounts of time to fixate on the eye and mouth AOIs $F(1, 80) = 1.275$, $p = .262$, Np2 = .016. Group membership did not impact on time taken to fixate on the AOIs $F(3, 80) = .212$, $p = .888$, $\eta^2_p = .008$.

Symbol type impacted on which AOIs were fixated on quickest $F(1, 80) = 17.930$, $p < .001$, $\eta^2_p = .185$. This significant interaction was investigated by looking at each AOI and comparing the stimuli type using paired samples t-tests. The children took significantly longer to fixate on the PECS eye AOI (m = 496.2ms) compared to the BM eye AOI (m = 288.3ms) $t(83) = 4.624$, $p < .001$. There was also a trend towards significance for the children to fixate quicker on the PECS mouth (m = 304.0ms) compared to the BM mouth (m = 392.1ms) $t(83) = 1.846$, $p = .068$. There was no significant interaction between Symbol type, AOI and Group $F(3, 80) = .955$, $p = .418$, $\eta^2_p = .035$. There was no significant effect of Group on overall time taken to fixate on the images $F(3, 80) = 1.207$, $p = .313$, $\eta^2_p = .044$.

5.2.3 Experiment 3

Mean proportion of fixation time.

Mean proportion of task fixation time was selected for correlation analysis to examine if attention to the object and face AOIs was significantly related to level of functioning across the autism spectrum. Examining fixation time may highlight how long the object and face AOIs maintained the children with ASD's attention.

	FACE AOI		OBJECT AOI	
	BM	PECS	BM	PECS
CARS	.009	.031	.272	.133
SCQ	-.065	.003	.240	.057

Table 5.7 Correlations between CARS, SCQ and proportion of mean task fixation time

There were no significant correlations between the CARS or SCQ scores and fixation duration on the face and object AOI s in the picture symbols (see Table 5.7). Showing that level of functioning did not impact on how these cartoon-like images were attended to.

Time taken to first fixation.

Time taken to fixate on the AOIs was examined to see if this was also indicative of functioning level of the children with ASD. How quickly the face or object AOIs attracted the attention of the children with ASD may vary according to the level of their social functioning.

	FACE AOI		OBJECT AOI	
	BM	PECS	BM	PECS
CARS	.024	-.318	-.005	.068
SCQ	-.109	-.300	.102	.070

Table 5.8 Correlations between CARS, SCQ and mean time taken to first fixation

Again there were no significant correlations between the CARS or SCQ and eye gaze behaviour (see Table 5.8) during the presentation of their picture symbols. These results may imply that level of functioning does not influence time taken to fixate on AOIs within the images.

Number of Fixations

By examining the number of times the object or face AOIs were fixated on may highlight if different visual strategies were adopted during the viewing of these different AOIs.

	FACE AOI		OBJECT AOI	
	BM	PECS	BM	PECS
CARS	.008	-.212	-.097	-.153
SCQ	.041	-.158	-.159	-.068

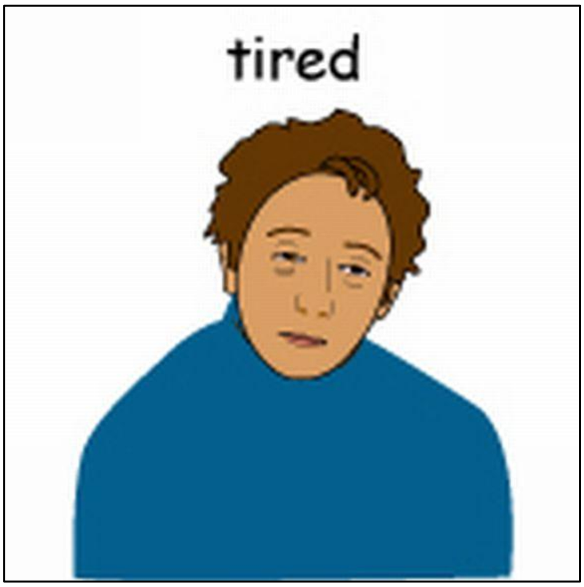
Table 5.9 Correlations between CARS, SCQ and mean number of fixations

There were no significant correlations between the CARS or SCQ score and the number of fixations on the face and object AOIs (see Table 5.9). This shows that level of functioning did not impact on how these areas were attended to by the children with ASD.

Appendix C

Images presented in Experiment 2

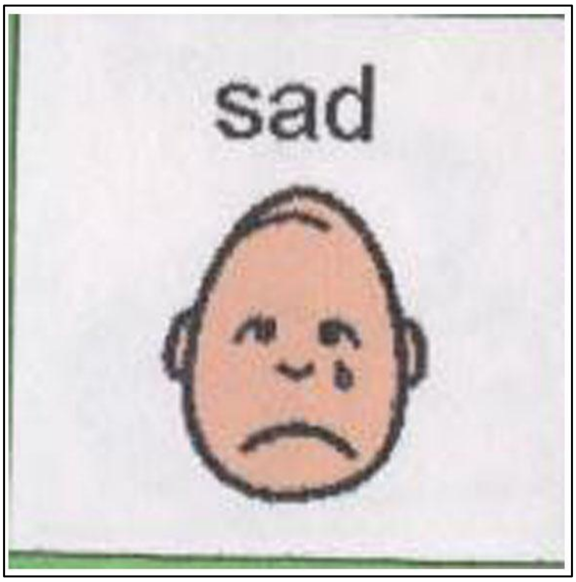
<u>PECS images showing emotions</u>




sad


sick

BM images showing emotion


sad


sore

Appendix D

Chapter 6 – Full Analysis of Results

6.2.1 Experiment 4

Fixation Duration

For fixation duration there was no overall difference in the time spent engaging in task $F(3,80) = 1.800$, $p = .154$, $MSE = 131.48$, showing that the ASD group (m = 6345.71ms MSE = 318.64) engaged in task similarly compared to their typically developing counterparts, CA (m = 7176.1ms, MSE = 203.48), VA (m = 6888.76ms, MSE = 246.02) and NVA (m = 6704.81ms, MSE = 255.67). However, because proportion of fixation time was used previously the same will be applied to the analyses in this chapter to maintain consistency.

Proportion of mean total face fixation time.

Proportion of mean fixation time

A mixed 4x3x2x2 ANOVA was carried out with between factors being Groups (ASD, CA, VA, NVA) and within subject factors being Familiarity of faces (familiar, unfamiliar, self), Gaze (direct and averted) and AOI (eye or mouth). There was a trend of Familiarity impacting on how long images were fixated on $F(2,159) = 2.359$, $p = .089$, $\eta^2_p = .029$. To investigate this trend towards significance paired samples t-tests were carried out. There was no significance differences between the familiar face AOIs (m = .269) compared to the unfamiliar face AOIs (m = .276) $t(83) = .426$, $p = .671$, and the self faces (m = .243) $t(83) = 1.659$, $p = .101$. There was a significant difference between unfamiliar AOIs and self AOIs $t(83) = 2.010$, $p < .05$. There was no significant interaction between Familiarity and Group $F (6, 159) = .605, p = .725, \eta^2_p = .022$.

All groups looked for a longer proportion of mean face time at the face AOIs which were direct (m = .300) compared to the AOIs which were averted (m = .225) $F (1, 80) = 31.014, p < .001, \eta^2_p = .279$. Therefore a direct face maintains attention longer than a face turned away from the observer. There was no significant interaction between Gaze and Group $F (3, 80) = .099, p = .960, \eta^2_p = .004$. The children fixated longer on the eye AOI (m = .400) compared to the mouth AOI (m = .125)$F (1, 80) = 72.727, p <.001, \eta^2_p = .476$. Group membership did not impact on attention allocated to AOIs $F (3,80) = 1.897, p = .137, \eta^2_p = .066$.

No significant interaction was observed between Familiarity and Gaze $F (2, 148) = 1.296, p = .276, \eta^2_p = .016$. The ASD group fixated similarly compared to typically developing groups on the faces across Familiarity and Gaze conditions $F (6, 148) = 1.509, p = .184, \eta^2_p = .054$. The children looked longer at the eye AOI (m = .400) compared to the mouth AOI (m = .125) $F (1, 80) = 72.727, p < .001, \eta^2_p = .476$.

Familiarity was observed to impact on how long the eye and mouth AOIs were fixated on $F (2, 155) = 3.288, p < .05, \eta^2_p = .039$. In order to investigate this significant interaction paired samples t-tests were carried out for each AOI (eye and mouth). There was no significant difference between proportion of face fixation time spent looking at the familiar eye (m = .392) compared to the self eye (m = .368), $t (83) = .802, p = .425$. There was a trend towards a significant difference between familiar eye (m = .392) and unfamiliar eye (m = .440) showing that there was a trend for the children to look longer at the unfamiliar eye compared to familiar $t (83) = 1.742, p = .085$. There was a significant difference between unfamiliar eye and self eye (m =

.368) fixation time t (83) = 2.396, $p < .05$ showing that all children fixated on the unfamiliar eye longer than the eye region of their own face. There was no significant difference between proportion of fixation length attending the self mouth (m = .117) compared to the unfamiliar mouth (m = .112) t (83) = .247, p = .806. There was a trend for children to look longer at the familiar mouth (m = .146) compared to unfamiliar mouth t (83) = 1.957, p = .054. There was a trend for the children to look more at the familiar mouth than the self mouth, t (83) = 1.682, p = .086.

There was also a significant interaction between factors Familiarity, AOI and Group F (6, 155) = 2.566, $p < .05$, $\eta^2_p = .088$. To investigate this interaction one-way ANOVAs were carried out between groups (ASD, CA, VA, NVA) for each AOI. A one-way ANOVA was carried out between the groups for familiar eye AOI and a significant effect was observed F(3,80) = 2.720, $p < .05$. Post-hoc bonferroni found that there was a trend for the ASD group (m =.527) to fixate longer on the familiar eye AOI compared to the CA group (m =.310) p = .053. One way ANOVAs were carried out for unfamiliar and self eye AOI however there was no significant effect of group for unfamiliar eye AOI F (3, 80) = 1.313, p = .276, or self eye AOI F (3, 80) = .775, p = .512.

A one way ANOVA was carried out for familiar mouth AOI and found that there was no significant effect of Group F (3,80) = 1.268, p = .291. There was no significant effect of Group for unfamiliar mouth AOI F (3,80) = 2.138, p = .102. There was a significant effect of Group for self mouth AOI F (3,80) = 2.793, $p < .05$. Post-hoc bonferroni showed the CA group (m =.344) looked significantly less at the self mouth AOI compared to the VA group (m=.331) $p < .05$.

Gaze impacted on how long the AOIs were fixated on $F(1, 80) = 6.055$, $p < .05$, $\eta^2_p = .070$. The eye region attracted more attention when the eyes were directed towards the viewer. Paired samples t-tests showed that the children fixated for a longer proportion of time on the eye AOI when gaze was direct (m = .456) compared to when gaze was averted (m = .345) $t(83) = 4.530$, $p < .001$. This was similar to what was found with the mouth AOI as for direct faces (m = .144) the mouth AOI was fixated on significantly longer than the mouth of averted faces (m = .106), $t(83) = 2.842$, $p < .01$ supporting the earlier results which showed that direct areas of interests were fixated on longer than regions of an averted face. There was no significant interaction between Gaze, AOI and Group $F(3,80) = .671$, $p = .573$, $\eta^2_p = .025$.

There was no significant interaction between the factors Familiarity, Gaze and AOI $F(2, 148) = 1.726$, $p = .184$, $\eta^2_p = .021$. Group membership did not impact on time spent fixating on eye and mouth AOIs during the Familiarity and Gaze conditions $F(6, 148) = 1.069$, $p = .382$, $\eta^2_p = .039$. There was no significant effect of Group across overall fixation $F(3,80) = 1.370$, $p = .258$, $\eta^2_p = .049$

Time to First Fixation

Time to first fixation was examined to highlight how long the children took to fixate on the relevant areas such as eye and mouth.

A mixed 4x3x2x2 ANOVA was carried out with between factors being Groups (ASD, CA, VA, NVA) and within subject factors being Familiarity of faces (familiar, unfamiliar, self), Gaze (direct and averted) and AOI (eye or mouth). Familiarity impacted on time taken to fixate on the images $F(2,151) = 7.117$, $p < .01$, $\eta^2_p = .082$. To investigate this significant effect, paired samples t-tests were carried out comparing Familiarity conditions. There was no significant differences between time taken to fixate on familiar AOIs (m = 639.4ms) and unfamiliar AOIs (m = 695.6ms) t (83) = 1.023, $p = .309$. All children fixated quicker on self AOIs (m = 495.7ms) compared to familiar AOIs, t(83) = 2.379, $p < .05$. The participants continued to fixate quicker on their self face AOIs compared to unfamiliar AOIs t (83) = 3.908, $p < .001$. Showing that their own face captured the children's attention quicker than any other face type.

Group membership impacted on time taken to fixate during the Familiarity conditions F (6, 151) = 2.005, $p = .073$, $\eta^2_p = .070$. To investigate this significant interaction repeated measures ANOVAs were carried out for each Group to examine the effect of Familiarity condition in each Group. There were no significant differences observed across the Familiarity Conditions in the ASD group F (2, 38) = .177, $p = .829$, $\eta^2_p = .009$. Therefore they looked similarly at the familiar AOIs (m = 507.5ms), unfamiliar AOIs (m = 457.1ms) and self face AOIs (ASD m = 500.3ms). This was similar to the NVA group where there was no significant effect of Familiarity observed F (2,36) = .373, $p = .667$, $\eta^2_p = .018$ showing that they looked similarly to the familiar AOIs (m = 708.6ms), unfamiliar AOIs (m = 744.0ms) and self AOIs (m = 650.2ms). There was a significant effect of Familiarity across the CA group F (2,37) = 5.529, $p < .01$, $\eta^2_p = .217$. Paired samples t-tests showed that the CA group fixated significantly quicker on their own face AOIs (m = 407.3ms) compared to familiar AOIs (m = 725.8ms) t (20) = 2.352, $p < .05$ and compared to unfamiliar AOIs (m = 792.4ms) t (20) = 3.663, $p < .01$. There was no significant difference between time taken to fixate on unfamiliar AOIs and familiar AOIs t (20) = .517, $p = .611$. A similar effect was observed for familiarity in the VA group F (2,39) = 5.514, $p < .01$, $\eta^2_p = .216$. Paired samples t-tests showed that the VA group fixated quicker on their own face AOIs (m = 456.1ms) compared to unfamiliar face AOIs (m = 819.6ms) t (20) = 3.503, $p < .01$. There was no significant differences observed between time taken to fixate on familiar face AOIs (m = 649.3ms) compared to self AOIs t (20) = 1.650, p = .114 and unfamiliar face AOIs t (20) = 1.587, p = .128. This showed that most typically developing groups were quicker to fixate on their own images compared to any other familiarity type.

Gaze also impacted on time taken to fixate on the images, showing that time to fixate on the AOIs was longer for faces which gaze was directed to the front (m = 713.8 ms) compared to the faces with averted gaze (m = 506.7 ms) F (1,80) = 19.691, $p < .001$, $\eta^2_p = .198$. This may be due to children being drawn to an averted face to examine where the face is directing attention and may be preparing to engage in gaze following. There was no significant interaction between Gaze and Group F (3,80) = 1.134, p = .341, $\eta^2_p = .041$.

No significant effect of AOI was observed across Groups and Familiarity conditions F (1, 80) = .724, p = .397, $\eta^2_p = .009$. Group membership did not impact on time taken to fixate on the AOIs, showing that groups oriented to the AOIs similarly F (3,80) = 1.449, p = .235, $\eta^2_p = .052$. There was no significant interaction between Familiarity and Gaze F (2, 158) = .537, p = .584, $\eta^2_p = .007$ showing that familiarity did not affect the time taken to fixate on direct or averted faces. Group membership also did not impact on time taken to fixate on the direct and averted faces during the Familiarity conditions F (6, 158) = .938, p = .469, $\eta^2_p = .034$. No significant interaction was observed between Familiarity and AOI F (2, 152) = 1.322, p = .269, $\eta^2_p = .016$. There was no significant effect of Group membership on general time to fixate on the images F (6, 152) = .744, p = .609, $\eta^2_p = .027$.

There was a significant interaction between Gaze and AOI F (1,80) = 11.932, $p < .001$, $\eta^2_p = .130$. To investigate this interaction paired samples t-tests were carried out, showing that there was no significant difference between time to first fixation on the eye AOI when gaze was direct (m = 658.9 ms) and when gaze is averted (m = 610.2ms) $t(83) = .845$, $p = .400$. However there was a significant difference between time taken to fixate on the mouth AOI when it was direct (m = 768.7ms) and averted (m = 403.1ms) $t(83) = 5.028$, $p < .001$ showing that all the children took longer to fixate on the mouth AOI when the gaze of the face was direct and were quicker to fixate on the mouth AOI when the face was averted. There was no significant interaction between Gaze, AOI and Group $F(3,80) = 1.086$, $p= .360$, $\eta^2_p = .039$.

There was a significant interaction between Familiarity, Gaze and AOI $F(2, 158) = 3.532$, $p <.05$, $\eta^2_p = .042$. To investigate this interaction between factors paired samples t-tests were carried out for each AOI (eye and mouth) examining Familiarity and Gaze. There was a significant difference observed between time taken to fixate on the eye AOI of a familiar face when the face was direct (m = 749.8ms) compared to when the face was averted (m = 543.3ms), showing that the groups took less time to fixate on the eye AOI when the face was averted $t(83) = 2.365$, $p < .05$. There was no significant difference between time taken to fixate on the eye AOI for the self face regardless of gaze being direct (m = 614.2ms) or averted (m = 520.5ms) $t(83) = .861$, $p = .392$. There was a trend towards a significant difference observed for unfamiliar faces showing there was a slightly longer time to fixate on the eye AOI when gaze was averted (m = 766.9ms) compared to when gaze was direct (m = 612.7ms), $t(83) = 1.685$, $p = .086$. Therefore Familiarity influenced how attention was allocated to the eye area during averted and direct conditions. For familiar faces time to fixate on eye area was less when it was averted. This may be caused by the child relying on the eye area of a familiar face for social signals for example, gaze following, social referencing. This was not observed for the unfamiliar eye area which the children fixated on quicker when it was directly facing which may be influenced by the children trying to identify the face.

For the mouth AOI, it was observed that all participants took longer to fixate on the mouth AOI of familiar faces which were gazing directly ($m = 746.7$ms) compared to when faces were averted ($m = 517.7$ms) $t(83) = 2.099$, $p < .05$. The mouth AOI was fixated on quicker when the face was unfamiliar and averted ($m = 474.2$ms) compared to when gaze was direct (928.6ms), $t(83) = 3.404$, $p <.001$. The children took quicker to fixate on the mouth AOI of self faces with averted gaze ($m = 217.3$ms) compared to the self faces gazing direct ($m = 630.9$ms) $t(83) = 3.694$, $p < .001$ which shows that for mouth AOI all children took longer to fixate on the mouth when the face was direct compared to the averted face.

There was no significant interaction between Familiarity, Gaze, AOI and Group $F(6, 158) = .339$, $p = .914$, $\eta^2_p = .013$. There was no significant effect of Group on overall time taken to fixate on the images. $F(3,80) = 1.946$, $p = .129$, $\eta^2_p = .038$.

Number of Fixations

Fixation number was examined to highlight if faces of varying familiarity attract a higher number of fixations.

A mixed 4x3x2x2 ANOVA was carried out with between factors being Groups (ASD, CA, VA, NVA) and within subject factors being Familiarity of faces (familiar, unfamiliar, self), Gaze (direct and averted) and AOI (eye or mouth). There was no significant effect of Familiarity $F(2, 160) = 1.291$, $p = .278$, $\eta^2_p = .016$. Group membership did not impact on number of fixations made on the familiarity conditions $F(6,160) = .368$, $p = .898$, $\eta^2_p = .014$.

All the children made a higher number of fixations on the faces with direct gaze (mean = 1.110) compared to the faces with averted gaze (mean = .606) $F(1, 80) = 99.246$, $p < .001$, $\eta^2_p = .554$. Group membership did not impact on number of fixations made on the direct and averted faces $F(3,80) = .619$, $p = .605$, $\eta^2_p = .023$. AOI influenced number of fixations made showing that all the participants looked more at the eye AOI (m = 1.270) compared to the mouth AOI (m = .446).$F(1,80) = 81.578$, $p < .001$, $\eta^2_p = .505$. Group membership did not influence how many times the AOIs were fixated on $F(3,80) = 1.745$, $p = .164$.

No significant interaction was observed between the factors Familiarity and Gaze $F(2, 160) = 1.357$, $p = .260$, $\eta^2_p = .017$. Group membership did not influence on the number of fixations made on the direct and averted faces across familiarity conditions $F(6,160) = .655$, $p = .684$, $\eta^2_p = .024$. Familiarity impacted on the amount of times the AOIs were fixated on $F(2, 160) = 2.711$, $p = .071$, $\eta^2_p = .033$. Repeated measure ANOVAs were carried out for each AOI. There was no significant effect of Familiarity on number of fixations made on the eye AOI $F(2, 164) = 2.198$, $p = .115$, $\eta^2_p = .026$. There was no significant effect of Familiarity across the mouth AOI $F(2, 166) = .961$, $p = .385$, $\eta^2_p = .011$. Groups did not influence number of fixations made on the AOIs during the Familiarity conditions $F(6,160) = 1.784$, $p = .108$, $\eta^2_p = .063$.

A significant interaction is observed between Gaze and AOI $F(1,80) = 30.940$, $p < .001$, $\eta^2_p = .279$. Investigating this interaction paired samples t-tests were carried out. There was a significantly higher number of fixations on the Eye AOI when gaze was direct (m = 1.64) compared to the eye AOI when gaze was averted (m = .90) $t(83) = 9.097$, $p <.001$. There was significantly more fixations on the mouth AOI in the direct gaze condition (m = .58) compared to the mouth AOI when gaze was averted (m= .31), t (83) = 6.047, p < .001. There was no significant interaction between Gaze, AOI and Group, F (3,80) = .792, p = .502, η^2_p = .029.

No significant interaction is observed between Familiarity, Gaze and AOI F (2, 160) = 1.859, p = .164, η^2_p = .023. Group membership did not impact on the number of fixations made on the AOIs during Familiarity and Gaze Conditions F (6,160) = .470, p = .811, η^2_p = .017. There was no significant effect of group on overall number of fixations F (3,80) = .306, p = .821, η^2_p = .011.

6.2.2 Experiment 5

Proportion of mean face fixation time

Correlations were conducted examining fixation duration with social and communicative scales which measure socio-cognitive abilities in the children with ASD. This can highlight if fixation duration to faces is associated with level of functioning across the autism spectrum.

	EYE AOI			MOUTH AOI		
	fam	unfam	self	fam	unfam	self
CARS	-.242	-.343	-.316	-.220	-.192	-.079
SCQ	-.386*	-.510**	-.452*	-.081	-.131	.012

* = correlation is significant at the 0.05 level (p < 0.025 after the application of a Bonferroni correction for multiple comparisons).

** = correlation is significant at the 0.01 level (p <0 .005 after the application of a Bonferroni correction for multiple comparisons).

Table 6.5 Correlations between CARS, SCQ and mean fixation duration

There are no significant correlations between CARS scores and proportion of mean face fixation time which does not support previous studies which have found such correlations (i.e. Riby & Hancock, 2008). However, there are significant negative correlations between the SCQ scores and all eye AOI across the familiarity conditions (see Table 6.5). This shows low level of socio-communicative ability (high scores on the SCQ) is related to spending a low proportion of fixation time looking at the eye AOI across all familiarity conditions. High scores on the SCQ (scores ≥ 15 implies presence of ASD) having a significant relationship with proportion time spent looking at the eyes shows that socio-communicative abilities are related to attention allocation of this area.

Time to First Fixation

Time taken to fixate on the eye and mouth AOIs was examined to show if time taken to fixate on the AOIs of a face were indicative of level of functioning across the autism spectrum.

	EYE AOI			MOUTH AOI		
	fam	unfam	self	fam	unfam	self
CARS	-.249	-.081	-.340	-.206	-.053	-.008
SCQ	-.290	-.095	-.228	-.211	-.094	-.082

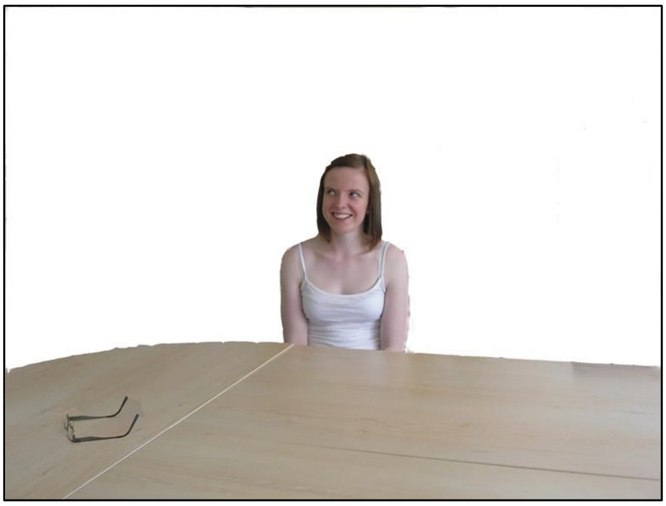
Table 6.6 Correlations between CARS, SCQ and mean time to first fixation

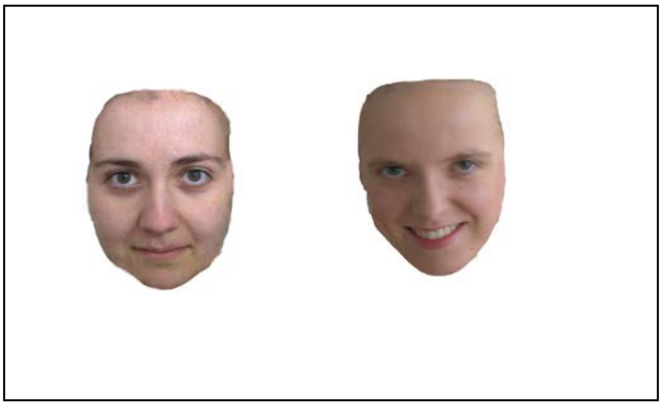
There were no significant correlations between the CARS scores or SCQ scores and AOIs across familiarity (see Table 6.6). This may imply that level of social functioning or level of autistic impairment is not related to how faces attract attention despite there being a relationship between fixation time and socio-communicative ability.

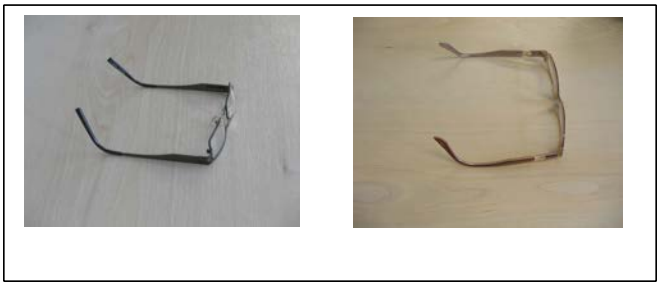
Appendix E

Images and choice sheets presented in Experiment 6 and 7

<u>One person one object condition</u>





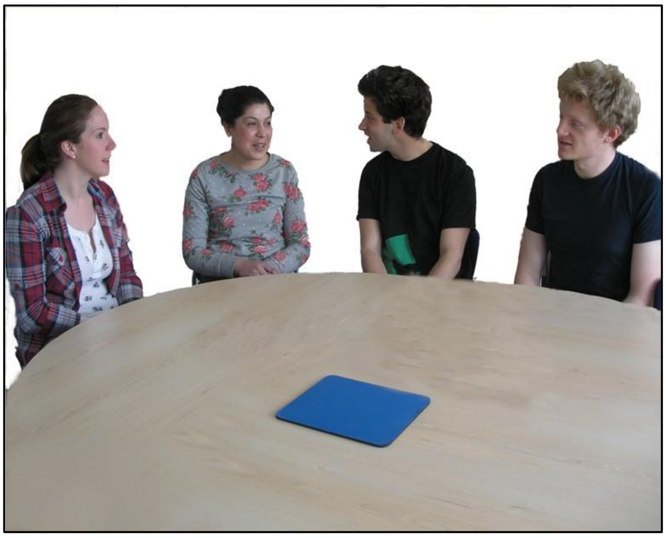


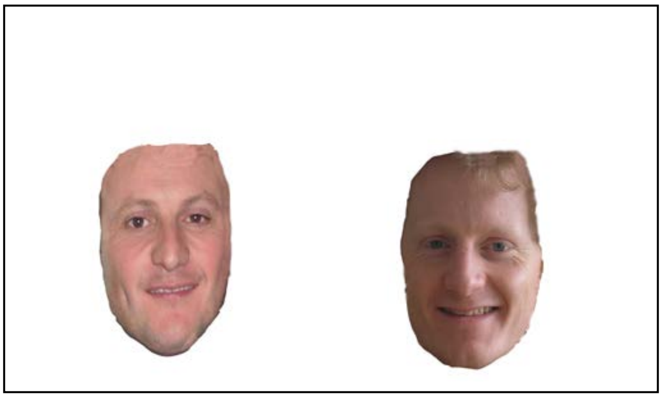
One person four object condition

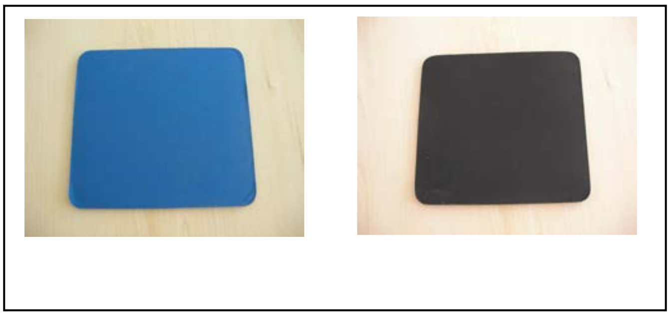
Two person one object condition

Two person four object condition

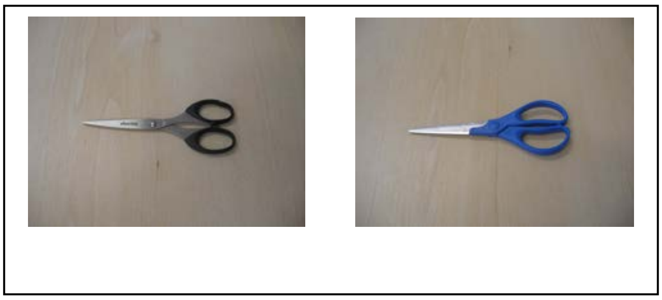
Four person one object condition







Four person four object condition



Appendix F

Chapter 7 – Full Analysis of Results

7.2.1 Experiment 6

Fixation Duration

Fixation duration was examined during the pilot study to highlight if manipulating item and social complexity affected how long face and object AOIs maintained attention. A within subjects ANOVA was carried out with within factors being Complexity Condition (1 person 1 object, 1 person 4 object, 2 person 1 object, 2 person 4 object, 4 person 1 object, 4 person 4 object) and the AOIs (face and object). Complexity was shown to impact on how attention was allocated to the face and object AOIs within the images $F(3, 66) = 29.290$, $p < .001$, $\eta^2_p = .560$. The children looked longer at the face and object AOIs during the 1 person conditions (low social complexity).The conditions fixated on the most was the 1 person 4 object condition (m = 2119.6ms). This was fixated on significantly longer compared to all conditions including the 1 person 1 object condition (m = 1661.10ms) $t(23) = 3.455$, $p < .01$, 2 person 1 object (m = 1245.25ms) $t(23) = 11.591$, $p <=.001$, 2 person 4 object image (m = 1580.16ms) $t(23) = 6.074$, $p < .001$, 4 person 1 object stimuli (m = 1198.50ms) $t(23) = 8.551$, $p < .001$, 4 person 4 object image (m = 1484.26ms) $t(23) = 6.074$, $p < .001$.

The 1 person 1 object condition was the next image to be fixated on most by the students. This was fixated on significantly longer compared to 2 person 1 object stimuli $t(23) = 4.119$, $p <.001$, 4 person 1 object image $t(23) = 4.514$, $p < .001$, and a trend to look significantly longer at the 1 person 1 object condition compared to 4 person 4 object condition $t(23) = 1.802$, $p = .085$. There was no significant difference between 1 person 1 object and 2 person 4 object condition $t(23) = .855$, $p = .402$.

The students fixated least on the 4 person 1 object image (high social complexity low item complexity). This was significantly less compared to 2 person 4 object t (23) = 5.362, $p < .001$ and 4 person 4 object image t (23) = 7.055, $p <.001$. There was no significant difference between the 4 person 1 object condition and the 2 person 1 object condition t (23) = .732, p = .472. This may have been caused by the 2 person 1 object condition being fixated on the least amount of time after the 4 person 1 object condition. The 2 person 1 object AOIs were fixated on significantly less than the 2 person 4 object AOIs t (23) = 6.326, $p < .001$ and the 4 person 4 object AOIs t (23) = 4.400, $p <.001$. There was no significant differences of how long the groups fixated on the 2 person 4 object image compared to the 4 person 4 object image t (23) = 1.756, p = .092. Therefore the participants seemed to fixate longer on the AOIs presented within the 1 person (low social complexity) conditions compared to the 4 person conditions (high social complexity).

AOI did not impact on fixation duration across the Complexity Conditions F (1, 23) = 1.121, p = .301, η^2_p = .046. Complexity impacted on how long the AOIs was fixated on F (4, 91) = 38.588, $p <.001$, η^2_p = .627. To investigate this significant interaction paired samples t-tests were carried out for each Complexity Condition to compare fixation duration on each AOI. The group was shown to fixate significantly longer on the face AOI (m = 2406.63ms) compared to the object AOI (m = 915.58ms) t (23) = 6.717, $p <.001$ during the 1 person 1 object condition. In the 1 face 4 object stimuli the participants were shown to fixate significantly longer on the object AOI (m = 2880.88ms) compared to the face AOI (m = 1358.38ms) t (23) = 6.645, $p < .001$. The face AOI (m = 1425.79ms) was fixated on significantly longer than the object AOI (m = 1064.71ms) during the 2 person 1 object condition t (23) = 2.726, $p < .05$. Participants looked significantly longer at the objects AOI (m = 2002.08ms) compared to the face AOI (m = 1158.23ms) during the 2 person 4 object image t (23) = 3.295, $p < .01$. Face AOIs (m = 1911.2ms) were fixated on significantly longer compared to object AOIs (m = 486.3ms) during the 4 person 1 object condition t (23) = 12.383, $p < .001$. The participants showed a trend of looking longer at the object AOI (m = 1670.21ms) compared to the face AOI (m = 1298.31ms) t (23) = 1.871, p = .074 during the 4 person 4 object stimuli.

Time to First Fixation

Time to first fixation was an eye-tracking measure examined during this study to highlight how quickly face or object AOIs attracted attention when presented within social scenes of varying complexity.

A within subjects ANOVA was carried out with within factors being stimuli Complexity Condition (1 person 1 object, 1 person 4 object, 2 person 1 object, 2 person 4 object, 4 person 1 object, 4 person 4 object) and the AOIs (face and object). Complexity impacted on time taken to fixate on the AOIs F (4, 77) = 13.899, $p < .001$, $\eta^2_p = .377$. To investigate the significant effect of condition paired samples t-tests were carried out comparing conditions. The 1 person 4 object AOIs (m = 660.7ms) were fixated on the quickest. This was significantly quicker compared to 2 person 1 object condition (m = 1086.7ms) t (23) = 3.161, $p < .01$, 2 person 4 object (m = 1107.3ms) t (23) = 3.821, $p < .001$, 4 person 1 object (m = 1519.5ms) t (23) = 4.507, $p < .001$, 4 person 4 object AOIs (m = 1511.1ms) t (23) = 7.321, $p < .001$. There was no significant difference between 1 person 1 object (m = 667.29ms) and 1 person 4 object t (23) = .066, p = .948, showing that the participants took similar amounts of time to fixate on these conditions. Participants were also quicker to fixate on the AOIs during the 1 person 1 object condition compared to 2 person 1 object t (23) = 3.199, $p < .01$, 2 person 4 object condition t (23) = 5.372, $p < .001$, 4 person 1 object AOIs t (23) = 4.635, $p < .001$, and 4 person 4 object image t (23) = 7.220, $p < .001$. The students took significantly longer to fixate on the 4 person 1 object image compared to 2 person 1 object image t (23) = 2.193, $p < .05$, 2 person 4 object t (23) = 2.276, $p < .05$. The participants fixated similarly on the 4 person conditions shown by no significant differences being observed between the 4 person 1 object image and the 4 person 4 object image t (23) = .048, p = .962. The participants also took significantly longer to fixate on the 4 person 4 object compared to 2 person 1 object AOIs t (23) = 3.188, $p < .01$ and 2 person 4 object condition t (23) = 3.637, $p < .001$. There was no significant difference between 2 person 1 object and 2 person 4 object AOIs t (23) = .154, p = .879.

There was a significant effect of AOI showing that the participants were quicker to fixate on the face AOIs (m = 828.2ms) across conditions compared to object AOIs (m = 1356.3ms), F (1,23) = 19.855, $p < .001$, $\eta^2_p = .463$. Complexity did not impact on what AOIs were fixated on by the participants F (4, 75) = 1.774, p = .155, $\eta^2_p = .072$.

<u>Number of Fixations</u>

Numbers of fixations were examined to show if how often the participants fixated on the object or face AOIs across the conditions. Number of fixations can be explored alongside fixation duration to highlight if the participants were quickly scanning the AOIs by showing many fixations but small durations. Therefore number of fixations can highlight visual strategies adopted during the scanning of the images.

A within subjects ANOVA was carried out with within factors being Complexity (1 person 1 object, 1 person 4 object, 2 person 1 object, 2 person 4 object, 4 person 1 object, 4 person 4 object) and the AOIs (face and object). Complexity impacted on number of fixations made on the images by the participants $F (3, 75) = 40.887, p < .001, \eta^2_p = .640$. The 1 person 4 object AOIs (m = 4.96) was fixated on the most compared to all the other conditions 1 person 1 object (m = 2.60) $t (23) = 6.796, p < .001$, 2 person 1 object (m = 2.07) $t (23) = 11.757, p <.001$, 2 person 4 object AOIs (m = 3.85) $t (23) = 3.120, p < .01$, 4 person 1 object AOI (m = 1.94) $t (23) = 9.504, p <.001$ and 4 person 4 object (m = 3.42) $t (23) = 4.802, p <.001$. The next condition which was fixated on the most was the 2 person 4 object condition this was significantly more compared to the 1 person 1 object AOIs $t (23) = 5.222, p < .001$, 2 person 1 object condition $t (23) = 8.536, p < .001$, and 4 person 1 object $t (23) = 7.658, p < .001$. There was a trend towards the students fixating more on the 2 person 4 object compared to the 4 person 4 object image $t (23) = 1.937, p = .065$. The participants fixated the least number of times on the 4 person 1 object out of all the Complexity Conditions. This condition was fixated on significantly less compared to 1 person 1 object $t (23) = 3.681, p <.01$, and 4 person 4 object $t (23) = 6.537, p < .001$. There was no significant difference between 4 person 1 object and 2 person 1 object condition $t (23) = .837, p = .411$. The 2 person 1 object AOIs was fixated on less compared to 1 person 1 object AOIs $t (23) = 2.644, p < .05$, 4 person 4 object $t (23) = 6.114, p <.001$. There was a significant higher number of fixations made on the 4 person 4 object image compared to 1 person 1 object image $t (23) = 3.039, p < .01$.

Participants fixated more times on the object AOIs (m = 3.94) compared to face AOIs (m = 2.35), $F (1,23) = 67.112, p < .001, \eta^2_p = .745$. Complexity was also observed to impact on the number of times AOI was fixated on $F (4, 85) = 64.135, p < .001, \eta^2_p = .736$. To investigate the significant interaction between the factors paired samples t-tests comparing the number of fixations on the object and face AOIs for each condition. The participants fixated more times on the face AOI (m = 3.08) compared to the object AOI ($m = 2.13$) $t(23) = 3.607$, $p < .01$ during the 1 person 1 object condition. During the 1 person 4 object condition the students fixated significantly more times on the object AOI ($m = 7.92$) compared to the face AOI ($m = 2.00$) $t(23) = 13.387$, $p < .001$.

For the 2 person 1 object condition the face AOI ($m = 2.48$) was fixated on more compared to the object AOI ($m = 1.67$) $t(23) = 3.254$, $p <.01$. The participants fixated more times on the object AOI ($m = 5.17$) compared to the face AOI ($m = 2.54$) during the 2 person 4 object condition $t(23) = 5.085$, $p <.001$. The face AOI ($m = 2.26$) was fixated on significantly more compared to object AOI ($m = 1.63$) during the 4 person 1 object condition $t(23) = 2.867$, $p <.01$. The participants fixated more times on the object AOIs ($m = 5.17$) compared to the face AOIs ($m = 1.67$) $t(23) = 7.453$, $p < .001$ during the 4 person 4 object condition. This seemed to show that as number of faces or objects presented increased so did number of fixations on the regions.

There was a significant effect of AOI showing that the participants were quicker to fixate on the face AOIs ($m = 828$ ms) across Complexity Conditions compared to object AOIs ($m = 1356$ms), $F(1,23) = 19.855$, $p < .001$, $\eta^2_p = .463$. Complexity Condition did not impact on overall number of fixations made by the participants $F(4, 75) = 1.774$, $p = .155$, $\eta^2_p = .072$.

7.2.2 Experiment 7

Proportion of fixation time

Proportion of fixation time was selected as an eye-tracking measure to highlight if image complexity impacted on how the object and face AOIs maintained attention.

A mixed 4x6x2 ANOVA was carried out with between factors being Groups (ASD, CA, VA, NVA) and within subject factors being Complexity Condition (1 person 1 object, 1 person 4 object, 2 person 1 object, 2 person 4 object, 4 person 1 object, 4 person 4 object) and the AOIs (face and object). Complexity impacted on how much time was spent fixating on the images $F(4, 312) = 40.279$, $p < .001$, $\eta^2_p = .346$, paired samples t-tests were conducted to investigate the significant effect of Complexity. The children fixated the least proportion of fixation time on the 4 person one object condition AOIs ($m = .133$) this was significantly less compared to 1 person 1 object condition ($m = .289$) $t(79) = 8.655$, $p < .001$, 1 person 4 object condition ($m = .347$) $t(79) = 12.275$, $p < .001$, 2 person 1 object ($m = .208$) $t(79) = 4.848$, $p < .000$, 2 person 4 object ($m = .263$) $t(79) = 8.325$, $p < .001$, 4 person 4 object ($m = .169$) $t(79) = 2.632$, $p < .01$. The condition looked at least after 4 person 1 object was the 4 person 4 object condition, this was significantly less compared to 1 person 1 object $t(79) = 6.021$, $p < .001$, 1 person 4 object, $t(79) = 10.599$, $p <.001$, 2 person 1 object, $t(79) = 2.885$, $p <.01$, 2 person 4 object $t(79) = 5.779$, $p < .001$. The condition which the children fixated more on the most was 1 person 4 object significantly longer compared to 1 person 1 object $t(79) = 2.520$, $p <.05$, 2 person 1 object, $t(79) = 6.892$, $p < .001$, 2 person 4 object, $t(79) = 4.181$, $p < .001$. The one person conditions continue to be fixated on most as the 1 person 1 object condition was fixated on longer compared to the 2 person 1 object $t(79) = 4.401$, $p < .001$. There was no significant difference between 1 person 1 object and 2 person 4 object $t(79) = 1.417$, $p = .160$. 2 person 4 object condition was fixated on the most after the 1 person conditions. The groups fixated significantly longer on the 2 person 4 object condition compared to 2 person 1 object image showing that the 2 person condition which presented the most objects attracted more attention $t(79) = 3.049$, $p < .01$.

Group membership did not impact on how long the images were fixated on for each Complexity Condition $F(12, 312) = 1.251$, $p = .246$, $\eta^2_p = .047$. The children fixated significantly more on the face AOIs of the images (m = .197) compared to the object AOIs (m = .273) across the complexity conditions showing that faces maintained attention for longer compared to objects $F(1, 76) = 22.395$, $p < .001$, $\eta^2_p = .228$. Group membership did not impact on what AOIs were fixated on showing that the ASD group did not attend to the object or faces differently compared to the other groups $F(3, 76) = 1.762$, $p = .162$, $\eta^2_p = .065$.

There was a significant interaction between Complexity and AOI $F(4, 276) = 39.302$, $p < .000$, $\eta^2_p = .341$. Paired samples t-tests were carried out to investigate this interaction, by comparing the AOIs in each condition. For the 1 person 1 object condition the children fixated significantly longer on the face AOI (m = .389) compared to the object AOI (m = .189) $t(79) = 6.323$, $p < .000$. In the 1 person 4 object image the children fixated significantly longer on the object area (m = .473) compared to the face area (m = .222), $t(79) = 5.707$, $p < .001$.

In the 2 person 1 object the children fixated longer on the object area (m = .248) compared to the face area (m =.169), $t(79) = 2.614$, $p < .05$. The children continued to fixate longer on the object AOIs in the 2 person condition as they fixated longer on the object (m = .381) compared to the face area (m = .145) in the 2 person 4 object $t(79) = 7.311$, $p <.001$. For the 4 person 1 object image the children fixated on the face AOIs (m = .178) compared to the object AOI (m = .088), $t(79) = 4.376$, $p <.001$. They also fixated on the object (m = .261) significantly longer compared to the face areas (m = .078), in the 4 person 4 object $t(79) = 7.057$, $p < .001$. Group membership did not impact on how the AOIs were attended to during each condition $F(11, 276) = .984$, p =

.461, η^2_p = .037. There was no significant differences between groups F (3,76) = .252, p = .860, η^2_p = .010.

Time taken to first fixation

Time taken to fixate on the object and face AOIs across complexity conditions was examined to highlight if the ASD group took different lengths of time compared to their typically developing counterparts to fixate on the object and face AOI.

A mixed 4x6x2 ANOVA was carried out with between factors being Groups (ASD, CA, VA, NVA) and within subject factors being Complexity Condition (1 person 1 object, 1 person 4 object, 2 person 1 object, 2 person 4 object, 4 person 1 object, 4 person 4 object) and the AOIs (face and object). There was no significant effect of Complexity F (4, 282) = 1.826, p = .129, η^2_p = .023. There was no significant interaction between factors Complexity and Group F (11, 282) = 1.597, p = .098, η^2_p = .059.

All the children fixated quickest on the face AOI (m = 795.7ms) across the Complexity Conditions compared to the object AOI (m = 1064.3ms) F (1, 76) = 6.923, p <.01, η^2_p = .083. Group membership did not impact on time taken to fixate on the face and object AOIs across Complexity Conditions showing that the ASD group took similar amount of time to fixate on the faces and objects compared to the typically developing groups F (3,76) = .127, p = .944, η^2_p = .005. There was no significant interaction between the Complexity Condition and the AOI F (3, 234) = 1.985, p = .115, η^2_p = .025. There was no significant interaction between Complexity Condition, AOI and Group F (9, 234) = .806, p = .614, η^2_p = .031. There was no significant effect across the Groups on overall time taken to fixate on the images F (3,76) = 1.060, p = .371, η^2_p = .040.

Number of Fixations

Fixation number was examined to highlight differences in the amount of times the object or face AOIs were fixated on across the complexity conditions. Number of fixations can be used alongside fixation duration to show the visual strategies adopted by the children whilst scanning the images.

A mixed 4x6x2 ANOVA was carried out with between factors being Groups (ASD, CA, VA, NVA) and within subject factors being Complexity Condition (1 person 1 object, 1 person 4 object, 2 person 1 object, 2 person 4 object, 4 person 1 object, 4 person 4 object) and the AOIs (face and object). There was a significant effect of Complexity $F(4, 289) = 27.883$, $p < .001$, $\eta^2_p = .268$. To investigate this significant effect of condition paired samples t-tests were carried out. It was found that the 1 person 1 object condition (m = 2.60) received the highest number of fixations from the participants, this was significant compared to all the other conditions. Including, 1 person 4 object condition (m = 1.50) $t(79) = 4.372$, $p < .001$, 2 person 1 object (m = 1.53) $t(79) = 4.556$, $p <.001$, 2 person 4 object image (m = 1.61) $t(79) = 4.552$, $p <.001$, 4 person 1 object (m = 1.39) $t(79) = 5.355$, $p <.001$ and 4 person 4 object (m = 1.19) $t(79) = 6.761$, $p <.001$. 2 person 4 object was the next condition to be fixated on most by the children however this was only significantly higher compared to 4 person 4 objects $t(79) = 3.406$, $p < .001$, there was also a trend towards the participants fixating more on the 2 person 4 object compared to 4 person 1 object condition $t(79) = 1.702$, $p = .089$. There were no significant differences compared to 2 person 1 object stimuli $t(79) = .507$, $p = .614$ and 1 person 4 object stimuli $t(79) = .680$, $p = .499$. The condition to be fixated on the least by the children was the 4 person

4 object condition, this was significant compared to the 2 person 1 object condition t (79) = 2.435, p < .05. There was a trend towards the children looking significantly less at the 4 person 4 object condition compared to the 1 person 4 object condition t (79) = 1.937, p = .056 and the 4 person 1 object condition t (79) = 1.788, p = .078. There were no significant differences between the 4 person 1 condition compared to the 1 person 4 object stimuli t (79) = .758, p = .450, and 2 person 1 object t (79) = 1.118, p = .267. There was no significant difference between 1 person 4 object and 2 person 1 object t (79) = .153, p = .879.

Group membership did not impact on number of fixations made on the Complexity Conditions F (11, 289) = .512, p = .900, η^2_p = .020. All children fixated significantly more times on the object AOIs (m = 2.85) compared to the Face AOIs (m = 1.64), F (1, 76) = 72.934, p < .001, η^2_p = .490. Group membership did not impact on how many times the object and face AOIs were fixated on across Complexity Conditions F (3,76) = 1.000, p = .398, η^2_p = .038.

Complexity Condition impacted on how many times the AOIs were fixated on F (4, 283) = 44.994, p < .001, η^2_p = .372. To investigate the significant interaction between Complexity Condition and AOI paired samples t-tests were carried out for each condition. It was found that the groups showed a higher number of fixations during 1 person 1 object condition on the object AOI (m = 1.03) compared to face AOI (m = 0.58) t (79) = 3.813, p <.001. The children also fixated significantly more times during the 1 person 4 object stimuli on the object AOIs (m = 1.02) compared to the face AOI (m = 0.52) t (79) = 4.107, p < .001. There was no significant differences between the number of times the object AOI (m = 1.10) and the face AOI (m = 0.77) on the 2 person 1 object t (79) = 1.172, p = .245. The groups didn't fixate significantly different during the 2 person 4 object image face AOIs (m = 0.92) and object AOIs (m = 1.11) t

(79) = 1.429, p = .157. The children did not fixate differently on the object areas (m = 0.97) and face areas (m = 1.08) during the 4 person 1 object condition t (79) = .802, p = .425 and the face AOI (m = 0.90) and object AOIs (m = 1.17) were fixated on similarly during the 4 person 4 object condition t (79) = 1.342, p = .183. Showing that despite conditions of high social complexity there is no bias to look at faces. There was no significant interaction between Complexity Condition, AOI and Group F (11, 283) = .351,p = .345 η^2_p = .042. There was no significant effect of Group F (3,76) = .649, p = .586.