Understanding attention to social information in adults with and without autism spectrum disorders

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Abstract

This thesis aims to further our understanding of social attention, and its manifestation in adults with autism spectrum disorders (ASD) and their typically-developed (TD) peers. Atypicalities in social attention have been proposed to play a crucial role in the development of autism. If social attention difficulties persist across the life-span, we would also expect them to impair ongoing social interactions in adolescents and adults with ASD. However, social attention in adulthood has been little examined. Instead, research tends to focus on more complex social cognitive difficulties, or to investigate attention to social stimuli presented in isolation. Our understanding of the role of social attention in autism is further inhibited by conflicting evidence on the influence of high-level input and low-level stimulus properties on selecting the focus of attention in TD individuals.

The studies presented here tackle these issues by assessing social attention in adults using stimuli which: present social information in a realistic context; measure spontaneous attentional processes; and provide control over the low-level properties of stimuli. Three studies each employed a method newly applied to the study of social attention. These were: a free-description task that coded verbal accounts of social scenes; a social change detection task that recorded change detection speed and accuracy for alterations to social and non-social aspects of a person; and a preferential-looking task that presented social and non-social scenes side-by-side, while recording eye-movements. It was predicted that findings from each study would indicate a social attention bias in TD adults, while people with ASD would have either a weaker social attention bias or no bias at all.

In contrast to predictions, these results showed that people with ASD spontaneously attend to social stimuli, as revealed by the social content of their verbal descriptions and their rapid and accurate detection of changes to eye-gaze direction. However, eye-tracking data in the preferential-looking task indicate that the social attention bias is subtly different in people with ASD, who show a reduced attentional priority for social information, and less persistence in looking at social stimuli over time, compared to TD participants. A series of cross-task analyses examining relationships between tasks indicated that a single social attention construct which operates across tasks and scenarios may not exist. These studies also emphasise the need to make distinctions between different types of social information and the idea of a hierarchy of social stimuli available in the real world is proposed.

Taken together, the studies reported in this thesis provide new data indicating that social attentional difficulties found in children with autism do not continue in adulthood. Strong attentional preferences for social information, which override the influence of low-level stimulus properties, are found in both TD and ASD groups. The findings also contribute a new way of thinking about the construct of social attention, in particular indicating that different types of social information may interact with individual attentional preferences.

These data are interpreted in the context of recent findings of perceptual atypicalities in people with ASD, which may interact with their social difficulties. The motion and multi-sensory properties of real-life social interaction may present specific processing difficulties for people with ASD. If so, the mild group differences found in our studies could translate into profound problems for people with ASD in the real world, and this is an area ripe for future research.

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1. Introduction

The research reported in this thesis has the principal goal of casting light on the nature of social attention, by an investigation of spontaneous attention to social elements of a visual scene in both typically developed (TD) adults and adolescents, and those with autism spectrum disorders (ASD). The principal hypothesis is that TD adults have an attentional preference for social information, which is reduced or absent in adults with ASD, and that this social attention impairment contributes to the maintenance of social problems in autism.

Social attention, meaning attention paid to social aspects of the world, has rarely been straightforwardly assessed in adults with ASD. Instead, it will be shown that experiments which purport to assess social attention often require other skills such as social cognition, confidence in social interactions, cross-modal sensory processing and motion processing. In the literature on visual attention in TD adults there is debate about the relative role of high-level input (such as a bias for social information) and low-level stimulus properties (such as colour, brightness and contrast) on attention. Definitions of social attention are wide-ranging, and the study of this construct itself is in its infancy in the field of vision science. As such, not only is the subject of social attention poorly understood in ASD populations, but it requires further examination in TD people.

This thesis will develop new methods for assessing spontaneous social attention preferences. These will be extensively piloted with TD adults in order to provide an understanding of normal responses, for comparison with people with ASD. Tasks will be related with one another, to demonstrate the presence, or not, of a single, underlying social attention bias which functions across tasks and scenarios. In addition, efforts will be made to look at individual differences in performance within and across tasks, in acknowledgement of the heterogeneity of any autistic, or indeed typical, group of individuals.

These assessments will contribute new ideas about the nature of social attention, which can currently be seen as a fundamental element of social interaction and social cognition. Taken together, the use of these methods will reveal whether people with ASD have difficulty in spontaneously attending to social information across different situations, addressing current views that social attention problems may be at the heart of this disorder in adulthood as well as childhood.

Throughout this thesis, the term 'autism' will be used to refer to the disorder in an abstract sense, but participants will always be referred to as 'people with ASD', regardless of their specific diagnosis, except in circumstances where that diagnosis is particularly relevant.

1.1 What is Social Attention?

Attention is the process of concentrating on selected items from the environment to the exclusion of other, unattended stimuli (Pashler, 1998). Social attention is a broad term currently used to refer to attention to social objects or social information, responses to social cues, or any attention occurring within a social interaction. It is crucial to disentangle these different types of social attention in order to understand how they operate in both TD individuals and people with ASD.

At the simplest level, and in line with the definition of attention given above, social attention can be defined as the attention paid to social elements of the environment, to the exclusion of other, unattended and non-social stimuli. This kind of social attention can be paid to an inanimate but social object, such as a memorial statue, whose meaning derives from a social construct. However, social attention occurs more obviously when someone attends to another person. Other human beings are the only social agents, and consequently the vast majority of social information derives from them. Attention to people is therefore the core of social attention.

Within this definition of social attention, as attention to social elements of the environment, some elements may be considered to be more social than others. For example, attention to someone's clothes is less social than attention to their facial expression. The former may impart social information, most obviously in the case when they are wearing a uniform, but attention to their face, and particularly the eye-region, has the potential to reveal much more. The face is a source of information which tells us not only an individual's identity and gender, but also their emotional state (Bruce & Young, 1986). The eye region alone can give us information about someone's mental state (Baron-Cohen, Wheelwright, & Joliffe, 1997). As such, attention to the face, and particularly the eye-region, can be considered the pinnacle of social attention. This idea of a 'hierarchy' of social information will be reflected in the methodological decisions taken throughout this programme of research.

Social attention provides an initial entry into a range of social attentive and social cognitive behaviours. Other people are also the source of social cues such as eye-gaze direction and pointing. These cues can direct our attention to interesting or useful aspects of the environment and may play a role in evolutionary survival (Frischen, Bayliss, & Tipper, 2007; Langton & Bruce, 2000), but in order to access this information, we have first to attend to people's gestures and eyes. Following another's social cues can also lead to a shared attention experience, when two individuals jointly attend to a third object. This type of attention is known to be a central part of typical development (Moore & Dunham, 1995) which is also impaired in children with ASD (Bruinsma, Koegel, & Koegel, 2004). Sharing attention with another individual has practical value and also has a developmental role in producing further social skills (Carpendale & Lewis, 2004), but a precursor of shared attention must be attention to other people. Further social cognitive skills also contain a component of social attention. While it has been demonstrated that we can use the eyes to infer someone's mental state (Baron-Cohen, Wheelwright *et al.*, 1997), applying this social cognitive skill in the real world requires that we attend to the eyes in the first place. Our adopted definition of social attention does not encompass social attentive behaviours, or social cognitive behaviours, though they incorporate a social attention element. If we are to understand social skills such as joint attention or mentalising, and their impairment in autism, we must investigate social attention first.

Throughout this investigation, the term *social attention* will be used to refer to attention to social elements of the environment. This definition incorporates an assumption that such attention indicates a preference, or bias, to attend to social information, to the exclusion of other, non-social aspects of the world. *Social attentive behaviours* are those behaviours which fall under the umbrella of a commonly used, wider definition of social attention and which follow from attending to social aspects of the world – this includes following social cues and sharing attention. *Social cognitive behaviours* are those which may be built on social attentive behaviours but also require further skills, such as inferring mental states, or judging emotions. It is proposed that such social attention is a necessary component of social attentive behaviours, and that it provides a developmental precursor for social cognitive behaviours.

We will first explore current theoretical models of development which place social attention impairments at the root of autism, and consequently emphasise social attention as a necessary skill for typical development. We will then critically examine the evidence for a strong social attentional bias in TD children and adults, and the corresponding evidence for this bias' reduction, impairment or absence in autism. Much of this evidence will be brought together in a discussion of the relative influence of high-level and low-level information on attention. An examination will also be made of possible complicating factors in the study of social attention, such as domain-general attention deficits in autism and heterogeneity of the disorder. Throughout, references will be made to research on social attentive and social cognitive behaviours which are connected to the thesis, such as joint attention and face processing. However, these large and complex literatures will not be examined in detail since our research does not directly address these topics. It is hoped that this critical review of our current understanding of social attention will provide a foundation for new assessments of social attention in adults, to be described in this thesis.

1.2 Developmental Theories of Social Attention in Autism

The possible role of social attention deficits in autism has been elucidated recently in three major developmental theories of autism, outlined in this section. In the first, Klin and colleagues propose an 'enactive mind framework' which highlights the "*central role of motivational predispositions to respond to social stimuli and a developmental process in which social cognition results from social action*" (Klin, Jones, Schultz, & Volkmar, 2003, p.348). Their embodied cognition approach suggests that mental representations are inseparable from "*bodily experiences accrued as a result of an organism's adaptive actions upon salient aspects of the surrounding environment*" (Klin *et al.*, 2003, p.345). Salient aspects of the environment are those that offer survival value, and this includes social stimuli, which offer the opportunity of interaction with conspecifics – an important survival function. The authors suggest that if infants and young children do not find social elements of their environment salient, their cognitive and neural development will be divergent from the norm as a consequence, leading to striking differences between themselves and their typical peers.

This is proposed to be the case in people with autism, whose limited social knowledge, instead of being genuinely embodied is "*acquired outside the realm of active social experience*" (Klin *et al.*, 2003, p.357). A further aspect of this theoretical description of the role of social attention in the development of autism is that the autistic individual is assumed to have no saliency map - an internal model of the most important or relevant aspects of the sensory world, used to direct attention - to replace the usual social saliency map employed by TD people. An example of an absence of social saliency comes from a study in which children with ASD were less likely to sort pictures of faces by emotional expression than TD children, instead sorting pictures by the type of hat worn by the person depicted (Weeks & Hobson, 1987). Klin and colleagues suggest that viewing the world as if all its elements were of equal salience would make us *"overwhelmed and paralysed by its richness"* (Klin *et al.*, 2003, p.354). This hypothetical scenario is strikingly close to the sensory experiences described by people with ASD, such as Temple Grandin (1986; 1995). The presence of social information may help a TD person process the world more efficiently, but without the same attentional bias, this information serves to confuse the person with ASD, both creating and perpetuating their difficulties.

Mundy & Neal have proposed a related, transactional model of the development of autism. This is based on the suggestion that the brain *"possesses self-organising functions that can, in fact, be altered by experience at certain sensitive periods of development"* (Mundy & Neal, 2001, p.139). By this account, it is crucial to learn the basics of social interaction at a point when the brain is able to encode these lessons. The central deficit of autism is in social orienting (by which the authors mean directing attention to social elements of the world), and without this skill, children with ASD fail to engage in social experiences. This absence of social engagement creates a negative feedback loop between experience and brain development, leading to pervasive and perhaps irreversible problems in social perception and cognition. This theory has recently been updated to emphasise that joint attention is a precursor of social cognition, rather than the other way around (Mundy & Newell, 2007).

Evidence for this model comes from studies of social development in children with congenital sensory impairments, which prevent access to a certain amount of social information, resulting in some autistic-like behaviours (Brown, Hobson, & Lee, 1997; Minter, Hobson, & Bishop, 1998; Peterson & Siegal, 1995). In the case of autism, it is possible that the negative feedback loop envisaged by Mundy & Neal is compounded by two factors: a reduction of social interactive bids from parents and siblings who have socially unresponsive children; and an increasing lack of motivation on the part of children with autism, who find social stimuli less appealing as they become less comprehensible (see Leekam & Wyver 2005 for discussion). Thus, again, a lack of social attention and consequent social experience serves both to create and perhaps to perpetuate the social problems of people with ASD.

Schultz likewise offers a social-perceptual account of the development of autism, focusing more on the issue of face processing (Schultz, 2005). Though this theory does not explicitly place social attention at the heart of autistic development, it is suggested that face processing deficits in people with ASD reflects a lack of attention to faces in infancy and childhood. This leads to an absence of the face specialisation evident in typical individuals, who are described as "*addicted to faces*" (Schultz, 2005, p.128). An early, elegant study of face processing (Langdell, 1978) demonstrated that children with ASD do not have the same strategy for recognising faces as TD or non-autistic, developmentally delayed children. Subsequent findings show that people with ASD do not use the upper half of the face in making judgements of identity (Hefter, Manoach, & Barton, 2006) and emotion (Baron-Cohen, Joliffe, Mortimore, & Robertson, 1997). They also show more piecemeal processing of faces, as of other stimuli; evidence for weak central coherence (Lopez, Donnelly, Hadwin, & Leekam, 2004). Finally they may scan faces atypically, spending more time looking at the mouth and peripheral features than at core features and the eyes (Pelphrey *et al.*, 2002). Schultz places this atypical face processing style at the centre of his account of the development of autism, making a causal connection between a lack of attention to faces, and parallel neural and behavioural atypicalities (Schultz, 2005).

A question arising from these developmental accounts of social attention and autism is whether such deficits can be expected to persist into adulthood. None of these three theoretical accounts make specific predictions regarding the state of social attention in adolescence or adulthood. Schultz and Mundy & Neal each explicitly describe the neural consequences of the developmental trajectories mapped by their theories, and review evidence for these (Mundy & Neal, 2001; Schultz, 2005). One the one hand, it is therefore plausible to suppose that the permanent atypical neural function and structure apparent in autism might not only arise from problems in social attention but continue to contribute to them throughout life. On the other hand, Schultz points out that, for example, the amygdala is implicated in the development of social attention, namely face preference, yet "*no fMRI studies in later childhood, adolescence or adulthood have ever implicated such reward centres during face perception*" (Schultz, 2005, p.135). The rewards inherent in social attention and activity are likely to play a role in development that may no longer be relevant for the study of adults. This raises the possibility that we cannot infer lifelong behavioural impairment from lifelong atypical brain structure and function in autism.

For the purposes of this investigation, we accept that social attention deficits in infancy and childhood would have a powerful effect on development, resulting in many of the problems central to autism. Crucially for this investigation, if social attention problems persist, they would have an effect on the behaviour of people with autism on a day-to-day basis as well as in development, thus maintaining the social impairments which define autism. For example, one can imagine a scenario in which a high-functioning person with ASD fails to meet people at a party, because he is busy admiring the computer in the corner rather than attending to the people around him. It is therefore important to discover whether adolescent and adult individuals with ASD still show social attention atypicalities. It is predicted that adults with ASD will show atypical attention to social elements of their environment.

However, before moving on to examine this hypothesis, we must first review the evidence from both typical and autistic individuals which supports a central role for social attention in development. We will present a limited review of principal findings from the literature which reveal social attentional preferences in typical childhood and their reduction in children with ASD, since the focus of this work is on social attention in adulthood. We will also refer to, but not examine in detail, related social attentive and social cognitive behaviours such as sharing attention.

1.3 Social Attention in Typically Developing Children

Social attention in typically-developing (TD) infants appears just a few days after birth. Studies presenting infants with pictures of faces or face-like stimuli have shown that newborn infants turn their eyes to look at faces, in preference to other patterned stimuli (Goren, Sarty, & Wu, 1975; Johnson, Dziurawiec Ellis, & Morton, 1991; Simion, Valenza, Umilta, & Dalla Barba, 1998). Infants also have a looking preference for faces which are gazing directly at them, as opposed to those with averted gaze (Farroni, Csibra, Simion, & Johnson, 2002). This social attention appears to be defined initially by the perceptual properties of the stimulus (Morton & Johnson, 1991). An eye-tracking study, which showed babies a series of short clips of a Charlie Brown cartoon, indicated that the viewing patterns of three-month-old infants map onto the areas of high-contrast and luminance in the scene (Frank, Vul, & Johnson, submitted). These data suggest that a non-social stimulus which had the low-level properties of a face, or of a pair of eyes, would 'trick' the infant's visual system into attending to it. However, Frank and colleagues also found that by nine-months old, infants' viewing patterns are predicted by the presence of faces on the screen (Frank *et al.*, submitted). Therefore, even if the earliest evidence of attentional preferences in typical infants shows a perceptual, rather than a cognitive basis, this rapidly develops into a socially-defined attentional bias (Morton & Johnson, 1991).

Social attention in infancy quickly produces more sophisticated social skills (Striano & Reid, 2006). At four months of age, infants' social attention preference has extended to an ability to follow an eye-gaze direction cue (Hood, Willen, & Driver, 1998), though they still require a movement cue to successfully follow an adult's eye-gaze (Farroni, Johnson, Brockbank, & Simion, 2000). Studies have shown that infants aged just four months look at an object from the cue of a person looking at that object (Reid & Striano, 2005; Reid, Striano, Kaufman, & Johnson, 2004) and that this joint attentional context enhances attentional processing of the object (Striano, Reid, & Hoehl, 2006). This evidence demonstrates that the effective social attention behaviours shown by infants very early in post-natal development quickly develop into more elaborate social-attentive behaviours such as following gaze cues and sharing attention.

This rapid development of social attention means that studies of later infancy and childhood rarely focus on social attention as defined here. While there is much evidence of social behaviours which contain a social attentive component, such as joint attention (e.g. Moore & Dunham, 1995; Mundy & Gomes, 1998; Mundy & Newell, 2007) this work falls outside the compass of this thesis. Instead, a great deal of our knowledge of social attention in TD children comes from comparative studies with children with ASD, which will be reviewed later. Further evidence for social attention biases comes from visual cognitive studies with TD adults, which will be reviewed next. This literature also considers the limitations placed on attention by the capacity of the visual system, and by the competing effects of low-level properties of a stimulus, such as areas of bright colour or contrast.

1.4 Social Attention in Typically Developed Adults

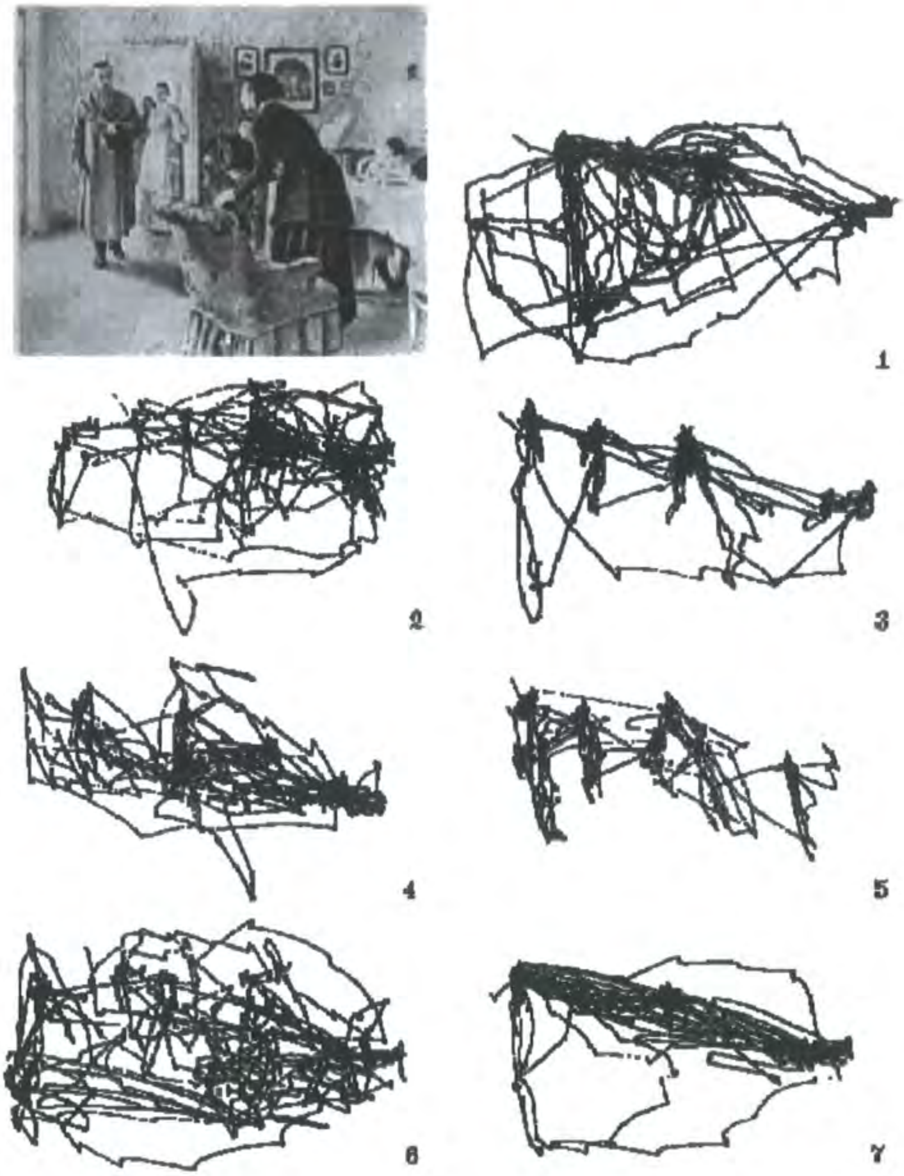
When viewing a complex scene, typical adults devote a large proportion of their attention to social elements of the stimulus. For example, people may be particularly able to detect changes to faces rather than other object categories (Ro, Russell, & Lavie, 2001). In fact, some have even found a 'pop-out' effect for faces in visual search paradigms (Herschler & Hochstein, 2005; Herschler & Hochstein, 2006). In addition, eye-tracking research shows that we look at people a great deal when they are presented as part of a naturalistic scene (Birmingham, 2007; Buswell, 1935).

These findings seem to mimic the experience of every day life, where typical adults can focus easily on the most relevant information – usually other people, their actions, expressions and voices – and exclude irrelevant distractors such as birdsong, patterned wallpaper, or traffic. We only turn our attention to these items when the task at hand calls upon us to do so – for instance when crossing the road. This theory suggests that we distribute our attention according to our current goal, setting biases to help us identify and process the relevant information (Hayhoe & Ballard, 2005). It is likely that attention to other people is a default bias which we adopt in the absence of other information.

For example, Yarbus showed typical adult participants the same picture repeatedly, and recorded where they looked when he asked them different questions (1967). The original image used, together with a series of scan paths relating to each task instruction is depicted in Figure 1.1. On the first viewing, with no instructions, people spent a large amount of their time looking at the people depicted. When called upon to estimate the material circumstances of the family, fixations on furniture and other objects increased accordingly (Figure 1.1, part 2). Likewise, when asked to make a judgement about one of the characters in the picture - arguably a more social task - people increased looking to the people again and particularly focused on their faces (Figure 1.1, part 7).

It is fair to claim that typical adults spend a large proportion of their attentional time focusing on other people – social elements of the environment around them. However, this does not always seem to be the case. For example, a real-world change detection study (Simons & Levin, 1998) showed that participants who were stopped in the street to provide directions did not notice when the person who had stopped them covertly switched places with another individual. This 'change blindness' was replicated using participants who knew that they were taking part in a psychological study, many of whom were familiar with the concept of change blindness (Levin, Simons, Angelone, & Chabris, 2002). Thus while we may attend to other

Figure 1.1: A series of scan-paths of the same image, for the same participant, given different viewing instructions. Reproduced from (Yarbus, 1967) ©.



Seven records of eye movements by one subject. 1) Free examination. Before the subsequent recordings, the subject was asked to 2) estimate the wealth of the family; 3) give the ages of the people; 4) surmise what the family had been doing before the arrival of the 'unexpected visitor'; 5) memorize the clothes worn by the position of the objects and people in the room; 6) memorize the location of the people and objects in the painting; and 7) estimate how long the 'unexpected visitor' had been away.

people, we do not necessarily hold this information as a complete mental representation which can then be compared with a new stimulus (Simons & Levin, 1997).

Another moderating factor in our attention to social elements of the environment in the visual domain, concerns our ability to select these items from peripheral vision. Our fovea provides the most accurate visual information about the item being fixated, but only subtends about 2 degrees of visual angle, and acuity decreases from the centre even within this small area (Millodot, 1972). Anything falling outside the foveated area is seen in increasingly less detail, and items in the far reaches of peripheral vision are hardly apparent at all. In the real world, we are often assisted by motion and aural cues, which help us locate people even when they are not in the centre of our vision, but in static scene viewing these are not available. For this reason, one might expect that only items with high contrast, brightness or colour would be identified in peripheral vision, and that the detail required to identify a face or even a body would not be available (Henderson, 2003). The successful identification of another person would therefore only be achieved after a series of initial, exploratory saccades were made, bringing a person nearer to the fovea by chance, so that attention could then be focused on that person.

This view might seem to be refuted by the previously-mentioned evidence of a 'pop-out' effect for faces (Herschler & Hochstein, 2005; Herschler & Hochstein, 2006). 'Pop-out' is the phenomenon whereby a particular stimulus is rapidly detectable from among distractors, regardless of how many distractors are used. However, other evidence suggests that this effect only occurs when the distractors used are easily differentiable from faces on a low-level basis. A visual search task using inverted or jumbled faces as distractors found no such pop-out effect (Brown, Huey, & Findlay, 1997). The previously-mentioned finding of enhanced change detection for faces (Ro *et al.*, 2001) has also been tempered by evidence which instead suggests that any unique object category is subject to the same enhancement (Palermo & Rhodes, 2003). In sum, while we do preferentially attend to social elements of our environment, in the visual domain, when motion cues are absent, it seems that our perceptual system is not accurate enough to pick out these elements rapidly.

However, recent evidence has begun to deny this assertion, and it seems that our attentional preferences may extend to an ability to select some complex items from peripheral vision. Studies have shown, for example, that semantic and context effects can moderate change blindness, such that changes to semantically interesting or contextually inappropriate items are rapidly detected (Hollingworth & Henderson, 2000; Rensink, O'Regan, & Clark, 1997). A forced-choice discrimination task (Kirchner & Thorpe, 2006) recently demonstrated that people can very rapidly (within 200ms) identify animals from peripheral vision and direct their eye-movements accordingly. These studies suggest that top-down information can influence perception in a very short time. Evidence that object categorisation of faces, while extremely rapid, is not any better than categorisation of animals (Rousselet, Mace, & Fabre-Thorpe, 2003) raises the possibility that while high-level input does influence attention, social information may not be subject to special processing.

Debate continues in the vision science literature over the exact influence of high-level information on perception and the precise limitations of the visual system in identifying semantically defined information, such as social stimuli, from peripheral vision. Therefore it will be crucial here to thoroughly pilot each new methodology in order to establish a standard pattern of responses before going on to investigate with a sample of individuals with ASD. Nevertheless, it is possible to conclude that there exists an attentional preference for high-interest elements of a scene in typical adults, and that this preference results in enhanced detection of changes to such items, and increased fixation on them as well. If we can assume that social information, usually in the form of other people, constitutes high-interest information then we can expect typical adults to show preferences for this information when presented as part of a complex visual scene. It remains a question to be answered whether social information has a unique or particularly strong top-down influence on attention. The experimental work presented here will thereby contribute to our understanding of the role of general high-level influences on attention in typical adults, and perhaps reveal social bias in particular.

1.5 Autism Spectrum Disorders

Before reviewing the evidence for social attention impairments in ASD, and their impact on our understanding of typical social attention, it is necessary to make a brief definition of autism. A recent large-scale study of the prevalence of autism indicates that up to one in every 86 children in the UK may warrant a diagnosis of an ASD (Baird *et al.*, 2006). The label 'autism' derives from Kanner's original case study of eleven children with what he termed "*autistic disturbances of affective contact*" (Kanner, 1943). This description emphasises the way in which autism impairs emotional relationships with others. Since then, autism has been classified by a triad of impairments in three behavioural symptom domains: social interaction, communication/imagination and restricted interests/repetitive behaviours (Frith, 1989; Wing & Gould, 1979). This triad is still in use today and inspired the domains used for diagnosis (APA, 1994; World-Health-Organisation, 1993).

Working at the same time as Kanner, Asperger also reported a series of case studies of children with what he called 'autistic psychopathy' (Asperger, 1944; Frith, 1991). These individuals were often more highly functioning than those in Kanner's report, and this and other differences have led to autism and Asperger's syndrome being separately classified in diagnostic manuals (APA, 1994; World-Health-Organisation, 1993). However, as the term 'autistic spectrum' indicates, more recently people with ASD have been conceived as lying on a spectrum which ranges from normal to severely autistic behaviour (Wing, 1996). There is even suggestion that the distinction between autism and Asperger's syndrome should be abandoned (Leekam, 2007; Mayes & Calhoun, 2003).

Even if Asperger's syndrome were no longer classified as a separate diagnosis, it would still be crucial to examine differences within a group of people with ASD, since within a diagnostic category there can be large variation in symptom profiles, IQ and experimental responses. This variation has been specifically observed in research into social attention in autism, where shared attention behaviours are linked to intellectual and language ability and to age (Leekam *et al.*, 1998; Leekam *et al.*, 2000; Mundy & Sigman, 1990; Mundy *et al.*, 1994). This relationship represents more than just a causal role for joint attention in the development of language; better intellectual and language skills can produce enhancements in joint attention. Comparisons of people with HFA and AS have found differences in social cognitive abilities (Ozonoff, Rogers, & Pennington, 1991) and other skills. For example, individuals with HFA and AS can succeed on tasks which purport to assess skills which many people believe define autism, such as false-belief (Bowler, 1997). This shows that within the autism spectrum, there is a continuum of social as well as intellectual and linguistic ability.

The current investigation focuses on the interactive and communicative aspects of autism, which impair relationships with others and set this condition apart from other developmental disorders. Developmental accounts suggest that social attention is a prerequisite for normal social and communicative development. In people with ASD, a deficit in social attention obstructs development of such social cognitive skills. This investigation considers whether, as well as playing a developmental role, the absence of an effective social attention bias could have ongoing consequences for every day social interaction in adulthood. There is ongoing investigation into the distinctions between autism and Asperger's syndrome (Baron-Cohen & Klin, 2006; Frith, 2004), the possibility of sub-groupings within the spectrum, and general heterogeneity among people with ASD. This assessment will attempt to address the issue of variation among people with ASD by, as far as possible, looking for individual differences and patterns of responding within as well as between participant groups. First, and in the light of these considerations, a review will be made of existing evidence of social attention problems in children and adults with ASD.

1.6 Social Attention in Children with ASD

It is very difficult to diagnose autism in children younger than about two years old (Howlin & Moore, 1997). Nevertheless, studies have found that social attention and related abilities are impaired in infants who are later diagnosed with ASD. Parents of children with ASD recollect that their children showed atypical eye-contact, atypical response to voices and atypical interaction with others in infancy (DiGiacomo & Fombonne, 1998; Gillberg *et al.*, 1990; Hoshino *et al.*, 1987; Ohta, Nagai, Hara, & Sasaki, 1987; Rogers & DiLalla, 1990; Volkmar, Stier, & Cohen, 1985). Likewise studies of video-tapes of infants show less social interaction, less social smiling, and failure to orient to name and faces in those later diagnosed with autism (Adrien *et al.*, 1991; Bernabei, Camaioni, & Levi, 1998; Maestro *et al.*, 2002; Mars, Mauk, & Dowrick, 1998; Osterling & Dawson, 1994; Zakian, Malvy, Desombre, Roux, & Lenoir, 2000). The reduction in social attention has also been highlighted in experimental studies of high-risk younger siblings of children with autism, which demonstrate that atypical eye-contact and reduced orienting to name may be early markers of autism (Merin, Young, Ozonoff, & Rogers, 2006; Zwaigenbaum *et al.*, 2005). Social attention deficits consequently play a significant role in early screening tools for autism (Baron-Cohen *et al.*, 1996; Robins, Fein, Barton, & Green, 2001; Stone, Hoffman, Lewis, & Ousley, 1994) though early joint attention problems may not be a similar early marker for Asperger's syndrome (Baird *et al.*, 2000; Cox *et al.*, 1999).

Difficulties with social attention in autism continue in childhood, where attention to both social aspects of the environment, and to active social bids for attention, have been observed to be impaired. First, children with autism do not spontaneously direct their attention to social elements of the environment. When faced with another human being, children with autism tend to look less at them and, in particular, engage in less eye-contact (Buitelaar, 1995; Hobson & Lee, 1998; Senju, Yaguchi, Tojo, & Hasegawa, 2003; Volkmar & Mayes, 1990). Some have suggested that this may be because autistic children find direct gaze aversive (Dalton *et al.*, 2005). This hypothesis is supported by the experimental finding that children with ASD show increased skin conductance responses, indicating anxiety, when viewing images depicting people with direct gaze compared to images of people with their gaze averted, while TD children show no such difference (Kylliainen & Hietanen, 2006). However, aversion to direct gaze cannot explain all findings, because lack of spontaneous social orienting is also apparent in the aural modality, where, unlike TD children, children with ASD do not preferentially attend to voices (Klin, 1991). One possibility raised by this evidence is that aversive responses to direct gaze result from a lack of understanding of social information, rather than being a causal factor in the development of autism.

Second, children with ASD are less likely than developmentally delayed or TD children to orient to an adult's bid for attention (Leekam, Lopez, & Moore, 2000; Leekam & Ramsden, 2006). Dawson and colleagues also investigated orienting to social bids for attention by contrasting name-calls and hand-clapping with non-social attention bids – a musical toy and a rattle (Dawson, Meltzoff, Osterling, Rinaldi, & Brown, 1998). This study showed that children with ASD oriented less to all types of bid in comparison with children with Down's syndrome and TD children, but in particular showed diminished responses to social bids. These studies are examples of work which experimentally demonstrates the social attention bias present in typical children, who readily respond to social bids for attention. The authors do not make a detailed discussion of the nature of 'social information' in their papers, but do give a series of examples of social stimuli: "*facial expressions, speech, gestures*" (Dawson *et al.*, 1998, p.479). It is interesting to note that the definition of social information implicit in this list of examples corresponds with our own independent definition of social information as being person-centred [see section 1.1, page 2].

A large number of studies, while not direct assessments of social attention, have explored more elaborate social attentive behaviours, which incorporate an element of social attention. For example, children with autism rarely respond to another's social cue and use it to direct their attention in real life (Willemsen-Swinkels, Buitelaar, Weijenen, & Van Engeland, 1998), and one possible cause of this behaviour could be an absence of attention to that cue in the first place. This was explicitly demonstrated by Leekam and colleagues who showed that children who were least responsive to initial bids for attention were also those who showed least gaze following in response to the experimenter's head-turn (Leekam *et al.*, 2000). This is despite the finding that children with ASD are capable of identifying where someone is looking, even when they do not spontaneously follow gaze (Leekam, Baron-Cohen, Perrett, Milders, & Brown, 1997; Leekam, Hunnisett, & Moore, 1998). These studies indicate that the geometric skills needed to follow eye-gaze direction cues are intact in autism, though it was noted that some children with ASD did use a strategy to succeed at the task, tracing a line from eyes to target with their finger and this was not seen in TD children.

Unsurprisingly, autistic impairments in social attention and related gaze-following in real life are related to the ability to share attention with others (Dawson *et al.*, 2004; Leekam *et al.*, 2000). A wealth of studies have shown that shared attention is impaired or absent in autism (for reviews see Bruinsma *et al.*, 2004; Mundy, 2003). Moreover, the absence of shared attention in autism has links to wider development, such as language ability and symptom level (Leekam & Ramsden, 2006; Loveland & Landry, 1986; Mundy & Sigman, 1990; Mundy, Sigman, & Kasari, 1994), supporting the hypothesis of a specific developmental role for difficulties in social attention in autism. However, this work into shared attention will not be reviewed here:

attention to social stimuli is just one component of sharing attention, and this thesis does not explore attention as part of a social interaction.

Not all research with children supports the hypothesis that social attention impairments are a core feature of autism. Eye-tracking research reveals normal scanning of cartoon scenes depicting people in children with ASD (van der Geest, Kemner, Camfferman, Verbaten, & van Engeland, 2002). The same authors also found normal scanning of faces in children with ASD, and in particular normal attention to the eye-region (van der Geest, Kemner, Verbaten, & van Engeland, 2002) though the children taking part in both studies were high-functioning. The one group difference in this study was unusual scanning of inverted face stimuli by children with ASD, which is likely to reflect differences in face processing strategy (featural rather than holistic) (e.g. Joseph & Tanaka, 2003; Lopez *et al.*, 2004). Further evidence against social attention impairments in autism comes from tasks which present social cues in isolation, which have demonstrated normal responses to shifts in eye-gaze direction, even in very young children with ASD (Charwarska, Klin, & Volkmar, 2003; Kylliainen & Hietanen, 2004; Senju, Tojo, Dairoku, & Hasegawa, 2004; Swettenham, Condie, Campbell, Milne, & Coleman, 2003).

These apparently contradictory data can be reconciled with reference to our original definition of social attention as attention to social elements of the environment with corresponding lack of focus on non-social stimuli. The face processing and eye-gaze cueing studies cited above all present social information in isolation, presenting no choice but to focus on these stimuli. In addition, cueing studies incorporate task instructions and a set-up both of which promote the use of a social cue in order to succeed. Van der Geest and colleagues did find normal social attention in their eye-tracking task which presented pictures of people in context, but the stimuli were unrealistic cartoon images and therefore are not comparable to social information in real life (van der Geest, Kemner, Camfferman *et al.*, 2002). Children with ASD seem to demonstrate a *capacity* to use social cues and scan faces, but this does not imply a *preference* to do so in real-life. This distinction emphasises the role of stimulus design and task instructions in the assessment of social attention in autism, an issue which the studies presented here aim to address.

In conclusion, these data provide further evidence of a social attentional bias in TD children, which is reduced or impaired in children with ASD. They are less likely to make eye-contact, to attend to social elements of the real world, and to respond to explicit social bids for attention. Evidence for the presence of similar social attention atypicalities in adults with ASD will be reviewed below.

1.7 Social Attention in Adults with ASD

Little is known about the presence of social attention deficits in autism in adulthood. Instead, many investigations purporting to have relevance to the issue of social attention have in fact focused on the more elaborate social cognitive behaviours which may stem from social attention, such as the ability to correctly identify another's mental state (Back, Ropar, & Mitchell, 2007; Baron-Cohen, Wheelwright, Hill, Raste, & Plumb, 2001). It is likely that, if social attention is absent in childhood and thereby contributes to the development of autism, an adult with autism would also show an absent, reduced or otherwise impaired social attention bias. Such a difficulty would have consequences for their day to day social functioning, playing a role the in maintenance of the disorder, as well as its cause.

An inspiring study by Klin and colleagues (Klin *et al.*, 2002b) produced evidence that adults with ASD do not attend to people as much as their typical peers, and in particular that they show reduced fixation on the eye-area. The study showed adults and adolescents with high-functioning autism and Asperger's syndrome a clip from the film "Who's Afraid of Virginia Woolf?". The movie depicts some extreme social machinations, including incidents of adultery,

Figure 1.2: A still from the film Who's Afraid of Virginia Woolf?, showing the point of fixation of viewers with ASD and TD viewers. Reproduced from (Klin, Jones, Schultz, Volkmar, & Cohen, 2002b) ©

Figure 2. Group data ($n = 16$) illustrating focus on eyes versus mouth. Viewers with autism: black crosses; typically developing viewers: white crosses.

violent arguments and revelations of surreal secrets. Under such circumstances, people were expected to look particularly at the faces and eyes of the characters, in order to successfully interpret their shocking actions. Participants with ASD looked more at background objects and less at people than the TD group. When looking at people, they looked less at their eye-region in particular. There was a tendency instead, for people with ASD to look at the mouth region (see Figure 1.2), and this pattern was related to social outcome, leading to the hypothesis that looking at the mouth was a learnt behaviour which could help people with ASD overcome social difficulties.

This study is a rare example of an assessment of social attention in adulthood, in which there was no requirement for further social cognitive ability. However, people with ASD have a documented difficulty integrating across sensory modalities (Gepner & Mestre, 2002; Iarocci & McDonald, 2006), processing stimuli globally (Frith & Happé, 1994; Happé & Frith, 2006), and processing movement (Bertone & Faubert, 2005; Milne, Swettenham, & Campbell, 2005). The study used a multi-modal, moving stimulus made up of many constituent parts, requiring processing across different sensory modalities. It also incorporated film-cuts and other editorial techniques. It is therefore possible that the deficits seen in people with autism resulted from non-social difficulties with the film used (Kemner & van Engeland, 2003). For example, increased fixation on the mouth area in the autistic group could represent effortful processing of simultaneous lip movements and soundtrack. This interpretation is supported by a second study by the same authors, in which toddlers with ASD showed increased attention to a point-light display of biological motion which depicted a person clapping, and was accompanied by a soundtrack of the clapping noise (Klin *et al.*, 2003). Those displays which did not exhibit such cross-modal contingencies did not receive enhanced fixation from toddlers with ASD.

Related studies have supported Klin et al's finding of reduced fixation on the eye-region in autism, but not increased fixation on the mouth. Pelphrey and colleagues found that people with ASD were less likely to fixate on all the 'core features' of the face (Pelphrey *et al.*, 2002) which are normally targeted by TD adults (Walker-Smith, Gale, & Findlay, 1977). Likewise, people with autism have been shown to have less fixation specificity to both the eye and the mouth regions of the face (Spezio, Adolphs, Hurley, & Piven, 2007). These data correspond with evidence of deficits in adults with ASD in responding to an eye-gaze direction cue (Ristic *et al.*, 2005; Vlamings, Stauder, van Son, & Mottron, 2005). However, different methodological techniques have not found the same kind of attentional pattern. For example, a dot-probe task (Bar-Haim, Shulman, Lamy, & Reuveni, 2006) showed that people with ASD and TD peers alike both responded quicker to probes which appeared between the eyes of a realistic face stimulus, than to probes appearing on the mouth.

One problem with all of these studies is that they present social information, a face, in isolation. While it is fascinating to note the possibility of unusual scanning of faces (e.g.Jemel, Mottron, & Dawson, 2006; Langdell, 1978; Sasson, 2006) the aim of the research reported here is to discover whether people with ASD look at faces, and other social stimuli, in the first place, rather than where they look when presented with a face in isolation.

In adult studies of social attention in autism, as in research with children, experiments often impose extra cognitive burden on the participant. For example, the reading-the-mind-in-the-eyes task requires a judgement to be made about the emotional state of an actor, based on their eye-region only (Baron-Cohen, Wheelwright, Hill *et al.*, 2001). It is possible that the difficulty people with ASD have correctly identifying emotions from the eyes is in part due to a lack of attention to the eye-area, which produces the developmental result of a lack of expertise in interpreting information from that region. In real-life, if we do not look at people's eyes we cannot learn to decipher what is represented there. However, this experimental task does not itself address this issue: all participants must attend to the eyes, as this is the only stimulus depicted, and so social attention is not tested. This concern is reproduced in studies which illustrate deficits in social cognition in people with ASD, and may invoke a social attentional explanation, but do not address this question specifically (e.g. Back *et al.*, 2007).

A great deal of research has focused on the ability to interpret social cues, face processing and social cognition in adults with ASD. Many of the findings from these studies are consistent with a hypothesis of reduced social attention in autism. However, only one study has specifically investigated attention to social elements of a naturalistic stimulus in adults with ASD (Klin *et al.*, 2002b). This study has been criticised for its use of a moving image, which could produce specific difficulties for people with ASD (Kemner & van Engeland, 2003). As well as requiring motion processing, understanding the stimulus presented may also have required sensory integration and global processing, both of which are impaired in autism (Frith & Happé, 1994; Iarocci & McDonald, 2006). Others have pointed out that the social scenarios depicted are not realistic, and have provided evidence that results from this study may not be replicated in a study using more accessible social scenarios (e.g. playing, and cheating, at a card game) (Norbury, 2007).

In the light of the evidence presented, it is clearly important to assess social attention in adults with autism without placing complex processing demands on participants, but while presenting social stimuli in a naturalistic context which provides non-social as well as social targets for attention. This methodological goal is in light of continuing investigation into the relative role of high and low-level input on attention, which will be more explicitly addressed here.

1.8 Influences on Social Attention

Much of the discussion of social attention, in both TD children and adults, and those with autism, can be couched in terms of the relative influence of high and low-level factors in selecting locations for focused attention. Low-level factors are perceptual influences on attention and visual processing, normally based around stimulus properties such as contrast and motion. High-level factors are influences on attention and visual processing which may be internal to the viewer, such as a social attention bias, but also relate to stimulus properties such as the emotional valence or semantic category of a stimulus, or its link to a present or supposed social agent. For example, changes to an item in a scene being looked at by a person are detected more quickly than to the same item not being looked at by a person, even though low-level characteristics are identical, because the former item is invested with social meaning (Langton, O'Donnell, Riby, & Ballantyne, 2006). The research presented here will not directly assess this debate: we will not contrast attention to stimuli which are perceptually versus socially defined. However, the fact that this theme runs through much of the literature reviewed above, means that the question should be explicitly acknowledged, as it will influence the interpretation of our data in the context of a wider field of research. This theme is also a way of uniting some of the issues present in research in both the ASD literature from developmental psychopathology and the literature on typical visual attention from cognitive psychology.

An excellent example of the distinction between low-level and high-level influences on attention comes from a study of the reflexive processing of eye-gaze direction cues. As we have seen, typically developing adults orient reflexively to shifts in eye-gaze direction, as shown by evidence of orienting when gaze does not predict the location of a target (Friesen & Kingstone, 1998). Researchers have since investigated the relative role of the low-level properties of eyes on this reflexive response: does reflexive orienting to eyes represent a response to a moving, high-contrast stimulus, or does it represent a social response to a fellow person? If the latter, at what stage in development does this response become socially defined?

One study to directly address this question (Ristic & Kingstone, 2005) showed participants a centrally-presented stimulus, which could either be interpreted as a picture of a car, whose hub-caps moved before the onset of a peripheral cue, or a pair of eyes with a hat on top, which likewise moved before the onset of a peripheral cue. Those participants who were told the picture was of a car did not exhibit reflexive orienting to the moving cue, but those who were told the picture showed a pair of eyes did respond reflexively. This study shows that typical adults' responses to eye-gaze direction cues are defined by the social nature of the cue, not by its perceptual properties.

This question is also relevant to the study of social attention in both typical individuals and those with ASD. Research into the development of visual attentional preferences for social information suggests that, in early infancy, attention is dependent on low-level perceptual characteristics (Farroni *et al.*, 2000; Morton & Johnson, 1991), though at nine-months old fixation location can be predicted by the presence of social information (Frank *et al.*, submitted). This developmental process feeds into a significant debate about the way in which social attention is defined at birth (e.g. Bakti, Baron-Cohen, Wheelwright, Connelan, & Ahluwalia, 2000). In the study of visual attention in typical adults, we have seen that there is some equivocal evidence of the role of high-level influences on attention. For example, people may be able to detect a face from among distractors rapidly and accurately (Herschler & Hochstein, 2005; Herschler & Hochstein, 2006) but there is also evidence that if those distractors are sufficiently similar to faces in their low level properties, as when scrambled or inverted faces are used as distractors, rapid detection in a visual search paradigm is not apparent (Brown, Huey *et al.*, 1997). Therefore, an attentional preference for social information is at the very least restricted by the capacity of the visual system to distinguish stimuli based on their low-level characteristics.

In the literature on social attention in autism, and related topics such as face processing, there is likewise a debate about whether the atypical behaviour of people with autism has its roots in perceptual processes or specifically social impairments. For example, people with autism may show abnormal scanning of faces (for a review see Jemel *et al.*, 2006; e.g Langdell, 1978) and this could be due to an absence of motivation to attend to faces resulting in deficient face expertise or a difficulty processing the specific characteristics of faces (Behrmann, Thomas, & Humphreys, 2006; Sasson, 2006). Some evidence for the former position comes from studies of how the supposed 'fusiform face area' of the brain may in fact be an area used for any fine distinction of stimuli familiar to an expert (Gauthier & Tarr, 1997; Gauthier, Tarr, Anderson, Skudlarski, & Gore, 1999; Grelotti, Gauthier, & Schultz, 2002; Grelotti *et al.*, 2005). However the latter position is also supported by the link between configural processing and aspects of face processing which are impaired in people with autism (e.g. Davies, Bishop, Manstead, & Tantam, 1994; Lopez *et al.*, 2004). For example, the configural characteristics of faces are largely defined by low-spatial frequency information and it is the processing of this kind of low-level information which may be impaired in autism. Likewise, since features are high-spatial frequency stimuli, featural processing of faces is intact in autism (Behrmann, Thomas *et al.*, 2006).

In the study of social attention, the debate between perceptual and social influences on behaviour has been less explicit. As we have seen, there has been little research into social attention in adults with ASD, and none explicitly comparing the role of perceptual and social information on attention. Nor will this be explicitly addressed in this thesis. However, a significant critique made here of what studies there are, is that a wide range of perceptual requirements has been placed on participants in tasks purporting to assess social attention. It is possible to explain differences in evidence for and against atypical social attention in ASD by the perceptual differences between tasks, as in the evidence for and against reduced attention to the eye-region in people with ASD (Klin *et al.*, 2002 vs. van der Geest, Kemner, Verbaten *et al.*, 2002). In addition, problems with dorsal stream processing of motion and the low-spatial frequency information used in configural processing of faces (Milne *et al.*, 2005; Pellicano & al., 2005; Spencer *et al.*, 2000) has been invoked to explain the performance of people with ASD in studies of both face processing and social attention (Kemner & van Engeland, 2003; Kemner & van Engeland, 2005). However, not all studies have found that low-spatial frequency processing is impaired in autism (Behrmann, Avidan *et al.*, 2006) and others question the dorsal stream processing explanation as a basis for motion processing problems in autism (Dakin & Frith, 2005; Mottron & Dawson, 2005).

We do not wish to divert attention away from the issue at hand: increasing our understanding of the nature of social attention and its manifestation in autism and typical adulthood. However, this description of the debate over the relative influence of perceptual and social processes shows that it is essential to consider that any difference in the behaviour of people with and without ASD could be rooted in different perceptual, rather than social, processes. This consideration has informed our interpretation of the existing literature on social attention in typical and autistic childhood and adulthood, and will likewise be relevant to the interpretation of our own data.

There is one further issue to address before presenting the final goals of this investigation and outlining the methods which will be employed to attain them: the possible role of domain-general attention deficits in autism and their interaction with social attention. As above, this question will not be explicitly tested in this thesis, but both existing data on social attention in autism and our own results must be interpreted in the context of this concerns.

1.9 Domain-General Attentional Deficits in Autism

The suggestion that domain-general attentional problems are involved in autism arose from a study which showed that children with ASD have a difficulty switching attention between two stimuli (Wainwright-Sharpe & Bryson, 1993). This hypothesis was later refined to suggest that there is a specific problem with the disengagement of attention in autism (Landry & Bryson, 2004). Studies of at-risk siblings of children with autism have indicated that atypicalities in disengagement of attention may be an early marker of the disorder (Zwaigenbaum *et al.*, 2005). In addition, evidence from neural networks (Gustafsson & Paplinski, 2004) has linked impairments in switching attention to an end-state which displays some autistic-like behaviours such as enhanced discrimination of stimuli (Bonnel *et al.*, 2003; Plaisted, O'Riordan, & Baron-Cohen, 1998a). These studies indicate a developmental role for attention shifting deficits in autism.

However, experimental evidence from the social attention literature suggests that a general deficit shifting attention cannot provide an explanation for the absence of social attention in autism. Leekam and colleagues showed that children with ASD were able to shift attention between objects in a real-world paradigm, even when disengagement was required, and so this could not explain the lack of shared attention in their sample (Leekam *et al.*, 2000). Likewise, Swettenham and colleagues showed that children with ASD made fewer spontaneous attention shifts between people, but not between objects, compared with a TD group (Swettenham *et al.*, 1998).

Other studies explicitly assessing domain-general attention shifting have not found impairments in children with ASD, suggesting that this problem may not be pervasive within the disorders (Kemner, Verbaten, Cuperus, Camfferman, & Van Engeland, 1998; Stahl & Pry, 2002; van der Geest, Kemner, Camfferman, verbaten, & van Engeland, 2001). One possible explanation for these discrepancies is that attention switching difficulties reflect a delay rather than a deficit in attentional processes in autism. Landry and Bryson (2004) note that the pattern of response shown by their autistic sample, aged around 6 years old, is similar to that shown in typically developing 2-year-olds. This possibility of delay rather than deficit is repeated in studies of sustained attention, where group differences may again reflect immaturity in the attentional processes of children with ASD (Pascualvaca, Fantie, Papageorgiou, & Mirsky, 1998).

One reading of the evidence might therefore be that domain-general attention switching difficulties in autism are secondary to other core problems. Given the suggestion of delay rather than deficit, one would expect that data from adults would show fewer attentional problems. However, it is here that we have the clearest evidence of a problem switching attention (Courchesne, Saitoh *et al.*, 1994; Townsend, Harris, & Courchesne, 1996; Townsend *et al.*, 2001) which has been linked to cerebellar dysfunction (Courchesne, Townsend *et al.*, 1994). Other studies have invoked an inefficient attentional lens as a cause of attention problems in adults with ASD, which could be linked to problems disengaging and switching attention, by limiting one's ability to note the presence of the second stimulus (Burack, 1994; Mann & Walker, 2003).

The evidence suggests that an attention switching deficit is present in at least some individuals with ASD. While this may interact with social attention abilities (Bird, Catmur, Silani, Frith, & Frith, 2006; Swettenham *et al.*, 1998), it is clear that social attention problems observed in autism cannot be fully explained by this domain-general attention deficit. In the current analysis of spontaneous social attention it will be important to assess the baseline performance of both typical and ASD groups throughout, as a measure of domain-general attention, and to be alert for the possibility that responses to social stimuli could be partly based in atypical attentional processes outside the social domain.

1.10 Summary and Research Goals

To summarise so far, social attention is a preference to attend to social information in the environment with a concurrent lack of focus on non-social stimuli, and this attentional bias is a component of social attentive behaviours such as following others' social cues and consequently sharing experiences with others. These in turn provide a developmental basis for social cognitive behaviours such as judging mental states.

Autism is a principally social disorder, in which attention to social elements of the environment is reduced in infancy and early childhood. The substantial evidence of social attention atypicalities in children with ASD supports a series of accounts of the role of social attention in the development of autism. However, little is known about how these deficits might be manifest in adulthood. Such deficits may only play a role in the genesis of the disorder, but if they persist through life, they would continually undermine any attempts to overcome social difficulties. Most research on skills related to social attention in adulthood focus on more elaborate social cognitive skills, or on processing of social stimuli, such as faces or eye-gaze direction cues, which are presented in isolation.

It is the goal of the studies presented here to identify whether adults with ASD have social attention impairments, and if so, to explore the nature of these impairments. Attention to social elements of the environment will be investigated, rather than assessing social attentional behaviours such as shared attention, or social cognitive behaviours such as inference of mental states. In addition, other forms of perceptual processing thought to be impaired in autism, such as sensory integration and motion perception, will be eliminated from this assessment. Nevertheless, social attention must still be assessed as a naturalistic process. This means presenting social information in a realistic context and providing non-social information to compete with social stimuli for attention. This is because the definition of attention involves not just a focus on certain stimuli, but also the exclusion of other unattended stimuli. In addition, attentional processes should be allowed to act spontaneously: this investigation is not concerned with what people with ASD are *capable* of doing, in response to direct instructions, but is instead focused on assessing attentional biases as they are likely to function in the real world.

This assessment of social attention will require new methods which are appropriate for use with an able, adult sample. Therefore a secondary goal of this investigation will be to adapt and create methods for assessing social attention in a spontaneous, naturalistic manner, which can also be compared with each other to shed light on the existence of an underlying social attention construct.

1.11 Methodological Goals and Preview

Studies used to assess social attention in autism can often be sorted into one of two stimulus categories: those using highly complex, multi-modal, moving stimuli; and those using isolated, social stimuli such as faces or moving eyes. The current investigation will develop assessments of social attention which use stimuli that do not place undue processing burdens on the participants, but that also provide a relatively naturalistic depiction of social stimuli. To this end, all stimuli used will be uni-modal and static visual scenes, which depict social information (human faces and bodies) in a real-life setting.

Another issue is that some studies of social attention have invoked social attentional explanations while, in fact, assessing more sophisticated socio-cognitive abilities. The current studies aim to develop methods for assessing social attention alone, which are nevertheless suitable for even the most high-functioning of participants. This investigation is concerned not with what a person with autism is capable of doing under special lab conditions, but with what they do spontaneously, in response to naturalistic stimuli. Therefore attempts will be made to balance rigorous and detailed assessment with minimal constraints and cues, thus tapping spontaneous social attention preferences.

The first study to be presented is an exploratory assessment aimed at capturing the social attentive component of people's descriptions of a social scene. This study employed a content analysis technique, using a specifically-developed coding scheme to analyse the social content of descriptions of social scenes. The development of this coding scheme helped to highlight different meanings of the terms 'social information' or 'social elements of the environment' which are the subject of social attention. The study considered the concept of a hierarchy of social information, whereby different aspects of people may be more or less social, and consequently demand more or less attention. Furthermore, the study provided an initial description of the type and amount of social attention paid by TD adults and people with ASD to these different aspects of the environment.

This study was followed up by two new experimental studies, explicitly addressing the presence of a social attention bias in people with ASD. The first used a change detection method to measure the degree to which people with and without ASD spontaneously selected a social element of a visual scene for attention. In this experiment, eye-gaze direction was the social element under scrutiny, because the method was not conducive to the study of multiple types of social information. Eye-gaze direction was selected because it is high in the hierarchy of social information: it has been shown to be an important social signifier, both acting as a cue for further shifts of attention and as an indicator of emotion, intention and mental state. The study demonstrated how a social attention bias can direct someone's focus to eye-gaze direction when it is presented as part of a complex visual scene. Response time measures provided a way of assessing the degree to which social information is prioritised for attention.

A second study presented social and non-social information simultaneously, using a preferential-looking paradigm. This was combined with eye-tracking methodology to record changes in attentional focus at a very fine level of temporal and spatial resolution. This method permitted direct assessment of an attentional preference for social information over non-social information, the priority given to social elements of a scene, and persistence in attention to social information over time. A condition in which a gender-discrimination instruction was introduced also addressed the role of task constraints on directing attention, and helped to distinguish between high and low-level influences on visual fixations.

Finally, a novel analysis was made of all three tasks in combination, with the incorporation of IQ, age, and other descriptive data. This analytical chapter provided a way to tackle issues of heterogeneity in our sample, and it made an evaluation of the novel tasks presented in this thesis. Most importantly, this analysis undertook to discover whether a single 'social attention' construct exists for the range of social information presented in this thesis, which defines individual performance on the tasks presented here, and which may be supposed to underpin social attention in a range of scenarios and contexts. The alternative is that social attention is not a unitary construct, and that theories placing social attention at the heart of autistic, and consequently typical, development, as well as experimental studies invoking a social attentional explanations, need to define the nature of this concept even further.

1.12 Hypotheses and Aims

The general hypothesis presented is that social attention deficits will be seen in able adults with ASD, though these may be more subtle than the impairments seen in children. This is because social attention is impaired in children with ASD, to the extent that it is proposed to play a major role in development of the disorder. One would therefore expect adults to show a similar reduction in their attentional preference for social information compared with TD people. If so, this social attention atypicality would contribute to the maintenance of social problems in autism, as well as their genesis. The fact that social attention is related to IQ, language and symptom presentation means that it is possible that in adults social attention impairments are small, and more subtle than those seen in children.

In order to reveal such group differences, attempts were made to design measures which map how attention is distributed over time, as well as taking gross measurements of general attentional biases. Therefore, studies investigated attentional preferences for social information, but also priority to attend to social information early on, and persistence in attending to social information over time. It is predicted that group differences will be found in all of these areas, but distinguishing between them will reveal exactly how social attention differs between people with ASD and their TD peers. Thus, tasks were designed to subtly and accurately measure spontaneous social attention to visual elements of a scene, and should also be suitable for future adaptation for research with other populations.

In conclusion, this thesis aims to explore the presence of social attention abilities in adults who are typically developed and those with autism spectrum disorders. Social attention has been re-defined at its most basic level, as a focus on social elements of the environment, to the exclusion of other, unattended and non-social stimuli. The studies presented here will explore both this definition and the presence of behaviour resulting from a social attention bias in people with and without ASD. At the end of this investigation, it is hoped that we will have increased knowledge of three things. First, whether adults with ASD show intact or impaired social attention in response to static, but complex visual scenes, and the way, if at all, in which it differs from that of TD individuals. Second, the way in which social attention functions in typical adults, in relation to low-level influences on visual attention and in different methodological scenarios. Third, the suitability of the construct of social attention to be invoked as a crucial factor in the development and maintenance of autism, and as an explanation for experimental findings.

2. Exploring the Meaning of Social Attention: A Free Description Task

2.1 Introduction

The first study in this investigation had two aims. First, to explore what we mean by social information, in the context of social attention, and second, to provide an exploratory description of the social attention bias of TD adults and those with ASD. The study simply required participants to freely describe what they saw in a picture, allowing them to follow their own preferences, in choosing to describe whatever information was salient or interesting.

2.1a Verbal Description as an Index of Social Attention

The design of this initial, exploratory task followed a similar idea by Klin (2000) which was designed to measure people's tendency to attribute social meaning to ambiguous visual stimuli. Klin's task presented participants with and without ASD with a short animated film, which depicted geometric shapes moving in such as way as to promote anthropomorphic interpretations on the part of the viewer (Heider & Simmel, 1944). Participants were asked to provide a verbal narrative matching the story depicted in the silent, animated film and these were coded for social content. TD adolescents and adults described the animations in terms which clearly showed that they treated the shapes as human, and attributed to them intentions, feelings and beliefs as well as physical actions. In contrast, participants with ASD did not make as many social attributions and the content of their attributions was more often irrelevant to the plot. The groups were matched on full-scale and verbal IQ measures, and these did not relate to social attributions.

This task, like other similar studies (Abell, Happé, & Frith, 2000; Bowler & Thommen, 2000; Castelli, Frith, Happé, & Frith, 2002) was designed to assess the ability to attribute social motivations to animated shapes. Here, the approach was adapted to investigate social attention. While participants were likely to make social attributions about the people or situation depicted, the proposed task also measured indicators of more basic social attention, such as comments about the relationship between two people, or about their emotions.

Two further sources provide inspiration for the task created here. First, a change blindness study (Rensink *et al.*, 1997), which aimed to investigate the influence of semantic importance on change detection. In order to categorise elements of a scene as either centrally or marginally important, Rensink and colleagues showed naïve observers single copies of unchanged images. These observers were asked to describe the scenes out loud and their descriptions were recorded and analysed. Elements of a scene which were mentioned by at least three out of five observers were designated as being of central importance, while elements not mentioned by any of the five observers were marginal. In this way, the importance of image elements in the scene was defined by their semantic role, rather than by their size or location. The authors then adopted these definitions to create two stimulus sets for their subsequent experimental study, which contrasted change detection ability for items of central or marginal importance.

Second, the Autism Diagnostic Observation Schedule (Lord, Rutter, DiLavore, & Risi, 1999) is an assessment tool which includes a component for more able children or young adults, in which they are asked to describe a scene. It has been anecdotally noted (Mottron, 2007) that children who later receive a diagnosis of ASD often describe the background or non-social elements of the scene before turning their attention to the people depicted. The unifying assumption of these two sources is that verbal descriptions can provide a measure of attention. Those items mentioned earlier in the description, or most often, are presumed to be of importance to the viewer. Consequently, items not mentioned, or mentioned later, are not interesting to the viewer.

2.1b The Choice of Method

The task is not an experimental assessment of social attention capacity or the exact nature of social attention in people with and without ASD. Instead, it is designed to provide a largely unconstrained description of the consequences of attention to social information. It has regularly been shown that individuals with ASD can demonstrate skills in the laboratory which are not apparently used in real life. For example, experimental studies have found intact orienting in response to eye-gaze in children with ASD (Charwarska *et al.*, 2003; Kylliainen & Hietanen, 2004; Senju *et al.*, 2004; Swettenham *et al.*, 2003), despite the fact that numerous studies record deficits in following another's gaze in a real-life situation (Cox *et al.*, 1999; Curcio, 1978; Dawson *et al.*, 2004; Leekam *et al.*, 1997; Leekam *et al.*, 1998; Leekam *et al.*, 2000; Mundy & Sigman, 1990; Wetherby & Prutting, 1984; Willemsen-Swinkels *et al.*, 1998). One of the crucial differences between experimental tasks and naturalistic assessment is that the former carry a lot of cues to behaviour. Participants in an experimental situation normally have an idea of what they are meant to do, even if this is not made explicit, and a task often implies a right or wrong response, causing participants to be further motivated to behave in a particular way. It has been suggested that naturalistic paradigms are more suitable for the study of social difficulties in autism (Boraston & Blakemore, 2007; Klin, Jones, Schultz, Volkmar, & Cohen, 2002a).

In contrast, while the new task developed here is still a quantitative assessment of social attention, it carried fewer cues to behaviour than traditional experimental tasks. Instructions were minimal and there was no apparent right or wrong response. In addition, little or no advance judgement of what constitutes social information needed to be made. A coding scheme for analysis of descriptions was developed according to the kind of social statements produced, rather than employing an *a priori* definition of social information. Finally, the content analysis methods used here have been noted as being unobtrusive and non-reactive (Bryman, 2001), producing naturalistic data with minimal influence on the participants. It is hoped that this task will suggest possible ways of appraising the social attentional biases of people with and without autism, providing a platform from which to design subsequent, experimental assessments of social attention.

2.1c Aims and Predictions of the Current Study

The current study will use descriptions of scenes to provide an initial, exploratory assessment of social attention. The clarification of the definition of social information, and possible elucidation of a hierarchy of stimuli of increasing social interest will provide a foundation of understanding for subsequent, experimental assessments of social attention. The task presents individuals with and without ASD with a series of complex, naturalistic scenes depicting a variety of social situations, and asks them to verbally describe what they see. Such static, visual stimuli exclude multi-sensory information or motion, which could create unique processing difficulties in people with ASD.

The study will not take a measure of the accuracy of the descriptions provided by the viewer, in terms of their social attributions. The focus is on whether participants attend to those elements of the scene that are social, rather than whether they correctly interpret the social meaning of what they see. This approach permits assessment of attention to social elements, as depicted in a naturalistic context, without requiring additional social cognitive abilities, such as correct identification of mental states.

The task is novel and aims to explore social attention in both TD and ASD adults and adolescents, so specific predictions will not be made. The first aim of this assessment is to elicit a set of definitions of social information; and second, to provide an initial observation of social attention in action in both TD adults and adults with ASD. In the absence of specific predictions it is nevertheless expected that the verbal descriptions of participants with ASD will indicate less attention to social information than those of TD participants. Participants' descriptions will be analysed both for the overall proportion of social information included but also for the distribution of social information throughout the description. For example, if participants produce a large amount of social information early on in their description of a scene, but this tails off towards the end, one might conclude that they show an attentional priority for social information but that this attention is not persistent over time.

2.2 Development of the Method

The method was developed in two stages. First, a preliminary study was run with TD adults to explore the methodology. This study was conducted to discover whether the images chosen elicited a significant amount of social and non-social information in descriptions, to check that the procedure was suitable and, in particular, to develop a suitable coding scheme for the recorded information. Adjustments were then made to the coding scheme as appropriate before moving on to the main study which compared responses from TD adults and those with ASD. The preliminary study method and results now follow.

2.2a Materials

The images viewed were all sourced from the internet and were selected by using search terms referring to social information such as emotions or social situations. Twelve images were selected for the final study, shown in Figure 1. These images were selected because they offered plenty of social interest.

2.2b Participants and Procedure

Eleven TD Durham University undergraduates and postgraduates took part in the study.

Participants were told that they would see twelve photographs, one at a time, and that they should describe the photographs out loud while their voices were recorded. The instruction was

Figure 2.1: Images used in the free-description task, in order of presentation (left to right, top to bottom).

to "*describe each photo in as much detail as you can*" and that participants should "*pretend that you are describing the photo to someone outside the room*". These instructions were chosen to provide minimal influence on descriptions and to allow participants to focus on whatever information in the picture they felt was most important or interesting. Alternative instructions, for instance implying that someone would later try to identify or draw the image from their description, were rejected for placing constraints on participants' descriptions.

Those participants who said very little for the first two images were encouraged by the experimenter to say a little more, using phrases such as "*Anything else? Can you say any more?*" Descriptions were recorded on a minidisk player.

2.2c Coding Scheme Development

A coding scheme was developed by the experimenter. This coding scheme was based on information from the descriptions, heard by the experimenter during the recording sessions. It was constructed after recording data from all eleven participants, but before transcribing the scripts in full.

The scenes chosen were selected to provide a large amount of social information. However, it was necessary that the coding scheme should ensure that social and non-social information could both be represented within a single description, so that the analysis could investigate attention to both social and non-social aspects of a scene. Therefore a distinction was made between descriptions of people which did not have social content, and descriptions of people which did have social content. The former fell into what was named the Social category, while the latter fell into the Human category. Items in the Human category included any physical descriptions of people or their accoutrements, while items in the Social category were descriptions of explicitly social information, such as emotions. For example, '*she's smiling*' is a comment on someone's physical properties and hence belongs in the Human category, while '*she's happy*' is a comment about an emotional state and belongs in the Social category, even though both phrases effectively convey the same information.

Examples of two descriptions, both of Image 4 (Figure 2.1), are included below. These examples demonstrate how it was possible to describe the same scene in terms which did not have social content (as in sample 1) or did have social content (as in sample 2) even though both descriptions are describing people.

Sample Description 1: Non-social 'Human' description

The next picture is of a... a man playing some sort of flute or wind instrument... He's wearing a green t-shirt, a blue jacket and jeans with a belt. He has spectacles on... The woman is wearing a blue t-shirt... with... dark trousers and a belt again.... with some sort of shirt wrapped around her shoulders. She appears to be listening to the music the man's playing and they're in some sort of old market place. It looks like some sort of outdoor market but they're in one of the stands, which seems to be selling quite a lot of musical instruments and brightly coloured things erm... that's about it

Sample Description 2: Social description

(laughs) erm... they look like erm they're on holiday. They look like a couple actually. They look like they're at a market stall 'cause there's lots of bright colours er and lots of little trinkets and stuff for like tourists to take home with them. The man in the picture who's playing the recorder-thing erm, actually I see they are married cause he's wearing a wedding ring. Erm he's playing the recorder and his wife I presume, she looks like she wants him to stop playing the recorder. Making an awful racket. She's got quite a pained expression on her face and she looks like she's tying to stop him from playing the recorder or trying to grab it off him or something. Um she's got quite touristy clothes on. Erm...

Both participants describe the two people depicted in the scene, and spend a little time as well describing the market stall. However the first description is largely 'Human' – referring to people's clothing and actions (listening, playing). The second description, in contrast, makes suggestions about the relationship between the two people, about the woman's thoughts and intentions and even about the quality of the man's playing! Even the clothes are described in social terms, as those worn by a particular category of person (a tourist) rather than according to their physical properties. These examples illustrate the distinction between Social and Human information.

A second goal of the coding scheme was to categorise some information as social, even when it did not pertain to people. This meant including references to scene elements such as the setting or context in the 'Social' category. For example, saying that a building looks like '*a university, maybe one in the Ivy League*" makes no reference to people, but is a social statement in that it makes reference to a social construct. One way of helping to include this kind of information in the 'Social' category was to provide exhaustive and exclusive sub-categories into which every phrase could be fitted and then use these to help define the Social and Human categories. This procedure also has the benefit of helping independent coders in their assessment of the scripts and producing highly-reliable results.

While sub-categories were mutually-exclusive, it proved impossible to create Social and Human categories which did not overlap each other. For example, the phrase "*they look like a couple*" both informs us about the presence of two people and makes a social judgement about their relationship. Therefore the final coding scheme used both exclusive sub-categories for initial classing of phrases and two, overlapping 'super-categories' into which all Social phrases and Human phrases were grouped.

2.2d The Coding Scheme

The coding scheme categorized each phrase as conveying information in one of the following, briefly described sub-categories:

- Layout: comment on position of objects within the scene
- Location: comment on setting of the scene, including time of day and season.
- Physical: description of the physical characteristics of people depicted, e.g. height, skin colour
- Object: description of objects, including clothes
- Photo: comment on the photo quality or photographer
- Action: description of visible action, e.g. "waving", "smiling"
- Story: hypothetical description of preceding or subsequent action, setting or situation depicted. e.g. "she just fell over"
- Emotion: description of a person's emotion
- Mentalising: description of someone's thoughts, character or social role
- Relationship: description of how two people are related e.g. "a couple"

The full version of this coding scheme, with examples of each phrase type, a sample marked script and a step-by-step guide for coders is included in Appendix 1a [see section 8.1, page 254]. Though these sub-categories do not directly relate to the investigation of social attention, they are crucial in providing a rigid structure in which coders can work. By helping coders first define every phrase in a description, they can much more easily identify which belong in the Social and Human super-categories.

From these coding categories, two super-categories were constructed for information referring to Human and Social information. Human information was any phrase referring directly to people, their actions, their posture, their characters, emotions and thoughts. This included some, but not all, phrases in the Physical, Action, Story, Emotion, Mentalising and Relationship categories. Social information was any phrase including social information or requiring social knowledge. This included some, but not all, phrases in the Location, Story, Emotion, Mentalising and Relationship categories. Phrases were often included in both of these categories: Social information could refer to humans (e.g. "*it's a couple*") or not (e.g. "*it's some sort of celebration*") and likewise Human information can be social (e.g. "*it's a couple*") or not ("*a male and a female*"). Therefore each of these two categories both contained phrases unique to that category and phrases which were included in both categories.

2.2e Coders' Instructions

A script refers to the full recording taken from each participant. These are divided into twelve descriptions, one for each photograph. Descriptions are then divided into phrases, which correspond to units of semantic information, as described below.

Scripts were recorded on a portable mini-disk recorder and then transcribed without temporal information. Pauses were transcribed using triple dots (...) but not measured for their length in real-time. The transcribed scripts were then divided into phrases, wherever a change of topic took place. A 'change of topic' refers to any change in the principal piece of information or idea being conveyed. For example, the following text is a description of Image 2, (depicted in Figure 2.1), divided into phrases by forward slashes (/).

<u>Sample Description 3: Image 2 description divided into phrases</u>

"ok the next picture is of / a couple... / they appear to be having a dance lesson /... the... it's a couple / a male and a female / the female is wearing / a black top with spots on it / and a long skirt / with a white boots... / it's a blue skirt um... / they appear to be in some sort of community centre maybe /... I don't know / whether it's a dance lesson / or some sort of function that they're at /... the guy's wearing / a red and blue check shirt / with dark jeans on / um there are few balloons / ... maybe leading you to the conclusion / that it's some sort of celebration"

The coder had to identify the number of Human phrases and Social phrases in each script and also in the first and second half of each description. This was to provide a measure of the distribution of social attention over time. Also, to explore whether Social and/or Human information is prioritised in the description, it was recorded whether the very first phrase in each description referred to Human and/or Social information.

In addition, the coder identified phrases in which information was repeated without adding any new perspective. An example of information repetition is "*she is crying*" and then later "*yeah, the girl's crying*". However the following series of phrases would not be identified as repetition: "*she is crying*"; "*she looks really unhappy*"; "*she's got her mouth open wailing*". While these three phrases all address the same issue, they each offer slightly new information to the listener. In addition, justifications were not counted as repetitions, as in the sequence: "*he's wearing a wedding ring / I think he's married / because he's wearing a wedding ring*" While the third phrase is a repetition of the first, it wouldn't be counted as such according to the coding scheme, because it is presented as evidence for an opinion.

The script section cited above was coded for Social and Human information and for repetitions as follows. Underlined sections fall into the Social category, red sections fall into the Human category and italicized sections are repetitions.

Sample Description 4: Image 2 description with super-categories

ok the next picture is of / a couple... / they appear to be having a dance lesson / ... *the... it's a couple* / a male and a female / the female is wearing / a black top with spots on it / and a long skirt / with a white boots... / it's a blue skirt um... / they appear to be in some sort of community centre maybe / ... I don't know...

/ *whether it's a dance lesson /* or some sort of function that they're at / ... the guy's wearing / a red and blue check shirt / with dark jeans on / um there are few balloons / ... maybe leading you to the conclusion / that it's some sort of celebration

2.2f Results

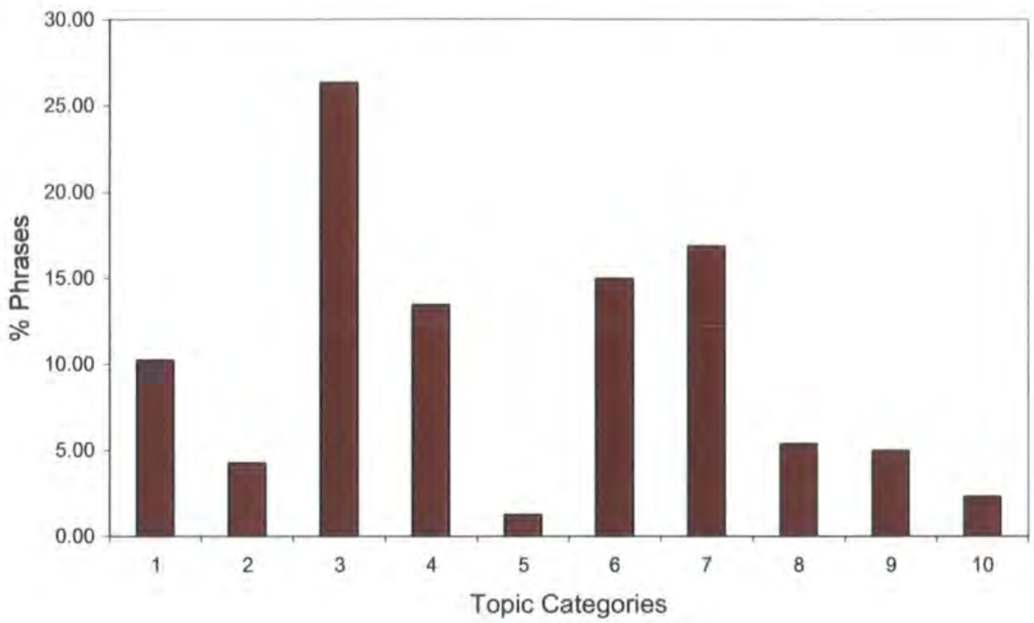
The preliminary data were all coded by the experimenter and since the sample size was small, the number of phrases in each sub-category was recorded as well as the super-category scores. Due to problems with the recording equipment, 12 descriptions from two scripts could not be transcribed. Therefore a total of 120 descriptions were included in the analysis. The mean percentage of phrases within each coding category is shown in Figure 2.2. Participants produced on average 177 phrases per script, which is about 15 phrases per image.

Participants devoted almost 68.7% of phrases to humans. This proportion was largely consistent across participants: the range of percentages of phrases in the Human category was 57% - 74%, with a standard deviation of 5%. Furthermore, on 72% of trials the opening phrase referred to humans, indicating a strong attentional priority for people upon first sight of each scene.

Participants made reference to Social information in about 30% of phrases. This category showed greater variation: the range of percentages of phrases in the Social category was 20% - 49%, with a standard deviation of 10%. Nevertheless, only two descriptions were produced which contained no Social phrases at all. On 33% of trials, participants' opening phrase fell into the Social category.

On average, participants repeated themselves only four times per script, though just under three of these repetitions were of Social information.

Figure 2.2: Percentage phrases devoted to each topic category



Topic categories: 1. Layout; 2. Location; 3. Physical; 4. Object; 5. Photo; 6. Action; 7. Story; 8. Emotion; 9. Mentalising; 10. Relationships

An item-wise analysis revealed that there was little variation between images in eliciting Social phrases: the range of percentages of phrases in the Social category was 23% - 36%, with a standard deviation of 4%. There was much more variation in the proportion of Human phrases which had a range of 52% - 89%, with a standard deviation of 10%. This was not related to the number of people visible in the scene: the largest proportion of Human phrases was elicited by Image 10 which depicts only two people. However this image also has the least number of objects depicted and all of those are associated with the people, (jewellery, spectacles): there are no background items apart from a blank white wall.

2.2g Conclusions

The analysis of the preliminary study data indicates that the images selected were very successful in eliciting references to Human and to Social information. In particular, participants spent on average almost three-quarters of their time describing people. However, a much smaller proportion of phrases described Social information, demonstrating that the combination of images chosen and the coding scheme successfully provided participants with a way of describing scenes without referring to Social information [for an example see section 2.2c, page 44, sample description 1]. There was a certain amount of variation between participants and among scenes, but no significant outliers were identified.

The coding scheme was very good in providing a way to categorise every kind of information. However, in the interests of providing excellent inter-rater reliability in the subsequent study, it was decided to introduce 6 new sub-categories to assist coders in correctly sorting the phrases into the Human and Social super-categories. This was because it was found that not all phrases produced fitted clearly into one of the existing sub-categories. These new sub-categories are described further in the subsequent Materials section [see section 2.3c, page 52] and Appendix 1b [see section 8.2, page 267].

The subsequent sections describe the method, results and conclusions from the main study, which used the free-description task piloted here to compare social attention in people with and without ASD.

2.3 Method

2.3a Participants

The TD group comprised 35 young adults (8 female) aged 17-31 years, from mainstream high schools and further education colleges in the Durham area and from Durham University.

The ASD group comprised 31 young adults (4 female) aged 17-25 years, with high-functioning autism or Asperger's syndrome. All these participants attended a specialist college in the Sunderland area for which a diagnosis of autism or AS was a criterion of admission. All had been diagnosed by experienced clinicians, (a psychiatrist or clinical psychologist employed by the National Health Service), working in specialised centres, as meeting DSM-IV criteria for either HFA or AS (APA, 1994). These diagnoses had been confirmed, upon each participant's admission to the college, by a second clinical psychologist.

Table 2.1: Descriptive statistics for participant groups, and p-values for group matching.

	ASD		TD		t-test sig. level
	Mean	SD	Mean	SD	
Age (years)	19	1.9	19	3.3	p=.40
Verbal IQ	93.5	14.7	95.3	15.7	p=.63
Performance IQ	95.8	15.8	101.5	15.1	p=.14
Full-scale IQ	94.5	14.2	98.2	15.6	p=.33

The groups were group-wise matched on age, full-scale IQ, verbal IQ and performance IQ (Wechsler, 1999) as shown in Table 2.1. Most importantly, it should be emphasised that the groups did not differ on verbal IQ.

2.3b Design

The study was a simple within-subjects design with a single independent variable: group membership (ASD or TD). A range of dependent variables were to be assessed, in particular proportion of phrases addressing Social information and proportion of phrases addressing information relating to humans. The data were in the form of scripts, one for each participant, which each contained twelve descriptions, one for each photo viewed.

2.3c Materials and Coding Scheme

Images were exactly the same as those used in the preliminary study, depicted in Figure 2.1 [see section 2.2a, page 42].

Based on the experience of coding the scripts in the preliminary study [see section 2.2g, page 50], six new topic categories were introduced, in the interests of providing a category for every kind of utterance made. These new categories were:

- Intro/outro: opening or closing statement, conveying little information
- Interacting: description of a mental interaction between people e.g. arguing
- Personal: personal comment relating to the participant's own feelings or knowledge
- Doubt: expression of uncertainty about the information being described
- Filler: phrases imparting no real information
- Justifications: phrases justifying a previous or subsequent piece of information but imparting no new information themselves

Once more, the full version of this coding scheme, with examples of each phrase type, a sample marked script and a step-by-step guide for coders is included in Appendix 1b [see section 8.2, page 267]. The full coding scheme was used in order to provide coders with a detailed way of categorizing information into the Human and Social super-categories, but it was only these two super-categories which were used for analysis. This is because the sub-categories did not relate directly to the assessment of social attention.

2.3d Procedure

Participants gave informed consent to be involved in this study. Before the task began, the WASI was administered. Participants were introduced to the task by a simple set of instructions. They were asked, as in the pilot study, to '*describe each photo in as much detail as you can*' and to '*pretend that you are describing the photo to someone outside the room*'. They were told they would see twelve photos in total and that their responses would be recorded. Those participants who said very little for the first two images were encouraged by the experimenter to say a little more, using phrases such as "*Anything else? Can you say any more?*" Descriptions were recorded on a portable minidisk recorder. Participants were given the opportunity to ask questions before and after the task. They were paid £5 for their involvement.

2.4 Results

2.4a Coding

The 66 scripts were transcribed and then divided into phrases by the experimenter. Fifty-two of these scripts were given to an independent rater for coding. The rater was blind to the diagnosis of the participants. However the rater was aware that some scripts came from people with ASD and some did not. The rater was asked to decide whether each phrase represented a piece of Human information and/or Social information. She was also asked to indicate those places where a piece of information was repeated and identify the repeated information as Social or not.

The remaining 14 scripts were coded in exactly the same way by the experimenter, who was blind to the diagnosis. In addition, the experimenter re-coded 20 scripts which had previously been coded by the independent rater, so that a measure of inter-rater reliability could be taken.

The measures of interest were the proportion of phrases in the Human and Social categories, in each half of each description and overall. In addition, particular attention was paid to the topic of the first and second phrase in each description, as a measure of the priority given to Social and Human information. The second phrase was analysed as well as the first, because a proportion of individuals in the pilot study opened every description with a phrases such as "*next photo*" or "*photo number 2*". It was thought possible that one of the experimental groups might contain more people who adopted this tactic, leading to apparent group differences of limited theoretical significance. Finally, the number of repeated phrases, and the proportion of these which referred to Social information, was also recorded.

2.4b Inter-rater reliability

Twenty participants had scripts which were coded by both raters. Inter-rater reliability was investigated for the following variables per script: number of Human phrases; number of Social phrases; number of repetitions of Social information; number of repetitions of Non-Social information (i.e. all repetitions not in the Social category); number of occasions in which the 1st phrase was categorized as Human; number of occasions in which the 1st phrase was categorised as Social; and also the same two measures for the 2nd phrase.

Cross-tabulation revealed very high inter-rater reliability across the 20 scripts coded by both raters. Spearman's r for correlations between rater scores did not drop below .9 for any of the variables above. Intra-class correlations, using an absolute-agreement method, also yielded coefficients of more than .9 for every variable, except for the analysis of Social and Non-Social repetitions, which nonetheless gave high coefficients of .74 and.79 respectively.

2.4c Unadjusted Phrase Data

Two scripts could not be fully transcribed due to a fault with the recording equipment. This led to 10 descriptions being lost, about 1.2% of the total number of descriptions recorded across all scripts. Seven of these lost descriptions were from a participant with ASD and three were from a TD participant. There was no significant difference in the amount of data successfully transcribed between the two groups ($p=.55$).

Both groups produced a similar number of phrases per script ($p=.11$). The variability in the number of phrases was very high, with some participants producing less than 5 phrases per description on average (ASD = 19 participants, TD = 16 participants) and some producing an average of more than 15 phrases per description (ASD = 8 participants, TD = 14 participants). The number of phrases produced was highly positively correlated with verbal IQ, Pearson's $r = .462$, $p<.001$.

The mean number of phrases produced by each group overall, and broken down into the two categories of interest, are shown in Table 2.2. Two independent-samples t-tests revealed no differences in the number of Human or Social phrases provided between the two groups (both $p>.12$). The number of Human phrases produced was again positively correlated with verbal IQ, Pearson's $r = .496$, $p<.001$, but there was no significant correlation between verbal IQ and Social phrases ($p=.065$).

Table 2.2: Number of phrases overall and in Social and Human categories for each group.

	ASD		TD	
	Mean	SD	Mean	SD
Total phrases	127	85	168	114
Human phrases	71	42	89	50
Social phrases	34	28	28	12

2.4d Percentage Data: Attentional Preferences

Despite the lack of group differences in the number of phrases produced, there was a large amount of variation between individuals, and so all analyses used scores calculated as a percentage of the total number of phrases in each category. Phrases in each topic category for each half of a description were calculated as a percentage of each half, rather than half of the percentage in the entire description. For example, a description containing 10 phrases, of which 2 phrases in the first half were in the Human category, would have a score of 40% Human phrases in the first half (2 out of 5 phrases). If there was one phrase in the second half referring to Human information, the score would be 20% in the second half (1 out of 5 phrases). These scores are shown in Table 2.3.

Table 2.3: Percentages of phrases in Social and Human categories for each group.

		ASD		TD	
		Mean	SD	Mean	SD
Human phrases	Overall	59.3 %	11.2	58.5 %	11.4
	First half	64.0 %	13.4	64.8 %	12.0
	Second half	53.6 %	14.9	51.8 %	14.4
Social phrases	Overall	28.4 %	15.4	23.2 %	13.4
	First half	27.8 %	14.1	23.3 %	12.4
	Second half	25.5 %	16.5	20.2 %	13.5

There were negative correlations between verbal IQ and the percentage of phrases produced in both the Human and Social categories: Human category, Pearson's $r = -.438$, $p<.001$; Social category, Pearson's $r = -.269$, $p=.029$. These correlations are interpreted as reflecting the fact that those people who produced the smallest number of phrases (and who also had the lowest verbal IQs) could produce a very high percentage of Human and/or Social phrases by only making one or two comments. For example, in the description below only one phrase is classed as Social ("*at some kind of celebration party*"), but in such a short description this phrase alone translates into a high proportion of Social phrases (33%).

Sample Description 5: Very short description with a high proportion of Social phrases

... people dancing / at some kind of celebration party... / and it looks as if it's at night-time...

Initial analyses aimed to discover what preference participants showed for Social and Human information, by analysing the proportion of phrases in these categories between the two groups. First we can see from Table 2.3 that more than 50% of phrases were references to Human information. Student's t-tests making a direct comparison of the two participant groups showed no significant differences in the proportion of Human phrases overall or in either half of the description (all $p>.60$). Group comparisons of the proportion of Social phrases again revealed no group differences (all p>.15). Participants devoted around 25% of their phrases to describing social elements of the scene or to describing people in social terms.

As shown by the standard deviations in Table 2.3, variation in the proportion of Human and Social phrases was consistent across the two categories and across each half of a description. The full range of Human phrases produced was very broad, running from a minimum of 42% to a maximum of 94%. Two participants, one from each group, were outlying by more than 2 standard deviations from the overall mean. The range of Social phrases produced was also very broad, but more evenly distributed around the overall mean: minimum 6% to maximum 61%. There were no outliers for the percentage of Social phrases. Despite the wide range, box plots indicated that the proportional variables for both Human and Social categories were normally distributed.

No formal analysis was made of the sub-categories of the coding scheme, since these categories did not relate directly to social attention. Nevertheless, it is informative to note the content of those phrases included in neither the Social nor the Human category. An example of a description with a lot of information falling outside both Human and Social categories is shown below.

<u>Sample Description 6: Example of a high proportion of phrases not included in either Human or Social categories</u>

> ... It's like a slow ballroom. There's balloons at the left hand side, two of them are sticking to the roof. There's two people dancing in the foreground. There's lots of chairs tables around. There's a man looking straight at the camera with glasses on. There's paintings in the background. There's erm a window and a door... there's more balloons. Towards the right there's chequered... covers on the tables... and with the table, what I can see, right in the background with the

> chequered cover, there's actually a chair behind that with stuff on it. There's lots of drinks as well, it looks like they're drinking tea... from a big pot

Attentional preferences for specifically Social information were less strong than for Human information in general – participants devoted about a quarter of their phrases to Social information. Often participants would make a single social statement as the conclusion to a longer period of description in physical terms, as in the following example:

Sample Description 7: Example of a single Social phrase to end a description

> Right in the middle of this picture there's a person, right... a black man, right... and he's pointing his finger... He's wearing a suit and he's like showing a bit of baldingness, like he's beginning to bald... Behind him there is a person with like a mask on, but you can still see like the face, the eye section, holding up a sign saying something or other... Probably a protest of some sort...

The opposite pattern was also common, when a single encompassing social judgement was made at the beginning of a description, then followed by a lot of physical statements:

Sample Description 8: Example of a single Social phrase to open a description

> We have what I'm guessing would be a fancy dress party kind of thing... Woman on camera right looks... like er... she's in a blue dress er... blonde hair... er... A woman sort of popping out from behind her, you can only see the head and her right shoulder... with er... She's really smiley. She's got her hair tied up and a woman popping out from just behind her as well with... er black hair, really short...

These examples illustrate some of the ways in which participants went about describing the scenes depicted, without providing a lot of phrases falling into the Social category.

2.4e Percentage Data: Attentional Priority and Persistence

A second way of analysing the scripts is to look at the distribution of Human and Social phrases throughout a description. A tendency to focus on Human or Social information early on indicates an attentional priority for these items, and the presence of quantities of Human or Social information consistently through a description indicates a persistence in attention to these elements. An analysis was made of the proportion of phrases in each topic category for each half of a description. These were calculated as a percentage of each half, rather than dividing the percentage in the entire description by two, as described in more detail previously [see section 2.2f, page 49]. These data were normally distributed with no evidence of significant outliers.

An ANOVA on Description Position (first half vs. second half) and Group (ASD vs. TD) for phrases in the Social category revealed a main effect of Description Position, $F(1,64) = 4.91$, $p=.03$, showing that a larger percentage of the first half of the descriptions was devoted to Social information than the second half. An ANOVA on Description Position (first half vs. second half) and Group (ASD vs. TD) for phrases in the Human category revealed a main effect of Description Position, $F(1,64) = 37.97$, $p<.001$, showing that a larger percentage of the first half of the descriptions was devoted to Human information than the second half. There were no group effects in either analysis.

These analyses indicate that information pertaining to both Human and Social categories is prioritised for the earlier part of a description, though proportions shown in Table 2.3 indicate a certain amount of persistence in attention to these information categories throughout descriptions. An analysis was also made of the opening two phrases of each description, to reveal the extent of this attentional Priority.

An ANOVA on Phrase (first vs. second) and Group (ASD vs. TD) for Social phrases revealed a main effect of Phrase only, $F(1,64) = 5.03$, $p=.028$, due to a larger percentage of second placed phrases than first placed phrases falling into the Social category (1^{st} phrase mean

= 26%, 2nd phrase mean = 33%). The same analysis on Human phrases also revealed a main effect of Phrase only, $F(1,64) = 8.88$, $p=.004$, again due to a larger percentage of second places phrases than first places phrases falling into the Human category (1st phrase mean = 64%, 2nd phrase mean = 74%). In neither analysis were there any significant group effects. These analyses indicate that both groups were more likely to refer to Human and Social information in second-placed phrases, and this is likely to be because first-placed phrases were often neutral comments such as "*Next picture*".

Finally, an analysis was made of the number of repetitions of social and non-social information made by participants, as a second measure of the persistence of social attention over time. Both of these variables were non-normal and highly skewed since a large number of people made no repetitions across all twelve images. A Mann-Whitney test showed no differences between groups in the number of Social or Non-social repetitions. Wilcoxon signed-ranks tests on each group separately also showed no differences in the number of Social and Non-social repetitions. Therefore, very little information was repeated in descriptions, and what was repeated was equally likely to be Non-Social as Social information. This pattern was the same in both groups.

2.5 Discussion

2.5a Results of the Study

The free-description task aimed to make a highly naturalistic, exploratory description of evidence for social attention in descriptions of a visual scene in TD adults and those with ASD. The content analysis approach was intended to make a clarification of what is meant by social information, within the definition of social attention as a focus on social information in the environment, to the exclusion of non-social stimuli. The approach adopted was to record verbal descriptions and a preliminary study developed a coding scheme which categorised description content referring to Social or Human elements of the scene. The task was successful in distinguishing between different types of person-centred information (which may be social or non-social) and different types of social information (which may be person-centred or not).

Participants produced a large number of references to Human and to Social elements of the scene, including hypothetical statements such as suppositions about characters' thoughts, feelings, relationships and preceding and subsequent actions. The two participant groups did not differ in the proportion of references made to either Social or to Human information. Furthermore, both groups showed a comparable tendency to prioritise information about humans and social aspects of the scene in their descriptions. Both groups produced more Human and Social information in the first half of a description than the second, though this distribution was more pronounced for phrases referring to Human than for Social information. In addition, both groups showed a similarly high proportion of opening and second phrases which referred to Human information and a lower proportion of Social opening phrases. Very few repetitious phrases were identified and therefore, though these were equally likely to refer to Non-social as to Social information, it is not thought that repetition of information is a useful way of assessing persistence of attention in a verbal description.

This study provided a description of the nature of social attention. Contrary to the prediction that ASD participants would show less evidence of a social attention bias, both participant groups devoted a similar proportion of their verbal descriptions to Social information. Participants in both groups also focused to a large extent on the non-social aspects of the people depicted, such as their clothing or appearance. This indicates that attention to people alone and attention to the social aspects of people may be both be components of social attention. The overlapping nature of these two categories as defined in our coding scheme prevents an assessment of the relative attention paid to social and non-social aspects of people. There was a fairly large amount of variation among participants in both groups, suggesting that attention to person-centred and explicitly social information may be subject to individual differences. The item-wise analysis in the preliminary study also showed how the nature of the scene being viewed can influence the attention paid to social information.

These findings have some significant consequences for the design of subsequent experimental studies of social attention. First, it will be important to make sure that the difference between attention to people and attention to social information is acknowledged: it may be possible to demonstrate that these two types of information form part of a hierarchy of social stimuli, dependent on their informativeness. While both may be components of a broader social attention construct, attention to people's clothes or appearance is less likely to play a part in the development and maintenance of autism, except to the extent that it is linked to attention to social information. Second, the variation between participants re-emphasises the need to incorporate assessments of individual differences in social attention. Third, the variation between images, shown in the preliminary data, demonstrates that materials for future studies must be carefully matched for content.

2.5b Relation to Previous Findings

The findings from this free-description task seem to contrast with studies that have established a difficulty attending to social and/or human elements of the environment (e.g. Dawson *et al.*, 2004), or social elements of a moving-image (Klin *et al.*, 2002b). One significant difference is that the current investigation uses static, but naturalistic visual scenes to investigate social attention, in order to eliminate multi-modal sensory information and motion processing demands. Therefore, it is possible that the social attention difficulties experienced by people with ASD in real-life, and in response to moving images, reflect to some extent their struggle to integrate information which is presented in motion and often in multiple sensory modalities (Bertone & Faubert, 2005; Bertone, Mottron, Jelenic, & Faubert, 2003; Gepner & Mestre, 2002; Iarocci & McDonald, 2006; Kemner & van Engeland, 2003; Kemner & van Engeland, 2005; Milne *et al.*, 2002).

The results of the current study also contrast with evidence from tasks which demonstrate a failure to make accurate social attributions in adults or children with ASD (Abell *et al.*, 2000; Bowler & Thommen, 2000; Castelli *et al.*, 2002; Klin, 2000). One reason for the discrepancy may be that these tasks have all used moving stimuli which create extra processing demands, as outlined above. Another way of reconciling our findings with these social attribution studies is to note that these tasks have often shown that people with ASD do produce social attributions, but that these may be inappropriate. For example, Abell and colleagues found no differences between typical, autistic or MLD (moderate learning difficulties) groups in the frequency of mental attributions, unless those attributions were split into appropriate and inappropriate attributions. Even then, there was a great deal of variation, with 60% of the sample with ASD producing no inappropriate mental state attributions (Abell *et al.*, 2000) – though some participants in this group may also have produced no mental state attributions at all.

The analysis of the free-description task did not investigate the accuracy of the social statements made by participants, partly because the stimuli were not designed to elicit any particular social comment and so there was no ad-hoc definition of a correct response. Moreover, the free-description task was designed to assess not social cognitive skills, but attention to social information, and consequently a measure of social cognitive ability was not included. The evidence presented here combined with that from more complex social tasks may indicate that people with ASD do attend to social information but do not have the skills needed to analyse or respond correctly to what they see.

The presence of attention to social information, as indexed by verbal description, in our ASD group suggests that there is a general understanding among able adults with ASD that scenes can be interpreted socially and that social information can be an interesting part of a description of a scene. Therefore, one might predict that if adults with ASD do have an impaired or reduced bias to attend to social information, this will only be apparent at a more subtle level of analysis.

2.5c Critique of the Method

This new free-description method can be assessed in terms of its contribution to our understanding of social attention in autism, but also for its suitability as a method for assessing social attention. The free-description task permitted assessment of a genuinely spontaneous attentional process as participants received minimal task instructions and there were no right or wrong responses. A range of social information was available to be commented upon by participants, including visible elements such as emotional expression and costume, but also non-visual suppositions such as the nature of an event, the thoughts of individuals represented and the back-story of characters depicted. The task offered an opportunity to clarify our definition of social attention and in particular to describe the different kinds of social information available in a naturalistic visual scene.

The free-description task was not an experimental assessment, in that no non-social comparison images were presented. It is possible that the groups' attention might have been differently distributed relative to comparative non-social scenes, for instance, depicting empty rooms or landscapes. A second fault of the free-description method was the fact that temporal information was largely removed from the scripts, with the intention of coding solely for content. This limits any conclusion about the priority given to social information – while both groups addressed social information in similar proportions in their first and second phrases, the time taken to prepare these phrases, following image onset, was not recorded. Likewise, throughout the descriptions, detailed records were not taken of the length of the pauses made by participants. It is possible that both groups produced similar content, but that the ASD group expended more effort in doing so, a difference which could have been revealed by a temporal analysis of the original recordings. Finally, the coding scheme developed, while making a valuable distinction between attention paid to non-social and social aspects of people, was not able to separate these two categories. Therefore, while the results provide guidance for future experimental designs, these data cannot inform us as to the relative attention paid to social and non-social aspects of a person.

2.5d Conclusions and Next Steps

In the current study adults with and without ASD gave verbal descriptions of a complex social scene. As these free descriptions were led by the interest of the participant, towards various aspects of the scene, it is assumed that their content provided an index of attention. Results showed that people with ASD are capable of spontaneous attention to social elements in their environment. It is possible that this may only occur under certain circumstances – when participants are under no pressure to make rapid judgements and when no extra processing demands are imposed by moving or multi-modal stimuli. However, the current study has a number of significant limitations: participants were not presented with a set of non-social control stimuli to describe; the coding process analysed only the content of participants' descriptions without temporal information; and social and non-social attention to people cannot be adequately distinguished. These limitations prevent the study from making any clear assessment of the extent of social attention in ASD as compared to that of TD people.

This exploratory assessment of social attention provides a foundation on which to design experimental assessments of social attention in ASD. TD people demonstrated a social attention bias which should be explored in an experimental design. Contrary to expectations, a similar pattern of data was produced by participants with ASD, indicating a comparable social attentional preference in this group. It is crucial to examine this finding in more detail to see whether a more precise method might reveal differences between those with and without ASD.

These data emphasise the need to make explicit definitions of social information, and the importance of careful matching of stimuli and assessment of individual differences.

3. Attention to Eye-Gaze Direction: A Social Change Detection Task

3.1 Introduction

3.1a Aims of the Current Study

The investigations in this thesis aim to further understanding of spontaneous attention to social elements of a visual scene in TD people and those with ASD. A sub-goal of these investigations is to find appropriate methods for measuring subtle social attentional processes in a simultaneously ecologically valid and experimentally controlled manner. The study reported in the previous chapter developed a new coding scheme to help define social information. This was used with a free-description task, to provide a description of social attention in people with ASD. Modelled in part on the Social Attribution Task (Klin, 2000) it appeared to offer a simple way of describing the spontaneous direction of attention to social elements of a visual scene, in the absence of specific task instructions. Both groups of participants spent a significant proportion of their time describing social aspects of the scenes. The task also demonstrated that there may be a useful distinction to be made between attention to non-social and social aspects of people. However, the task was seriously flawed by its inability to quantify adequately these two types of attention, since the relevant coding scheme categories were not mutually-exclusive.

The current study aims to make an experimental assessment of attention to social information, by explicitly contrasting attention to non-social and social aspects of a person. This will address the issue of whether attention is preferentially paid to social aspects of a person by TD adults, and if so, whether this bias is also present in adults with ASD. The study will help to fulfil our original aims by further describing the nature of the social attention bias purported to be present in typical adults and absent in people with ASD. This would help us to understand the role of social attention in autism as factor which helps to maintain the social deficits of autism throughout life, as well contributing to its development in infancy and childhood. This study adopts a 'change detection' paradigm from the visual cognition literature to assess social attention, which may be a useful model for assessments of high-level influences on attention in the future.

3.1b Change Detection Methodology and Theory

'Change blindness' describes the phenomenon whereby an individual finds it very difficult to spot the difference between two near-identical images presented one after the other, with an interruption in between (Simons & Levin, 1997). The change is normally produced by taking an image of an object or scene and duplicating it, then making a change to the duplicate image. The two images are then presented successively in the same location on a screen, such that they replace each other, creating an impression of 'flicking' between the two images. The interruption between the images, normally a briefly presented blank screen, serves to mask the transient movement cue created by the changing object, making changes presented in this way very hard to detect (Rensink, O'Regan, & Clark, 2000). These interruptions can also consist of blinks, saccades, 'mud-splashes', cuts in a motion picture or even real-world interruptions (Grimes, 1996; Levin *et al.*, 2002; O'Regan, Deubel, Clark, & Rensink, 2000; O'Regan, Rensink, & Clark, 1999; Simons, 1996). Another way of inducing change blindness is to make the change appear very slowly (e.g. a car turning gradually from red to green) such that no movement cue is produced by the change (Simons, Franconeri, & Reimer, 2000).

Humans experience a visual world that seems detailed and complete. Despite having very poor peripheral vision and a blind-spot near the centre of our visual field, we are not usually aware of any gaps in our visual experience. This is partly thanks to the rapid eye-movements constantly being made (about 3 times per second) by our eyes to promote the experience of complete visual awareness. This perceptual experience led researchers to conclude that the brain likewise stores a rich and detailed representation of the visual scene (McConkie & Currie, 1996). Evidence to support this hypothesis comes from studies which show exceptionally good long-term memory for visual scenes. For example, participants shown 612 colour scenes had 99.7% accurate recognition when tested two hours after initial viewing (Shepard, 1967) and other studies have shown that this recognition ability reduces only slightly for thematically similar scenes and for scenes identical except for a switch in left-right orientation (Standing, Conezio, & Haber, 1970).

However, the phenomenon of change blindness questions the assumption that a full and detailed representation of the visual world is available to us (though also see Noe, Pessoa, & Thompson, 2000). The inability to detect a change between two scenes immediately has been interpreted in a number of ways. The visual system may fail to store an adequate representation of the former or latter scene, or else fails to make a full comparison between the two scenes. This may either be because representations are not available for conscious perusal, or because the latter representation 'overwrites' the former (Simons, 2000). Whatever the final explanation, most theorists agree that focused attention is crucial for successful detection of changes (Henderson & Hollingworth, 1999a; Rensink, 2002; Simons & Levin, 1997; Tse, 2004).

Rensink's coherence theory (not to be confused with the weak central coherence theory of autism) describes a perceptual system that can only coherently represent attended items, while representations of unattended items in the visual scene have limited coherence (Rensink, 2000a). Normally, the motion signal created by a change attracts attention automatically, but in change detection paradigms, this signal is masked and consequently "*a more effortful attentional scan must be used*" (Rensink, 2001, p.172). It is suggested that this kind of online attention can be given to about five items in a scene at once (Rensink, 2000b) and this corresponds with estimates of attentional capacity from other methods (Pashler, 1998). It is also possible that these five items are not represented online simultaneously: only one item is actively attended to, while four recently attended items are represented in short term memory (Henderson & Hollingworth, 2000). The phenomenon of change blindness has clearly had a significant impact on our understanding of visual attention and there remains a great deal of work to be done to understand fully the mechanisms behind change detection. However for the purposes of the current investigation, it is most important to note that focused attention is required to identify a change, and that this must result from a conscious attentional scan of the depicted scene.

3.1c Group Differences in Change Detection

Little work has been done to investigate what high or low-level factors direct the attentional scan which produces successful change detection. Work showing that change detection is more accurate for changing items of higher semantic interest, and for contextually inappropriate items suggests that high-level expectations or attentional biases can have an influence (Hollingworth & Henderson, 2000; Rensink *et al.*, 1997). Individual differences can also have an effect, since experts on American football are more likely than novices in the sport to detect changes to tactically-significant elements of an American football image (Werner & Thies, 2000). Following Werner and Thies' observation, we might think of typical adults as social experts, whose interest and experience of social information will direct their attention rapidly and spontaneously to social aspects of a scene. In contrast, people with ASD might be considered to be social novices, who lack interest in and experience of social information and so will not demonstrate reduced response times or higher accuracy for social changes.

As well as being used to expose group differences (Carlin *et al.*, 2003; Rutkowski, Crewther, & Crewther, 2003; Snowden, Dann, & Gray, 2004; Tager-Flusberg, Plesa-Skwerer, Schofield, Verbalis, & Simons, in press), and developmental change (Fletcher-Watson, Collis, Findlay, & Leekam, submitted; Shore, Burack, Miller, Joseph, & Enns, 2006), change detection paradigms have also been employed to assess attention to social information in particular. Ro and colleagues (Ro *et al.*, 2001) found that changes to the identity of a face were more rapidly and accurately detected than changes to objects from other categories. This finding has been questioned by evidence suggesting that changes to any object from a unique category not otherwise represented in the display are preferentially detected (Palermo & Rhodes, 2003). However, changes to a face's expression and identity can be picked up from among a series of unchanging face distractors (Large, Cavina-Pratesi, Vilis, & Culham, 2007), suggesting that there is something particular about faces and the information they contain after all. All of these studies investigating the potential for a change detection paradigm to reveal something about social attention have so far presented faces in isolation, among single object distractors. Our aim is to investigate attention to information which is socially informative, and which is presented in a more ecologically valid manner, as part of a naturalistic scene.

3.1d Social Change Detection: Aims and Predictions

Limitations in the previous study reported in this thesis highlight the importance of making a distinction between the non-social and social aspects of a person [see section 2.5c, page 65]. Therefore, in this experimental assessment of social attention, social information is represented by eye-gaze direction. While many other aspects of a person have social value – for instance, we could have made changes to emotional expression, posture or gesture – eye-gaze direction is a particularly powerful social stimulus. If we imagine a hierarchy of social information based on the informativeness of different social stimuli, eye-gaze direction would doubtless be near the top.

The eye-area and gaze direction provide a reflexive cue for attention (Friesen & Kingstone, 1998) and are important in conveying complex social information, ranging from another person's desires (Baron-Cohen, 1995) to their intentions (Friere, Eskritt, & Lee, 2004) and emotional states (Baron-Cohen, Wheelwright *et al.*, 1997). The eye area has also been indicated in previous research as receiving less attention from individuals with ASD than other parts of the face (Klin *et al.*, 2002b). It has also been suggested that the eye-area, and specifically direct gaze, is aversive to people with ASD (Dalton *et al.*, 2005) and this suggestion has been borne out by evidence of increased skin conductance responses to images of direct gaze in children with ASD (Kylliainen & Hietanen, 2006). Therefore, in our search for what may be subtle impairments in social attention, given the absence of group effects in the preceding study reported in this thesis, using changes to eye-gaze direction provides the surest means to identify differences between our typical and ASD groups. Likewise, if there are no differences we can be relatively confident that in an investigation of less powerful social aspects of a person, such as changes to gestures, we would also see no group differences.

Our new change detection task also required a comparison change to a non-social aspect of a person. After extensive piloting [see sections 3.2 and 3.3, page 74-81] non-social changes in the final experimental work were represented by the presence or absence of spectacles. The control changes to spectacles were chosen due to their having the same location within the image (relative to the image contents) and a near identical location within the face. Controlling for location is important because research has shown that there is a direct relationship between how close one's gaze falls to the site of a change and the likelihood of detecting that change (Henderson & Hollingworth, 1999b), although even changes viewed foveally are not always detected (O'Regan *et al.*, 2000).

It is proposed that TD adults show a bias to attend to people, but in particular to social aspects of people. This should result in enhanced detection of changes to eye-gaze direction compared to changes to spectacles, which are distinguishable only by their social meaning. It is possible that people with ASD have domain-general attentional deficits which could produce an effect in change detection overall. A previous study (Fletcher-Watson, Leekam, Turner, & Moxon, 2006) found an effect which was interpreted as stemming from a problem switching attention between different elements in a scene. However, the same study also found no overall differences between an ASD and a TD group in their ability to detect changes. Both TD and ASD participants directed their attention to the scene according to high-level considerations including the semantic and contextual role of the item within the scene, and so no main effect of group is predicted here. Instead, a domain-specific effect is predicted, whereby the participants with ASD show an impairment only in attention to social aspects of a person relative to the TD group. Therefore, we would expect less efficient detection of eye-gaze changes only, by the participants with ASD, relative to the TD group.

3.2 Developing the Method: Preliminary Study 1

3.2a Introduction

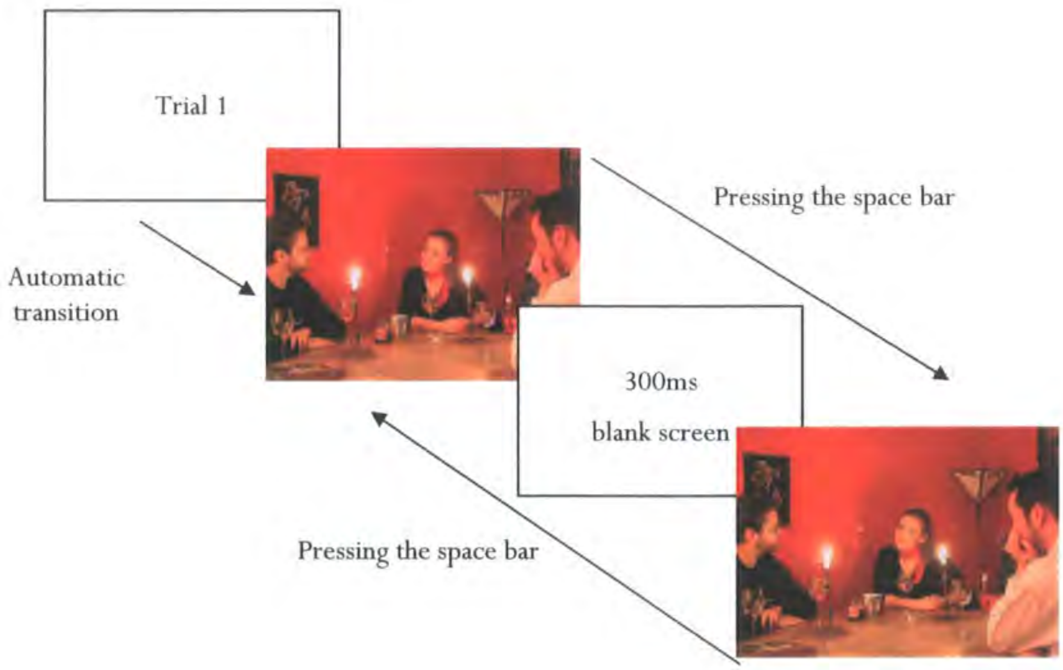
Before beginning the main experiment, a series of studies was conducted to explore the suitability of a change detection method for assessing social attention. Many factors had to be considered, including the difficulty of creating stimuli with eye-gaze direction changes, finding appropriate control stimuli and selecting the particular presentation method.

This first preliminary study formed part of a masters dissertation project which preceded the PhD research, and it is reported here to provide the background to the method development and final social change detection study (Fletcher-Watson, 2004).

3.2b Method

A set of 18 stimuli were developed, each comprising a pair of images, where image B was a duplicate of image A, in which a single change had been introduced. Of these, six stimuli showed changes to an individual's eye-gaze direction, six contained matched control changes to

Figure 3.1: The sequence of events within a trial in Preliminary Study 1.



The images depicted show an eye-gaze direction change.

various non-social aspects of people and six contained filler changes. All images featured at least one person. Control changes were to non-social aspects of a person and were selected to correspond to eye-gaze direction changes in terms of location of the changing item within the borders of the image and size of the area affected by the change. Examples of non-social control changes are changes to the shape of a moustache and to the presence of an earring. Filler changes were to objects such as the presence of a jam pot or a framed photograph on a wall.

These stimuli were presented in a modified flicker paradigm, identical to that described in our previous study (Fletcher-Watson *et al.*, 2006) and illustrated in Figure 3.1. This method meant that participants were in control of the rate of presentation of the stimuli, in that the switch between image A and image B was made by pressing a space bar, rather than occurring automatically. Participants viewed the image pair in each trial as many times as they wished, and pressed a key when they had identified the change, thereafter reporting the change verbally to the experimenter. Participants were 22 individuals aged 17-27 years, with high-functioning autism (HFA) and Asperger's syndrome (AS), collectively referred to as the ASD group. All these participants attended a specialist college in the Sunderland area for which a diagnosis of autism or AS was a criterion of admission. All had been diagnosed by experienced clinicians, (a psychiatrist or clinical psychologist employed by the National Health Service), working in specialised centres, as meeting DSM-IV criteria for either HFA or AS (APA, 1994). These diagnoses had been confirmed, upon each participant's admission to the college, by a second clinical psychologist.

There was also a comparison group of 22 typically developed (TD) participants aged 17-32 years. These individuals were recruited from mainstream 6^{th} form colleges and further education colleges in the Durham area.

Both groups contained 3 females, and were also matched for chronological age, $p=.91$. Groups differed significantly in their full-scale and performance IQ, $t(40) = 3.17$, $p=.003$ and $t(40) = 3.60$, $p=.001$. In both cases the TD group scored more highly that the ASD group: TD FSIQ mean = 105.1, SD = 17.2; ASD FSIQ mean = 90.2, SD = 13.0; TD PIQ mean = 105.9, SD = 17.2; ASD PIQ mean = 87.9, SD = 15.1. The groups did not differ significantly in verbal IQ ($p=.08$).

3.2c Results

Throughout this thesis, every effort was made to match participant groups on IQ variables. However, in cases such as this, when group matching has not been achieved, IQ was included as a covariate only if it correlated with the dependent variable of interest with a coefficient greater than .4, since any lesser correlation does not provide enough power to justify the use of ANCOVA (Keppel & Zedeck, 1989). Correlations of full-scale, performance and verbal IQ with response time to eye-gaze direction changes, and control changes did not exceed the cut-off of .4 (all $r<.36$). Therefore no IQ measures were included in the subsequent analysis of main and group effects.

Analyses were performed using ANOVAs on Change-Type (eye-gaze vs. control) and Group (ASD vs. TD). Results revealed that there was a main effect of Change-Type such that changes to eye-gaze direction were detected more rapidly than control changes to non-social information, $F(1,42) = 99.34$, $p<.001$. There were no group effects.

3.2d Discussion

Results show that changes to eye-gaze direction are detected more quickly than control changes to non-social aspects of people, by individuals with and without ASD. This could reflect enhanced attention by both groups to a social element of a person, i.e. eye-gaze direction. However, six eye-gaze direction changes were included in a study consisting of only 18 trials, while control changes were to a variety of locations and items such as facial hair and jewellery. Therefore an alternative explanation for these results is that participants quickly learnt to expect changes to eye-gaze direction and used this expectation to direct their search for changes. A new stimulus set was required to determine whether changes to eye-gaze direction could be detected quickly as a result of a purely social advantage over other change-types.

3.3 Developing the Method: Preliminary Study 2

3.3a Introduction

The stimulus set created for Preliminary Study 1 fell into two experimental categories. The stimuli representing social information all featured a change to someone's eye-gaze direction. In contrast, the control images featured a range of different changes to non-social aspects of a person such as the presence/absence of an earring, or the shape of a moustache. Therefore faster detection of social changes could merely have reflected the ease of detecting a series of predictable, repeated changes, albeit in different images and on different people.

It is possible to develop stimuli which deal with this fault in one of two ways. First, we could increase the range of social changes used, for example by including changes to a person's facial expression, gesture or posture. This would remove the opportunity to use an expectation-based strategy to detect these changes. However, using such a range of different types of change could produce problems at the analysis stage, because different types of social information might receive different attentional priority. Including enough exemplars of each category of social change such that they could be analysed separately would reintroduce predictability of changes and also create an unfeasibly large stimulus set.

Instead, we chose once again to use changes to eye-gaze direction to investigate attention to this powerful social signifier. We then developed a new set of control changes, which were to people's spectacles. These form an excellent category of non-social control change for four reasons. First, the presence or absence of a pair of spectacles provides no social information. Second, using a repeated series of a single type of change made our control changes as predictable as the eye-gaze changes, meaning that both were equally subject to the use of a expectation-based strategy to search for changes. Third, spectacles are located in the same place on the face as eyes, so general attention to faces or even the eye-region would not distinguish between these changes. Fourth, we were able to compare our spectacles and eye-gaze changes on a number of relevant low-level factors, such as contrast, location and size [see section 3.5c, page 85]. Therefore, if enhanced ability to detect changes to eye-gaze direction relative to spectacles changes were found, we could be confident that the social nature of the eye-gaze changes had created that difference. In fact, social information would be revealed to have a grasp on attention over and above merely directing attention to a certain location, such as the eye-area.

In addition, the adapted flicker paradigm used in Preliminary Study 1 had some drawbacks in that the demands placed on participants were quite high. They had to think about one button press to switch between images and another to terminate the trial. This led to a number of errors where trials were accidentally terminated before the second image was viewed. Participants also had to verbally report the location of the change, placing demands on their vocabulary and other verbal skills. A new change detection method in which participants see trials in which a change occurs and trials in which there is no change, and respond Yes or No according to whether a change was seen, would eliminate these problems, and yield accuracy as well as response time data, enriching results.

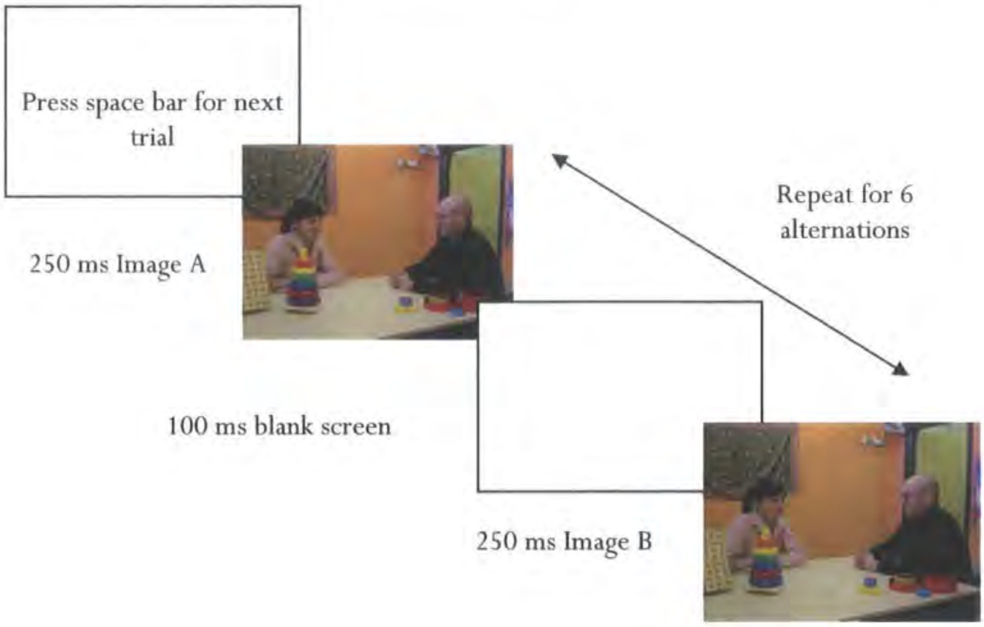
3.3b Methods

Two methods made up this new experiment, to investigate separately the effects of a new stimulus set and a new presentation method. The new stimulus set consisted of a set of nine eye-gaze changes and nine spectacles changes as well as a number of filler changes to objects visible in the scene.

Method 1 was a direct replication of the previous method [see section 3.2b, page 74], with a new stimulus set, to check that the new stimuli produced the same effect as the previous set. Here six eye-gaze changes, six matched spectacles changes and six filler changes were displayed, using the modified flicker illustrated in Figure 3.1 [see page 73]. Participants were required to identify the change occurring and their response time was recorded.

Method 2 incorporated all 18 new eye-gaze and spectacles changes, as well as 30 filler changes and 30 trials in which no change occurred. In this second version, stimuli were presented in a traditional flicker paradigm, in which automatic switches are made between two versions of the same image, as illustrated in Figure 3.2. There was a total of 78 trials, presented in two blocks of 40 and 38 trials. Participants were required merely to press a key according to whether they had seen a change or not. Their response time and accuracy were recorded.

Figure 3.2: The sequence of events within a trial in Preliminary Study 2, Method 2.



Each image was seen six times, and the blank screen was presented eleven times, in each transition, making the total trial length 4100ms. The image depicted here shows an eye-gaze direction change.

Participants were 22 TD university students aged between 18 and 22 years, 11 of whom completed each of the two methods.

3.3c Results

Results from Method 1, which used the new stimuli in the old presentation program, showed a significant effect of Change-Type such that eye-gaze changes were detected significantly more quickly than spectacles changes: $t(10) = 3.28$, $p=.008$; eye-gaze mean = 13288ms, SD = 7748ms; spectacles mean = 20795ms, SD = 11719ms. An item-wise analysis revealed no outlying stimuli.

Results from Method 2, which used the new stimuli in a new presentation method, showed again that eye-gaze changes were detected more rapidly than spectacles changes: $t(10) = 5.34$, $p<.001$; eye-gaze mean = 3489ms, SD = 705ms; spectacles mean = 4393ms, SD = 789ms. In addition, the number of correctly identified changes was significantly higher for eye-gaze changes: $t(10) = 4.54$, $p = .001$; eye-gaze mean = 7.9 correct, SD = 0.8; spectacles mean = 6.4 correct, SD = 1.6.

An item-wise analysis of data from Method 2 revealed that one eye-gaze stimulus, which had not been included in Method 1, produced significantly slower response times and lower accuracy than the others in the eye-gaze category. However, this image was not an outlier when all eye-gaze and spectacles stimuli were analysed together. Therefore, and also because of the small pilot sample size, it was decided that this stimulus should remain in the final set for the main experiment.

3.3d Discussion

Method 1 demonstrated that changes to eye-gaze direction can be detected more rapidly than control changes, due to their uniquely social nature. Since equal numbers of trials featuring eye-gaze direction and spectacles changes were included, both types of change could have been detected quickly by using a conscious search strategy, focusing on the eye-region. Therefore enhanced ability to detect eye-gaze direction changes was a result of an attentional bias towards social aspects of a person.

Method 2 provided two ways of assessing change detection, showing that eye-gaze direction changes can be detected more accurately as well as more rapidly than changes to spectacles. The new presentation method also successfully incorporated a larger number of experimental and filler changes. With a simpler response system, participants could focus on the task for longer – in fact all participants moved straight on to the second block of trials without wanting to take the short break offered. In addition, no key-press errors were made, meaning that data were successfully collected for every trial, for every participant. The rate of presentation and number of cycles used was also successful in producing variable performance among participants, without ceiling or floor effects.

3.4 Social Change Detection: Final Experiment

3.4a Introduction

As described above, two preliminary studies using three methods were run to develop a new way of assessing attention to eye-gaze direction changes. These studies have shown that it is important to take into account the predictability of changes used, and acknowledge that participants can use different strategies to direct their search for a change. In investigating the effect of social information on change detection ability it is crucial to ensure that control changes are used which differ from social changes only in the absence of social significance. This means that if changes to social information are detected more rapidly and accurately than non-social changes we can be sure that it is the difference in social status of the two change types which produces the response time and accuracy effects.

It has been demonstrated that typical adults have their attention rapidly captured by a change to eye-gaze direction, because of the social significance of such a change. Non-social changes to people, situated in the same region are not detected as quickly nor as accurately. The use of eye-gaze direction to investigate social attention biases in a change detection paradigm is very successful. The experimenter has been able to develop a method for producing these changes in an scene which is both natural and precise. Ways of matching eye-gaze direction and spectacles changes for low-level properties have also been developed, and these are outlined below [see section 3.5c, page 85].

In Preliminary Study 1 which ran with a group of people with ASD as well as TD participants, no group differences were found. However, in that study it was possible to use an expectation-based strategy to direct one's search and detect changes to eye-gaze direction. Now that eye-gaze changes can only be distinguished from changes to spectacles by their social role, a different prediction can be made. It is expected that participants with ASD will not show enhanced detection of these changes to social information. This would be demonstrated by an interaction between change type and group. No main effects of group are expected, since previous studies have shown that people with ASD are as quick to detect non-social changes as TD participants (Fletcher-Watson *et al.*, 2006).

3.5 Method

3.5a Participants

The TD group comprised 36 young adults (6 female) aged 17-32 years, from mainstream sixth-form colleges and further education colleges in the Durham area. The ASD group comprised 36 young adults (6 female) aged 17-25 years, with HFA or AS. All these participants attended a specialist college in the Sunderland area for which a diagnosis of autism or AS was a criterion of admission. All had been diagnosed by experienced clinicians, (a psychiatrist or clinical psychologist employed by the National Health Service), working in specialised centres, as meeting DSM-IV criteria for either HFA or AS (APA, 1994). These diagnoses had been confirmed, upon each participant's admission to the college, by a second clinical psychologist.

Table 3.1: Descriptive statistics for both groups, and p-values for group matching.

	ASD		TD		
	Mean	SD	Mean	SD	t-test sig. level
Age (years)	18.72	2.20	19.92	3.97	p = .12
Verbal IQ	93.92	15.47	94.61	13.92	p = .84
Performance IQ	95.94	14.91	100.64	12.76	p = .16
Full-scale IQ	94.72	13.96	97.22	13.02	p = .44

Thirty-five members of the TD group and 31 members of the ASD group also took part in the free-description study described previously [see section 2.3a, page 51], though the two studies took place in separate sessions. In addition, 14 members of the ASD group took part in

Preliminary Study 1 [see section 3.2b, page 74], though this session took place at least 12 months before the current experiment.

The groups had equal gender distributions and were group-wise matched on age, full-scale IQ, verbal IQ and performance IQ (Wechsler, 1999) as shown in Table 3.1.

3.5b Design

The experiment consisted of a single change-blindness task using a 'flicker' paradigm (e.g. Rensink *et al.*, 1997). Participants were shown pairs of images separated by a blank screen. These image pairs were realistic scenes which were either identical, or different in one single detail. The participants' task was to view the alternating image pairs and then decide whether a change was present or not.

Three categories of stimuli were developed for use in this task, as described in the subsequent materials section. Social stimuli contained a displacement change to a social aspect of a person; their eye-gaze direction. These are referred to as eye-gaze changes. Non-social stimuli contained an appearance/disappearance change to a non-social aspect of a person; the presence or absence of spectacles. These are referred to as spectacles changes (see examples in Figure 3.3). Filler stimuli were also included, containing changes to random objects in a scene, some of which were associated with people (e.g. jewellery) and others not (e.g. furniture). All filler stimuli contained at least one person, and efforts were made to select stimuli depicting people wearing spectacles to produce potential for spectacles changes. The filler stimuli did not form part of the main experimental design, but were included to prevent ceiling effects in detection of eye-gaze and spectacles changes.

The study used a mixed-design with Change-Type, eye-gaze and spectacles, as a within-subjects factor and Group, ASD and TD, as a between-subjects factor. Filler images were only analysed to provide a baseline assessment of change detection ability [see section 3.6e, page 98].

3.5c Materials

The experimental photographs used were all taken by the experimenter on a 2 mega-pixel, Sony Cybershot digital camera. Filler images were sourced from the internet. A total of 104 trials included 26 experimental trials comprising 13 eye-gaze changes and 13 spectacles changes, 38 filler change trials and 40 trials in which no change occurred. Most of these stimuli had been used previously when developing the method [see section 3.3b, page 79] though none were used in Preliminary Study 1, in which some current participants had previously taken part. Further examples of the stimuli are shown in Figure 3.3 and in Appendix 2 [see section 9, page 270] and a full set of experimental stimuli with some filler stimuli are also available in the CD of supplementary material, which accompanies this thesis.

Changes were introduced into the experimental stimuli in the following manner. First, two photographs (Image A and Image B) were taken in which the subject was asked to first look one way, then another, (or wear and then remove their spectacles), without turning their head or otherwise moving. Image A was then duplicated. The relevant eye-area from Image B was then cut out and pasted into the duplicate of Image A, using a graphics package to hide the boundaries of this pasted area. The two images used in the experiment were therefore duplicates of Image A, in one of which a change had been introduced by pasting a section from Image B. In this way, it was ensured that each image-pair featured only a single change.

Each stimulus appeared in two separate trials: once with a change falling into one of the categories outlined above (eye-gaze, spectacles or filler) and once either with a different change or as a no-change trial. So, for example, a stimulus featuring an eye-gaze change would be re-used either in a trial where there was no change, or with a change to a person's spectacles (see Figure 3.3). Six images appeared with both an eye-gaze and a spectacles change in this way. Seven more images appeared once with an eye-gaze change and once more with no change. Likewise there were seven stimuli which appeared once with a spectacles change and once with

Figure 3.3: Examples of matched eye-gaze and spectacles changes (top left), twinned eye-gaze and spectacles changes (right) and a filler change (bottom left).

no change. Among the fillers, most appeared once with a change and once without, but six filler stimuli appeared twice with two different changes.

This complex system allowed for two different types of stimulus matching. The six stimuli which appeared, on separate trials, with both a spectacles and an eye-gaze change were perfectly matched for image complexity and low-level features such as brightness and colour, because the same image was being used twice. Seven more eye gaze and seven more spectacles stimuli were individually matched for orientation, number of faces, eyes and people visible (representing 'potential for change', all $p>.35$), location of the change within the image borders (distance from left and top edge, both $p>.12$), and there were also no differences in the size of the images (all $p>.38$).

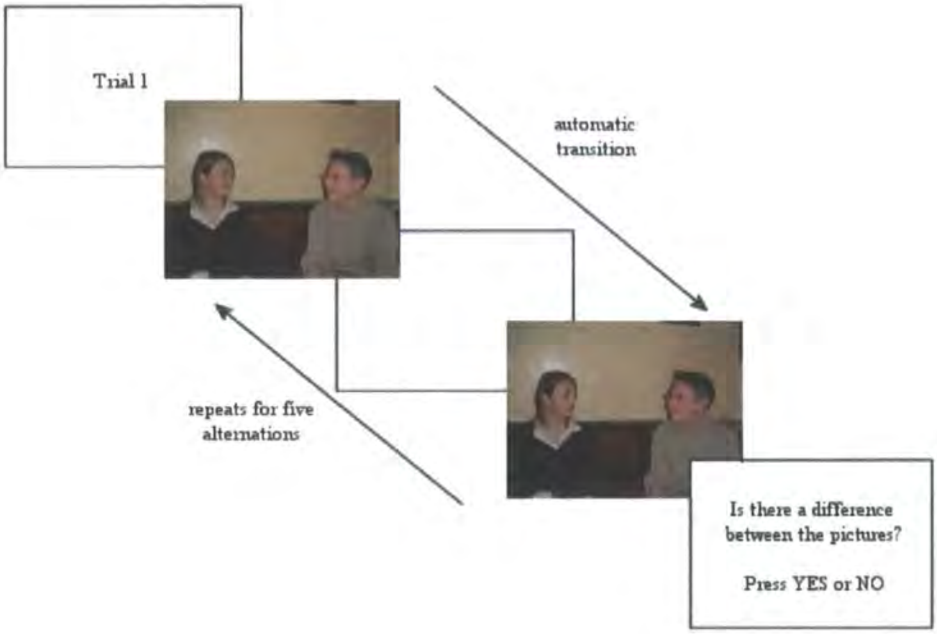
A measure of contrast level on the site of each experimental change was also taken. The section of concern was isolated (consisting of either the eyes including pupil, white and lashes or the frames of a pair of spectacles and bordering skin / hair) and measures taken of maximum and minimum luminance within that section. Contrast within a section was calculated as the difference between maximum and minimum luminance divided by the sum of maximum and minimum luminance. This measure was taken twice for each stimulus, once in the unchanged image and once in the changed image. The contrast measure revealed no significant differences between unchanged eye-gaze and spectacles stimuli ($p=.59$), though changed spectacles stimuli tended towards having higher contrast levels than eye-gaze stimuli ($p=.06$, eye-gaze mean contrast = .70, $SD=.13$; spectacles mean contrast = .80, $SD=.11$).

There was also no significant difference between eye-gaze and spectacles stimuli in the inter-quartile range of luminance (both $p>.13$), indicating that images were also well matched for the range of luminance affected by each change. The spectacles changes did affect a greater area of the scene in pixels than eye-gaze changes, $t(24) = 2.65$, $p=0.014$, due to the fact that spectacles changes involved the area of the side of the face crossed by the arm of the spectacles as well as the eye area. Finally, the spectacles changes consisted of an appearance/disappearance which could have proven easier to detect than the eye-gaze displacement changes (Cole, Kentridge, & Heywood, 2004).

3.5d Program

The stimuli were incorporated into a specially-designed program and run on a Sony Vaio laptop with a 15-inch LCD screen. This program was based on the flicker paradigm (Rensink *et al.*, 1997) and all responses were made by the participant using a button box attached to the computer and containing two buttons (labelled YES and NO). Within each trial the program ran as illustrated in Figure 3.4. Participants could make a decision about the presence or absence of a change at any point during the cycle of alternations, or wait for the response screen prompt if needed.

Figure 3.4 The sequence of events within a trial in the final experiment



Each image was seen five times for 300ms each, and the blank screen was presented nine times, for 100ms each time, making the total trial length 3900ms. At this point the response screen appeared and was present until a response was made, though participants could respond earlier, during the cycle of alternations, if they wanted to do so. The image depicted here shows an eye-gaze direction change.

Participants were given instructions, and then had the opportunity to complete five practice trials (two without a change, three with an appearance/disappearance change to an object) before beginning the experiment. None of the images in the practice set depicted any people. All participants responded correctly on at least three of the five practice trials before beginning the experiment (and did not simply press the YES button on every trial). The experimental trials were presented in two reversed orders, counter-balanced between participants. Stimuli were ordered semi-randomly with the exception that no two eye-gaze stimuli or spectacles stimuli were allowed to follow each other in succession. Also, no two trials using the same image could be within five places of each other.

3.5e Procedure

Participants were tested in a quiet room in their college or school. They were given an information sheet and were then asked to fill in a consent form. The WASI (Wechsler, 1999) was administered and then participants were introduced to the computer program by a set of instructions on the screen. The instructions were read out and explained if necessary by the investigator. Following the five practice trials was a brief reminder of the keys to use. Each participant then completed all 104 trials of the experimental task, with opportunities provided for a break every 20 trials. Participants were then debriefed and paid £5 for their participation.

3.6 Results

3.6a Preparing the Data

Timing started with the presentation of the first image and the second image within each trial pair appeared after 400ms (see Figure 3.4). In ten experimental trials (six from the ASD group and four from the TD group) the response key was pressed before this time and these trials were removed from the analysis.

Participants undertook the task in one of two reversed orders: a t-test found no main effects of order nor were there any interactions between change-type (eye-gaze versus spectacles) and order. Fourteen participants in the ASD group had previously taken part in Preliminary Study 1, which also presented eye-gaze direction changes. A comparison was made of participants within the ASD group who had and had not taken part in this earlier study, to check that previous experience of change detection and a similar set of changes (albeit twelve-months previously) did not affect performance in this new experiment. There were no differences between groups in response time or accuracy for experimental or filler changes (all $p>.28$). This indicates that previous experience with a similar paradigm and set of stimuli did not affect performance in this final experiment.

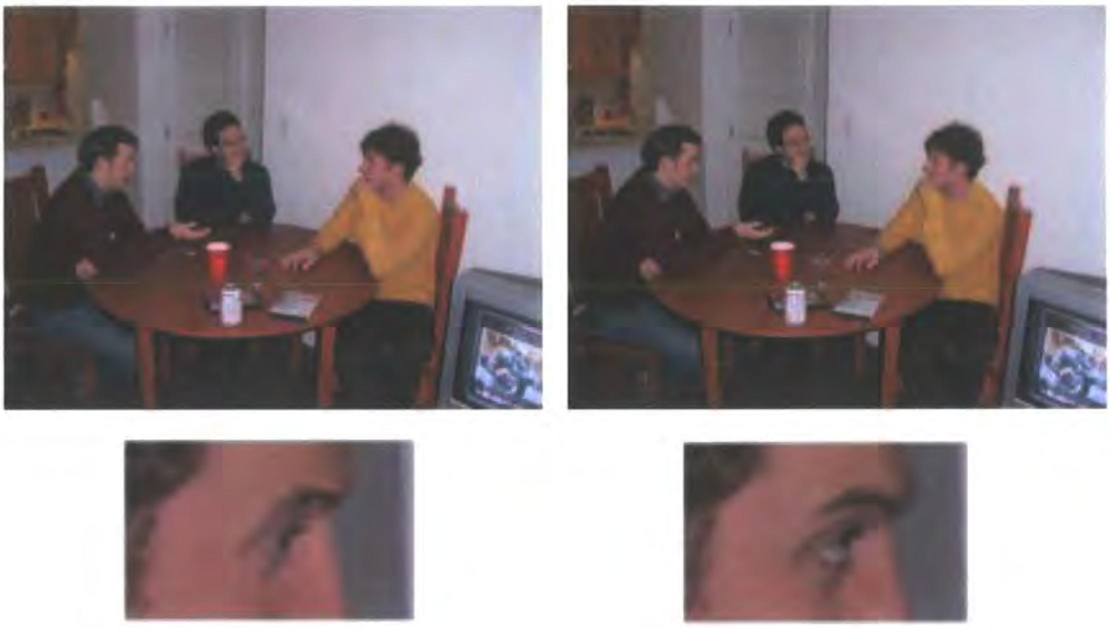
Analysis of the distribution of participant-wise responses revealed kurtosis in the distribution of accuracy scores for both eye-gaze and spectacles stimuli ($k = 6.79$, $k = 2.15$ respectively). This was because accuracy was very high for both of these change types. To eliminate kurtosis a transformation was applied in which all accuracy scores for experimental trials were squared. This transformation reduced the kurtosis to an acceptable level for both eye-gaze and spectacles stimuli: (eye-gaze trials kurtosis = .80; spectacles trials kurtosis = -.50). Otherwise, all data was normally distributed.

3.6b Item-wise analyses

Among the eye-gaze stimuli, one produced response times 2.4 standard deviations above the mean for eye-gaze images, with an accuracy score of only 18%, 2.95 standard deviations below the mean for all experimental images. This was the same stimulus which had been an outlier in Preliminary Study 2, Method 2 [see section 3.3c, page 80]. Inspection of this stimulus revealed that the eye-gaze direction change was particularly hard to see, because the individual depicted was in profile to the camera. Their pupil and iris were barely visible, and therefore the eye-gaze direction change was noticeable only from the shift in their eye-lashes and a slight increase in the amount of eye-white visible (see Figure 3.5). This change was not thought to adequately represent social information as it was not apparent how the person's eye-gaze direction had changed. Data from this stimulus were therefore removed from the analysis. The remaining item-wise data were normally distributed.

Experimental images were matched with each other in two different ways [see Figure 3.3, and section 3.5c, page 85-86]. Twinned images appeared twice, once with an eye-gaze change and once with a spectacles change. Matched images appeared once with an experimental (eye-gaze or spectacles) change and once with no change. Response times and accuracy (% correct responses) did not differ for matched versus twinned images within each experimental category (all $p > .5$). In addition, it was noted that some eye-gaze images showed changes in which eyes

Figure 3.5: An image which was excluded from all subsequent analyses, together with a close-up of the depicted eye-gaze direction change.



moved from looking up or straight-ahead to looking down. In the case where eyes were shown looking down, it was thought the change could have been interpreted as the person depicted closing his or her eyes, rather than as a change of gaze direction. However a comparison of those cases in which eyes moved up and down versus those in which the eyes moved from side to side revealed no significant differences in response time or accuracy (all $p>.6$), indicating that both types of eye-gaze direction change were detected similarly.

All subsequent response time and accuracy analyses were performed on both a participant-wise and an item-wise basis, reported as a type 2 analysis, following the convention widely used in other experimental studies (Clark, 1973). This was to account for the fact that only one type of change, eye-gaze direction or spectacles appearance/disappearance, was used in each experimental category. The presence of any effects across all items as well as across participants would strongly support any conclusions regarding the significance of social information in directing attention.

Table 3.2: Response time and accuracy scores for experimental trials for each group.

		ASD		TD	
		Mean	SD	Mean	SD
Response time (ms)	eye-gaze	3277.84	1115.96	2776.73	1288.64
	spectacles	3449.79	1047.09	3163.91	1069.67
Accuracy (% correct)	eye-gaze	81.19	19.98	90.72	14.61
	spectacles	69.66	19.11	79.06	14.55

3.6c Group Comparison

Correlations of full-scale, verbal and performance IQ with response time and percentage accuracy for eye-gaze direction changes and spectacles changes did not exceed the cut-off of .4 required for inclusion of a covariate in subsequent analyses (all r<.25). In addition, groups in this study were well matched on IQ and other descriptive measures. Therefore no IQ measures were included in the subsequent analysis of main and group effects [see section 3.2c, page 76].

A mixed ANOVA was performed on accuracy data (% correct responses, squared) comparing Change-Type (eye-gaze vs. spectacles) and Group (ASD vs.TD) as within and between subjects factors respectively. A main effect of Change-Type was found, F1 (1, 70) = 33.87, p<.001, reflecting reduced accuracy to spectacles compared with eye-gaze images (see Table 3.2). This effect was replicated in the item-wise analysis, F2 (1,23) = 4.62, p=.042.

In addition there was a main effect of Group in both analyses, F1 (1, 70) = 9.48, p=.003, F2 (1,23) = 26.78, p<.001, reflecting reduced accuracy overall for the ASD group compared to the TD group (see Table 3.2). There was no interaction between Group and Change Type in either analysis.

A mixed ANOVA was performed on response times to experimental trials comparing Change-Type (eye-gaze vs. spectacles) and Group (ASD vs. TD) as within and between subjects factors respectively. A main effect of Change-Type was found, F1 (1, 69) = 15.75, p<.001, reflecting reduced response times to eye-gaze over spectacles images (see Table 3.2) across both groups. This was not replicated in the item-wise analysis (p=.21), indicating that the image-effect held across participants but not across all exemplars. In the item-wise analysis a main effect of Group was found, $F2\ (1,23) = 49.05$, $p<.001$, indicating slower response times in the ASD group, though this was not replicated in the participant-wise analysis (p=.13). No Group by Change-Type interaction was found in either analysis, indicating that both participant groups were responding at a similar relative rate to the difference types of images.

In addition, each participant's response times to only those trials where a correct response was given were analysed, on a participant-wise basis. A mixed ANOVA was performed on this score, comparing Change-Type (eye-gaze vs. spectacles) and Group (ASD vs. TD). No significant Group or Change-Type effects were found.

3.6d Expectation and Social Information Advantages

The task was constructed such that there were two ways in which a participant could do well on experimental trials. First, they could use their expectation of certain types of change, having noticed that spectacles and eye-gaze changes appeared often, to detect all of these changes quickly and accurately. Second, a personal bias to attend to social information would aid detection of eye-gaze, but not spectacles, changes. To investigate the use of these two strategies, two difference scores were constructed.

The first difference score was calculated as baseline response time (to change-present filler images) minus response time to spectacles images. This indicates the advantage to be gained from using expectation of certain types of change to succeed at the task, which will be termed the expectation-advantage. The second was calculated as response time to spectacles images minus response time to eye-gaze images. This indicates the advantage to be gained from attending to social information specifically, and will be termed the social-advantage. Similar difference scores for accuracy (percentage correct) were calculated by subtracting baseline accuracy from spectacles accuracy and spectacles accuracy from eye-gaze accuracy. For all variables, a positive value indicates an advantage of expectation or social information, and a negative score indicates the opposite pattern.

Table 3.3: Expectation-advantage and social-advantage scores for each group

Difference scores		ASD		TD	
		Mean	SD	Mean	SD
Expectation advantage	Response time (ms)	253	450	300	463
	Accuracy (% correct)	35.4	20.0	34.1	19.3
Social advantage	Response time (ms)	172	596	387	600
	Accuracy (% correct)	11.5	20.4	11.7	16.8

Student's t-tests revealed no significant differences between groups on the difference scores for response time or for accuracy (all $p>.13$). Both groups showed an advantage for using their expectations, and an advantage for using social information to complete the task, as depicted in Table 3.3.

The variability in these difference scores was very great and so a regression analysis was carried out to discover what underlying characteristics underpinned these advantages. However, none of group membership, gender, age, full-scale IQ, performance IQ or verbal IQ were significant predictors of either difference score.

An inspection of individuals revealed that, for the expectation-advantage, fourteen participants with ASD and seven TD participants had a negative score, showing no advantage in response time. Of these, only four participants (two from each group) had a negative score of greater absolute value than their own group mean, an indicator of not just an absence of the usual advantage but a bias in the opposite direction. These same four participants also showed no expectation-advantage in accuracy, but none of these individuals had a negative accuracy score of greater absolute value than their group mean. In sum, the expectation-advantage, while variable, was relatively consistent across individuals from both groups. Some showed no advantage of using their expectations to detect changes, but no-one showed a consistent advantage in the opposite direction, detecting filler changes more accurately and faster than changes to spectacles. The distribution of expectation-advantages across individual participants are illustrated in Figure 3.6 [1].

The distribution of social advantages across participants are illustrated in Figure 3.7. The social advantage was not seen in twelve ASD and eight TD participants' response time scores. Of these, ten ASD and three TD participants had a negative score of greater absolute value than their group mean. For accuracy, twelve ASD and seven TD participants' scores showed no social advantage and these were largely the same participants who showed no advantage in response time. Only four ASD and two TD participants had an advantage for spectacles over eye-gaze changes, showing negative accuracy scores of greater absolute value than their group mean. Therefore the social advantage was still largely consistent across participants in both groups, but a few showed no advantage and a small minority showed the opposite pattern.

[1] Figures 3.6 and 3.7 show accuracy scores multiplied by ten, to facilitate their depiction on the same scale as response time scores. Z-scores could not be used as this transformation prevents identification of those individuals who do not show a rule advantage and of those who show the opposite pattern to the norm.

Figure 3.6a: Expectation-advantage scores (response time and accuracy) for individuals in the ASD group.

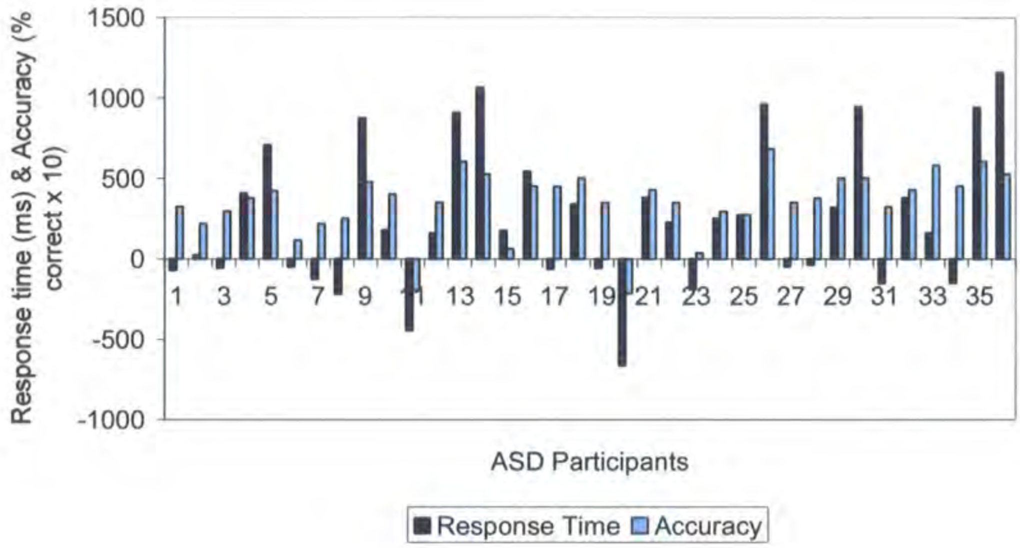


Figure 3.6b: Expectation-advantage scores (response time and accuracy) for individuals in the TD group.

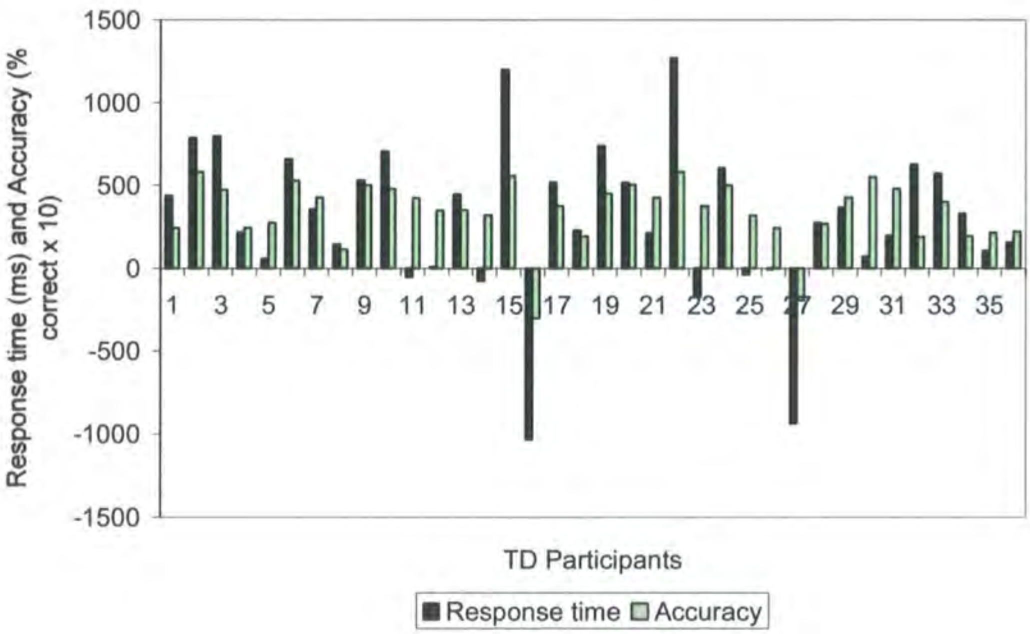


Figure 3.7a: Social advantage scores (response time and accuracy) for individuals in the ASD group.

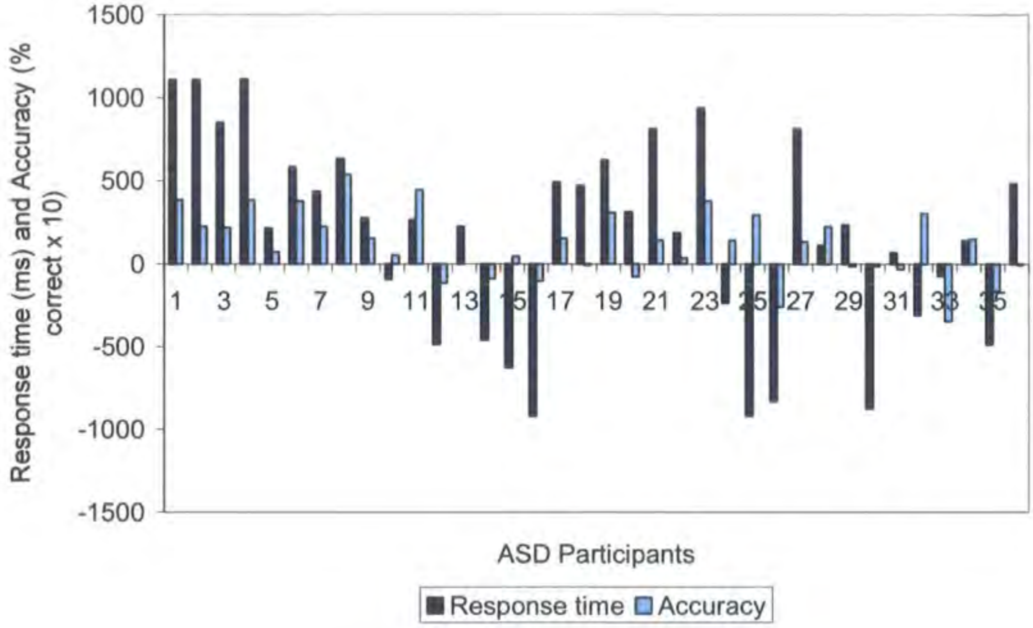
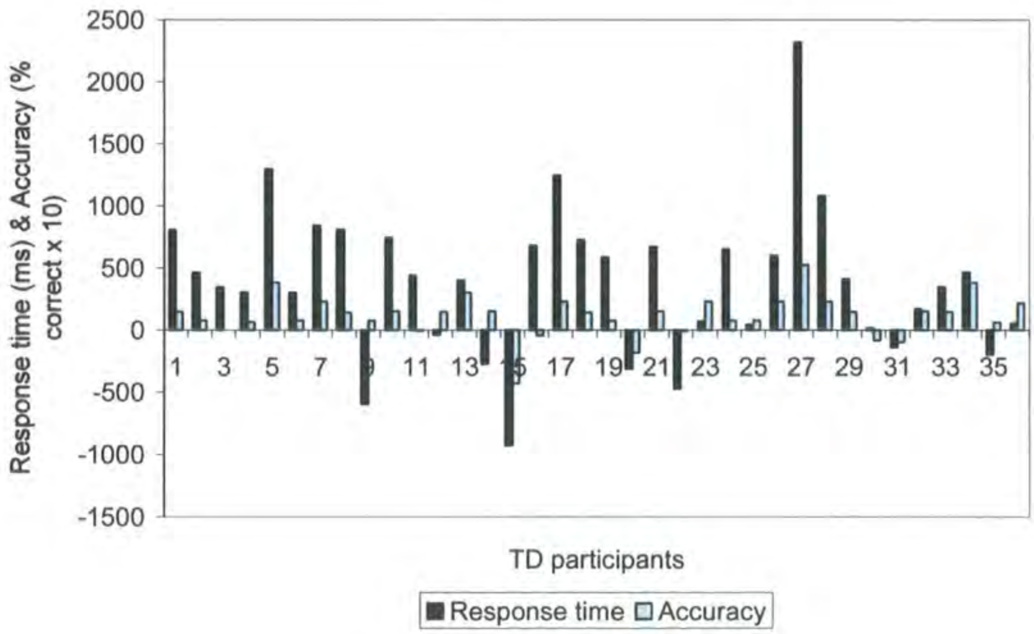


Figure 3.7b: Social advantage scores (response time and accuracy) for individuals in the TD group.



3.6e Baseline accuracy

The response time data indicate that both groups responded similarly to the task, showing faster change detection for changes to eye-gaze than changes to spectacles. However, the accuracy data, while supporting this conclusion, in addition reveals reduced accuracy across all experimental trials for the autistic group. A previous study did not suggest that autistic people found change blindness trials harder than a typical group when social information was not being manipulated (Fletcher-Watson *et al.*, 2006). Both eye-gaze and spectacles changes occur on the face and so it is possible that the reduced accuracy found in this study reflects reduced looking to faces overall by people with ASD. Therefore, accuracy scores for filler images were assessed.

A between-groups t-test revealed a significant difference in percentage correct responses to all non-experimental trials which featured a change (as opposed to no-change trials): $t(70) = 4.61$, $p<.001$; TD mean = 45%, SD = 10.0; ASD mean = 34%, SD = 8.6. Though four out of the 38 filler trials did feature changes to the face area, (e.g. earrings, moustache), it is unlikely that only these stimuli could create such a robust significant difference. Therefore we conclude that this difference in accuracy applies across all types of change presented. In support of this, there was also no difference in correctly identifying trials where no change occurred: $p=.312$; TD mean = 70%, SD = 6.3; ASD mean = 66%, SD = 4.9.

3.7 Discussion

3.7a Social Attention in Autism: Findings so Far

Despite findings from the free-description study previously reported in this thesis, it was predicted that individuals with ASD would be slower and less accurate in detecting changes to eye-gaze direction. This prediction was made following findings of reduced attention to eye regions in adults with autism (Klin *et al.*, 2002b), and because the free-description study result was limited by flaws in that method. Results from this new social change detection method did not support the prediction. Participants with ASD showed a change detection advantage for eye-gaze over spectacles changes in both response times and accuracy. These data therefore indicate an intact social attention bias in both groups participating in our study. This finding corresponds to studies which have shown an ability to correctly follow eye-gaze direction cues in young children with ASD (Charwarska *et al.*, 2003; Kylliainen & Hietanen, 2004; Senju *et al.*, 2004; Swettenham *et al.*, 2003)}, and studies which show normal fixation of the eye-area of another person when presented in the context of the whole face (Bar-Haim *et al.*, 2006; van der Geest *et al.*, 2001).

Our new results extend these findings by showing that attention to eye-gaze direction occurs even when it is presented naturalistically, as part of a complex visual scene. This is an important development since experiments which show social stimuli in isolation are extremely limited in their ability to inform our understanding of social attention in the real world. Such studies exclude one aspect of a basic definition of attention, which is that attention should constitute a focus on certain stimuli, *to the exclusion of others*. Our data show that attention to a social aspect of a scene was present in people with autism even when other non-social stimuli were present, and equally subject to the potential to change.

The finding also supports the results of the previously-described free-description task [see section 2.4d, page 56], which showed no group differences in the proportion of social information produced in verbal descriptions of complex scenes. One possibility suggested by that study was that the lack of group differences found were a consequence of the particular method chosen. The free-description task was a descriptive assessment only, which did not incorporate a non-social description condition for comparison and which confounded attention to both social and non-social aspects of a person. The social change detection study shows that people with ASD do have a bias to attend to specifically social aspects of a person, presented in a complex visual scene.

In the social change detection task, participants had very little time to view the stimuli – less than four seconds in total, with switches between two versions of the image occurring every 250ms. Participants also had to make a specific response to what they saw. Evidence from the expectation-based advantage measure suggests that virtually all participants successfully adopted conscious search strategies, indicating that they showed effortful engagement in the task. Therefore, the combined conclusion of these two tasks is that people with ASD attend to social information in a complex scene, both in circumstances without any cue to behaviour and when placed under greater constraint and consequent pressure.

3.7b Theoretical Consequences

The presence of an apparent social attention bias in our group with ASD has relevance for developmental theories which place social attention deficits at the root of autism (Klin *et al.*, 2003; Mundy & Neal, 2001; Schultz, 2005). Our data indicate that while social attention impairments may exist in childhood, and contribute to the development of the disorder, they may not be present in adults, and so do not explain the maintenance of social problems in autism in adolescence and adulthood. This could be related to the fact that social attentive skills vary with age, developmental level and degree of autism (Leekam & Ramsden, 2006; Mundy & Sigman, 1990; Mundy *et al.*, 1994; Ruffman, Garnham, & Rideout, 2001). It is possible that the high ability and age of the group in this study facilitated their success on this task and that such a group have overcome social difficulties which were present in their childhood. Alternatively, the milder forms of autism present in this group may be the developmental outcome of an ability to attend to and learn about social information across development, not present in those more severely affected by the disorder. Those individual participants who did not show a social advantage for detecting eye-gaze direction changes over spectacles changes may also have other social problems. Although attempts were made to secure this information, the absence of symptom profiles for our participants means that this conjecture cannot be examined.

Although a social attention bias was present in both groups, data also revealed reduced accuracy to all experimental changes for the ASD group. We considered the possibility that this reflected reduced attention and looking to faces in general, since both eye-gaze and spectacles changes occurred on the face. However group differences in accuracy to filler changes, and the lack of a difference in rate of false positives, refute this suggestion.

One possible explanation for the reduced overall accuracy in the ASD participants is that, while the task is not explicitly a measure of attention switching, the search for a change must involve moving attention from one element of the scene to another (Fletcher-Watson *et al.*, 2006). Our change detection task results could be interpreted as support for the presence of a domain-general attention shifting deficit in ASD (Courchesne, Townsend *et al.*, 1994; Landry & Bryson, 2004; Townsend *et al.*, 1996; Wainwright-Sharpe & Bryson, 1993). However, there is also evidence that continuous attention shifting, of the type presumably required in this task, is not impaired in autism (Pascualvaca *et al.*, 1998). Furthermore, it is not clear why, if this explanation were correct, differences would be seen in accuracy but not response time scores.

Another possibility is that the participants with ASD showed reduced accuracy due to a difficulty co-ordinating their visuo-motor response to the stimuli depicted. Motor integration has been suggested to be impaired in autism (Dawson & Watling, 2000; Pacherie, 1998). This explanation would correspond with the fact that a previous study showed no group differences in overall accuracy (Fletcher-Watson *et al.*, 2006). This study measured accuracy by a verbal identification of the change and so did not require participants to make an accurate button-press response. It therefore seems likely that participants with ASD in this task had less accurate responses due to a simple visuo-motor co-ordination problem with pressing the correct key.

3.7c Strengths and Limitations of the Method

This study aimed to devise a method for assessing social attention which would permit a degree of experimental control, in an assessment of spontaneous attentional processes in response to social stimuli presented in context. The study can therefore be judged in terms of what it adds to understanding of social attention in autism, but also in terms of its success as a method.

First of all, the experiment successfully revealed a social attentional bias in a group of typically-developed adults. These young adults detected the social (eye-gaze) changes more rapidly and with greater accuracy than non-social (spectacles) changes, despite their both being located on the face of a person. This reinforces the need, highlighted in the previous chapter, for a distinction to be made between attention to social and non-social aspects of people. Though both can be considered components of social attention, the two types of stimulus convey very different quantities and types of social information, and could be on different levels of a social stimulus hierarchy.

The enhanced detection of social changes also indicates that high-level information, such as social meaning, can influence the distribution of attention more than low-level visual characteristics. Spectacles changes had two potential low-level advantages over social eye-gaze changes: it has been demonstrated in other change detection studies that appearance / disappearance changes are usually detected faster and more accurately than other types of change (Cole *et al.*, 2004); and the area affected by changes to spectacles was on average larger than that affected by eye-gaze changes. This shows that the social information conveyed by the eyes attracted attention more than the low-level characteristics of the spectacles.

The main effects of image-type demonstrate that eye-gaze direction is a powerful social signal which is picked up rapidly and independently, and that this power can be measured in a change detection paradigm. A strength of this method is that it is suitable for use with young populations (e.g. Fletcher-Watson *et al.*, submitted; Shore *et al.*, 2006) and so has potential to investigate social attentional process in children with ASD. The principle of change detection can also be investigated in different sensory modalities (e.g. Gomot *et al.*, 2005; Gomot, Giard, Adrien, Barthelemy, & Bruneau, 2002) which could be of use in understanding social attention to other kinds of stimulus in autism. However, it would be difficult to use this type of task with a non-verbal population and thus it is most suited to work with relatively able participants.

The method provided an excellent opportunity to combine experimental control with ecological validity, as it permitted the use of complex, naturalistic stimuli that were nevertheless well matched on a series of relevant variables. By including carefully selected and developed non-social changes a baseline measure was created, with which to contrast the magnitude of an individual's social attentional bias. Comparing filler trials with changes to spectacles, and changes to spectacles with changes to eye-gaze direction permitted an investigation of change detection strategies and individual differences in response to the task. The inclusion of a measure of symptom severity would have enhanced this element of the analysis and in future attempts should be made to incorporate such a measure into the experimental procedure.

The comparison of filler trials with changes to spectacles was also originally intended to provide an opportunity to assess attention biases to people, as well as attention biases to specifically social aspects of people. However, the realisation following Preliminary Study 1 [see section 3.2d, page 77] that participants could use an expectation-based strategy to search for repeated changes to spectacles, meant that this comparison no longer assessed attention to non-social aspects of people. Furthermore, some of the filler changes were to aspects of people, such as their jewellery, or clothing, since these were the areas of the image suitable for making changes. Therefore, this study, while retaining a useful distinction between attention to social and non-social aspects of people, only made a real assessment of attention to social aspects of people. Once more, future studies should continue to attempt to address the way in which attentional preferences may relate to the degree of social information conveyed by different level of social stimulus.

In this assessment, the study was limited by its manipulation of only eye-gaze direction information. The difficulty of equating different types of social changes, combined with the need to keep the number of trials at a reasonable level, meant that we could not include changes to other social elements of the scene, such as gestures, posture or facial expression. Eye-gaze direction was chosen because of its significance as a source of multiple types of information about other people and the environment (Baron-Cohen & Goodhart, 1994; Baron-Cohen, Wheelwright *et al.*, 1997; Friere *et al.*, 2004; Langton, Watt, & Bruce, 2000; Reid *et al.*, 2004). It was predicted that if a null result was found for detection of changes to this highly informative social stimulus, we could conclude that groups would also not differ for detection of changes to lesser social stimuli. However it is also possible that this significance makes eye-gaze direction changes easiest for individuals with autism to detect, since they are among the most obvious of social cues. A change to a more subtle social stimulus might have still been detected quickly by the TD group, but have caused problems for the ASD participants. Moreover, while eye-gaze direction is a key social signifier, many other forms of social information are available to us in the real world, and these were not under scrutiny here.

Another requirement of the method was that it should tap subtle and spontaneous attentional processes and this goal may have been weakened by that fact that the task elicited specific attentional strategies. Participants were required to search for a change in two, rapidly alternating scenes, separated by a blank screen. This task differs from normal attention to scenes in a number of obvious ways: we are not normally called upon specifically to search for changes, and if changes occur they usually attract our attention by virtue of the movement cue they produce – a cue which is masked in a change detection paradigm. Therefore, these scenes are limited in the ecological validity they achieve.

3.7d Conclusions and Next Steps

The results of this study provide support for the importance of social information in directing typical attention. The TD group display a powerful advantage in detecting social changes to a person, presented in a complex scene, quickly and accurately. This finding argues strongly for an independent and specific ability for eye-gaze direction changes to attract attention. That this ability seems to be intact in autism is unexpected and could be related to our use of a very able, adult sample. In adulthood, people with ASD may have overcome early social attention impairments, suggesting that social attention does not play a role in maintenance of the disorders. Another possibility is that our able participants have always had a normal social attention bias, questioning those accounts which place an absence of the usual social attention preference at the root of autism.

Due to limitations in the methodology, most notably the use of a single type of social change and the presence of task constraints, this study does not complete our assessment of the nature of social attention. A future attempt to investigate social attention in ASD should aim to remove constraints on attention, while retaining experimental control and the distinction made between attention to social and non-social aspects of a person. A change detection paradigm, while useful in investigating a single type of social information, is not suitable for such an unbounded exploration. An eye-tracking methodology would provide a more detailed assessment of attention to different components of a social scene, providing precise information about the distribution of attention over time.

4. Attention to Social Information in a Preferential-Looking Task: Eye-Movements in Typical Adults

4.1 Introduction

4.1a A New Assessment of Social Attention

The goal of this thesis is to further understanding of social attention by investigating spontaneous social attentional preferences in TD people and those with ASD. This research focuses on the use of naturalistic but static stimuli, as these provide a degree of ecological validity while permitting maintenance of experimental control. Using this kind of stimulus also controls for the possibility that performance might be affected by abilities in motion perception, making inferences about social information (high-level social cognition) and the integration of information from different sensory modalities, all of which are likely to be impaired in ASD (e.g. Baron-Cohen, Wheelwright, Hill *et al.*, 2001; Iarocci & McDonald, 2006; Milne *et al.*, 2005).

An associated methodological goal of this investigation is therefore to develop new ways of assessing social attention, using static but complex visual scenes, with able, adult participants. One problem with this goal is that there is debate over how TD people distribute attention across a scene, and in particular the influence of high-level properties of the stimulus (e.g. Henderson & Hollingworth, 1999a). This section concerns itself with building on the lessons of previous studies in designing a new assessment of social attention, and using that assessment to first gain a better knowledge of TD social attention, before moving on in a subsequent chapter to make a comparison with participants with ASD.

4.1b Lessons from Previous Social Attention Methods

The first set of studies described in this thesis [see Chapter 2, page 37] developed a free-description task to investigate spontaneous attention to social scenes. This task was suitable for an initial exploratory description of spontaneous social attention, because it did not impose constraints on participants. The presentation of a series of complex scenes incorporated a range of potential social attention targets, including people's eye-gaze direction, gestures, posture, thoughts, and emotions. Limitations included the fact that the content analysis technique used to score the descriptions did not incorporate temporal information and therefore it was not possible to assess properly how social attention is distributed over time. In addition, the lack of a set of non-social control scenes meant that there was only a limited opportunity for participants to describe non-social information, and no baseline measures. Furthermore, while acknowledging the presence of a hierarchy of social information available in the scenes used, the task did not adequately distinguish between attention to social and non-social aspects of a person.

The second set of studies, presented here [see Chapter 3, page 68], developed a social change detection task to investigate spontaneous attention to eye-gaze direction. These built on the lessons of the free-description task in creating a novel comparison of attention to social and non-social elements of a person, depicted in a complex scene. The final experiment in this chapter [see section 3.4, page 82] revealed a specific detection advantage for eye-gaze direction changes, but it did not reveal group differences. This meant that both participant groups showed focused attention on social elements of the scenes, indicating the presence of an attentional preference for social information. Limitations were that the task only included eye-gaze direction instead of a full range of social attention targets and it was also highly constrained: the presence of a clear right or wrong response invoked the use of search strategies and consequently prevented an assessment of authentically spontaneous participant behaviour.

The third study proposed in this investigation of spontaneous social attention builds on the lessons of the two previous experiments reported in this thesis, to create a new method which combines their strengths while eliminating their weaknesses. The task designed is a preferential-looking paradigm, combined with recording of eye movements. The task pits two scenes against each other, in competition for attention, thus permitting an assessment of genuine attentional preference. The position of every fixation will be recorded, measuring attention to non-social elements of a person (e.g. their clothing) and social elements (e.g. their eyes and their direction of gaze). This will help to uncover what information is highest in individuals' hierarchies of social stimuli and consequently receives the most attention. The temporal nature of eye-tracking recordings meanwhile, make it possible to measure both priority for social information and persistence of social attention over time.

This task incorporates five specific elements which make it particularly suitable for achieving the goal of furthering our understanding of social attention in TD people and those with ASD. First, like both the previous tasks, it uses naturalistic, static scenes to provide a realistic environment for controlled assessment of attention. Second, like the free-description study, the task has minimal instructions and therefore provides an opportunity to assess unconstrained, spontaneous social attention. Third, again like the free-description study, the task provides a wide range of social targets for attention, of different levels of social significance. Fourth, like the social change detection task, social information is matched with non-social information to provide an opportunity to compare directly attention to social and non-social elements of the display. Fifth, the eye-tracking method provides more information than either the response times and accuracy scores of change detection or the content analysis of recorded descriptions. This task permits a detailed assessment of social attention, incorporating three key elements of interest: preference for social stimuli, priority of social attention and persistence in social attention. As with the previous two, novel tasks, in order to fully develop the method it is necessary first to explore the responses of typical adults to this kind of task. This will elucidate social attention in TD adults, and furnish us with a model for analysis of complex eye-tracking data for use in the subsequent chapter's comparison of TD and ASD groups.

4.1c Understanding Typical Scene Viewing

When viewing a natural scene or a two-dimensional depiction of such a scene, individuals make a series of saccadic eye movements to direct attention successively at different details (Henderson, 2003). The location of the fixations between saccades are thought to provide a behavioural assessment of the locus of attention (Shepherd, Findlay, & Hockey, 1986). In an early series of studies (Buswell, 1935) it was noted that in scenes containing human figures, these figures were disproportionately likely to be fixated. This finding has been replicated consistently, although the exact proportion of fixations on people is modulated by cognitive factors such as task instructions (Yarbus, 1967). It has not yet been established at what point in the viewing sequence the preference for human figures emerges. The traditional view (Henderson & Hollingworth, 1999a) suggests that very early fixations on a scene are determined by low-level visual factors, such as contrast or brightness, and are not influenced by semantic characteristics of the scene content. Prior to the direction of gaze to a specific location, some aspect of the stimulation from this location must have been analysed in peripheral vision to allow the selection processes to operate. It is well known that simple visual features, such as high-contrast borders, can be detected rapidly in peripheral vision so that, for example, they can be used to direct the first saccade in a visual search task (Findlay, 1997).

However, there is now considerable evidence suggesting that more complex visual stimuli may be processed rapidly, even in the visual periphery (e.g. Thorpe, Gegenfurter, Fabre-Thorpe, & Bülthoff, 2001). In a recent study (Kirchner, Bacon, & Thorpe, 2003; Kirchner & Thorpe, 2006) participants were presented with two images of natural scenes simultaneously, one containing a non-human animal and one not. Their task required participants to make a saccade as rapidly as possible to the scene containing an animal. Participants were not only capable of achieving around 90% accuracy in selecting the correct scene, but also produced correct responses significantly above chance when the saccade was made as little as 120ms after stimulus onset. This research indicates the capacity for attentional capture by animal stimuli, independent of lower-level visual cues. The authors conclude that "*object related visual information can be extracted extremely rapidly from complex natural scenes*" (Kirchner & Thorpe, 2006 p.1775).

In contrast to Kirchner and Thorpe's results, an earlier study (Brown, Huey *et al.*, 1997) had failed to find evidence for rapid processing of human face stimuli in peripheral vision. Participants were asked to make an eye movement to one intact face, presented among three or seven inverted or jumbled face distractors. When first given this task, no participant succeeded in generating more first saccades to the intact face than the proportion expected by chance. Improvement occurred following training, but this improvement was accompanied by a substantial delay in the initiation of the first saccade. One possible explanation of these contrasting results is that participants detected a non-human animal in the visual periphery, but not a human face, because of the difference in size of stimuli used in these two studies.

The literature on the distribution of visual attention in typical adults is therefore equivocal. The traditional view that eye-movements can only be directed by the low-level properties of items in peripheral vision is being challenged, but has not yet been refuted. It is possible that social elements of a scene can only be identified from peripheral vision when other cues such as movement or the presence of an entire body, help to direct attention. Our study aims to discover how attention to social stimuli, in particular different aspects of human figures, is distributed across a scene in people with ASD. If typical adults cannot locate people in peripheral vision then we might not expect fixation to fall on faces and bodies until relatively late in a period of scene viewing, though we would still expect to find a preference for looking at people over the full viewing period. However, if typical adults can fixate people rapidly and accurately we can specifically look for this extraordinary ability in a group with ASD. Therefore it is necessary to conduct a thorough investigation of the typical ability to fixate social elements of a scene before we could go on to investigate possible atypicalities in a population with ASD.

4.1d Aims and Predictions

In the current study[2] we used a paradigm similar to that of Kirchner and Thorpe (Kirchner & Thorpe, 2006) presenting two natural scenes, side by side, one of which contained a human figure. The first goal was to examine spontaneous looking patterns; to determine whether a complex visual object, such as a person, would capture gaze without being a search target. Of particular interest was the rapidity with which participants might direct their gaze to this complex stimulus. We aimed to discover whether the short latencies for eye-movements to an animal stimulus found in Kirchner and Thorpe's search task could be replicated for a human stimulus under free-viewing conditions. In addition, we wanted to see what aspects of a human would be selected for more or earlier attention: if participants focus more on the eyes and face region this would indicate a socially-motivated attention pattern; if they focus on the body, this would indicate interest in people, but not necessarily in their most socially informative components.

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[2] This research is shortly to be published in *Perception* as Fletcher-Watson, Findlay, Leekam, & Benson, in press.

In addition to the main goal of tracking spontaneous eye-movements as an indication of attentional preference, we also wanted to examine the effect of specific instructions on scene viewing. We chose an instruction that asked participants to identify the gender of the person depicted. This gender-discrimination instruction was chosen as providing a task goal which could be the same for every scene presented and did not require complex social knowledge. We reasoned that providing such an instruction would provide a naturalistic viewing goal, while avoiding any ad hoc strategy that might be employed if specific search instructions were used. We predict TD adults to show a preference for looking at people even without specific instructions, but this preference is expected to be enhanced by an instruction which specifically directs attention to the person depicted in the scene. When this method comes to be used with a group with ASD one might expect that differences between TD and ASD scan-paths in the free-viewing condition would be reduced when both followed the same, externally imposed goal.

We additionally took the opportunity to investigate a further question of interest. It is known that others' eye gaze and head direction form a powerful cue to direct the typical attentional system towards objects in the environment (Chance & Larsen, 1976). This 'gaze-following' process, which operates from early in human development, has also been found when typical adults and children view static images (Friesen & Kingstone, 1998; Langton, 2000; Langton *et al.*, 2006; and see Frischen *et al.*, 2007 for a review). We developed a way to test whether gaze-following would occur automatically, both in the spontaneous condition and also when participants are given instructions, even though for the instruction condition this response would not contribute to the task in hand (making a gender judgement).

By making a thorough assessment of spontaneous viewing in TD adults, and investigating their specific response to a gender-discrimination instruction, we can better understand how TD adults' attention is distributed across both social and non-social elements of complex scenes. This model will provide a platform from which to move on to investigate differences between people with and without a diagnosis of ASD in the subsequent chapter.

4.2 Method

4.2a Participants

Participants were twelve typically-developed university undergraduate and postgraduate students with normal uncorrected vision. Ages ranged from 18-22 years (mean age, 20.5 years) and five of the participants were male.

To check that participants did not have autistic symptoms, all participants completed the Autism Quotient Questionnaire (AQQ: Baron-Cohen, Wheelwright, Skinner, Martin, & Clubley, 2001), which is a self-report measure of autistic-like behaviours. All participants had scores well below the suggested cut-off for autism (suggested cut off = 32, group mean = 14.5, range = 8 - 27). While most assessments of typical scene-viewing do not include measures such as the AQQ, we wanted to create a model of typical visual attention, for comparison with that of people with ASD, and so ruling out accidental inclusion of people on the broad autistic spectrum was important. Moreover, inclusion of this measure would permit an assessment of individual differences in visual scene viewing according to quantity of autistic-like symptoms. Such measures have been useful in other research with typical populations to demonstrate a relationship between the broader autistic phenotype and experimental performance (e.g. Bayliss, di Pellegrino, & Tipper, 2005; Bayliss & Tipper, 2005).

4.2b Materials and Apparatus

Eighty colour photographs of rooms and gardens were taken, each picture either containing one person (person-present), or containing no-one (person-absent). Four location-types were used: living rooms, offices, kitchens and gardens. Each particular setting was used twice,

Figure 4.1: Sample stimuli from Sets 1 and 2, with their respective location-controls

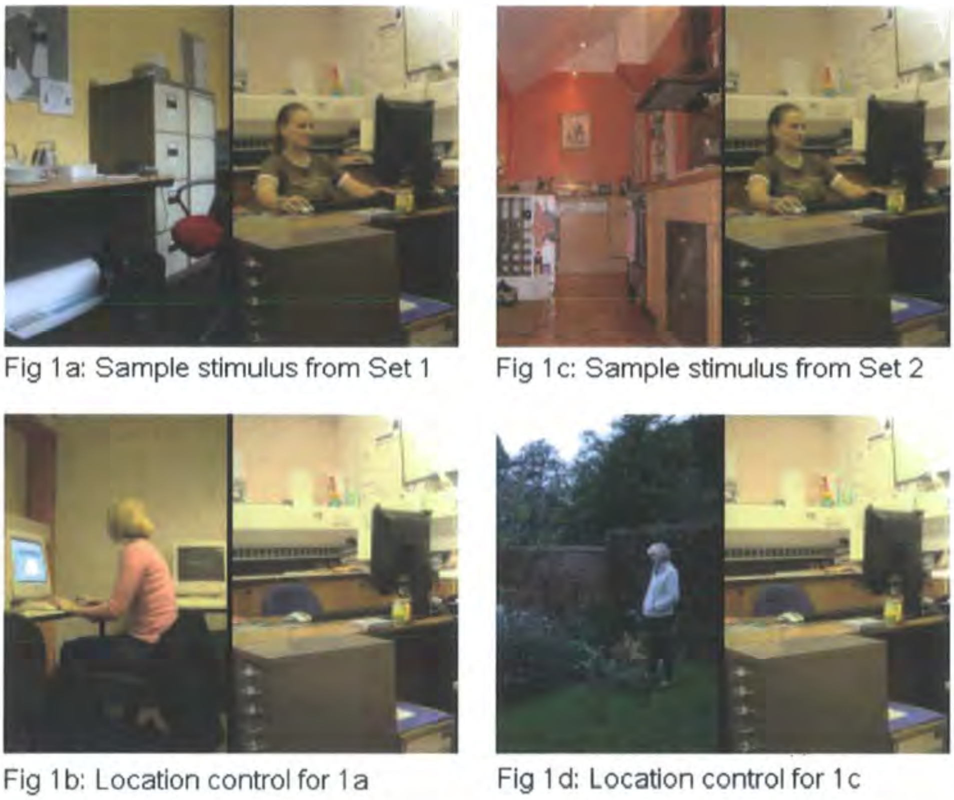


Figure 4.1a: A sample stimulus from Set 1, in which person-present scenes were matched with a scene from the same location category (e.g. offices). Figure 4.1b: A second stimulus from Set 1, in which the location of the person-present scene in Fig 4.1a is re-used as a person-absent scene, providing a control, across trials, for scene complexity. Figures 4.1c and 4.1d show the same person-present scene and its control, this time matched with randomly-selected scenes from different location types, as part of Set 2.

photographed once with and once without a person, to provide matching across the full set of stimuli for scene complexity and content (see Figure 1). Person-present scenes were composed to provide a naturalistic example of an individual in a setting. Therefore the people depicted had different body positions and were engaged in different types of activities. However all were photographed while looking at an inanimate object in the room (not looking at the camera) and had a neutral expression. The object being viewed by the person depicted was visible in the photograph in 26 out of the 40 scenes.

As can be seen in the examples in Figure 4.1, the stimuli varied in the amount of face and body visible, and in the size of these areas compared to the area of the scene taken up with non-person items. The analysis therefore includes calculations of eye-movement data relative to the size of these areas, as well as an exploration of the relationship between face-size and early fixations on the face, to specifically address the role of stimulus size in directing fixations.

From these 80 scenes, two sets of 40 stimuli were constructed, each consisting of a person-present scene paired with a person-absent scene and separated by a narrow black bar. In Set 1, a person-present scene was always paired with a person-absent scene from the same type of location (see Figure 4.1a). So a scene depicting a person in a kitchen would be paired with a scene depicting a different, empty kitchen. No scene was ever paired with a scene from exactly the same location (i.e. the same particular kitchen), since it was thought that this would create a sensation of having to 'spot the difference' between the scenes. Since the only difference was the presence of a person, this could have artificially created more fixation on the person depicted. In Set 2, person-present and person-absent scenes were randomly paired (with the exception that, again, a particular setting was never paired with itself) so that a picture of a person in a kitchen might be paired with an empty garden, living room, office or, occasionally, another kitchen (see Figure 4.1c).

These two Sets were designed to provide a complete matching of person-present and person-absent scenes. Set 1 matched scenes from the same location-type, thus providing a good match for scene content. However, in Set 1, it is possible to describe a stimulus as containing only two semantic object categories. For example, for two scenes depicting an office, one empty and one with a human figure, all items could be classed in one of two categories: "office items" and "people". The person might receive preferential attention not because they are a social stimulus, but because they are in a unique object category. Set 2 stimuli contained three object categories; for example, "kitchen items", "office items" and "people". This meant that stimuli were less well-matched but also that the person-absent scene provided a richer competitor for attention. If the person receives preferential attention in this Set we can be more certain that they do so because of their social informativeness, not simply because they are different to their surroundings.

Both sets of stimuli were in full colour and processed in a graphics package (Paint Shop Pro), such that overall luminance and contrast range were equated across the image-pair to create a stimulus whose two halves were matched for these low-level characteristics.

Each set of 40 stimuli was divided into two blocks of 20, and these blocks were matched for content of the person-present scene, using various content categories. These categories included the location of the scene (garden, office, living room, kitchen), the position of the person-present scene in the display (on the left or right of the display), the direction of gaze of the person depicted (into or away from the person-absent scene), the posture of the person depicted (sitting or standing), the fixation of the person depicted (on a visible object or off-camera), the amount of face visible, the head angle of the person depicted (level, looking up or looking down) and finally the gender of the person depicted. Because the blocks were matched according to the content of the person-present scene only, they were the same blocks for both Set 1 and Set 2. For example, the stimulus depicted in Figure 4.1a was in Set 1, Block B. The figure depicted in Figure 4.1c features the same person-present scene (but a different person-absent scene) and was in Set 2, Block B.

Participants either saw Set 1 or Set 2, each of which contained all 80 of the original scenes, and only differed in how the person-present and person-absent scenes were paired together. Within their Set, participants saw all 40 stimuli, either seeing Block A in the free-viewing condition, followed by Block B in the gender-discrimination condition or vice versa. Within each block, stimuli were presented in a random order, different for each participant. In addition, 4 extra practice stimuli, identical in format to the experimental trials, were constructed. These were shown at the beginning of each block.

Stimuli were presented on a colour monitor and filled the entire screen (1024 x 768 pixels). Eye movements from one eye were recorded using a Dual Purkinje Image eye tracker as participants viewed the stimuli binocularly from a distance of 1 metre. The stimuli therefore subtended a visual angle of approximately 22° x 15°. Participants' eye movements were monitored at a rate of 200 recordings per second. Analysis software gave an output including the path of each saccade and the location and duration of every fixation.

4.2c Procedure

Participants were given an information sheet outlining the study and gave their consent to be involved. They were introduced to the eye-tracking apparatus and a nine-point calibration was taken before each half of the experiment. Half the participants saw Set 1 (stimuli matched with another from the same location-type) and half the participants saw Set 2 (stimuli matched randomly).

The first half of the experiment was the free-viewing condition, in which no instructions were given beyond, "*You are going to see some colour pictures. Just have a look.*" Each trial consisted of a one second blank screen followed by a one second central fixation cross and then presentation of the experimental stimulus for three seconds. Participants viewed 21 stimuli, of which the first was a practice stimulus with no data recorded.

The second half of the experiment was the gender-discrimination condition, in which participants were told "*You're going to see some more pictures just like before, but this time I want you to decide on the gender of the person in the picture.*" Trials proceeded as before but with the addition of a response screen, saying "Respond Now", which appeared after the experimental stimulus had been on display for the full three seconds. This response screen was presented until the participant made a button-press response to the gender. Participants were not able to respond earlier, during presentation of the trial display. Participants viewed 23 stimuli, of which the first three were practice stimuli with no data recorded.

Participants were finally debriefed and paid £5 for their involvement.

4.3 Results

4.3a Data Preparation

Each data set was run through an automatic saccade detection programme, which detected the beginning and end of every saccade and these selections were then checked manually (for more details see Findlay, 1997). Variables were calculated for each scene separately: person-present (PP) and person-absent (PA). In addition, each stimulus presented during the experiment was then divided into five domains (see Figure 4.2) demarcating the face and body of the person in the PP scene, the background of each scene and the black central bar separating the images. The tracker output was then combined with these domains to produce a data set recording how fixations were distributed across domains.

Each trial lasted 3000ms, however due the exclusion of blinks and fixations, the mean fixation time recorded was much shorter. In addition, in some cases tracker loss meant that very little data could be recorded. Since a partial recording may not be representative, all trials in which less than 500ms of fixation time data were recorded were excluded. This resulted in the exclusion of 4% of all trials. For the remaining trials, an average of 2095ms of fixation time data were recorded per trial, with a standard deviation of 160ms.

Three major measures were used in the analysis. First, the viewing time spent in each domain was calculated, as a percentage of that trial's total viewing time. It was also possible to analyse the number of separate fixations made in each domain, but since this measure always produced the same results as the analysis of viewing time, it does not feature in this report.

Figure 4.2: A sample stimulus and the domains used for initial analysis

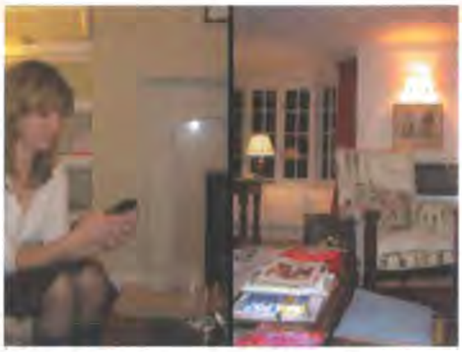


Fig 2a: Trial stimulus example

Fig 2b: Basic analysis domains

NB: This is a sample stimulus from Set 1, in which PP Scenes were matched with PA scenes from the same location-type

Second, the location of the first fixation in each trial was identified, calculated as a percentage of all first fixations within a viewing condition. This measure is crucial in providing information about whether a person presented with a new stimulus can identify an item of interest immediately, and make a saccade to that item. With each new saccade, a knowledge of the display builds up, directing gaze to areas of interest or novelty. The very first fixation can only be made based on *a priori* personal preferences and perceptual abilities. Thus the first saccade can reveal the ability of the visual system to identify items from peripheral vision and gives a direct measure of attentional bias. In addition, the time spent programming the saccade which led to this fixation was recorded (referred to hereafter as the 'first saccade latency'). This measure gives an insight not only into which domains are prioritised but also how quickly gaze is directed to them.

Finally, it was also possible to map the distribution of fixations over time, in order to reveal the order of precedence given to each domain.

Data from all measures were normally distributed: there was no evidence of skew, kurtosis or outlying stimuli or participants.

4.3b Comparing Set1 and Set 2

An initial comparison between the two stimulus sets was made, to investigate and rule out influence of the location-type of the PA scene. In Set 1, seen by 6 people, PP scenes were matched with another from the same location-type (e.g. kitchen) and in Set 2 PP scenes were matched with a randomly selected PA scene. Therefore most stimuli in Set 2 featured two different location-types.

A participant-wise analysis comparing the two Sets revealed a significant difference in the number of excluded trials (less than 500ms recorded) between the two sets for the free-viewing condition only, $t(10) = 2.47$, $p=.033$, with more trials excluded from Set 2 than Set 1. This is due to the fact that there was more tracker-loss for participants viewing Set 2, because these participants happened to be harder to track. There was no difference in the number of excluded trials in the gender-discrimination condition. Furthermore, analysis of the total amount of data (ms) recorded across all 20 trials in each condition revealed no differences (both $p>.35$). In addition, there were no differences between Sets in the mean viewing time recorded per trial nor in the mean fixation duration across both viewing conditions (both $p>.37$). Therefore, despite a difference in the number of excluded trials for free-viewing only, the amount of data collected for participants viewing each Set was very similar.

A series of t-tests revealed no significant differences between participants who saw Set 1 versus those who saw Set 2 on percentage viewing time or number of first saccades to the PP and PA scenes and their sub-domains, for each viewing condition separately (all $p>.17$). There was some evidence of differences in latencies of first saccades, though not in the gender-discrimination condition (both $p>.38$). In the free-viewing condition, differences between Sets in latencies to each scene approached significance: PA scene $p=.06$; PP scene $p=.095$. In both cases, first saccade latencies tended to be shorter for Set 1. However, because four t-tests were performed on first saccade latencies alone, a Bonferroni adjustment states that we require a p-value of .0125 or less for significance, meaning that these findings do not represent a difference of concern.

These analyses were replicated on an image-wise basis, where domain-size could be taken into account. This analysis supported the findings from the participant-wise data, in finding no effects of Set for: percentage viewing time and number of first saccades; PP and PA scenes; and free-viewing and gender-discrimination conditions.

Since these analyses reveal no differences of note between Sets, and since also the analysis is principally focused on how attention is distributed to the PP scene (which does not change between sets), all further analyses are conducted with data from both Sets combined.

Table 4.1: Viewing time in each scene; unadjusted and domain-relative scores (means with standard deviations in brackets).

	Unadjusted score				Domain-relative score			
	Percentage viewing time				Proportion viewing time			
	Free		Gender		Free		Gender	
Person-absent scene	36.9 %	(8.8)	17.2 %	(7.2)	0.72	(0.16)	0.37	(0.17)
Person-present scene	57.9 %	(10.2)	78.8 %	(9.9)	1.07	(0.27)	1.51	(0.3)

NB: In all tables, Free and Gender refer to the two viewing conditions: free-viewing and gender-discrimination. Proportional scores in the right half of each table are calculated relative to domain size [see section 4.3d, page 122]. In Table 4.1, percentages for the Person-Absent and Person-Present scenes do not sum to 100% because a small proportion of fixations were made on the central black dividing line (see Figure 4.2b).

4.3c Viewing Time: Unadjusted Scores

Initial comparisons were made between the entire PP scene and the PA scene. Table 4.1 shows how the total proportion of viewing time was distributed between these two scenes. Unadjusted scores show that in each condition, participants spent a significantly greater proportion of their time looking at the PP scene than the PA scene; free-viewing condition, $t(11) = 4.0$, $p=.002$, gender-discrimination condition, $t(11) = 12.6$, $p<.001$.

This result was very consistent between individual participants. For the free-viewing condition, only one participant did not show this bias; their fixation time was roughly equally distributed between both scenes. The remaining eleven participants all showed a difference, whereby the fixation time to the PP scene was at least seven percentage points above that to PA scenes, and five participants showed a difference of over 30 percentage points. For the gender-discrimination condition, eleven participants showed a difference of over 50 percentage points and the remaining participant showed a difference of approximately 25 points. This was not the same individual who had shown no bias in the free-viewing condition.

Table 4.2: Viewing time in sub-domains of the person-present scene: unadjusted and domain-relative scores (means with standard deviations in brackets).

Person-present scene	Unadjusted score				Domain-relative score			
	Percentage viewing time				Proportion viewing time			
	Free		Gender		Free		Gender	
Total PP scene	57.9%	(10.2)	78.8%	(9.9)	1.07	(0.27)	1.51	(0.3)
Background	27.9%	(6.3)	22.3%	(11.4)	0.59	(0.13)	0.46	(0.2)
Body	12%	(4.7)	23.2%	(7.5)	2.4	(1.1)	4.86	(1.91)
Face	18%	(6.6)	33.3%	(13.6)	72.6	(37.6)	150.47	(71.3)

Each PP scene could also be divided into domains: these were initially the Background, Body and Face domains. Table 4.2 shows how viewing time was distributed between domains within the PP scene. This table shows that participants in the free-viewing condition spent over half of their viewing time within the PP scene looking at the Person (Body or Face). They looked at the, much larger, background area a little less than half of the time within the PP scene. This pattern of preference for the Person over the Background was exaggerated in the gender-discrimination condition when over two-thirds of the time in the PP scene was spent looking at the Person (Body or Face). This increase in looking at the Person was driven by increases in viewing time in both the Body and Face domains.

4.3d Viewing time: Domain-Relative Scores

The domains varied in size between images, and in particular, face domains were always much smaller than any other domain. Therefore scores were adjusted to give domain-relative measures. Viewing times as percentages were divided by the size of the relevant domain, also expressed as a percentage of the total stimulus size. If fixations were spread randomly across the stimulus, one would expect a score close to one (e.g. 50% of fixation time / 50% of stimulus size). If fixations were being directed to a domain more than randomly predicted, this score would be greater than one, and vice versa. Tables 4.1 and 4.2 show domain-relative scores for each scene and for the domains of the PP scene.

In the free-viewing condition, the normalised viewing times to the PA scene and to the PP scene background were significantly less than 1 (both $p<.001$). In fact, there was no significant difference between domain-relative viewing time in the PA scene and the PP scene Background ($p=.12$), indicating that the difference in viewing time between these two scenes is entirely due to time spent looking at the Body and Face domains. There is also a disproportionately large normalised viewing time for fixations to the Body and particularly the Face domain (both $p<.001$). The same pattern is found for the gender-discrimination condition; all scores are significantly different from 1 (all $p<.001$), in the same direction as for free-viewing, and once more there is no significant difference between viewing time in the PA scene and the PP scene Background ($p=.11$). These results indicate that taking domain size into account reveals a very strong attentional preference for social stimuli (the Person, and especially their Face).

4.3e First Fixations

The first fixation is defined as that fixation following the first saccade made after trial-onset. This measure indicates which items received attentional priority in the scene, rather than simply which items received the greatest amount of viewing time. Data on the distribution of first fixations are shown in Tables 4.3 and 4.4.

In the free-viewing condition, significantly more first fixations fell on the PP scene than the PA scene, t (11) = 5.1, p<.001, indicating that the attentional bias found in the viewing time measure is present from the very first fixation. Once more, this bias was very consistent among participants. Only one participant showed the opposite bias, making two more first fixations in the PA than in the PP scene under free-viewing conditions. This was a different individual to those two who had shown lesser or absent PP scene biases for percentage fixation times [see section 4.3c, page 121]. Seven of the twelve participants made over three times as many first fixations in the PP as in the PA scene.

Table 4.3: First fixations in each scene; unadjusted and domain-relative scores (means with standard deviations in brackets).

	Unadjusted score				Domain-relative score			
	Percentage first fixations				Proportion first fixations			
	Free		Gender		Free		Gender	
Person-absent scene	21.7 %	(10)	10.0 %	(7.7)	0.43	(0.52)	0.24	(0.42)
Person-present scene	60.8 %	(19.6)	77.9 %	(19.1)	1.20	(0.4)	1.52	(0.39)

Table 4.4: First fixations in sub-domains of the person-present scene: unadjusted and domain-relative scores (means with standard deviations in brackets).

Person-present scene	Unadjusted score				Domain-relative score			
	Percentage first fixations				Proportion first fixations			
	Free		Gender		Free		Gender	
Total PP scene	60.8%	(19.6)	77.9%	(19.1)	1.2	(0.4)	1.52	(0.39)
Background	20.4%	(9.1)	25.5%	(11.6)	0.51	(0.73)	2.46	(0.6)
Body	25.8%	(13)	25.4%	(9.6)	5.57	(8.2)	5.71	(9.13)
Face	14.6%	(11.7)	27%	(16)	51.53	(152.23)	87.1	(153.9)

In addition, in the free-viewing condition, 26% of first fixations fell on the Body and 15% on the Face domains. When converted to domain-relative scores, the proportion of first fixations falling the Body domain is 5.57 while the Face domain score is 51.5. This indicates that the Face received a disproportionately high amount of first fixations relative to the space it took up in the display. The number of first fixations falling on the Body was significantly negatively correlated with the distance of the Body from the central fixation cross, Pearson's $r = -0.479$, $p<.001$, 1-tailed. Likewise, there was a significant negative correlation between the number of first fixations on the Face for each stimulus, and the distance from the central fixation cross to the centre of the face, Pearson's $r = -0.290$, $p=.007$, 1-tailed.

In the gender-discrimination condition there was again a significant difference between first fixations on the PP and PA scenes, $t(11) = 10.1$, $p<.001$. Every participant showed a PP bias in their distribution of first fixations.

In this condition, 25% of first fixations fall on the Body and 26% fall on the Face. As domain-relative scores these proportions are 5.7 for the Body domain and 87.1 for the Face domain. Again there was a significant correlation between the number of first fixations on the Body and distance of the Body from the fixation cross, Pearson's $r = -0.279$, $p = .009$, 1-tailed, and between first fixations on the Face and distance of the Face from fixation cross Pearson's $r = -0.210$, $p=.037$, 1-tailed.

As in the analysis of percentage viewing times, these domain relative scores indicate a powerful attentional preference for social information. However the relationship between first fixations and distance from initial site of foveation demonstrates that even these strong attentional preferences are subject to the limitations of the perceptual system.

4.3f First Saccade Latencies

Brown and colleagues (Brown, Huey *et al.*, 1997) found that improved discrimination of faces in peripheral vision occurred when the first saccade was delayed. Thus it may be that first fixations on the Face and Body are only achieved by extending the programming time; i.e. increasing the latency of the saccade before the first fixation. To investigate this question, all first fixations were allotted to one of a series of 50ms latency 'bins'. We could then examine the distribution of possible locations of the first fixation within each latency bin. Figure 4.3 illustrates the distribution of first fixations on the PP scene and PA scene, within each bin under free-viewing (4.3a) and gender-discrimination (4.3b) conditions. This clearly illustrates that the preference for first fixations to go into the PP scene is manifest for saccades with short latencies.

Overall, there was no significant difference in mean first saccade latencies between the two conditions, ($p=.27$, free-viewing mean = 276ms, gender-discrimination mean = 229ms). In both conditions the majority of first saccades had latencies between 100ms and 249ms; free-viewing 56% and gender-discrimination 73%. Across both viewing conditions, the majority of first saccades to each PP scene domain fell into the same range of latencies; PP scene background 73%, body 75%, face 80%. This indicates that no PP scene domain entailed longer first saccade latencies than any other. The PA scene had only 41% of saccades in the 100ms-249ms range. As shown in Figure 4.3, the PA scene entailed slightly longer first saccade latencies than the PP scene, in the free-viewing condition.

A small number of cases were found where the first saccades had latencies of less than 100ms, and these participants appear equally likely to make their first fixation in either scene. These saccades may be assumed to be anticipatory (Wenban-Smith & Findlay, 1991).

In the free-viewing condition, the bias to fixate on the PP scene appears in the 100-149ms bin to which six participants contributed a total of 9 fixations. Here, five out of six participants show a bias for the PP scene (in fact four of them make every first fixation in the PP scene) with a mean latency of 142ms. The one participant who does not show this bias made only one first fixation in this bin which was to the PA scene. Ten participants contributed to the 150ms latency bin, which contains a total of 56 fixations, and all showed a bias for the PP scene: this pattern persists for the next three latency bins, to which all participants contribute.

Figure 4.3a: First fixations in the free-viewing condition, by latency bin.

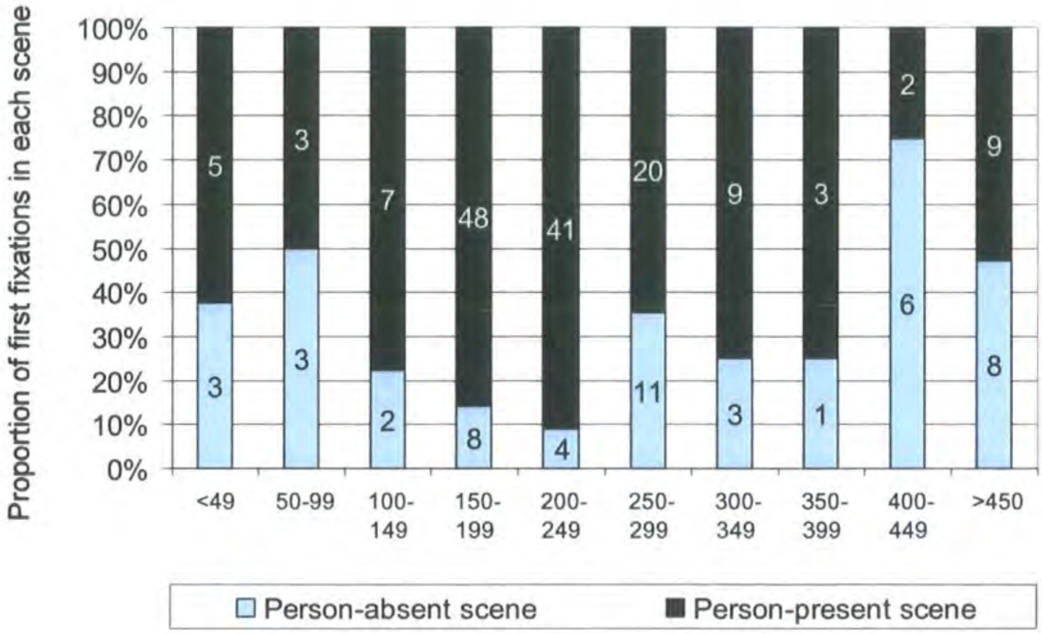
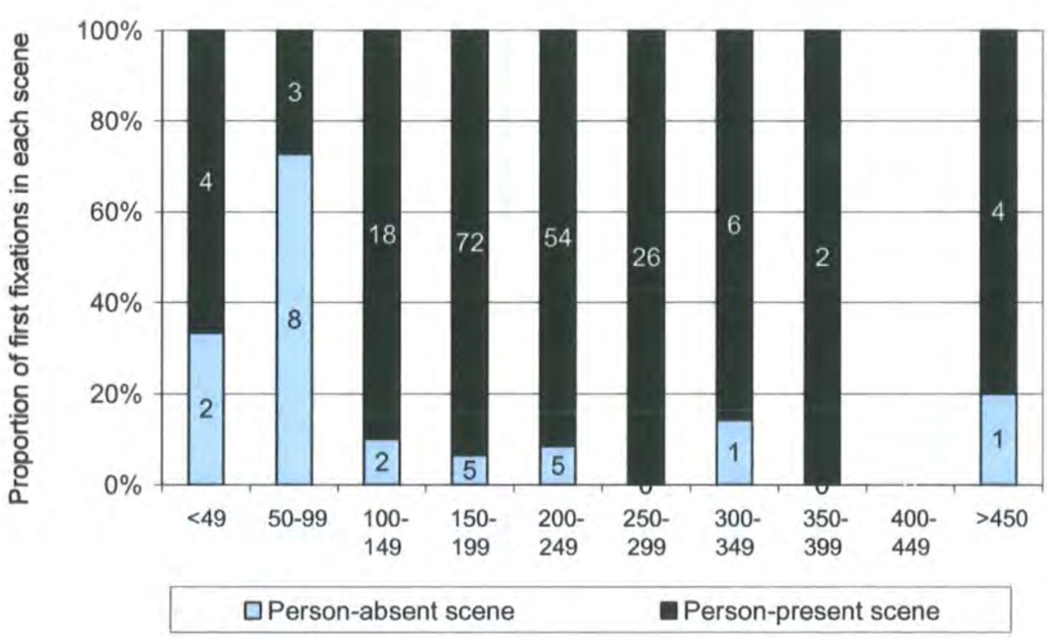


Figure 4.3b: First fixations in the gender-discrimination condition, by latency bin.



NB: The numbers on the bars indicate the number of fixations which contribute to each bin.

In the free-viewing condition, the highest latency bins indicate a return to near-random distribution of first fixations between the two scenes. This may be because longer latencies are produced when there is unusually large conflict between the two scenes in terms of the interest they present. This occurs in a minority of cases (only 13% of first fixations occurred after saccade latencies greater than 400ms).

The gender-discrimination data reveal a similar pattern (see Figure 4.3b) in terms of the near random distribution of fixations with the shortest saccade latencies, followed by a very strong preference for fixating the PP scene from the 100-149ms latency bin upwards. In this condition, three out of four participants showed the PP bias in the 100-149ms bin, with a mean latency of 136ms. Again, the one participant who did not show this bias made only one fixation in this bin. In the 150-199ms bin, to which 11 participants contributed a total of 77 fixations, all participants showed a PP scene bias.

In contrast to the free-viewing data, the gender-discrimination data does not indicate a return to evenly distributed fixations at the longest latencies. Presumably the task requirement of locating the scene character overrode any conflicting interest coming from the PA scene.

4.3g Comparisons Between Conditions

Comparing the proportion of viewing time per domain between the two conditions (free-viewing and gender-discrimination) reveals a strong effect of task requirement on looking behaviour. The proportion of viewing time spent in the PP scene and also in the Body and Face domains is significantly greater under the gender-discrimination condition: PP scene, $t\ (11) = 6.3$, $p<.001$; Body, $t\ (11) = 5.2$, $p<.001$; Face, $t\ (11) = 4.4$, $p<.001$. Likewise, the proportion of viewing time spent in the PA scene is less in the gender-discrimination condition; $t\ (11) = 7.0$, $p<.001$.

A similar pattern is revealed by the distribution of first fixations which shows a significantly larger number in the gender-discrimination condition for the PP scene and Face domain: PP

Figure 4.4: Viewing-cone and Object domains

Fig 4a: Viewing cone domain

Fig 4b: Object domain

scene, t(11) = 4.3, p=.001; Face, t(11) = 3.3, p=.007, though no difference for the Body domain. Again, there are also fewer first fixations in the PA scene in the gender-discrimination condition; t(11) = 6.2 , p<.001.

4.3h Looking Where Others Look

Two new domains were also developed, depicted in Figure 4.4, in order to investigate the secondary question of whether participants looked at the areas looked at by the person represented in the scene. The first 'Viewing Cone' domain represented the area that could conceivably be being viewed by the scene character, as defined by a 30° cone extending from the centre of the person's eye area. This cone included any objects falling within the cone, but not any body-parts (as shown in Figure 4.4). The 30° size was selected because it has been suggested that this is the area which can be viewed by an individual by moving their eyes but not their head (Sanders, 1963).

In addition, for the subset of scenes (26/40) in which the object viewed by the person was visible in the displayed scene, this Object was analysed separately with its own domain, though it always fell almost entirely within the Viewing Cone.

Domain relative fixation time scores were calculated as before: a score of one indicates randomly allocated viewing, less than one indicates a paucity of viewing of this area and scores greater than one indicate an excess of viewing in this area. The data show that participants directed their fixation to the Object being fixated by the scene character more than would be predicted by a random viewing pattern in the free-viewing condition, $t(11) = 2.2$, $p=.05$, and this marginally significant finding is confirmed by a large effect size, $d = .64$. This significant finding was not replicated in the gender-discrimination condition ($p=.08$), though the effect size here was not small, $d=.55$. This suggests that the Object domain was subject enhanced processing in both conditions, but particularly in the free-viewing condition.

The Viewing Cone did not receive a significantly inflated amount of fixation in either condition (free-viewing proportional score = 1.21, gender-discrimination proportional score = 1.5). The slightly enhanced scores can probably be attributed to time spent looking at the Object, which was wholly or mostly encompassed by the Viewing Cone.

4.3i Distribution of Fixations Over Time

The pattern of looking over time was examined by plotting the percentage of first, second, third, fourth etc. fixations made within each domain in each condition (see Figure 4.5). The graphs illustrate that first fixations are as likely to be made in the Body as in the Face domain. Attention to the Face increases over the first two fixations, then decreases and becomes stable from the fourth fixation onwards in both conditions. This indicates that participants may be using the human figure as a whole to direct their first saccade. They can then use the location of their first fixation to direct a second saccade to the most interesting part of the person, usually the Face. Attention to the Body diminishes following the first fixation in the free-viewing condition. This trend is not visible in the gender-discrimination condition indicating that information from the Body was being used to identify gender.

Figure 4.5a: The distribution of fixations in the PP scene, free-viewing condition

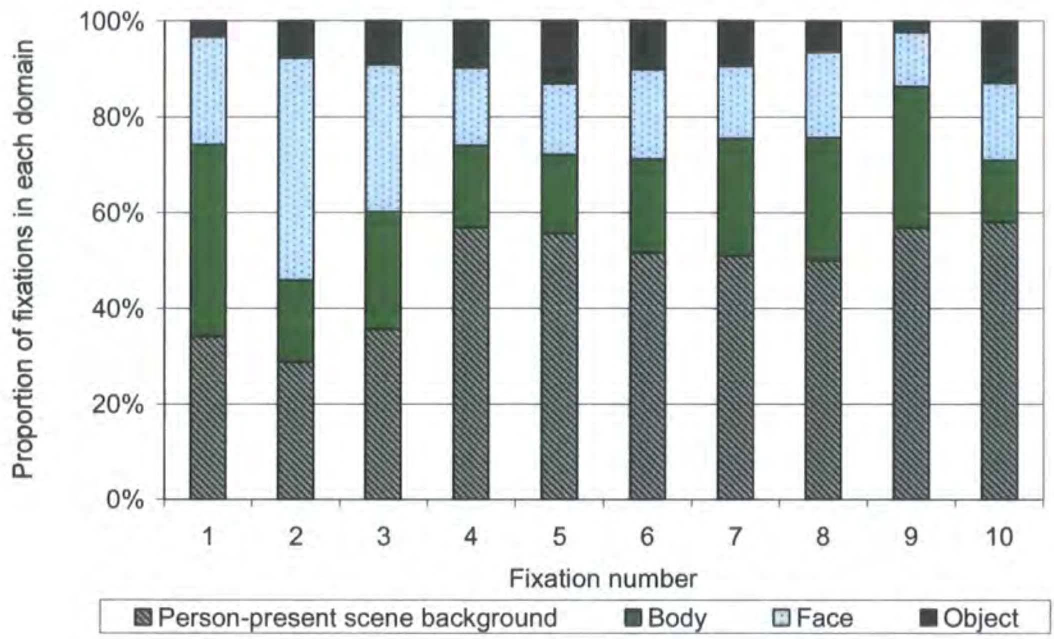
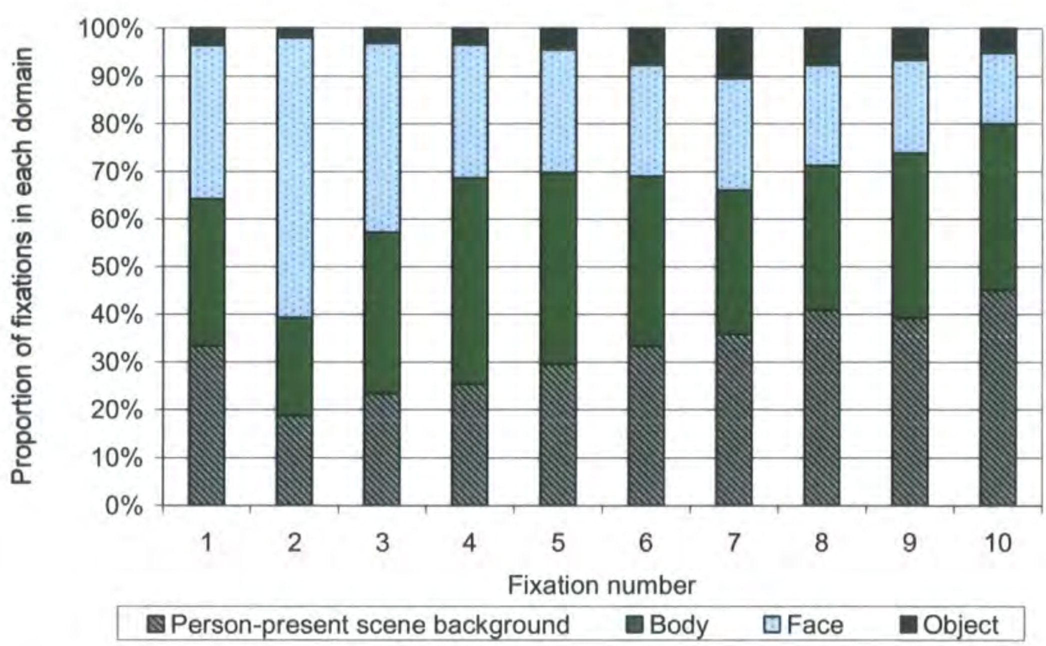


Figure 4.5b: The distribution of fixations in the PP scene, gender-discrimination condition



Attention to the Object fixated by the person in the scene does not appear until slightly later and increases as looking at the Face domain decreases. This indicates that gaze-following may be occurring, whereby the participant looks first to the Face of the person depicted in the scene and then to the object being fixated by that person.

4.3j Correlations with Autism Quotient Score

The participants taking part in this study were asked to complete an Autism Quotient Questionnaire, a self-report measure of autistic-like behaviours (Baron-Cohen, Wheelwright, Skinner *et al.*, 2001). This was introduced for two reasons: first, to make sure that data collected from this sample represented a model of TD adult attention and was not influenced by autistic-like performance. Second, to permit an analysis of whether degree of autistic-like behaviours related to social attentiveness in this task. The AQQ has been used before in this way, to examine differences in behaviour across the broad autistic spectrum.

Links between autism-like behaviours and social attention in our task were measured by a series of correlations of AQ score (a higher score indicating more autistic behaviours) and viewing time/percentage of first fixations. For each of the two scenes and viewing conditions, there were no significant correlations between AQ and either viewing time or percentage of first fixations. Even when viewing time and first fixations to the Face, the domain conveying the most social information, were correlated with AQ, no significant relationships were found.

4.4 Discussion

4.4a Findings and Theoretical Impact

This study clearly shows a strong bias in typically-developed adults towards attending to a scene containing a person and particularly towards that person themselves. Even when no task instructions are given, this bias leads people to spend well over half their time looking at the person-present scene and when looking at this scene, to spend most of their time looking at the person. In fact, there are no differences in looking to the background of the person-present scene and to the person-absent scene, when domain size is taken into account. This indicates that the difference between time looking at the person-absent and person-present scene is entirely due to the time spent looking at the person.

When looking at the person, the preference is to look more at the face than the body, as a percentage of the total viewing time. Since the face can be considered the most social component of a person, this indicates that attention to the person is largely focused on their social aspects, though the body does still receive a proportion of fixations. Future studies should also specifically investigate fixation on the eye-region, which can be considered the most socially-informative region of a face. The large number of fixations on the face region in this study indicates that inclusion of such a small domain might nevertheless yield enough data for analysis.

The bias to look at social information affects the landing position of the very first saccade, which can occur as early as 100 ms after the scene presentation. This finding replicates recent work (Herschler & Hochstein, 2005; Herschler & Hochstein, 2006; Kirchner & Thorpe, 2006; Rousselet *et al.*, 2003; Smilek, Dixon, & Merikle, 2006) that has demonstrated rapid attentional capture by high-level stimuli. This process is clearly very effective in directing attention, although some limits to its power are shown by the negative correlation between proportion of person-directed first fixations and the distance of the person from the initial site of foveation. Nevertheless, participants can identify people from peripheral vision and use that identification to accurately and rapidly fixate on that person. Though participants often made a first fixation directly to the face, a larger number of first fixations fell on the body, suggesting that the preference for the most social aspects of a person is not in place from the very first fixation. This is likely to be because the body is easier to identify in peripheral vision than the face. Therefore, although fixations are unlikely to be driven by low-level properties - since the bias to fixate the PP scene is consistent across stimuli which vary greatly - nevertheless low-level constraints, such as size of the stimulus or distance from the fovea, can exert an influence on the placement of the first fixation.

It is crucial to note that in this study, face-stimuli were presented as part of a whole person, in a real-world scene. It is plausible that one should find it easier to detect a face when its whereabouts is indicated by other cues, such as the presence of a body. Although the face is a socially powerful stimulus, it is also relatively small and thus covers a smaller angle in visual periphery than the body. In this task, first fixations were more likely to be directed to the body than face in the free-viewing condition. Figure 4.5 [see page 131] shows that the likelihood of fixating the face increases, in both conditions, between fixations one and two. Domain relative scores emphasise the importance of the face area, illustrating a highly non-random distribution of fixations with a powerful focus on fixating the face. Therefore, although the pattern of fixations may have the aim of bringing gaze to the face, this often occurs in stages and our data suggest that it is the entire human figure, rather than the face, that is subject to a social attention bias. This interpretation could explain the failure of Brown and colleagues to find any advantage for isolated faces in a visual search task (Brown, Huey *et al.*, 1997).

When a task requirement was introduced, namely to identify the gender of the person in the scene, looking to the person predictably rose, although the differences were only marked after about the third fixation. Fixations were still rapidly and accurately directed to the person-present scene, and to face and body domains specifically. As in the free-viewing condition, 40% of the time looking at the person was spent on their body. However, in the gender-discrimination condition, fixation on the body was spread more consistently over time. The gender-discrimination condition was originally included to explicitly test the influence of an externally imposed task goal on viewing patterns. However it also indicates that not only may the body attract initial attention in a spontaneous viewing situation but that it contributes significantly to making a decision about a person's gender.

Finally, the data provide evidence of gaze-following behaviour in typical adults' viewing patterns, further emphasising the social influence on fixations in scene viewing. Participants fixated the object being looked at by the scene character more than would be randomly-predicted, though this increased viewing of the area fixated by the scene character did not extend to the whole viewing cone. The distribution of fixations over time shows that looking to the object domain seemed to occur following fixation on the face, indicating that looking at a static scene can incorporate a genuine gaze-following pattern. The evidence reveals a certain amount of control over this process, since looking to the object domain was less enhanced in the gender-discrimination task (when gaze-following was irrelevant to the task in hand). Conversely, the fact that gaze-following occurred while observing a static photo stimulus at all indicates a certain amount of automaticity, since participants could not have had a successful interaction with the person depicted. This findings corresponds to evidence of reflexive following of non-predictive eye-gaze direction cues (Friesen & Kingstone, 1998). These data also illustrate the precision of our gaze-following system in that participants did not increase looking to the entire visual field of the scene character (the viewing cone) but only to the specific item being looked at by the character.

4.4b Using the Task with an ASD Group

The results from this study suggest that this task provides an excellent platform from which to investigate social attentional processes in adults with ASD. The eye-tracking data provides an assessment of attentional preference in comparing viewing of the two scenes, of attentional priority in measuring first fixation location and latency, and of attention persistence in mapping the distribution of fixations over time. The study can also compare how attention is distributed to different components of a social stimulus, such as the body and face of a person, thus accessing the concept of a hierarchy of socially informative stimuli. For these reasons, and because of the rich data source provided by eye-tracking, this study represents an advance eon previous attempts to investigate social attention in ASD, presented in this thesis

The differences between our results and other studies in the visual attention literature indicate that low-level stimulus characteristics may play a role in the distribution of social attention in typical adults. For example, visual search paradigms have shown that it may be difficult to identify faces from peripheral vision (Brown, Huey *et al.*, 1997), whereas the faces presented here, in a naturalistic context, with accompanying body, were identified frequently and rapidly. Therefore these findings re-emphasise the importance of augmenting current studies of social attention to ASD which have often used either isolated images of faces (e.g. Bar-Haim *et al.*, 2006) or moving, multi-sensory stimuli (e.g. Klin *et al.*, 2002b) with studies which exploit the suitability of photographs to provide both realistic context and experimental control.

The preferential-looking task tested here, also creates an opportunity to specifically investigate other relevant factors in social attention. First, the role of task instructions can be explicitly addressed by comparing scan-paths in a condition without specific instructions with a condition in which an external goal is imposed by the experimenter. The choice of goal, gender-discrimination, also means that the second condition provides an opportunity to reveal what elements of a scene or a person are used to identify their gender. We know that people can easily identify gender from the face alone (Bruce & Young, 1986) and that this ability is impaired in autism (Strauss *et al.*, 2007). We also know that body and face cues both play a part in more complex skills such as the identification of emotion (Meeran, van Heijensbergen, & de Gelder, 2005). This study suggests that the body may also play a part in identifying gender, when that information is available, for typical adults, and it is possible that this will not be the case for people with ASD.

Finally, the stimuli permit an investigation of the presence of gaze-following behaviours in response to static images. While people with ASD have a documented difficulty with, or reluctance to engage in, shared attention in real-life scenarios (Bruinsma *et al.*, 2004; Mundy, 2003), it is possible that this difficulty would be removed by the use of a static stimulus. This would correspond with a demonstrable ability to compute eye-gaze direction that has been shown in children with ASD (Leekam *et al.*, 1997; Leekam *et al.*, 1998) even though they do not follow gaze spontaneously (Leekam *et al.*, 2000). Alternatively, perhaps people with ASD, who may see little value in sharing attention with others, would be even less likely to follow the gaze of another when that person is merely depicted in a picture and hence following their gaze can have no useful result.

4.4c Conclusions

These results strongly suggest that human figures and their faces are subject to special visual attention when presented as part of a scene. Typical adults are often able to direct their gaze to a scene containing a person, and frequently right to their face, very rapidly and they do so even when no task constraints are in place. This bias towards fixating the social scene and specifically the person therein, argues strongly for a visual system that is tuned to high level properties. Our participants showed priority to attend to social information, in preference to a non-social control stimulus, and their attentional bias persisted over time. It is now possible, using the same paradigm, to investigate the presence, or absence, of such behaviour in a group with ASD. In addition, the task permits an investigation of some additional methodological and social issues, including the effect of task instructions, the identification of gender and the presence or otherwise of shared attention.

5. Attention to Social Information in a Preferential-Looking Task: Comparing Typical and Autistic Groups

5.1 Introduction

5.1a Preferential-Looking as a Measure of Social Attention

The previous study piloted a preferential-looking task combined with eye-tracking technology, to investigate how typically-developed (TD) adults distribute their attention across social and non-social stimuli. The study made four major conclusions. First, that TD adults show a strong attentional preference for social scenes, and are capable of identifying human figures and even faces in peripheral vision and moving their eyes directly to that spot, with no delay in eye-movement processing time. Second, that this attentional preference to look at people from the first fixation continues throughout viewing of the scene, with a strong bias across time to look at the most social component of a person, their face. Third, that looking at people is increased by the introduction of a task requirement to identify the gender of the person depicted. And finally, that over time there is evidence of a kind of gaze-following process, in which the viewer looks at the person depicted and subsequently the area being fixated by that person.

All of these findings are united under the heading of social attention behaviours, a term which covers both a focus on social elements of the environment (social attention) and also elaborate behaviours such as gaze following. TD people have a preference for looking at social information, which extends to prioritising and identifying this information rapidly and accurately from peripheral vision, and which largely persists across a viewing period. This method therefore reveals a number of elements of social attention, drawn from the rich data source provided by eye-tracking. Extending this method to investigate social attention in people with ASD is an excellent way of assessing their social attention to a naturalistic stimulus, with minimal task constraints, while simultaneously allowing experimental rigour and quantitative data collection. In addition, we can explicitly examine the effect of a task instruction on social attention, the information used to discriminate gender, and also provide a window on shared attention type behaviours.

5.1b Aims and Predictions

This new study will use the same method and stimuli employed in the previous chapter [see section 4.2, page 113] to investigate social attention in a group of participants with ASD. In addition, a new group of TD adults, matched with the ASD participants, will undertake the study to reinforce our conclusions about typical social attention and provide a comparison for the ASD results.

There has been some interest in oculomotor control in autism (Rosenhall, Johansson, & Gillberg, 1988), suggesting that people with ASD show atypical saccades and other types of eye-movement (Kemner *et al.*, 1998; Takrae, Minshew, Luna, Krisky, & Sweeney, 2004; Takrae, Minshew, Luna, & Sweeney, 2004). However it is possible that people with ASD only have difficulty in volitional direction of saccades, when participants are called upon to exert conscious control over saccades and override reflexive attentional tendencies to look directly at a target onset (Minshew, Luna, & Sweeney, 1999). This type of oculomotor control is not required in our study. Nevertheless, it will be important to make an initial comparison of participant groups to rule out or take account of differences in basic eye-movement patterns.

Based on results from preceding studies in this thesis, we might expect that we would find no group differences in this task. However, eye-tracking technology permits analysis of very fine-grained aspects of attention, at the level of the individual fixation. In addition, the task presents social information in direct competition with a non-social scene. It is therefore possible that while previous results have shown no group differences in social attention, this task will reveal some subtle differences.

First, given that the preferential-looking method permits a direct assessment of attentional preference: it is predicted that, faced with two simultaneously presented and therefore competing stimuli, only one of which contains social information, the ASD group will show a preference for the person-present scene which is less pronounced that that of their TD peers. In addition, when looking at the person-present scene the exact distribution of attention to the person compared to background items, and to the face compared to the body will provide a way of distinguishing attention to different levels in a hierarchy of social information.

Second, it is possible that people with ASD will not show a priority in directing attention to social elements of the display (i.e. people) from the very start of each trial. The social change detection task [Chapter 3, page 68] indicated that people with ASD can detect a change to a social element of a complex scene within the four seconds of each trial. Here, we will have the opportunity to investigate whether attention is given to social elements of the display at the very first fixation, about 200 milliseconds after stimulus onset.

Third, it is possible that people with ASD may not show persistence in their attention to social information over the full viewing time. Though the results of the free-description task [Chapter 2, page 37] indicated that people with ASD had a normal distribution of attention to social information across their descriptions, this method lacked a temporal measure. The eye-tracking data recorded here will permit a more fine-grained analysis of attention over time.

The task permits an assessment of two new aspects of social attention, originally defined as attention to social aspects of the environment, to the exclusion of other non-social stimuli. The imposition of a task instruction, namely to identify the gender of the person depicted, will reveal how people with ASD respond to a specific instruction to attend to social information (a person). This instruction may bring ASD and TD scan-paths more inline with each other than in the free-viewing condition. Previous studies have shown that people with ASD are capable of exhibiting social attention behaviours when cued to do so in an experimental task (Charwarska *et al.*, 2003; Kylliainen & Hietanen, 2004; Senju *et al.*, 2004; Swettenham *et al.*, 2003). However, these tasks also presented social information in isolation, effectively ruling out any alternative behaviours. An alternative prediction for this part of the task is that the gender-discrimination condition will reveal new differences between people with and without ASD, in terms of the information they require to identify an individual's gender.

Second, the experiment will assess shared-attention type behaviour, in following the gaze of the person in the scene. This is not strictly social attention, under our definition, but a more elaborate social attentive behaviour which often follows from basic social attention, developmentally and within a real-life interaction. Here, we do not expect the ASD group to show gaze-following to the same degree as TD people. A wealth of research has indicated that people with ASD do not have an interest in sharing attention with other people (Dawson *et al.*, 2004; Leekam *et al.*, 2000; Mundy & Sigman, 1990) though they have the geometric skills required to do so (Leekam *et al.*, 1997; Leekam *et al.*, 1998). If people with ASD do fixate the area being looked at by the person depicted in the scene, we would not expect this fixation to be linked to a previous fixation to the person's face. In other words, looking at the object will be independent of looking at the person.

5.2 Method

5.2a Participants

The TD group comprised 15 young adults (2 female) aged 17-48 years, from mainstream high schools and further education colleges in the Durham area. This new group of TD participants were recruited in order to provide a better match to the participants with ASD than the Durham University undergraduates recruited for the preceding study. While it was not possible to match the two groups used here on IQ, they were comparable in terms of educational level. In addition, this second TD group provided an opportunity to confirm the findings of the preceding study [see section 4.4a, page 132].

The ASD group comprised 12 young adults (2 female) aged 16-23 years, with high-functioning autism or Asperger's syndrome. All these participants attended a specialist college in the Sunderland area for which a diagnosis of autism or Asperger's syndrome was a criterion of admission. All had been diagnosed by experienced clinicians (a psychiatrist or clinical psychologist employed by the National Health Service) working in specialised centres, as meeting DSM-IV criteria for either high-functioning autism or AS (American Psychiatric Association, 1994). These diagnoses were confirmed, upon each participant's admission to the college, by a second clinical psychologist.

Of the ASD group, six participants had previously taken part in the social change detection task [see section 3.5a, page 83] of which five participants had also taken part in the free-description task [see section 2.3a, page 51]. None had taken part in the social change detection Preliminary Study 1 [see section 3.2b, page 74]. Within the TD group, three had previously taken part in both the social change detection and free-description tasks. Both of these sessions took place at least 12 months before the current study.

The groups were group-wise matched on age. Both groups also completed the Autism Quotient Questionnaire (Baron-Cohen, Wheelwright, Skinner *et al.*, 2001) and differed significantly in their scores. There were significant group differences in full-scale IQ, verbal IQ and performance IQ (Wechsler, 1999). It was thought that since IQ did not relate to responses on previous social attention tasks with similar groups, these differences were acceptable. As in previous studies, IQ scores are included as covariates only if there is evidence of a significant correlation with dependent variables (Keppel & Zedeck, 1989). Descriptive statistics and t-test results for group differences are illustrated in Table 5.1.

Table 5.1: Descriptive statistics for each group, with t-test results for group comparisons

	ASD		TD		
	Mean	SD	Mean	SD	T-test result
Age (years)	18.8	2.3	21.5	7.8	t (25) = 1.19, p=.24
AQ	21.8	6.0	16.5	4.9	t (25) = 2.49, p=.02
FSIQ	91.3	12.7	107.1	13.5	t (25) = 3.06, p=.005
VIQ	87.2	12.3	104.5	13.0	t (25) = 3.53, p=.002
PIQ	97.3	15.9	108.7	13.5	t (25) = 2.02, p=.054

5.2b Materials and Apparatus

The 40 stimuli used were those used in Set 2, as reported in the previous chapter [see section 4.2b, page 113]. To recap, these stimuli consisted of 40 pairs of scenes, combined into a single display, bisected by a black line. Each pair contained one person-present (PP) scene and one person-absent (PA) scene. These scenes were paired randomly, such that a PP scene set in a living room could be paired with another from the same location-type or from another location-type (office, kitchen, garden). A sample stimulus is depicted in Figure 5.1. Stimuli were divided into two blocks of 20 combined scenes, as in the preceding study [see section 4.2b, page 113], and these blocks were matched for content of the PP scene, using various content categories. Participants saw all the stimuli, either seeing Block A in the free-viewing condition, followed by Block B in the gender-discrimination condition or vice versa. Within each block, stimuli were presented in a random order, different for each participant.

Figure 5.1: A sample stimulus, with the domains used in analyses

Fig 1a: Sample stimulus

Fig 1b: Basic analysis domains

As in the preceding study, stimuli were presented on a colour monitor and filled the entire screen (1024 x 768 pixels). Eye movements from one eye were recorded using a Dual Purkinje Image eye tracker as participants viewed the stimuli binocularly from a distance of 1 metre. The stimuli therefore subtended a visual angle of approximately 22° x 15°. Participants' eye movements were monitored at a rate of 200 recordings per second. Analysis software gave an output including the path of each saccade and the location and duration of every fixation.

5.2c Procedure

Participants were given an information sheet outlining the study, which the experimenter read through with them, and gave their consent to be involved. They were introduced to the eye-tracking apparatus with a warm-up exercise in which they looked at a series of eight images (pictures by Mondrian, chosen to be entirely abstract – see Figure 5.2) for three seconds each. This warm-up task was designed to ensure that the experimental data were not influenced by whether a participant was nervous about the eye-tracking experience. Though there was some initial wariness about the eye-tracking apparatus, once participants had had a go on the tracker, none of them exhibited any anxiety about continuing the experiment.

Figure 5.2: An example of one of the warm-up stimuli.

A nine-point calibration was taken before each half of the experiment. The first half of the experiment was the free-viewing condition, in which no instructions were given beyond, "*You are going to see some colour pictures. Just have a look.*" Each trial consisted of a one second blank screen followed by a one second central fixation cross and then presentation of the experimental stimulus for three seconds. Participants viewed 21 stimuli, of which the first was a practice stimulus with no data recorded.

The second half of the experiment was the gender-discrimination condition. This fixed order of conditions was selected because otherwise the gender-discrimination instruction could have prevented genuine 'free-viewing'. Here, participants were told "*You're going to see some more pictures just like before, but this time I want you to decide on the gender of the person in the picture Press the right-hand button if you see a man and left-hand button if you see a woman.*" Trials proceeded as before but with the addition of a response screen, saying "Respond Now", which appeared after the experimental stimulus. This response screen was presented until the participant made a button-press response to the gender. Participants viewed 23 stimuli, of which the first three were practice stimuli with no data recorded.

Participants also completed the AQQ (Baron-Cohen, Wheelwright, Skinner *et al.*, 2001) and the WASI was administered (Wechsler, 1999). Participants were finally debriefed and paid £10 for their involvement.

5.3 Results

5.3a Data Preparation

Each data set was run through an automatic saccade detection programme, which detected the beginning and end of every saccade and these selections were then checked manually. Each stimulus presented during the experiment was divided into six domains (see Figure 5.1b) demarcating the Eyes, the Face-remainder and the Body of the person in the scene, the Background of each scene and the black central bar separating the images. The eye-region was newly introduced at this stage to provide an extra assessment of attention to the most social area of the person depicted. The Face-remainder domain consisted of the rest of the face, not taken up by the Eyes domain. The tracker output was then combined with these domains to produce a data set recording how fixations were distributed across domains.

Each trial lasted 3000ms, however due to tracker loss and the exclusion of blinks, only some of this time was recorded. Since a partial recording may not be representative, all trials in which less than 500ms of data were recorded were excluded. This resulted in the exclusion of 4.25% of all trials.

There were no differences between groups in the number of excluded trials, the number of fixations recorded overall, the amount of time recorded overall, the number of lost first fixations or in accuracy to identify gender (in the gender-discrimination condition only). There was also no difference in the mean number of fixations made within a trial (and consequently also the mean number of saccades), suggesting that participants had similar basic eye-movement control in this task. The use of a percentage measures of viewing time and first fixations, and a relative measure of first saccade latency [see sections 5.3b, 5.3e and 5.3f, from page 147] means that any non-significant group differences in basic oculomotor control or quantity of data recorded would be accommodated in the subsequent analysis. Finally, there were no correlations between autism quotient score and percentage viewing time or first fixations to either scene.

Three major measures were used in the analysis, as in the preceding chapter [see section 4.3a, page 118]. These were: the percentage of total viewing time spent in each domain; the location of the first fixation in each trial; and the time spent programming the saccade which led to this fixation (referred to hereafter as the 'first saccade latency'). Again, the distribution of fixations over time was mapped, in order to reveal the order of precedence given to each domain.

5.3b Viewing Time in Each Domain

None of full-scale, verbal or performance IQ measures correlated with viewing time to either scene, nor to viewing time to the Person (Body plus Face-remainder plus Eyes domains) in either viewing condition (all $r<.178$ and all $p>.373$). Therefore, despite the lack of group matching on IQ, viewing-time scores were analysed without IQ as a covariate [see section 3.2c, page 76]. Viewing time statistics for each group for each scene are shown in Table 5.2 and for domains within the PP scene are shown in Table 5.3.

Comparisons were made between groups for the percentage of viewing time spent in each scene and then in each domain. These comparisons investigate how attention is distributed between the two scenes, and also within sub-domains of the PP scene, across the full-viewing period of three seconds. The analyses first compare the two scenes as a whole, then compare sub-domains of the PP scene with each other: Background vs. Person; Body vs. Face; Eyes vs. Face-remainder. The Person domain consists of the Body and Face domains, summed together and the Face domain consists of the Eyes and Face-remainder domains summed together.

Table 5.2: Percentage of total viewing time in each scene, for each group.

Viewing time (%)		Person-Absent Scene		Person-Present Scene	
		Mean	SD	Mean	SD
Free	ASD	38.1 %	7.0	55.4 %	7.6
	TD	37.2 %	8.9	58.9 %	9.4
Gender	ASD	23.5 %	9.6	71.2 %	11.2
	TD	19.6%	11.9	77.2 %	11.2

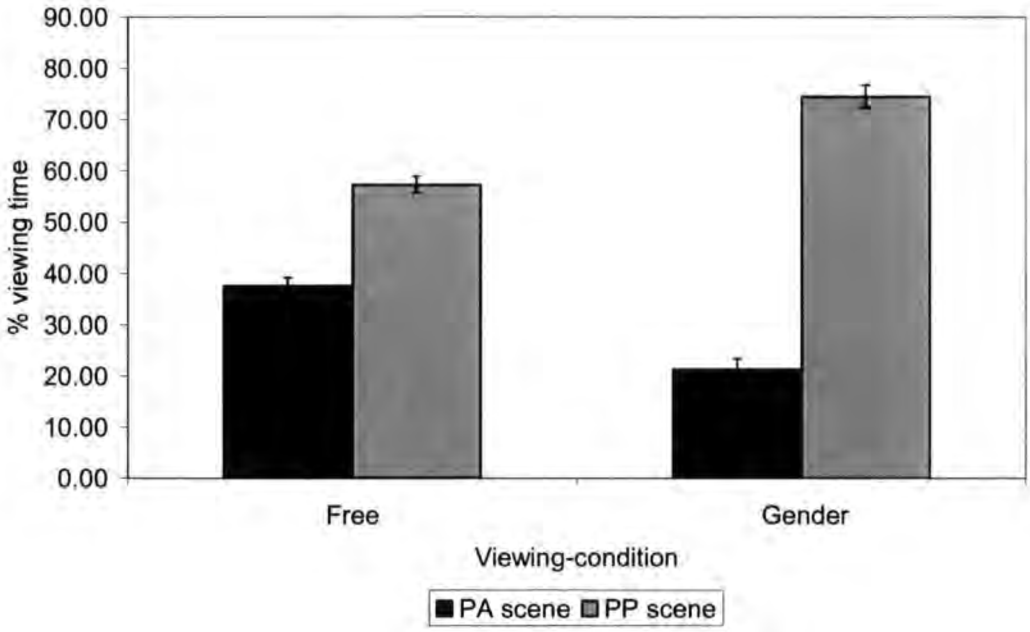
NB: In Table 5.2, percentages for the Person-Absent and Person-Present scenes do not sum to 100% because a small proportion of viewing time was spent in the central bar diving the two scenes (see Figure 2).

Table 5.3: Percentage of total viewing time in domains within the person-present scene, for each group.

Viewing time (%)		Person-present scene							
		Background		Body		Face-remainder		Eyes	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD
Free	ASD	28.2%	7.0	13.3%	5.3	9.6%	10.6	4.3%	5.9
	TD	25.9%	6.8	15.8%	5.6	11.9%	9.6	5.3%	5.6
Gender	ASD	24.0%	8.0	23.2%	8.9	17.2%	10.2	6.8%	5.2
	TD	19.8%	9.8	28.2%	9.7	19.7%	10.7	9.5%	9.1

To compare viewing time between the two scenes (see Table 5.2), an ANOVA was performed on Scene (PP scene vs. PA scene), Group (ASD vs. TD) and Condition (free-viewing vs. gender-discrimination). This revealed a main effect of Scene, $F(1,25) = 197.59$, $p<.001$, such that a greater percentage of viewing time was spent in the PP scene across all participants and conditions. There was also a significant interaction between Scene and Condition, $F(1,25) = 41.33$, $p<.001$. This showed that the difference in viewing time between scenes was increased in the gender-discrimination condition compared to the free-viewing condition (see Figure 5.3). There were no other significant effects, including no main effects or interactions involving Group.

Figure 5.3: The interaction between viewing time in each Scene and Condition (all participants)



The bias to spend more time viewing the PP Scene was largely consistent between individual participants. For the free-viewing condition, only one participant, from the TD group, did not show this bias; their fixation time was roughly equally distributed between both scenes (PP = 45%, PA = 49%). Note that these percentages do not sum to 100% because a small proportion of viewing time (most notably the first fixation on stimulus presentation) was spent looking at the central black bar which separated the two scenes.

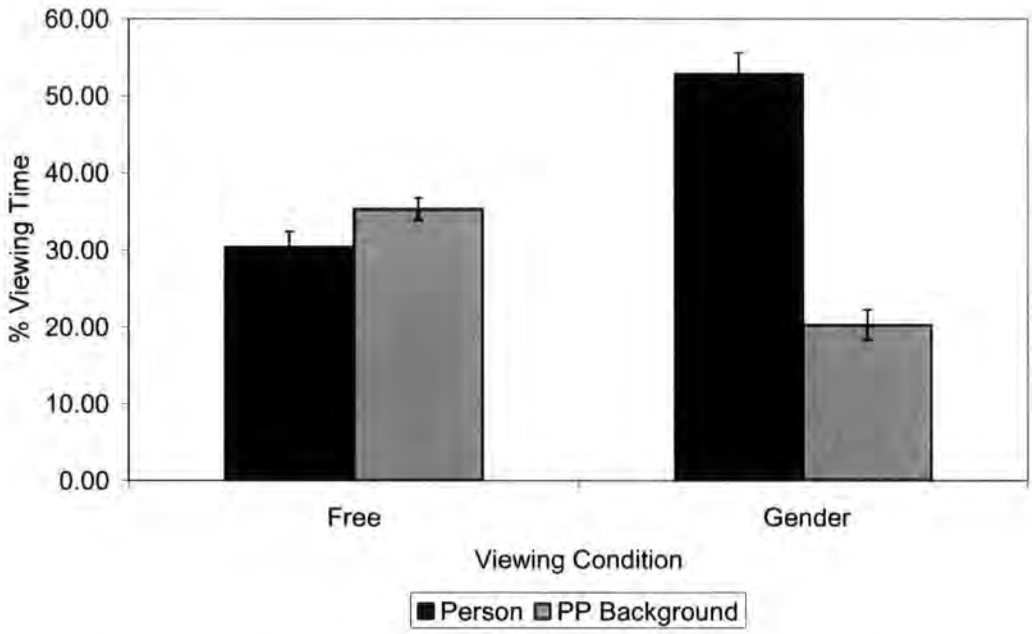
Five participants with ASD and three from the TD group showed a bias towards the PP scene of 10 percentage points or less. The remaining participants all showed a difference where the fixation time in the PP Scene was at least 10% higher than in the PA Scene and nine participants, (three ASD and six TD), showed a difference of more than 25%.

For the gender-discrimination condition, all but three participants showed a difference of over 25 percentage points in preference for the PP Scene. One TD and one ASD group member showed differences of 18% and 19% respectively. Both of these individuals showed a normal bias in the free-viewing condition. In addition, one more individual with ASD showed a bias of only 10% in this condition, and this person also showed only a small PP bias (4%) in the free-viewing condition.

To investigate viewing time within the PP scene, a comparison was made between the Background of this scene and the Person (consisting of the Body and Face domains summed together). This ANOVA revealed a main effect of Domain, $F(1,25) = 29.50$, $p<.001$, such that a higher percentage of viewing time was spent looking at the Person than at the PP Background. There was also a main effect of Condition, $F(1,25) = 40.35$, $p<.001$, because there were more fixations in both Background and Person domains combined, in the gender-discrimination than in the free-viewing condition. Finally, there was an interaction between Domain and Condition, $F(1,25) = 73.62$, $p<.001$, which showed that there was a greater difference between looking at the Person and the Background in the gender-discrimination condition (see Figure 5.4). There were no effects of Group.

A comparison was also made between viewing time in the Body and Face (consisting of the Eyes and Face-remainder domains summed together) domains, to investigate how attention was distributed between different parts of the person. This ANOVA again revealed a main effect of Condition, $F(1,25) = 90.22$, $p<.001$, because more viewing time was spent in both the Body and Face domains in the gender-discrimination than in the free-viewing condition. There was also a borderline main effect of Group, $F(1,25) = 3.94$, $p=.058$. This had a small effect size (partial $\eta^2 = .136$) but represented a tendency for the ASD group to spend less viewing time on both Body and Face domains overall, compared with the TD group. There were no other significant effects.

Figure 5.4: The interaction between viewing time in two Domains (Background vs. Person) and Condition (all participants)



Finally an ANOVA was performed on the sub domains of the Face. This was to investigate the distribution of attention to the most social element of the Person, their eyes, and to test the specific hypothesis that people with ASD look less at the eye-region (Klin *et al.*, 2002b). This ANOVA compared Domain, (Eyes vs. Face-remainder), Group (ASD vs. TD) and Condition (free-viewing vs. gender-discrimination). There was a main effect of Condition, $F(1,25) = 25.34$, $p<.001$, because, once again, more viewing time was spent in both domains in the gender-discrimination than in the free-viewing condition. There was also a main effect of Domain, $F(1,25) = 27.41$, $p<.001$, such that more time was spent viewing the rest of the face than the eye-region specifically. There were no Group effects in this analysis.

5.3c Viewing Time, Adjusted According to Domain Size

Each stimulus was divided into six major domains for analysis (as depicted in Figure 5.1b, page 123). These were the PA scene, the PP scene Background, the Body, the Face-remainder, the Eyes and the central black dividing bar. In addition, new domains could be created by summing the Body and Face domains to create a whole Person score and also by summing the Face-remainder and the Eyes domains to create a whole Face score.

The domains varied in size between images, and in particular, Face-remainder and Eyes domains were always much smaller than any other domain. Therefore viewing time scores were adjusted to give domain-relative measures. Viewing times as percentages were divided by the size of the relevant domain, also expressed as a percentage of the total stimulus size. If fixations were spread randomly across the stimulus, one would expect a score close to one (e.g. 50% of fixation time / 50% of stimulus size). If fixations were being directed to a domain more than randomly predicted, this score would be greater than one, and vice versa. Scores for each domain and each group are illustrated in Table 5.4.

Table 5.4: Domain-relative viewing time by group for domains within the person-present scene

Domain-relative viewing time		Person-present scene							
		Background		Body		Face-remainder		Eyes	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD
Free	ASD	.68	.17	2.27	.78	58.9	54.3	68.1	75.2
	TD	.62	.17	2.84	1.04	68.6	45.3	110.3	136.6
Gender	ASD	.58	.19	4.79	1.98	112.3	71.4	148.4	117.5
	TD	.47	.23	5.53	2.34	111.1	64.8	164.0	164.2

Since the PP and PA Scenes were always the same size, a comparison of these domain-relative scores was not performed. However, ANOVAs comparing each pair of sub-domains (PP Background and Person; Body and Face; Eyes and Face-remainder) were performed as above. In the interests of simplicity, full statistics for significant results will only be reported where these differ from findings in the analysis of unadjusted viewing times.

The comparison of PP Background and Person domains again revealed main effects of Domain and Condition and an interaction between Domain and Condition, all $p<.001$, as in the previous analysis of unadjusted scores.

The comparison of Body and Face domains again revealed a main effect of Condition ($p<.001$) because both domains received a smaller proportion of viewing time in the free-viewing condition. This time there was also a main effect of Domain, $F(1, 25) = 68.27$, $p<.001$, such that the Body received less size-adjusted viewing time than the Face. There was also a new interaction between Domain and Condition, $F(1, 25) = 17.30$, $p<.001$, such that the difference in viewing time between domains was greater in the gender-discrimination condition. However, this time no effect of Group was found ($p=.812$). The presence of new effects of domain in this analysis of size-adjusted scores is unsurprising since this variable takes account of the difference in size of the Body compared to the Face, (mean size: Body = 7.6%; Face = 0.4%).

The final comparison of the Eyes region with the Face-remainder again found a significant effect of Condition, $p=.004$, as before, but this time there was no main effect of Domain. The Eyes and the Face-remainder domains differed in size, (mean size: Eyes = .05%, Face-remainder = .35%) but there was no effect of domain-relative viewing time in this case. This indicates that there was no difference in fixation probability between the Eyes region and the rest of the face.

A further way to investigate the domain-relative scores is to compare them with a value of one. As stated above, if fixations were spread randomly across the stimulus, one would expect a score close to one (e.g. 50% of fixation time / 50% of stimulus size). If fixations were being directed to a domain more than randomly predicted, this score would be greater than one, and vice versa. A series of t-tests were conducted for each group separately, investigating whether scores differed significantly from one. In order to reduce the number of t-tests required, this analysis was only performed on data from the free-viewing condition. Because 12 t-tests were being performed, (2 groups x 6 domains), a Bonferroni adjustment was made such that a p-value of .004 or less was required for significance. Both groups showed a domain-relative score significantly different from one (all $p<.004$) for every domain analysed so far (PP Background, Person, Body, Face, Face-Remainder) except the Eyes domain. Viewing time to the Eyes domain did not significantly differ from 1 in either participant group, indicating that this region was viewed only as much as would be expected by chance. For the PP Background, domain-relative viewing times were less than one, indicating that this domain was fixated less than would be predicted by a random viewing pattern. The other four domains were all fixated more than would be predicted by a random viewing pattern.

Domain-relative viewing time for the background of the PP Scene did not significantly differ from that for the entire PA Scene, for either group or viewing condition (all $p>.10$), indicating that differences in viewing times between these two scenes is due to the time spent looking at the person depicted.

5.3d Summary of Viewing Time Analysis

Despite its complexity, the viewing time data analysis has revealed a consistent pattern of results. First, participants from both groups show a preference to look at social elements of the display: the PP scene is viewed more than the PA scene, the Person is viewed more than the Background. These biases are consistent across individual participants, and exaggerated in the gender-discrimination condition.

The Body and Face receive an equal proportion of viewing time to each other, though the TD participants tend to look at both domains more than the ASD group. This is the only group effect in the viewing time data and it was only marginally significant. Both Body and Face also receive more viewing time in the gender-discrimination condition than in the free-viewing condition. Across both conditions, the Eyes are looked at less than the rest of the face.

Domain-relative scores show that, after correcting for the size of each domain, the Face has a higher probability of fixation than the Body, but the Eyes and the rest of the Face are equally likely to be fixated. All domains are more likely to be fixated than would be predicted by chance, except for the Eyes, the background of the PP scene and the entire PA scene. There is no difference in fixation probability between these two latter domains, indicating that the attentional preference for the PP scene is entirely driven by fixations on the Person depicted.

5.3e First Fixations

The first fixation is defined as that fixation following the first saccade made after trial-onset. This measure can examine which items received attentional priority in the scene, rather than simply which items received the greatest amount of viewing time. Data on the distribution of first fixations are shown in Tables 5.5 and 5.6.

Table 5.5: Percentage of first fixations in each scene, by group.

First fixations (%)		Person-Absent Scene		Person-Present Scene	
		Mean	SD	Mean	SD
Free	ASD	21.4 %	13.0	73.7 %	14.0
	TD	15.0 %	9.6	81.7 %	12.2
Gender	ASD	13.7 %	9.8	81.2%	12.1
	TD	7.2 %	4.4	92.1 %	5.2

NB: In Table 5.5, percentages for the Person-present and Person-absent scenes do not sum to 100% because a small number of first fixations were made in the central bar dividing the two scenes.

None of the IQ measures (full-scale, verbal or IQ) correlated with the percentage of first fixations made in the PP scene, the PA scene or the Person in either viewing condition (all Pearson's $r < .19$, and all $p > .32$). Therefore no IQ measures were included in the analyses of first fixations [see section 3.2c, page 76]. As in the analysis of viewing times, a series of

ANOVAs were used to compare the percentage of first fixations made in each Scene and the domains within the PP scene.

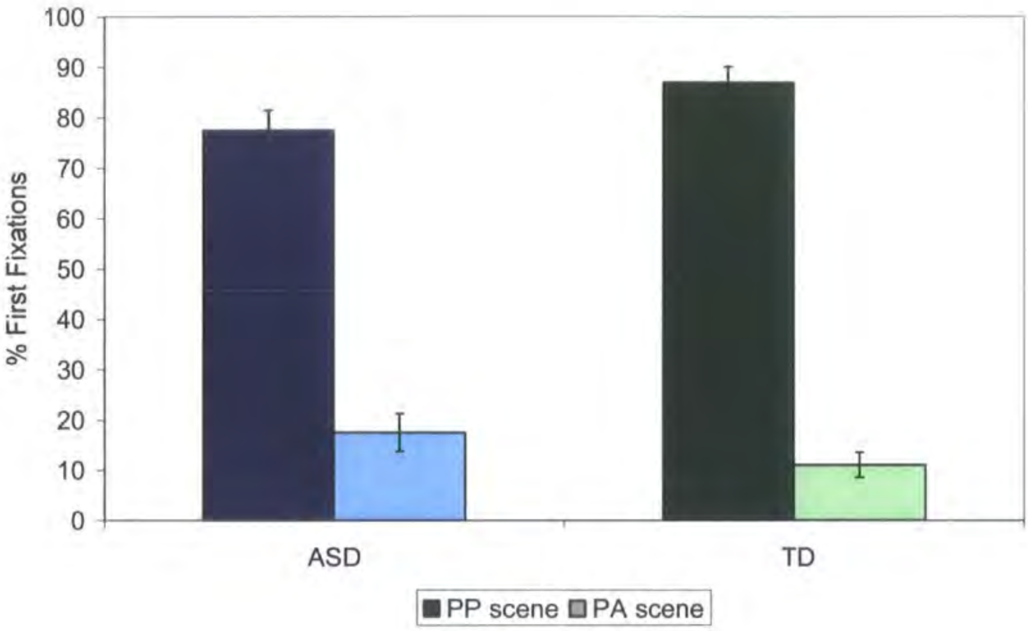
Table 5.6: Percentage of first fixations in domains within the person-present scene, by group.

First fixations (%)		Person-present scene							
		Background		Body		Face-remainder		Eyes	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD
Free	ASD	37.3%	11.6	25.0%	10.5	8.6%	9.1	2.7%	4.3
	TD	23.3%	10.2	35.2%	9.1	21.2%	18.8	2.1%	4.7
Gender	ASD	32.7%	12.2	36.3%	15.3	10.5%	8.2	1.8%	2.7
	TD	25.7%	17.3	37.1%	14.4	25.4%	12.2	4.0%	4.3

An ANOVA on Scene (PP Scene vs. PA Scene), Group (ASD vs. TD) and Condition (free-viewing vs. gender-discrimination) revealed a main effect of Scene, $F(1,25) = 394.73$, $p<.001$, indicating that a larger percentage of first fixations fell in the PP Scene than the PA Scene. There was also a Scene by Condition interaction, $F(1,25) = 21.39$, $p<.001$, showing that the difference in the distribution of first fixations between scenes was greater in the gender-discrimination condition. A Scene by Group interaction, $F(1,25) = 5.41$, $p=.028$, showed that the TD group had a larger bias to make first fixations on the PP Scene than the ASD group (see Figure 5.5). Post-hoc t-tests revealed that both groups did have a bias to make a higher proportion of first fixations in the PP scene (both conditions' data combined), despite the difference in degree of bias: TD group $t(14) = 22.15$, $p<.001$; ASD group $t(11) = 9.44$, $p<.001$.

Despite the interaction between Scene and Group, there was a bias to fixate the PP scene present in all participants. All participants showed a bias of at least 6%, and all but three participants showed a bias of more than 30%. In the gender-discrimination condition every

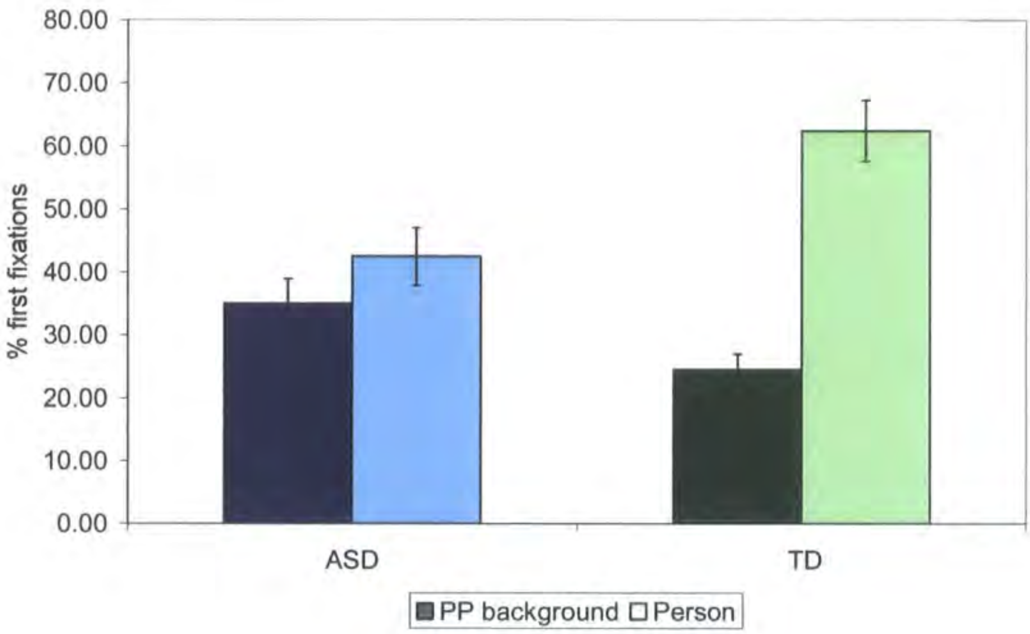
Figure 5.5: The Interaction between percentage of first fixations in each Scene and Group



participant showed a person-present bias in their distribution of first fixations of at least 40% and 15 participants showed a bias of 80% or more.

An ANOVA compared two domains within the PP Scene (PP Background vs. Person), Group (ASD vs. TD) and Condition (free-viewing vs. gender-discrimination). There was a main effect of Condition, $F(1,25) = 17.77$, $p<.001$, and of Domain, $F(1,25) = 22.65$, $p<.001$, showing a larger percentage of first fixations in the Person, and in the gender-discrimination condition. Here there was also a main effect of Group, $F(1,25) = 6.31$, $p=.019$, because the participants with ASD made a smaller percentage of first fixations in both these PP scene domains combined. In addition, there was a Group by Domain interaction, $F(1,25) = 10.23$, $p=.004$, showing that the TD group had a strong bias to make more first fixations on the Person than the PP Background, but that this bias was reduced in the ASD group (see Figure 5.6). Post-hoc t-tests revealed that in fact the bias present in the TD

Figure 5.6: The interaction of percentage of first fixations in two Domains (PP background and Person) and Group.

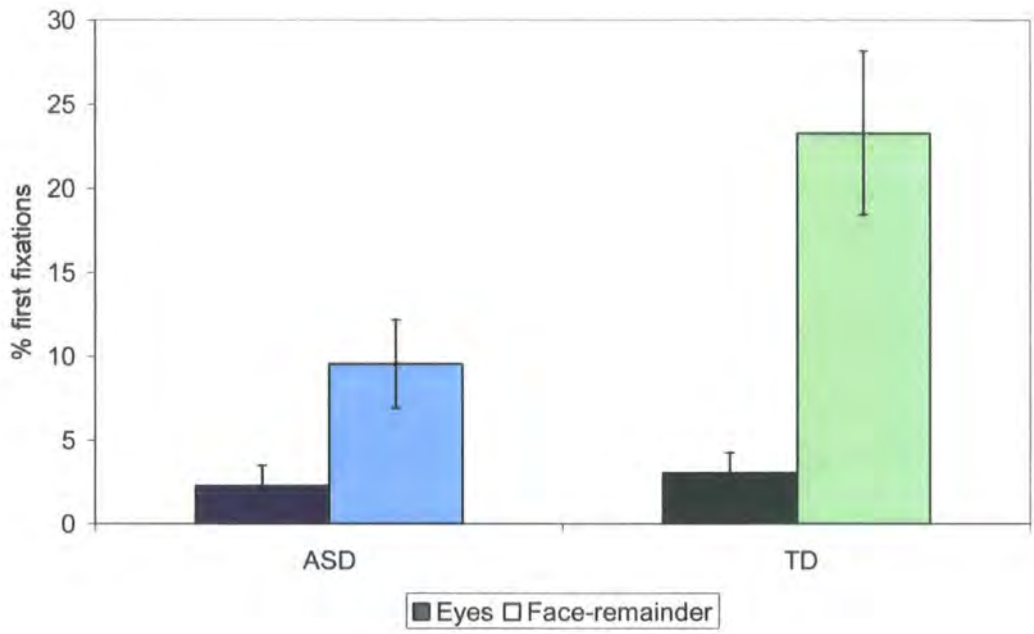


group was not significant for the ASD group: TD group t (14) = 6.87, p<.001; ASD group t (11) = 1.98, p=.073.

An ANOVA also compared the two domains within the Person (Body and Face). Again, there were main effects of Condition, F (1,25) = 8.15, p=.009, and Domain, F (1,25) = 23.51, p<.001, showing a larger proportion of first fixations in the Body, and in the gender-discrimination condition. There was also a main effect of Group, F (1,25) = 11.52, p=.002, showing that the ASD group again made a smaller percentage of their first fixations in both of these domains combined.

A final ANOVA compared the two face domains (Eyes and Face-remainder), revealing a main effect of Domain, F (1,25) = 73.40, p<.001, indicating that a smaller percentage of first fixations were made to the eye-region than to the rest of the face. There was also a main effect of Group, F (1,25) = 11.92, p=.002, showing again that the ASD group made fewer first fixations in both domains combined. Finally, there was also an interaction of Group and

Figure 5.7: The interaction of percentage of first fixations in two Domains (Eyes and Face-remainder) with Group.



Domain, F (1,25) = 15.98, p<.001, which resulted from both groups making a similar percentage of first fixations on the (very small) Eyes domain, while the TD group made a much larger percentage of first fixations to the rest of the face (see Figure 5.7). Post-hoc t-tests showed that in this case, both groups did show a significant bias to look at the rest of the face more than the eye-region: TD group t (14) = 8.27, p<.001; ASD group t (11) = 5.51, p<.001.

5.3f First Saccade Latencies

The first saccade latency (FSL) refers to the time between onset of a trial and the start of the first fixation. This is a measure of programming time for the first fixation and therefore measures people's ability to identify the stimulus they are looking for and prepare to move their eyes to it. For example, in a visual search task in which a face was presented among jumbled or inverted face distractors, people were able to move their eyes directly to the upright face, but only by extending their first saccade latency (Brown, Huey *et al.*, 1997). Before this analysis, all first saccades with latencies of less than 80ms or more than 500ms were removed, to exclude those saccades made in error.

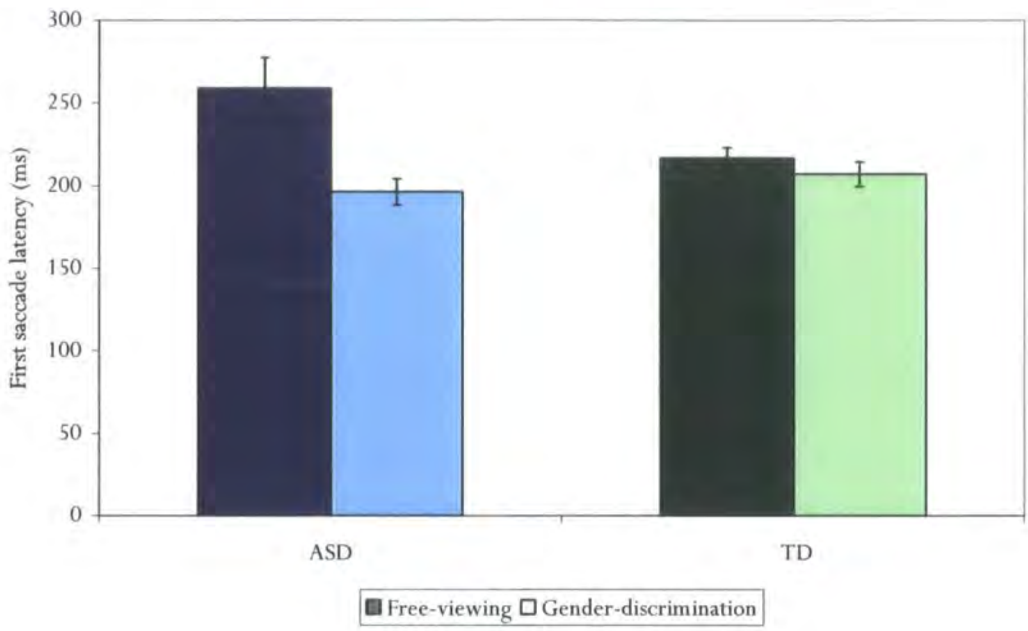
Two initial t-tests reveal that the group with ASD overall have a slightly longer FSL in the free-viewing condition, $t(25) = 2.36$, $p=.026$, though not in the gender-discrimination condition ($p=.33$). To account for this group difference, FSLs to individual domains were calculated as a relative score for each individual participant. Each participant's mean FSL for a particular domain was subtracted from their personal mean FSL for the entire viewing condition. Therefore if an individual made faster-than-usual saccades to a particular domain, their relative-FSL would be a positive number and slower-than-usual saccades would produce a negative score. These relative-FSLs by domain are illustrated in Table 5.7.

Table 5.7: Relative first saccade latencies for each scene and major domains, by condition and group

		Person-absent scene		Person-present scene							
				Whole PP scene		Background		Body		Face	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Free	ASD	32.4	82.1	2.84	34.1	-5.31	39.9	19.6	59.7	18.1	74.2
	TD	-14.6	46.7	-1.15	14.6	-10.2	41.7	1.97	17.3	-0.63	29.4
Gender	ASD	-31.6	53.7	2.35	5.49	5.16	23.3	4.36	20.6	-3.57	23.2
	TD	16.9	64.7	0.92	10.5	4.11	38.0	5.40	22.9	-9.38	39.0

As was the case with other variables of interest - percentage viewing time and percentage of first fixations – there were no correlations between any IQ measure (full-scale, performance and verbal) and first saccade latency to either scene or the Person domain (all $r<.168$ and all $p>.402$). Therefore IQ was not included in subsequent analyses. Analyses progress from a

Figure 5.8: The interaction of first saccade latency in each Condition with Group



NB: This interaction does not involve a Scene or Domain variable, therefore Figure 5.8 depicts absolute, rather than relative, first saccade latencies.

comparison of the two Scenes, to comparisons of ever smaller pairs of domains, in order to reveal attentional preferences both between and within scenes.

An ANOVA was performed on Scene (PP Scene vs. PA Scene), Group (ASD vs. TD) and Condition (free-viewing vs. gender-discrimination). Some participants made no first saccades to the PA Scene, therefore this ANOVA was based on a sample of 10 ASD and 12 TD participants. This revealed a Condition by Group interaction, $F(1,20) = 15.58$, $p=.001$, such that the TD group had similar length latencies in both conditions but the group with ASD showed faster first saccades in the gender-discrimination condition (see Figure 5.8). Post-hoc t-tests showed that only the ASD group showed a significant difference in first saccade latency between the two Conditions: TD group, $t(14) = 1.31$, $p=.21$; ASD group, $t(11) = 4.73$, $p=.001$.

Figure 5.9a: The interaction of relative first saccade latency to each Scene with Condition – ASD group data

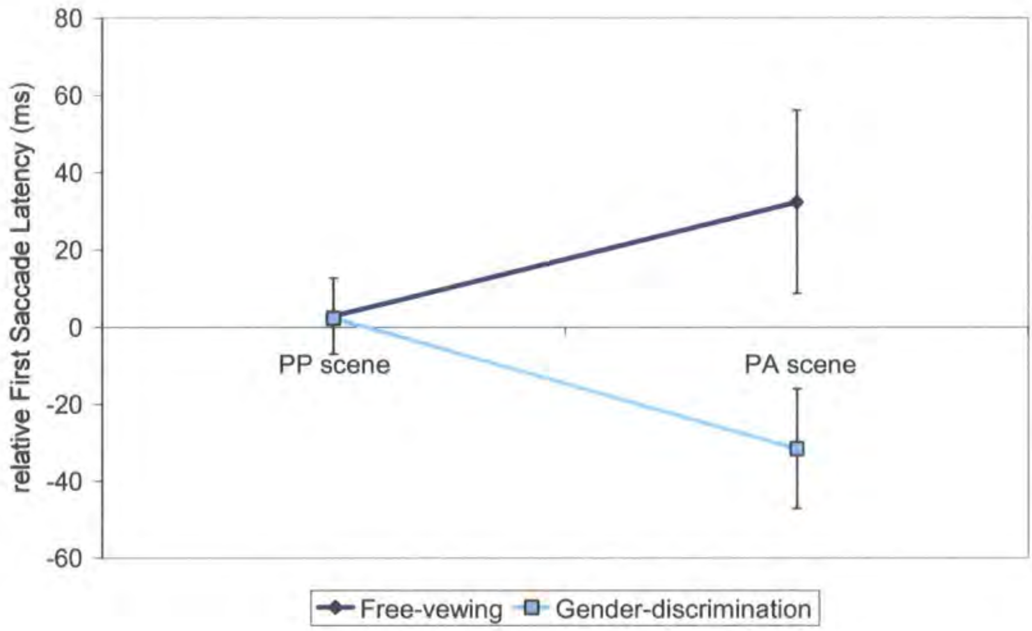
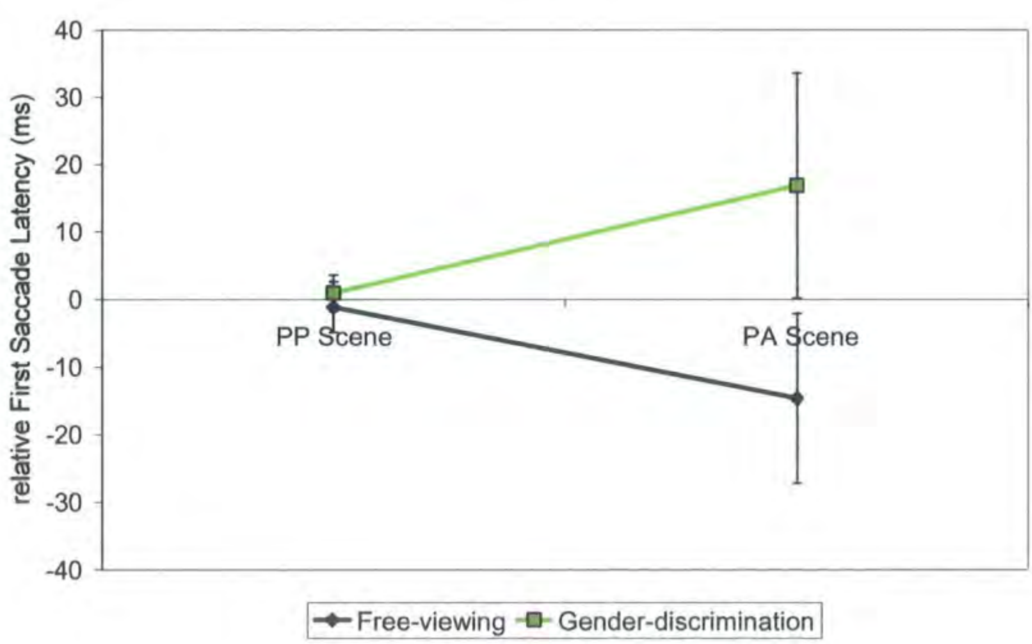


Figure 5.9b: The interaction of relative first saccade latency to each Scene with Condition – TD group data



It is important to note here that the gender-discrimination condition always succeeded the free-viewing condition. Therefore the faster first saccades in the gender-discrimination condition shown by the ASD group could simply reflect more confidence with the task.

There was also a three-way interaction between Scene, Condition and Group, $F(1,20) = 6.68$, $p=.018$, illustrated in Figure 5.9. In both groups relative FSL to the PP scene was not affected by the viewing-condition, but relative FSL to the PA scene showed a large effect of condition. In the TD group, PA scene FSLs were slower in the free-viewing condition, whereas in the ASD group they were slower in the gender-discrimination condition. This finding is tempered by the fact that both groups showed much greater variability in relative FSL to the PA scene, supporting the conclusion that first saccades to this Scene can be treated as 'errors'. This interpretation will be considered further in the discussion [see section 5.4d, page 178].

Comparisons of first saccade latencies to domains within the PP scene (PP background and Person, Body and Face) revealed no significant effects of domain, condition or group. It was not possible to investigate first saccade latencies for the eyes contrasted with the rest of the face, because so few first saccades were made directly to the eye region. Only four participants (two in each group) made first saccades directly to the eyes in both viewing conditions.

5.3g Looking Where Others Look

As in the preceding chapter [see section 4.3h, page 129], two new domains were also developed (see Figure 5.10), in order to investigate the secondary question of whether participants looked at the areas looked at by the person represented in the scene. The Viewing Cone domain represented the area that could conceivably be being viewed by the scene character, as defined by a 30° cone extending from the centre of the person's eye area (Sanders, 1963). In addition, for the subset of scenes (26/40) in which a visible object was being fixated by the person in the scene, this Object was analysed separately with its own domain.

Figure 5.10: Viewing cone and object domains

Fig 10a: Viewing cone domain

Fig 10b: Object domain

NB: These domains are for the stimulus depicted in Figure 5.1

Domain relative fixation time scores were calculated as before: a score of one indicates randomly allocated viewing, less than one indicates a paucity of viewing of this area and scores greater than one indicate an excess of viewing in this area.

An ANOVA was conducted comparing domain-relative viewing time in the Viewing-Cone domain with the rest of the PP scene background, along with Group (ASD vs. TD) and Condition (free-viewing vs. gender-discrimination). This revealed a significant effect of Domain, $F(1,25) = 25.43$, $p<.001$, indicating that across both groups and conditions the Viewing-Cone was fixated more than the rest of the PP scene background.

A second ANOVA was conducted to specifically look at viewing time to the Object, comparing this with the rest of the PP background, and again there was an effect of Domain, $F(1,25) = 14.45$, $p<.001$, such that the Object received more viewing time than the rest of the PP scene background. There was also a borderline three-way interaction between Condition, Domain and Group, $F(1,25) = 4.23$, $p=.05$, depicted in Figure 5.11. Both groups viewed the PP scene background a similar amount in both viewing-conditions, but the TD group viewed the object more in the free-viewing condition, while the ASD group viewed the object more in

Figure 5.11a: Interaction of relative viewing time in two Domains (PP background and Object) with Condition – ASD group data

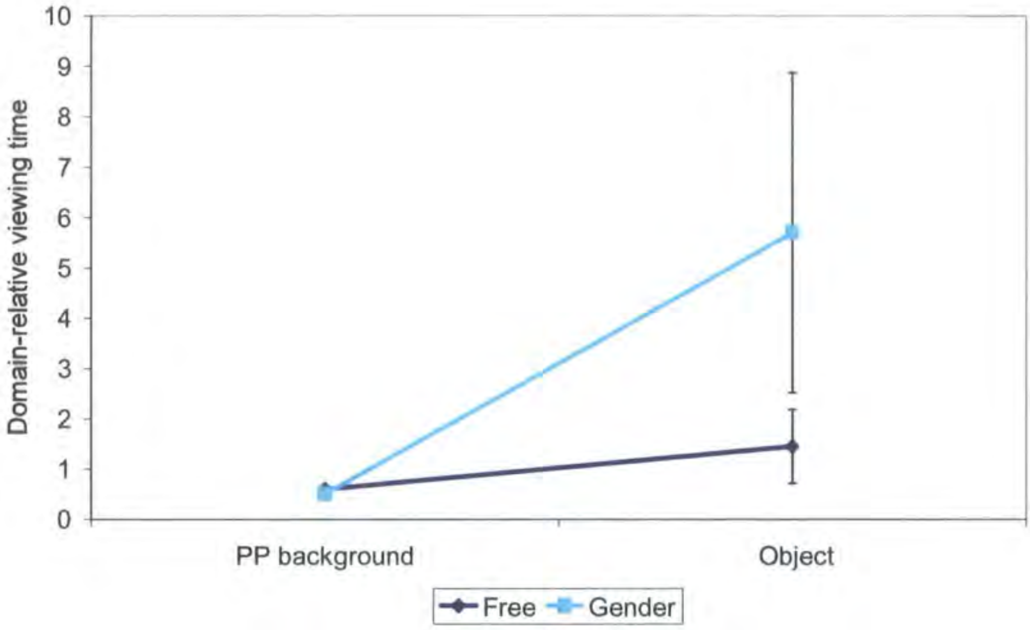
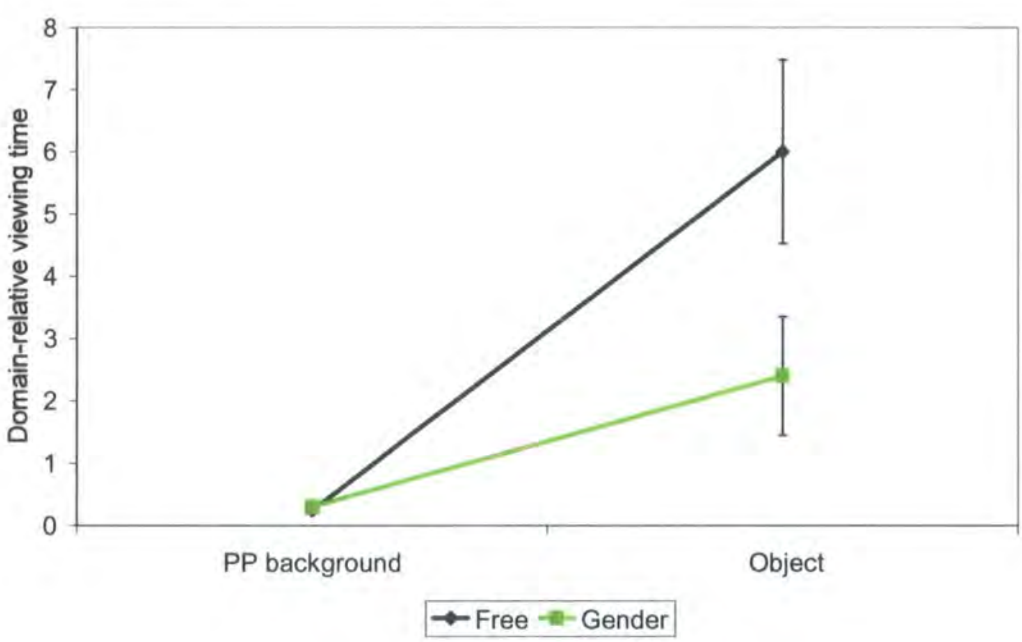


Figure 5.11b: Interaction of relative viewing time in two Domains (PP background and Object) with Condition – TD group data



the gender-discrimination condition (though this latter was highly variable across individuals).

As previously, a second analysis was conducted in which domain-relative viewing time scores for the Viewing-Cone and Object domains were compared to one. Once more, a score significantly above one indicates viewing of this domain more than would be expected by chance, whereas a score of less than one indicates less viewing than would be expected by chance. These t-tests showed that looking at the Viewing-Cone never differed significantly from one, across both Groups and Conditions, indicating that this region was fixated neither more nor less than a random viewing pattern would predict. The Object domain was also not fixated more than randomly predicted by the ASD group in both conditions. However the TD group did fixate the Object more than expected, $t(14) = 3.36$, $p=.005$, in the free-viewing condition only. This result was confirmed by a t-test showing a significant difference between groups for domain-relative viewing time in the Object in the free-viewing condition, $t\ (20.15) = 2.57$, $p=.018$ (equal variances not assumed, $F = 7.73$, $p=.01$). This result suggests that the TD group were more inclined to look at the Object in the free-viewing condition than the ASD group.

5.3h Distribution of Fixations Over Time

The pattern of looking over time was examined by plotting the percentage of first, second, third, fourth etc. fixations made within each domain in each condition. Figures 5.12a and 5.12b illustrate fixations over time to the PP and PA Scenes in the free-viewing condition, for each group separately.

These graphs show a similar pattern for both groups with a strong bias to fixate the PP Scene from the very first fixation. This bias tails off rapidly in the ASD group who show no clear Scene preference from the 3rd fixation onwards. The bias tails off more slowly in the TD

Figure 5.12a: The location of fixations over time by Scene in the free-viewing condition – ASD data

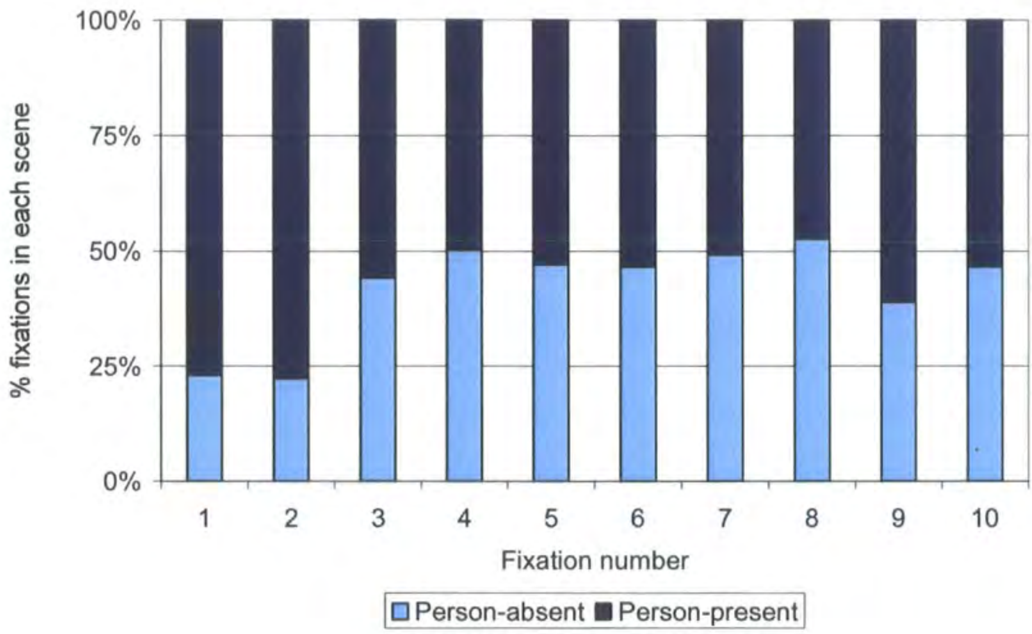


Figure 5.12b: The location of fixations over time by Scene in the free-viewing condition – TD data

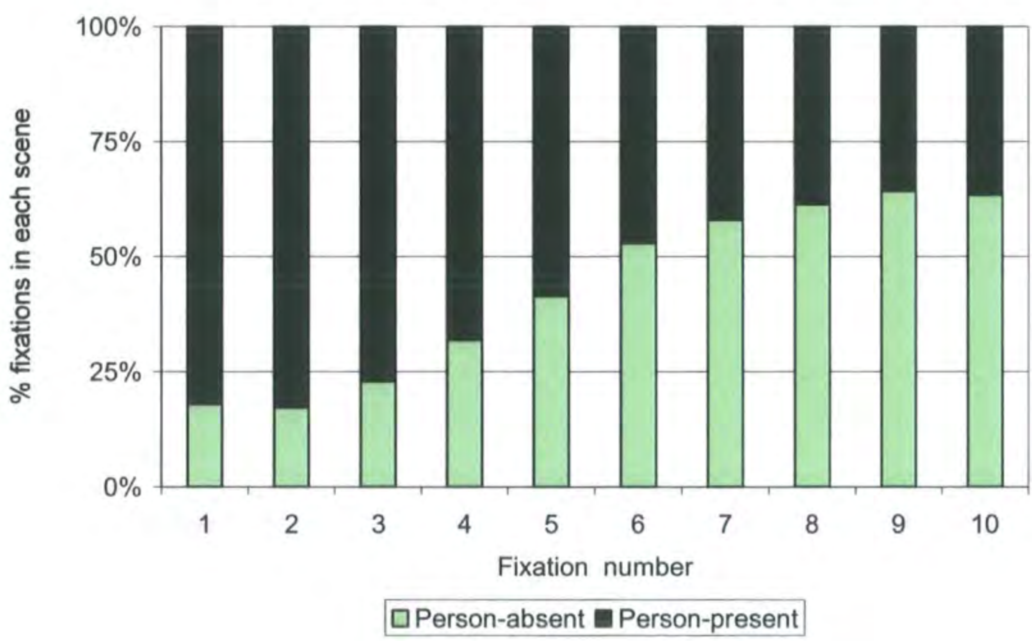


Figure 5.13a: The location of fixations over time by Scene for the gender-discrimination condition – ASD data

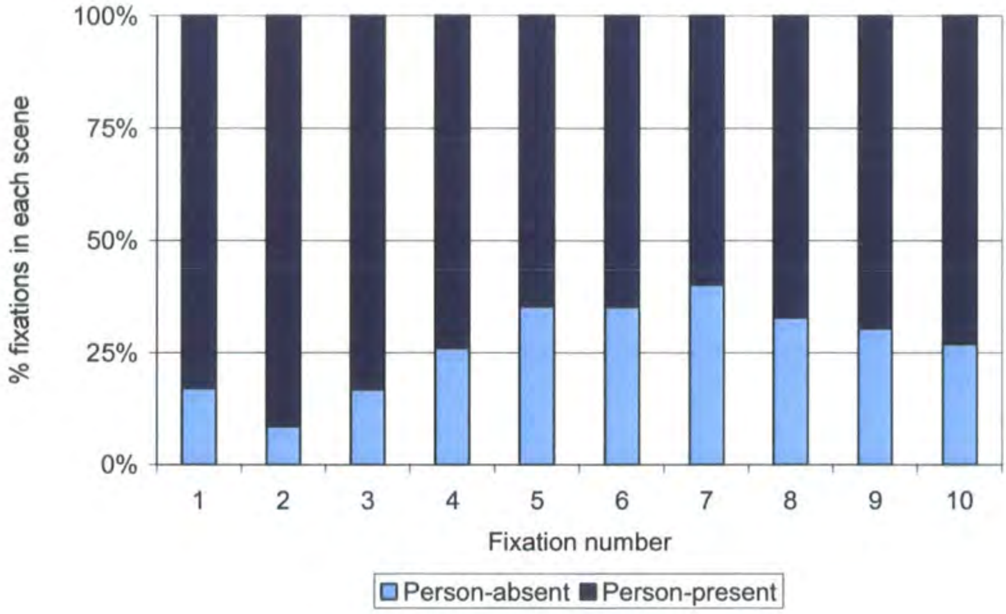
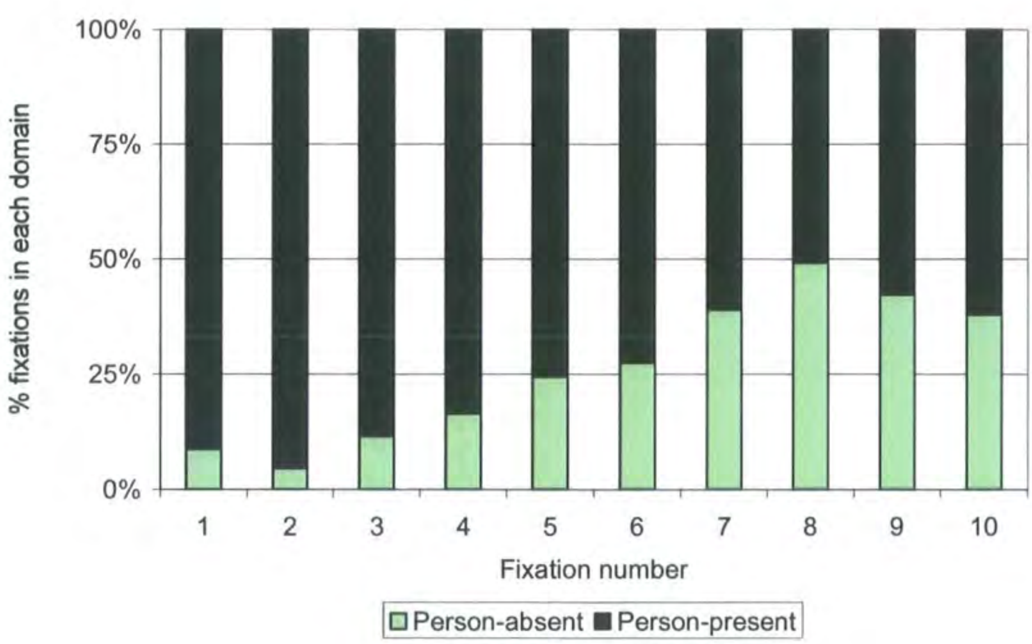


Figure 5.13b: The location of fixations over time by Scene for the gender-discrimination condition – TD data



group, whose preference for the PP scene does not disappear until the 5th fixation, though they also go on to show more of a preference for the PA scene in the final fixations (8, 9 & 10). Those graphs indicate that while both groups show similar viewing time to each Scene overall, it is distributed differently over time.

Figures 5.13a and 5.13b show the same data for the gender-discrimination condition. In both graphs we see a very strong bias to fixate the PP scene, again from the very first fixation, which persists across time. Both groups show a slight reduction in preference over time, with virtually no bias around the 7th and 8th fixations, but the two group patterns are largely the same.

A similar analysis of fixations over time to the PP Scene sub-domains of Person and PP background is illustrated in Figures 5.14a and 5.14b. In this case, as we know from the analysis of first fixations above, the TD group show a bias to fixate the Person rather than the background right from the first fixation, but the ASD group do not. However these graphs show that the ASD group do seem to 'catch up' by the second fixation, where almost 75% of fixations in the PP scene are on the Person. Thereafter, the two groups' fixation distributions look very similar, both hovering around a fifty-fifty split between fixations on the PP Background and the Person, but with a general tendency to look more at the background.

This analysis in the gender-discrimination condition, illustrated in Figures 5.15a and 5.15b, reveals slightly more group difference. Both groups show a strong bias to fixate the Person for the first four or five fixations. However after this, the TD bias largely persists, while the ASD group begin to split their fixations more evenly between the Person and PP Background domains.

Finally, the same analysis was done on a comparison of looking at the Body and Face domains. In the free-viewing condition, depicted in Figures 5.16a and 5.16b, both groups make most first fixations on the Body, but look more to the Face by the second fixation. However for

Figure 5.14a: The location of fixations over time within the PP scene, for the free-viewing condition – ASD data

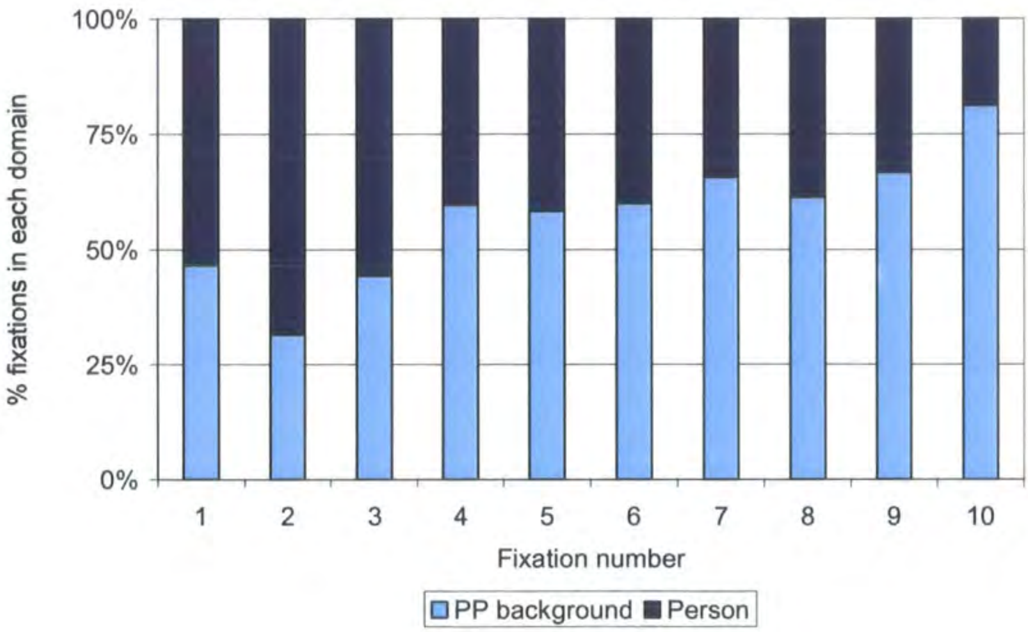


Figure 5.14b: The location of fixations over time within the PP scene, for the free-viewing condition – TD data

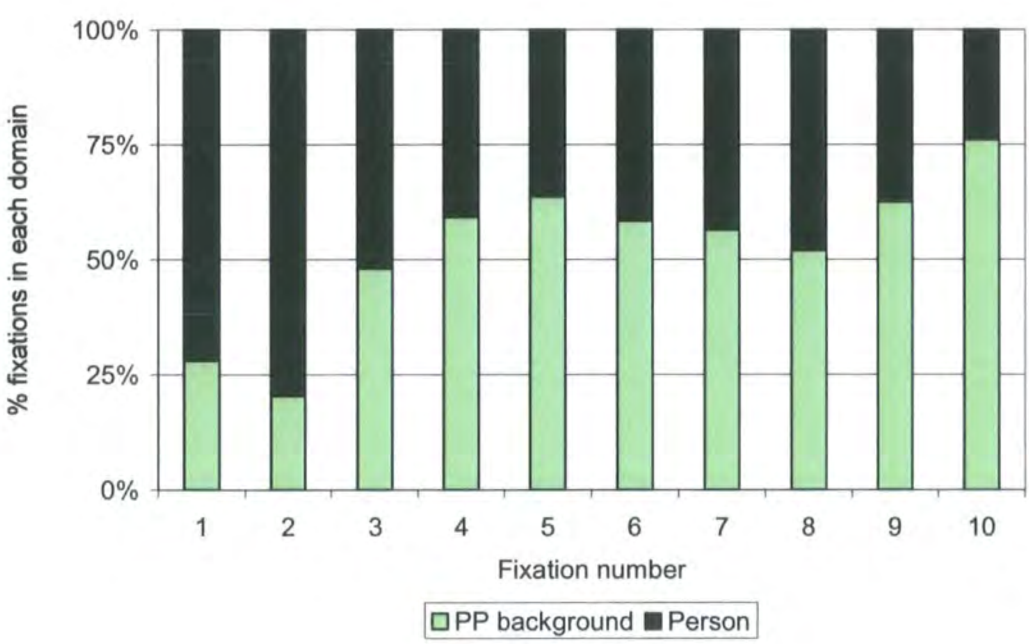


Figure 5.15a: The location of fixations over time within the PP scene, for the gender-discrimination condition – ASD data

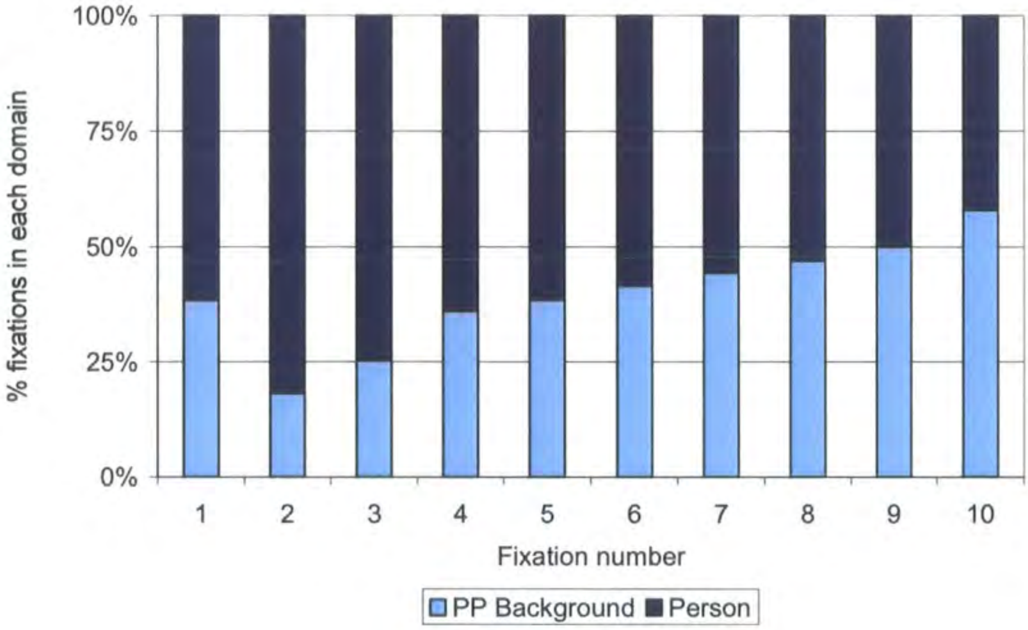
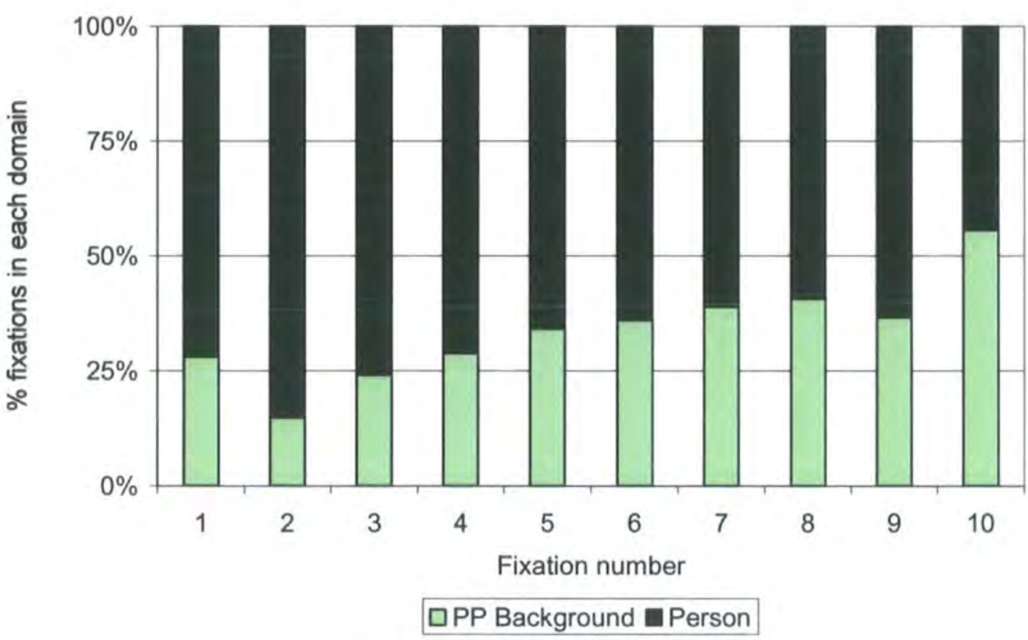


Figure 5.15b: The location of fixations over time within the PP scene, for the gender-discrimination condition – TD data



the ASD group only, this increase in looking to the Face at fixation two does not reach to a full-blown preference for looking at the face (i.e. more than 50% of fixations on the Face).

Thereafter, both groups tend to look more at the Body, though the number of fixations on the Face does not drop below 25% except in the 10th fixation, for the ASD group. This difference at the end of the participants' viewing time is unlikely to be significant, since not all participants made as many as ten fixations during the three-second viewing period.

Figures 5.17a and 5.17b depict the same data from the gender-discrimination condition. Once again, the TD group show a bias to fixate the Face over the Body in the second fixation, while the ASD group show only a limited bias, later on, in the third fixation. Thereafter, as in the free-viewing condition, most fixations are on the Body though throughout a significant percentage are directed to the Face by both groups.

5.3i Summary

Eye-tracking data afford many opportunities for analysis, although the richness of the data obtained can be confusing. However the results described above can be synthesised into a relatively simple account of social attention in people with and without ASD. All analyses show a strong bias for the TD group to look at the person-present scene and particularly the Person themselves. This bias appears in the first fixation and persists throughout the viewing time. The ASD group differ from the TD group only at a subtle level: they too show a bias to fixate the person-present scene, though they spend slightly less time looking at the Body and Face domains than the TD participants. Their preference for social information is either less strong, or does not appear at all in the first fixation, indicating a reduced attentional priority for social elements of a scene. Observation of the pattern of fixations over time also suggests that people with ASD may be less persistent in their attention to social elements of a scene over time. The ASD group also do not show spontaneous gaze-following in their fixation of the Object domain

Figure 5.16a: The location of fixations over time within the Person, for the free-viewing condition – ASD data

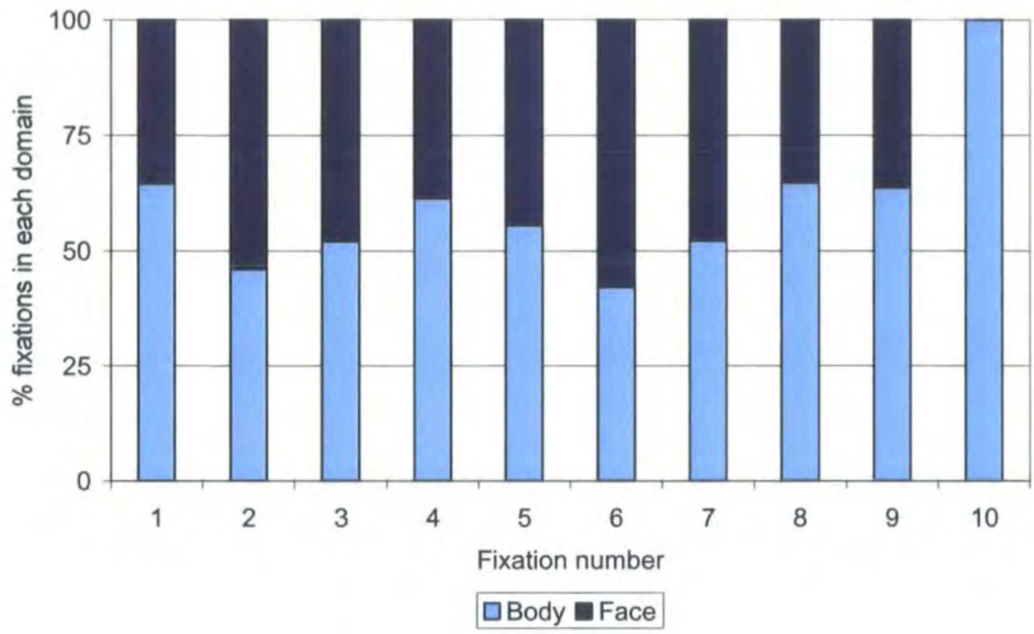


Figure 5.16b: The location of fixations over time within the Person, for the free-viewing condition – TD data

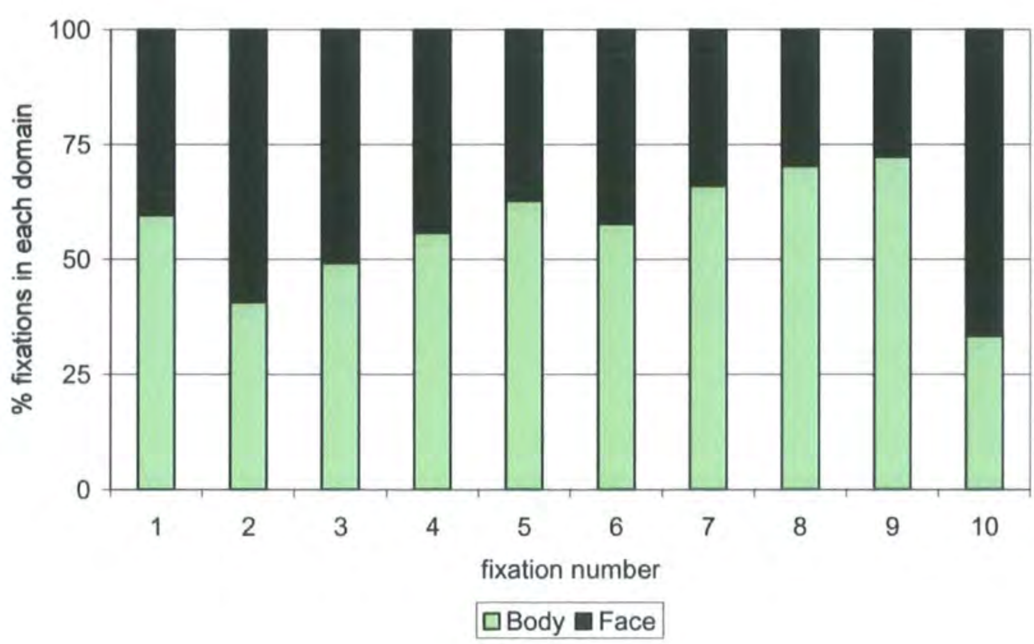


Figure 5.17a: The location of fixations over time within the Person, for the gender-discrimination condition – ASD data

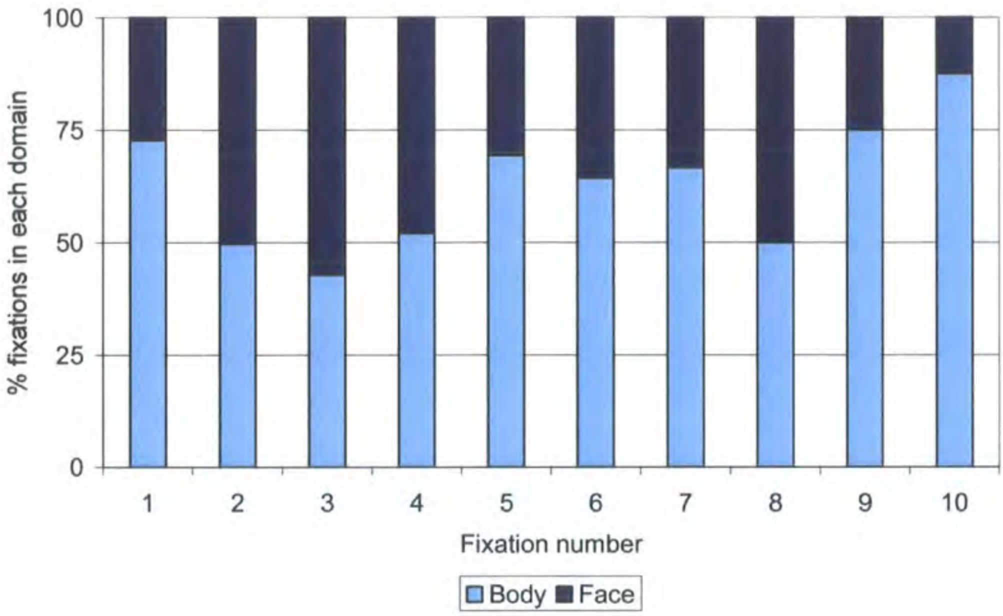
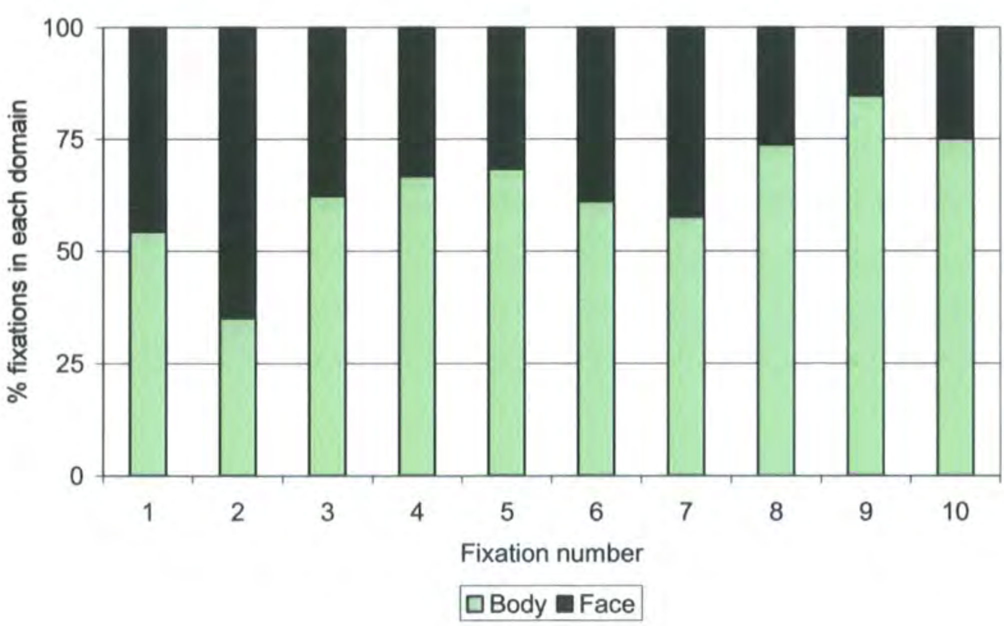


Figure 5.17b: The location of fixations over time within the Person, for the gender-discrimination condition – TD data



in the free-viewing condition; a behaviour which is present in the TD group. They do fixate the object in the gender-discrimination condition, perhaps using it as a clue to gender or because their attention has already been externally directed to the person depicted.

5.4 Discussion

5.4a Group Differences in Social Attentional Bias

The current study used a novel preferential-looking task to investigate how attention is distributed across social and non-social scenes, and social and non-social elements within a scene. The task was combined with an eye-tracking methodology which produced a rich data set, with potential to investigate very subtle differences between groups. Moreover, the method permitted spontaneous, naturalistic attention, while simultaneously incorporating precise measurement. For these reasons, and despite the fact the preceding studies presented in this thesis had found no differences between groups, it was predicted that this study would reveal a reduced social attentional bias in people with ASD compared to their TD peers.

The TD group showed a strong bias to fixate the person-present scene, and particularly the Person themselves, a bias which was particularly notable when controlling for domain size. In fact, a domain-relative comparison of looking to the person-present background and the entire person-absent scene showed that the difference between time spent looking at these two scenes was driven by the time spent looking at the Person. Furthermore, the bias to fixate preferentially the person-present scene persisted for about half of the viewing period, or longer in the gender-discrimination condition. These data replicate the findings of the previous chapter in revealing a strong preference, rapid priority and persistent bias to fixate social information (i.e. people) even when non-social visual stimulation is also available.

On a gross level, the ASD group show a similar viewing pattern to their TD peers, also preferentially looking at the person-present, rather than the person-absent scene, but this preference is less marked at the first fixation. They also show no preference to look at the Person in preference to the background of the person-present scene at the first fixation. Where the ASD group do have preferences for social information, these do not appear from the first fixation, and do not appear to persist over time as strongly as the TD group's biases.

While looking at the Person, TD participants split their attention fairly equally between the Body and the Face, but make faster first saccades to the Body. This is presumably because the Body, being larger and often with stronger low-level visual properties (colour, contrast) than the Face, is easier to detect in peripheral vision. When domain-size is accounted for we can see that a disproportionately large amount of time is spent looking at the Face. Within the Face, time is distributed fairly equally between looking at the Eye region and the rest of the Face, when domain size is accounted for. These biases are all replicated in the ASD group, indicating that although participants with ASD may look at the person less overall, when they do so their attention is distributed among their features in a typical manner.

This finding corresponds with some evidence of normal attention to facial regions in autism (Bar-Haim *et al.*, 2006; van der Geest, Kemner, Verbaten *et al.*, 2002). However, a more common finding is that people with ASD do not process faces normally (Sasson, 2006) to the extent that their fixations on faces are atypical (Pelphrey *et al.*, 2002; Spezio *et al.*, 2007). Our data are not sufficient to identify the reason for differences between these findings, since our stimuli were not suitable for a detailed analysis of fixations on different facial regions. Nevertheless, they do reinforce the importance of studying social attention in the presence of non-social information, which is also available for attention, since people with ASD may show particular atypicalities in directing attention to social stimuli, if not in fixations within that stimulus.

5.4b Evidence for Gaze-Following

TD participants show a tendency to look at the object being fixated by the person in the scene, in the free-viewing condition only. This finding replicates data from a preceding study with a TD sample [see section 4.4a, page 132] and indicates that a form of gaze-following behaviour is occurring in response to these static stimuli; participants are motivated to discover the object of the attention of the person depicted, even though they cannot actively share attention with them. The ASD group only show evidence of gaze-following behaviour in the gender-discrimination condition, and even here they do not fixate the viewing-cone or object more than would be predicted by a random viewing pattern. They may fixate the object in the gender-discrimination condition because the person has already been highlighted by the task instruction, or even because they think the object can provide a clue to the person's gender. For example, if following gender stereotypes one might infer that someone looking at a washing machine, while putting clothing into it, was female. Unfortunately, these data cannot distinguish between these two interpretations, but nevertheless, these findings provide evidence that the drive to follow gaze is absent or weak in this group, despite their age and high-functioning status.

5.4c The Effect of Task Instruction

There were some main effects of viewing condition and interactions between condition and domain. All of these supported evidence from the preceding study [see section 4.4a, page 132] which found a strong effect of task instruction on viewing patterns. The instruction to identify the person's gender increases viewing of the PP scene and particularly of the relevant person-domains, from the first fixation. This instruction had a similar effect on both groups of participants, and thus the prediction that our two groups of participants would show larger differences in the free-viewing condition than in the gender-discrimination condition, resulting in two-way interactions between condition and group, was not upheld. This suggests that the

ASD group's slightly reduced preference for looking at Body and Face domains, in particular from the first fixation, was not overcome by the instruction to identify gender.

The analysis of fixations over time indicates that the ASD group were quicker to take their gaze away from the Person and fixate elsewhere in the gender-discrimination condition. This could be interpreted as showing an aversion to People, but this is not compatible with results from the free-viewing condition where the group with ASD fixated the Person on average over 25% of the time. Instead, the attention of participants with ASD was perhaps not held by the Person, and having correctly identified their gender, they were more keen than the TD group to investigate the other items visible in the stimulus.

5.4d Interpreting First Saccade Latencies

The analysis of first saccade latencies provides some potentially intriguing evidence for group differences. The difficulty in interpreting these data is that very short and very long saccade latencies can both indicate a lack of preference for the target stimulus. Very short saccade latencies can result from the saccade having been programmed before the stimulus appeared, termed an 'anticipatory' saccade (Wenban-Smith & Findlay, 1991). While all first saccades with latencies of less than 80ms (or more than 500ms), were excluded from the analysis, latencies less than about 150ms fall in an area of doubt, where the saccade may or may not have been anticipatory. These very short latencies could indicate a case where the participant has rapidly and accurately identified a target, or could be anticipatory.

Very long latencies could also be indicative of three different states in the viewer: one, 'dithering' over where to look, either caused by a lack of preference or an inability to find the desired target (e.g. a person in the gender-discrimination condition); two, a long programming time due to a lengthy but successful search for a target; three, extensive processing of the currently fixated position. The latter cause can be discounted in this case, since the first fixation upon stimulus onset was almost always on the central black bar. It is unlikely that processing of this uninformative region would have delayed an eye-movement to a different part of the scene.

Of the other two possible explanations, the first would result in an 'unsuccessful fixation', the second in a 'successful' one. It is hard to distinguish between these two states, since we cannot identify 'successful saccades'. For example, in the free-viewing condition no target was imposed by the instructions, and what might be a successful saccade for one person (e.g. landing on a face) would be unsuccessful for another, who is, for instance, more interested in the computer in the background. Even in the gender-discrimination condition 'success' is a moot point – is the Body or the Face the best place to start when identifying gender? It therefore makes sense to interpret the group differences in first saccade latency according to the findings from other measures, summarised above.

First, in absolute latencies, the ASD group made faster first saccades in the gender-discrimination than in the free-viewing condition, while the TD group showed no such difference. The gender-discrimination condition was always presented second. Thus, one possibility is that the ASD group had shorter latencies in the gender-discrimination condition because they had become more confident with the task over time. This interpretation is supported by the fact that the pattern of data shows that the ASD group had longer latencies in the free-viewing condition, and 'caught up' with the TD group in the gender-discrimination condition. A warm-up session on the eye-tracker, which preceded collection of experimental data was intended to eliminate this kind of effect, but may not have been fully effective.

Another possibility is that if the ASD participants had no strong preference in the free-viewing condition, this could have led to longer first saccade latencies in this condition only. The imposition of a goal in the gender-discrimination condition would then have eliminated 'dithering' in first saccade programming, reducing first saccade latencies. The TD group's similar length latencies for both conditions suggest that this group were less aided by the task instruction. This could be taken as indicating that the TD group had a stronger internal goal, presumably to fixate the person, which minimised dithering even in the free-viewing condition. Unfortunately, our data do not permit a distinction to be made between these two explanations, and first saccade latencies could have been affected by both.

Recall that subsequent analyses were done on first saccade latencies relative to each participant's own average. Therefore, these conclusions do not apply to absolute saccade programming time, but instead reflect saccades being made either faster or slower than the norm. In looking to the person-absent scene only, both groups showed differences in first saccade speed between conditions, but latencies for the person-present scene were not affected by condition. In the ASD group, person-absent scene latencies were faster for the free-viewing condition, and slower for the gender-discrimination condition, relative to person-present latencies. In contrast, the TD group were slower in the free-viewing condition and faster in the gender-discrimination condition.

First, for both groups, relative first saccade latencies to the person-present scene were close to zero, representing average latencies for each group. Latencies for the person-absent scene can therefore be considered relative to this 'normal' response. The person-absent scene latencies are interpreted as reflecting errors, since neither group showed a preference for the person-absent scene in percentage of first fixations. Moreover, these latencies showed very great variability within each group, supporting the idea that they represent errors rather than a fixation-preference. Therefore fast saccades represent a larger number of anticipatory saccades than usual, and slow first saccades represent trials when the participant 'dithered' before making an eye-movement, because no clear preference was rapidly identified. According to this interpretation, the TD participants dithered more in the free-viewing condition and made more anticipatory errors in the gender-discrimination condition. The ASD group had the opposite pattern, dithering more in the gender-discrimination condition and making more anticipatory saccades in the free-viewing condition.

5.4e Conclusions

The findings from this preferential-looking task, with eye-tracking data, have illustrated subtle differences in social attention between the two groups. This task builds on the work of the previous chapters in establishing a method for assessing social attention which uses static but realistic stimuli and combines experimental design and rigorous measurement with spontaneous, naturalistic attentional processes. Even in the very high-functioning autistic sample who took part in this study, we can see evidence of marginally weaker social attention preferences, with less priority for social information and less persistence in social attention over time. This supports the suggestion from the developmental literature that poor social attention may contribute to both the development and maintenance of deficits in social cognitive and social attentional behaviours in people with ASD. While we cannot know what this sample's preferences were as children, it is plausible to suggest that the hints of social attention difficulties we see today were once more significant and perhaps played a large role in determining the atypical developmental pathway that they followed.

Nevertheless, within a social stimulus (namely a person) both TD and ASD participants showed a similar hierarchy of attention to increasingly socially informative regions, when domain-size was taken into account. These results emphasise the need to investigate attention to different kinds of social information, presented in a realistic context. It is also possible that individual differences play a part in directing attention to different kinds of social stimulus. If we are to gain a fuller understanding of social attention as a construct, and its manifestation in TD adults and those with ASD, these questions must be addressed.

6. The Nature of Social Attention: Comparing Tasks and Contrasting Individuals

6.1 Introduction

So far, this thesis has introduced the need to further investigate the nature of social attention, both as a construct and as a determinant of behaviour in TD adults and individuals with ASD. Three novel experiments each presented differing types of social information in different methodological formats. These have indicated that people with ASD seem to have a largely normal attentional preference for social information, even when other non-social stimuli are also available in the display. Some subtle atypicalities have been found, indicating that people with ASD do not have a strong preference for social information at the first fixation. The wide variety of methods and stimuli used mean that a new analysis is required to integrate these findings. The current chapter will first review the methodological decisions made in this thesis so far and then introduce aims for a new and final analysis of behaviours thought to index social attention.

6.1a Methods for the Study of Social Attention in Adults

Throughout, this investigation has sought to understand social attention by discovering what biases are apparent when viewing complex visual scenes, for both TD adults and those with ASD. This has involved the development of three novel methods, since existing paradigms were considered unsuitable for a variety of reasons. Some studies are not appropriate for use with able and intelligent young adults – for example testing orienting to social sounds by having an experimenter name-call or clap (Dawson *et al.*, 2004) would likely have provoked enquiries and confusion in our participants as well as the likelihood of behaviour at ceiling. Other studies use stimuli whose complexity may provide additional obstacles to processing by people with

ASD. In particular, Klin and colleagues (Klin *et al.*, 2002b) used moving images with a simultaneous soundtrack and editing techniques such as film cuts. Differences between participant groups in this study may not have reflected a straightforward social attention difficulty, since the task also involved multi-sensory and movement processing, both of which are thought to be disordered in people with ASD (Iarocci & McDonald, 2006; Milne *et al.*, 2005). Finally, other experiments bypass the assessment of basic attention to social information, either by presenting social stimuli in isolation (e.g. Bar-Haim *et al.*, 2006; van der Geest, Kemner, Verbaten *et al.*, 2002) or by assessing the judgements of mental state, emotion, identity, and gender which occur once attention is already focused on a social stimulus (Back *et al.*, 2007; Baron-Cohen, Wheelwright *et al.*, 1997; Grossman, Klin, Carter, & Volkmar, 2000; Hefter *et al.*, 2006; Strauss *et al.*, 2007).

One goal of the current investigation was to find ways of studying social attention which used tasks appropriate to the age and ability of the participants involved, but measured social attention in a basic form. The definition of this basic social attention is a focus on social elements of the environment, to the exclusion of other, non-social stimuli. This definition emphasises the importance of presenting social information in a realistic context, and incorporating non-social stimuli into the display. At the same time, we wanted to use stimuli which did not required processing of multi-sensory information or motion. The solution was to present social information in a naturalistic but static visual scene. All three methods developed in this thesis use this kind of stimulus.

On the surface, this unity in methodology seems to imply that all three tasks should have assessed a single form of social attention. However, our exploration of the meaning of 'social information' [for example, see section 2.2c, page 43], has shown that a wide range of stimuli constitute social information. In particular, we have consistently referred to a distinction between attention to people (who, as social agents, may be considered inherently social), and attention to specifically social aspects of people. For example, attention to a person's body and clothing versus attention to the face and direction of gaze. These different types of social stimulus can be conceptualised as forming a hierarchy of social information, according to degree of social informativeness. This hierarchy may vary across circumstances, for example, depending on what information an individual wants to extract.

If we wish to achieve the goal of this investigation, and make a genuine contribution to our understanding of the meaning and manifestation of social attention in both typical adults and people with ASD, it is important to compare the findings of our different tasks. This comparison can provide a way of looking for evidence of a single, social attention construct which influences behaviours in a variety of experimental (and potentially real-life) settings.

6.1b Individual Differences and Social Attention

The participants with ASD involved throughout this thesis represent only a subset of the autistic population: all have normal range IQs, excellent language, and are in specialist education at a college which explicitly teaches social skills including the use of eye-contact. In fact, these participants had a great deal of insight into both their condition and the experiments in which they took part. For example, one autistic participant in the social change detection study said that there might be a problem with the experiment because a lot of the changes were in the eye-area and people with autism tend not to look at eyes very much! Given the ongoing debate about the suitability of current diagnostic categories within the autistic spectrum (Leekam, 2007; Mayes & Calhoun, 2003) it is crucial to tackle the issue of individual differences head on. The studies presented in this thesis have consistently looked for individual differences in responding. These new analyses will take this a step further by integrating data from all experiments, and also incorporate some symptom profile information, including diagnostic category and details of co-morbid conditions.

The analyses in this section focus on individual differences not only within but also across diagnostic boundaries, to address, to some extent, recent debate about the inadequacy of traditional group-matching assessments for furthering understanding of autism (Burack, 2004). In most studies in this thesis, participants have been matched on basic descriptive variables at an appropriate alpha-level (Mervis & Klein-Tasman, 2004). The Wechsler abbreviated Scales of Intelligence (Wechsler, 1999) have been used to provide verbal, performance and full-scale IQ scores. This has been demonstrated to be a suitable tool for matching participants with ASD (Minshew, Turner, & Goldstein, 2005), though Wechsler profiles can be uneven in ASD (Happe, 1994). Moreover, matching strategies such as these have been questioned (Burack, Iarocci, Flanagan, & Bowler, 2004; Jarrold & Brock, 2004) in part because of the heterogeneity among people on the autistic spectrum. We hope this new analysis goes some way to providing a more complete understanding of group differences, and similarities, in our research.

6.1c Aims and Predictions

It is the goal of this chapter to take a more detailed investigation of our existing data in order to investigate a number of questions. In first place, how do these three new tasks – free-description, social change detection and preferential-looking - relate to each other? Are they underpinned by the same skills or do they involve different aspects or types of social attention? Does IQ or any other basic skill seem to make a contribution or is social attention an independent quality? This section of the analysis focuses on what data from our tasks can reveal about the nature of social attention.

The second part of the analysis will focus on what our tasks can reveal about the nature of ASD, in contrast to typical development. It will investigate variation among both TD and ASD participants, to see whether individuals, who do not always differ when compared in diagnostic groups, show different patterns of responding across tasks. One approach is to try to use the combined results of our tasks to accurately distinguish between individuals with and without a diagnosis of ASD. This section will also contain a case study of a single individual with ASD, to provide a more in-depth assessment of social attention skills and their relationship to symptom presentation and other characteristics.

6.2 Method

6.2a Participants.

Some participants had already taken part in all or most of the tasks presented here, as mentioned in preceding chapters. Others, marked by a star in Tables 6.1 and 6.2, were recruited explicitly for this analysis.

Twelve participants with ASD were included in these analyses. They had a mean age of 18 years (range 17-22 years) and a mean full-scale IQ of 93.58 (range 69-118). All these participants attended a specialist college in the Sunderland area for which a diagnosis of autism or AS was a criterion of admission. All had been diagnosed by experienced clinicians, (a psychiatrist or clinical psychologist employed by the National Health Service), working in specialised centres. These diagnoses had been confirmed, upon each participant's admission to the college, by a second clinical psychologist.

Participants completed a short a self-report measure of level of autistic characteristics, the Autism Quotient Questionnaire (Baron-Cohen, Wheelwright, Skinner *et al.*, 2001). Scores on this self-report measure for our sample were not above the suggested cut-off for autism, of 32, though it must be noted that this is not a diagnostic tool. The low scores in our group are partially attributed to a lack of self-awareness on the part of our participants with ASD, which produced often inaccurate responses to the questionnaire items from the point of view of the experimenter. For example, for the item "*I enjoy social chit chat*" many responded '*agree strongly*' though the experimenter had not observed this in action! The scores from participants with ASD on this questionnaire were still higher than those of the TD participants. The score is included in this assessment to provide a way of relating degree of autistic traits (albeit self-reported) across both participant groups, to task performance, and it has been used successfully in this way before (e.g. Bayliss & Tipper, 2005).

In previous studies presented here, we were unable to access records at the college to confirm the exact diagnostic category: Asperger's syndrome or otherwise. However in this case further information was gathered and diagnostic details are presented in Table 6.1. Participants all have a diagnosis of Asperger's syndrome, except two whose diagnoses are of autism spectrum disorder (ASD) and pervasive developmental disorder, not otherwise specified (PDD-NOS) respectively. In addition, three have co-morbid conditions: Tourette's syndrome; attention deficit/hyperactivity disorder; dyslexia and dyspraxia. Of these, ADHD is most likely to have an impact on results since this disorder affects domain-general attentional processes. In addition, there is evidence suggesting that people with dyslexia may be worse at change detection tasks (Rutkowski *et al.*, 2003). The question of whether any of these co-morbid conditions influences our results will be addressed in an analysis of outlying participants.

In addition, a comparison group of fourteen typically-developed (TD) individuals were included in the analysis. They had a mean age of 22 years (range 17-48) and a mean full-scale IQ of 110.60 (range 97-120). These participants were recruited from higher-education colleges in the Durham area, and also from among Durham University clerical staff and students. Exact matching between groups was not attempted because the planned analysis will investigate individual differences and patterns of response, rather than simply contrasting group performance. Attempts were made however, to find a range of ages and abilities across both groups in order to provide greater variation for investigation. Descriptive data for these individuals is presented in Table 6.2, including a note regarding their highest educational achievement level.

Table 6.1: Descriptive data for people with ASD participating in cross-task analyses

Name	Gender	Age	Diagnosis	Fullscale IQ	Verbal IQ	Performance IQ	Autism Quotient
CD*	Female	20	AS	118	126	106	25
JB*	Male	17	AS, ADHD	96	92	99	32
KL	Female	17	AS	88	78	102	20
LW	Male	17	AS	105	89	120	21
MR*	Male	17	AS	116	119	108	21
MW*	Male	17	AS	69	71	73	26
PB*	Male	17	AS	87	86	93	16
PG*	Male	18	PDD-NOS	85	78	95	31
PS	Male	20	ASD	95	83	109	14
PS2	Male	18	AS	95	91	99	22
SP	Male	22	AS, dyspraxia, dyslexia	85	89	84	23
SB	Male	18	AS, Tourette's	84	95	76	14

Table 6.2: Descriptive data for TD people participating in cross-task analyses

Name	Gender	Age	Education	Fullscale IQ	Verbal IQ	Performance IQ	Autism Quotient
DM	Male	18	FE college	113	114	108	15
CB*	Female	17	FE college	109	108	109	19
DW*	Male	17	FE college	114	115	109	13
EB*	Female	26	FE college	102	89	117	17
HT*	Male	20	University	112	114	107	18
IT*	Male	23	FE college	111	109	109	16
KG	Male	17	FE college	97	101	105	17
MO	Male	19	FE college	103	100	105	23
OM*	Male	19	University	132	126	129	23
RR*	Male	24	FE college	106	96	116	12
SO	Male	17	FE college	106	107	103	13
TB*	Male	20	University	116	118	110	17
TM*	Male	48	FE college	108	99	118	13
VH*	Female	22	University	120	115	120	10

6.2b Materials

Materials were identical to those described in preceding chapters and an example of each type of stimulus is depicted in Figure 6.1. These stimuli are briefly described again below.

Free description (FD) stimuli were colour photographs. These depicted single people or groups of people engaged in social situations –interacting and/or exhibiting emotion. A coding scheme was constructed to rate transcribed verbal descriptions of these scenes. This coding scheme is included in Appendix 1b [see section 8.2, page 267].

Social change detection (SCD) stimuli consisted of pairs of colour photographs of complex scenes. Each pair featured a single small change. Changes fell into three categories: social changes to eye-gaze direction, control changes to spectacles and filler changes to small objects such as the presence or absence of a badge on a t-shirt.

Preferential-looking (PL) stimuli consisted of pairs of images, one depicting a person (person-present or PP) and one depicting an empty room or garden (person-absent or PA).

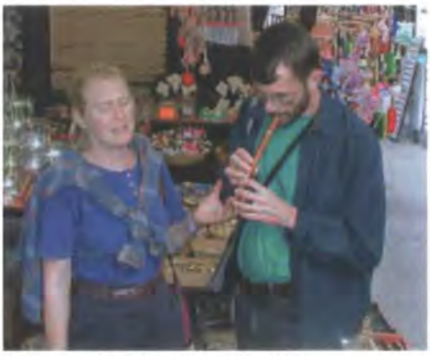
6.2c Design

The study is an exploratory analysis of existing data sets. The design takes three different formats. One is a task-wise analysis looking for relationships between tasks across TD and across all participants. Next, an analysis of participants investigates individual differences. Finally, there will be a short case-study of one autistic participant for whom clinical records have been secured. All analyses incorporate summary statistics to represent the social attention element of each task.

6.2d Procedure

Some participants were involved in these studies over a number of years, and they participated in each experimental task during a separate session in quiet room at their school or at Durham University. However, most (marked with a star in Tables 6.1 and 6.2) were newly

Figure 6.1: Sample stimuli from the three social attention assessments included in this analysis



1a: Sample stimulus from the free-description task

1b: Sample stimulus from the social change detection task, depicting a 'spectacles' change

1c: Sample stimulus from the preferential-looking task, with the PP scene on the left

recruited for this analysis alone and were not part of the samples in the preceding chapters. They participated in the experimental tasks during a single session of varying length.

These participants undertook all experimental tasks in a fixed order, during a single two hour session. The events in the session were structured as follows: information sheet and informed participant consent; preferential-looking task (free-viewing condition followed by gender-discrimination condition); autism quotient questionnaire (Baron-Cohen, Wheelwright, Skinner *et al.*, 2001); ten minute break; social change detection task; administration of Wechsler abbreviated Scales of Intelligence (Wechsler, 1999); ten-minute break; free-description task; debrief and payment. For individual methods please refer to the relevant chapters as listed in Table 6.3.

The fixed order of tasks was designed first to identify those potential participants who could not be successfully tracked in the preferential-looking task. In addition, the order of tasks was chosen to separate experimental tasks and minimise interference between tasks. Participants were encouraged to take short breaks between tasks and the experimenter debriefed them on all tasks at the end of the session.

Table 6.3: Participant numbers for each individual task, and cross-references to full methodological details

Task	# TD	# ASD	Cross-reference for methodology
Free-description (FD)	13	9	See section 2.3, page 51
Social change detection (SCD)	14	12	See section 3.5, page 83
Preferential-looking (PL)	11	9	See section 5.2, page 141

6.3 Results

6.3a Missing Data

It was not possible to secure complete data sets for all participants in every study. Therefore the number of participants for whom there are data for each study is shown in Table 6.3. Descriptive data (age, IQ, AQ etc) were available for all participants.

6.3b Replicating Experimental Data

Before embarking on an analysis of the relationships between tasks and of individual differences, it was necessary to check that these data reflected the findings in the original experimental analyses of each task. If this were not the case, it would not be possible to extrapolate from the current cross-task analysis to draw conclusions about the tasks or about the wider population.

The FD data replicate the main findings, with all participants producing more phrases referring to people in the first half of each description than in the second half, but no differences in the distribution of social phrases. There is one new group difference in these data, $F(1, 20) = 5.38$, $p=.031$, showing that the ASD group spend a larger percentage of their phrases talking about people than the TD group: TD mean = 54%, SD = 5.2; ASD mean = 61%, SD = 10.5.

For the SCD task, the expected main effects of change-type are present. The only notable diversion from the original results is that the social change detection study here produces a small main effect of group, $F(1,24) = 5.83$, $p=.024$, indicating that the ASD group have slower responses to all experimental changes (eye-gaze direction and spectacles) than the TD group: TD mean = 2466ms, SD = 846; ASD mean = 3100ms, SD = 784. This corresponds to the finding in the main experimental study that the ASD group were overall less accurate at detecting all changes than the TD group. This group difference was thought to reflect a difficulty with the visuo-motor coordination of the response required [see section 3.7b, page 100] though another possibility is that this group difference could reflect a problem shifting attention between different components on the scene.

For the PL task the significant effects of domain are reproduced here, with the data indicating a bias to fixate the person-present scene, and in particular the person, both over time and on the first fixation. As in the main experimental study, the two groups differ only subtly, with participants with ASD showing a lesser priority for social information at the first fixation.

This analysis of the major elements of each task indicates that the current data set is a good model for each larger experimental data set.

6.3c Summary Statistics

The initial analysis aims to find relationships between tasks. However each task produced a series of measures representing difference aspects of that task. These measures are described in Appendix 4 [see section 11, page 277], together with full calculations for each summary score. To permit comparison between them, it was necessary to combine these measures into summary scores for each task.

The FD task uniquely did not present control stimuli. Therefore social attention is indexed by the percentage of phrases referring to social information, across all descriptions. In addition, the priority given to social information is indexed by the percentage of first-placed phrases referring to social information.

The SCD task produced a measure of the change detection advantage to be gained from having a bias to attend to social information. This was calculated by subtracting response time to eye-gaze direction changes from spectacles response time [see section 3.6d, page 95]. A higher number indicates a greater effect of social attention bias on change detection.

The PL task produced the largest output of different scores and so it is particularly challenging to adequately summarise data from this study into one or two variables. It was decided that two measures should be developed, as for the FD task, one representing social attention over time, and one representing the priority given to social information. Social information is principally embodied by the person depicted (the PP scene is only social to the extent that it contains a person) and therefore social attention is defined by the difference between viewing time to the Person versus the PP scene Background. Likewise social priority is represented by the difference in the percentage of first fixations on the Person versus the PP scene Background. Again, the higher each summary score, the greater the social attention implied. All of these measures are taken from the free-viewing condition only, to give an assessment of spontaneous rather than task-directed processes.

To recap, the summary statistics calculated are as follows:

- FD descriptors: a measure of the proportion of phrases devoted to social information when describing a scene.
- FD priority: a measure of the proportion of opening phrases in a description, devoted to social information.
- SCD advantage: a measure of the degree to which participants can use social information to enhance chance detection speed.
- PL viewing time: a measure of the attentional preference given to social over background items in a scene.
- PL first fixation: a measure of the attentional priority given to social over background items in a scene.

6.3d Correlations Between Tasks

The first stage of this exploratory analysis concerns how these new tasks relate to each other. The first prediction is that these three tasks, all of which purport to assess social attention, should show evidence for an underlying social attention factor. To investigate this possibility, correlations were sought between the summary scores for these tasks (see Table 6.4). All of these scores should be higher when a large social attention bias is present, therefore one-tailed significance tests only were sought. A Bonferroni adjustment was applied, to account for the high number of comparisons being made, such that an alpha-level of $p=.005$ ($p=.05 \div 10$ comparisons $= 0.005$) was required for significance.

When all participants' data were analysed together, no significant correlations appeared, according to the adjusted alpha-level given above. The two correlations which are closest to significance, highlighted in grey in Table 6.4, are between PL viewing time and PL first fixation and between FD descriptors and FD priority. These are both correlations of two measures within a single task, reinforcing the conclusion that the tasks are not highly related to each other.

Table 6.4: Correlation matrix for social attention task summary scores, across all participants

		FD descriptors	FD priority	SCD advantage	PL viewing time	PL first fixations
FD descriptors	Pearson's r		.512	.277	-.220	.160
	Significance		.007	.106	.198	.269
FD priority	Pearson's r			-.093	.078	.312
	Significance			.340	.382	.111
SCD advantage	Pearson's r				-.082	.105
	Significance				.365	.329
PL viewing time	Pearson's r					.456
	Significance					.022

The analysis was repeated on a split file, according to diagnostic group, to see whether different relationships between the tasks appeared in TD and ASD responses. The TD group produced a correlation between FD descriptors and PL first fixations, Pearson's r = .848, p=.001. This indicates that the proportion of first fixations made to a social stimulus relative to the rest of the scene is related to the proportion of phrases devoted to describing social information in a scene. The ASD group produced only one correlation, for the PL task measures only, between PL viewing time and PL first fixations, Pearson's r = .849, p=.002.

Only the TD group data indicates any relationship between different tasks. The correlation between PL and FD scores which both index attention to social information over a period of time (as opposed to priority given to social information at the beginning of a trial) indicates that looking at people is related to describing them in social terms. The absence of this correlation among the ASD data raises the possibility that people with ASD may look at people without that being related to their social interpretation of what they see. This conclusion is very tentative, since the FD score also includes social references which are not person-centred. However the high value of the TD correlation and its absence from among the ASD data does not suggest that this is a spurious finding.

6.3e Correlations with Descriptive Scores

Correlations were also performed between each of the five task summary scores and participants' descriptive scores, in order to look for relationships between the tasks and domain-general qualities. The descriptive scores entered (one at a time) were autism quotient (a self-report measure of the level of autistic characteristics of participants), verbal IQ, performance IQ, full-scale IQ and chronological age. For each descriptive score, five comparisons were made, giving a Bonferroni adjusted alpha-level of $p=.01$ for significance. None of these had a significant relationship with any of the social attention task summary scores, indicating that performance on all tasks was not related to overall intellectual level, age, or degree of self-report autistic behaviours. This finding reinforces the absence of IQ effects in the original analyses of each task.

6.3f Principal Components Analysis

The above investigation of correlations between summary scores is a rudimentary way of exploring links between tasks. In order to further investigate whether performance on the social attention tasks provides evidence of a common construct which underpins all three, a principal components analysis was a carried out. While this kind of analysis is most commonly used to look for underlying factors for different questionnaire items, here it will be used to look for an underlying factor for different tasks. Principal components analysis has been chosen instead of factor analysis, as it relies on fewer assumptions (Field, 2000), though this does mean that one should not impute too much meaning to the outcome, especially if component loadings are low.

Another concern is the small sample size available: it is often suggested that 10-15 participants are required per variable. For our five summary scores, this would mean a sample size of at least 50, and we have just 26 individuals. However, others have suggested that changes in the ratio of sample-size to variable have little effect on analysis outcome (Arrindell & van der Ende, 1985) and that component loadings are significant determinants of reliable solutions (Guadagnoli & Velicer, 1988). For these reasons, this principal components analysis suppressed coefficient absolute values less than .60 to reveal only sufficiently strong relationships between tasks.

When all participants' data were analysed together, two clear components were extracted, both with eigenvalues greater than 1.5 and together accounting for 64.5% of the variance. The unrotated component matrix for this analysis is depicted in Table 6.5.

Table 6.5: PCA component matrix, with Eigenvalues and Variance Explained (five variables)

Variable	Component One Loading	Component Two Loading
FD descriptors	.879	
FD priority	.807	
SCD advantage		.634
PL viewing time		.616
PL first fixation		.777
Eigenvalue	1.72	1.51
Variance explained	34.3 %	30.2 %

The FD task summary scores both loaded uniquely onto the first component. The second component comprised the summary scores for the SCD and PL tasks. This analysis therefore suggests a link between the SCD and PL task while the FD task stands largely alone.

One difference between the SCD and PL tasks on the one hand, and the FD task on the other, is that the latter had a large verbal component. Participant responses to some extent depended on their vocabulary and linguistic competence or confidence: verbal IQ, but no other IQ measure, was correlated with the amount of phrases produced by participants in the original FD study [see section 2.4c, page 55]. Therefore the principal components analysis was repeated with verbal IQ included and three components with eigenvalues greater than one were extracted, together accounting for 80% of the variance. Two variables loaded highly onto more than one component and so a rotated solution (varimax method) was sought. The rotated component matrix is depicted in Table 6.6.

Table 6.6: PCA component matrix, with Eigenvalues and Variance Explained (six variables)

Variable	Component One Loading	Component Two Loading	Component Three Loading
FD descriptors	.838		
FD priority	.818		
SCD advantage		.844	
PL viewing time			.964
PL first fixations		.701	
Verbal IQ	-.726		
Eigenvalue	2.25	1.51	1.03
Variance explained	37.5%	25.2%	17.2%

Once more, both FD task scores load onto the first component, though this time they are joined by negative loading of verbal IQ. This suggests that FD task social responses were not underpinned by verbal IQ. Instead, this relationship echoes the findings from the original study [see section 2.4c, page 55]. Here, high verbal IQ was associated with absolute number of phrases produced. Those participants generating the smallest number of phrases, who had the lowest verbal IQs, produced higher proportional scores for phrases in the Social category, resulting in a negative correlation between verbal IQ and proportion of Social content.

Component two again shows a relationship between SCD and PL tasks, but this time the PL viewing time measure loads onto its own, separate component.

The principal components analyses both indicate that SCD and PL tasks relate to each other, while the FD task stands alone. Results upon inclusion of a verbal IQ measure do not support the suggestion that the reason for this difference is that the FD task requires better verbal skills than the other tasks. Instead, perhaps the pressure imposed on participants by the short stimulus presentation times in both SCD and PL tasks provides an element of similarity, which does not apply to the FD task, in which participants could take their time in viewing the display and making a response.

Another possibility for the distinction between tasks could be the different types of social information targeted in each case. The social information assessed in the FD task had to be explicitly social in nature, and excluded non-social references to people. The FD score also includes social comments which were not person-centred. In contrast, the summary scores from the PL task index attention to a person, and not necessarily to explicitly social aspects of that person. This could explain the lack of association between FD and PL tasks. However, the SCD task summary score provides an index of attention to explicitly social information (eye-gaze direction) as compared to a 'baseline' of attention to non-social but still person-centred information (spectacles). This score however, is associated with the PL scores and not the FD task scores, indicating that the type of social information presented in each task my interact in a complex way with responses.

6.3g Individual Difference Summary Scores

An analysis of individual differences poses a new problem. We have seen from the preceding chapters that groups only differ in subtle ways, but that the variation in response is often very great. In order to investigate the different ways in which people respond across all these tasks we would ideally incorporate the full range of variables in our analysis. However using such a large number of variables with such a small participant sample is unsuitable Therefore it is necessary to try to capture participant responses in a small number of variables which encapsulate 'success' on each of our tasks.

For the SCD task we can re-use the summary statistic described above, which provides a measure of the advantage conferred by use of a social attentional bias to detect eye-gaze direction changes. We can also calculate an expectation-advantage score, which measures the use of a expectation-based strategy to detect changes which are often repeated. This score is calculated as the difference between response time to filler images and response time to spectacles changes: the higher the score, the greater the advantage conferred by use of a expectation-based strategy to search for likely changes. These two continuous variables can also be converted into two categorical scores, whereby a participant receives a score of one if their social advantage or expectation advantage results are above the mean, and zero if their score is below the mean. A third score obtainable from this task is the baseline response time, which provides a general measure of change detection ability.

For the FD and PL tasks a score was constructed according to whether the individual performed better or worse than the average candidate. In the FD task, participants scored one every time their individual result exceeded the mean (across all participants, not just their own group) for the following variables: number of social repetitions, percentage of phrases describing people, percentage of phrases in the first half of each description describing people, percentage of phrases describing social information, percentage of phrases in the first half of each description describing social information, percentage of first and second phrases describing people or social information. This created a score out of nine for each participant, which is a broad measure of social attentiveness.

Likewise, for the PL task, participants scored one every time their individual result exceeded the mean for the following variables: percentage viewing time looking at the body, percentage viewing time looking at the face, percentage viewing time looking at the eyes, percentage of first fixations on the body, percentage of first fixations on the face, percentage of first fixations on the eyes. They also received a score of one for every individual result less than the mean for the following variables: first saccade latency to the body, first saccade latency to the face, first saccade latency to the eyes. All of these variables were drawn from the free-viewing condition and therefore the final score, out of nine again, reflects spontaneous attention to social information.

To recap, the following summary scores were constructed to provide a concise but detailed representation of responding across all three tasks.

- SCD advantage: reflecting the extent to which a social attention bias aids change detection, as used previously [see section 3.6d, page 95]
- SCD expectation: reflecting the extent to which an expectation aids change detection [see section 3.6d, page 95].
- SCD baseline: a baseline response time variable, for responses to filler trials.
- FD composite: a composite score reflecting spontaneous social attention as evidenced in verbal descriptions.
- PL composite: a composite score reflecting spontaneous social attention as evidenced in eye movements (both fixation location and latency).

In addition, the summary scores used in the previous section [see section 6.3c, page 193] to represent social viewing time and social first fixations were also available for use in the analysis of individual differences. Group means and SD for each of these summary scores are shown in Table 6.7.

Table 6.7: Individual difference summary scores by participant diagnostic group

	ASD		TD	
Score	Mean	SD	Mean	SD
SCD Baseline	4081 ms	793	3676 ms	631
SCD expectation	1202 ms	644	1412 ms	512
SCD advantage	102 ms	546	280 ms	238
FD composite	4.67	2.45	3.54	1.85
*PL composite	3.00	1.87	4.55	1.13
PL viewing time	-3.56	17.0	7.20	13.1
*PL first fixations	-1.88	25.2	39.3	27.6

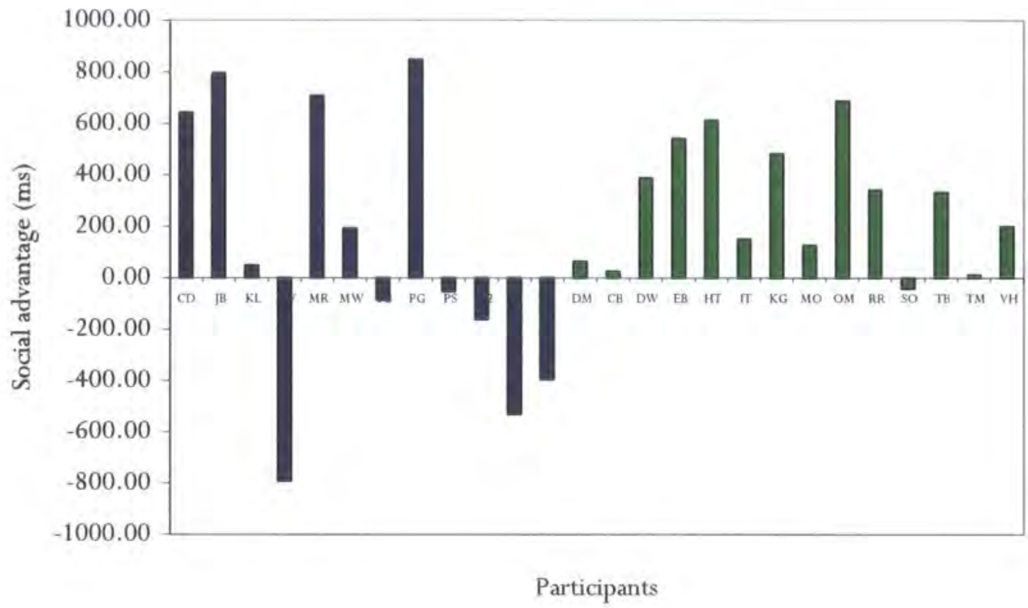
* These scores produce significant group differences

6.3h Analysis of Summary Scores

First, a brief analysis was made of group differences in composite and summary scores, using the existing diagnostic categories (ASD and TD). A series of t-tests exposed only two significant differences between groups, both for PL task scores. ASD participants had a lower PL first fixation score, $t(18) = 3.46$, $p=.003$, and a lower PL composite score, $t(18) = 2.29$, $p=.035$. This echoes the findings of the original study, indicating that the PL task was the most successful in distinguishing between participants with and without ASD.

Other scores also indicate a difference between groups but entail such large variances that these differences are not significant. One such score is the SCD advantage, which is higher in the TD group. This variation can be explored further by plotting individual scores, as in Figure 6.2. This figure shows that the TD group have a much less variable distribution of SCD advantage scores than the ASD group. All but one TD participant shows a positive advantage of using social information to detect changes. The one negative score is close to zero, and indicates an absence of advantage rather than the opposite bias.

Figure 6.2: SCD advantage scores (ms) by individual participant

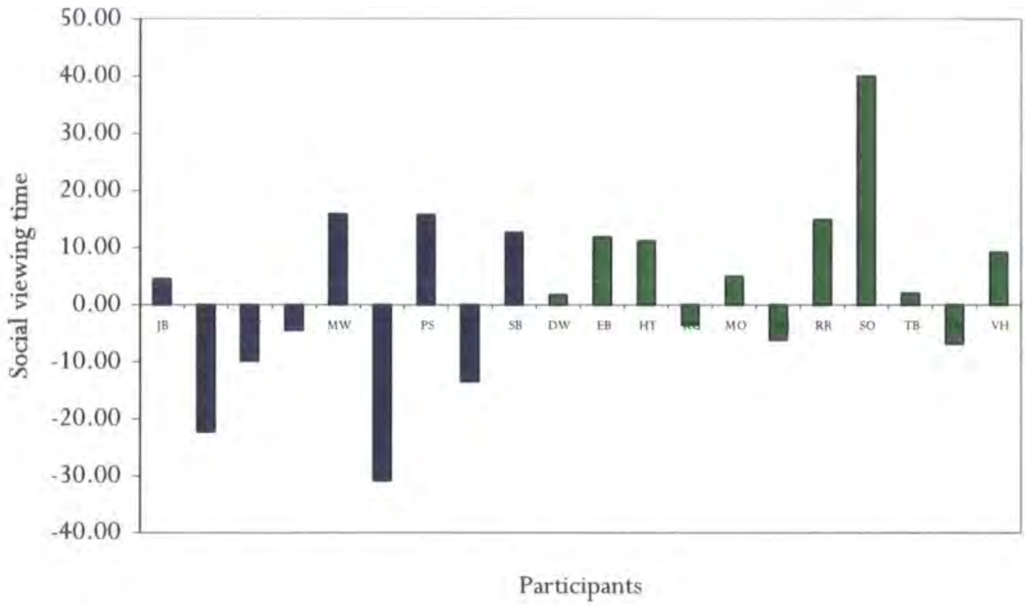


NB: data from participants with ASD are marked in blue and TD data are marked in green. This score was calculated as the difference between response time to Eye-gaze direction and Spectacles changes.

In comparison, the participants with ASD show simultaneously the largest social advantages, with three participants scoring over 750ms, and the largest disadvantages, with 50% of participants with ASD having negative scores. This suggests that attention to social information in ASD is greatly variable.

Another score which indicates a difference between groups but entails very large variances is the PL viewing time score, which is much higher in the TD group. Figure 6.3, a plot of individual scores on this measure, shows that both groups are variable in their distribution of PL viewing time scores. However, the TD group has fewer negative scores, which indicate more attention to the background than to the person, and those negative scores are close to zero. There are negative scores for over 50% of people with ASD, and four of these are greater than 10%, indicating a preference for looking at the background rather than the person depicted.

Figure 6.3: PL viewing time scores by individual participant



NB: data from participants with ASD are marked in blue and TD data are marked in green. This score was calculated as the difference between viewing time in the PP scene background and the Person.

Again, this suggests that attention to social information in ASD is greatly variable, but that some individuals do lack normal social attention biases.

Inspection of these two graphs (Figures 6.2 and 6.3) also informs our investigation of links between tasks. It appears that these two measures of social attention, one from the SCD and one from the PL task, do not necessarily correspond within individual participants. For example, SO is the only TD participant to have a negative score on the SCD advantage measure, but he also has the highest, positive score of all participants in the PL viewing time measure. For him at least, a strong preference to look at people rather than background objects did not translate into an ability to detect changes to eye-gaze direction. Among the ASD participants, only two of the six individuals who have a negative SCD advantage score also show a negative score in the PL viewing time measure.

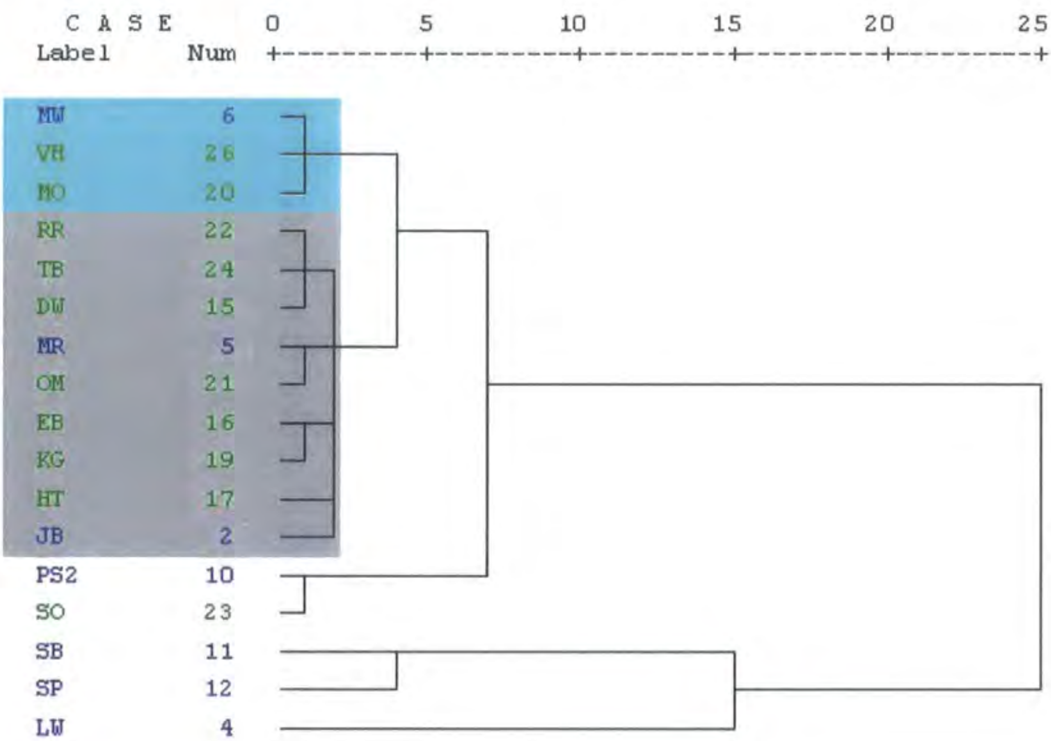
6.3i Hierarchical Cluster Analysis

A more formal way of looking for patterns of behaviour among participants is to use a cluster analysis to group individuals according to their task responses. This analysis will explore whether participants can be sorted according to their task scores and to what extent, if at all, these clusters correspond to our existing diagnostic categories. K-means clustering requires a large sample size, but hierarchical clustering is considered suitable for small samples (Aldenderfer & Blashfield, 1984), particularly when significance testing will not be carried out and the analysis is for exploratory purposes only (Tabachik & Fidell, 1996).

As an initial, exploratory step, a hierarchical cluster analysis, using nearest-neighbour clustering, was performed on scores from experimental tasks only (SCD advantage, FD composite and PL composite) to investigate whether participants could be distinguished from each other on the basis of their responses to these tasks alone. Although clustering is robust to the effects of missing data, only the seventeen participants who had scores for all three variables and were included in this cluster analysis, in order to give the clearest possible outcome. The dendrogram resulting from this analysis is shown in Figure 6.4. Participants with ASD are marked out in blue text and TD participants in green text and the initials correspond to those used in Tables 6.1 and 6.2 [see section 6.2a, page 186].

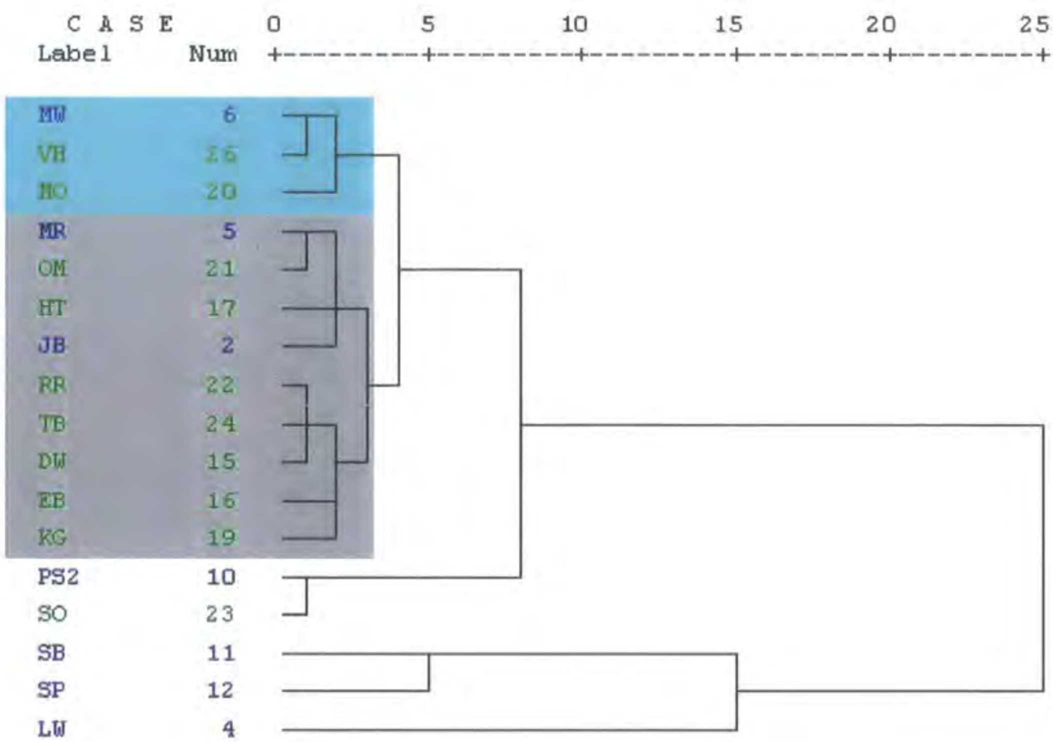
From this dendrogram, we can see that nearly all TD participants are grouped in a single cluster, marked in grey. Only two participants with ASD are included in this cluster, MR and JB. The remaining participants with ASD are more disparate, one clustering with two other TD participants, (marked in turquoise), but the others not fitting into well-defined clusters. This finding reiterates early suggestions that ASD participants show greater variation in their task responses than TD participants.

Figure 6.4: Dendrogram resulting from a hierarchical cluster analysis on three SCD, FD and PL task summary scores



The hierarchical analysis was repeated with a larger number of task variables, though still only those thought to represent social attention: SCD advantage, FD composite and PL composite plus PL viewing time, PL first fixations and FD descriptors. The resultant dendrogram is depicted in Figure 6.5: again TD participants are marked in green text and ASD participants in blue text, and initials correspond to those used in Tables 6.1 and 6.2 [see section 6.2a, page 186].

Figure 6.5: Dendrogram resulting from a hierarchical cluster analysis on six SCD, FD and PL task summary scores



Despite the inclusion of a larger number of variables, the results of this cluster analysis are remarkably similar to those above, indicating that the solution is robust in regard to the ratio of participants to variables. One large cluster (marked in grey) contains the same seven TD participants and two ASD participants as the largest Cluster in the previous analysis. Again there is a smaller cluster (marked in turquoise) containing three participants, one with ASD, the same individuals as in the previous analysis. Finally, the remaining four participants with ASD and one TD participant are largely unclustered.

It is worth noting that this TD participant, SO, is also the individual who showed a large difference in his responses to the SCD task compared to the PL task as depicted in Figures 2 and 3, making it unsurprising that he is not easily clustered.

Unfortunately, the small sample used combined with the absence of more than one clear cluster of considerable size means that a comparison of mean scores between clusters is not possible. We can observe that the large cluster marked in grey seems to represent the majority of TD participants, and that those with ASD are often unclustered, but we cannot perform an analysis of how members of different clusters are distinguished by their IQ, age or autism quotient. However, findings from previous sections have indicated that these are not likely to be factors in performance on our social attention tasks, so it is probable that such an analysis would not have yielded significant results in any case.

6.3j Individual Outliers

To extend the analysis of individual differences, it is possible to look at those participants whose scores are outlying on different tasks and ask whether these outliers indicate a certain pattern of response. In addition, three participants in the ASD group also had a diagnosis of a second, co-morbid condition: if these participants have outlying responses this could be interpreted in terms of the effect of their co-morbid conditions on task performance. Throughout this section, outlying scores are defined by being 2 or more standard deviations from the overall mean (incorporating all participants).

In the FD task, on measures of phrases referring specifically to social information, there was only one outlying participant. SP produced an atypically large proportion of social information in the first half of his descriptions (43%, 2.09 SDs above the mean) and also a large proportion of social information in the second placed phrase in each description (58%, 2.17 SDs above the mean). This same participant also made an atypically large percentage of first fixations in the PL task on the background of the PP scene (58%, 2.12 SDs above the mean). This participant's outlying status was partly confirmed by an analysis of his scores relative to the ASD group means only, where these three scores were respectively 1.64 SDs, 1.72 SDs and 1.61 SDs above the ASD group means.

This case confirms that a tendency to describe social information in the FD task, even early on in a description, does not necessarily correspond to an ability to identify social information quickly from a complex scene. The case highlights the fact that a lack of temporal coding information in the FD task prevented a genuine assessment of attentional priority for social information. If we had information on whether this participant paused before beginning his descriptions in the FD task, this data would provide a more direct way of comparing his FD and PL task responses. This participant has a diagnosis of Asperger's syndrome, with dyspraxia and dyslexia, but there is no evidence that this participant's co-morbid conditions had an effect on his social attention. In fact, his verbal IQ was 89, only two points below the ASD group mean for verbal IQ. His raw scores on the vocabulary and similarities sub-tests of the WASI were respectively 51 and 30, relative to ASD group means of 46.6 (vocab, SD = 12) and 33.4 (similarities, SD = 6.22).

In the SCD task, two participants showed atypically slow response times for both eye-gaze direction and spectacles changes. TM was typically-developed and had an eye-gaze direction response time of 5100ms, 2.67 SDs above the mean, and a spectacles response time of 5024ms, 2.47 SDs above the mean. This participant was not outlying on any baseline measures of response time, suggesting that he was not impaired in his general change detection ability. In line with this conclusion, his expectation-advantage score (the difference between spectacles and filler response times) was second lowest in the sample, at just 210ms, compared to a mean of 1315ms and an SD of 574ms, implying that he did not benefit from using an expectation of repeated spectacles and eye-gaze direction trials to detect these changes. His social advantage score was also low, at 10.97ms, showing that he also did not have a strong attentional preference for eye-gaze changes. Therefore, this participant showed very little strategic or preferential direction of attention in this task.

PG had a diagnosis of PDD-NOS and had an eye-gaze direction response time of 4865ms, 2.41 SDs above the mean, and a spectacles response time of 5375ms, 2.89 SDs above the mean. In addition, PG had an outlying response time for detecting changes to filler stimuli, at 5623ms, 2.42 SDs above the mean. While his response time for trials in which no change was present was not outlying, it was the maximum response time recorded (5115ms). This indicates that for PG, change detection responses were uniformly slow, though his accuracy scores were not outlying. He had a normal score for SCD expectation (the difference between response time to filler and spectacles changes) and for SCD advantage (the difference between response time to spectacles and eye-gaze direction changes). This shows that he had a difficulty with change detection overall, but that he was subject to normal effects of expected and of social information.

This participant's data uphold our assumptions about the way in which individuals can approach the SCD task. He used the repetition of changes to spectacles and eye-gaze direction to enhance his change detection response times, even though his baseline performance was very slow. Subsequent differences in response time between eye-gaze direction and spectacles changes were due to the use of a social attention bias to preferentially attend to and subsequently detect changes to eye-gaze direction.

In the PL task, first fixation scores revealed two outlying participants, though there were no outliers for the PL viewing time score. EB was typically-developed and had a social priority score (first fixations to the Person minus first fixations to the PP background) of 94%, 2.21 SDs above the mean. Likewise MO, also typically-developed, had a social priority score of 88%, 2.04 SDs above the mean. Both of these TD participants showed a particular priority for the Person compared to the background items in the same scene, indicating not only an attentional preference for this information but also an ability to detect relevant features (i.e. bodies and faces) from peripheral vision. These participants made, respectively, 94% and 93% of their first fixations in the free-viewing condition direct to the person depicted.

In the case of EB, this enhanced ability to look directly at people could have been related to her familiarity with some of the people depicted. Some of the persons shown were members of the Durham University psychology department, where EB was employed as a member of support staff. It is possible that her familiarity with some of the settings and individuals used in the stimuli enhanced her ability to fixate people quickly and accurately. However, only about 50% of the stimuli used depicted individuals with whom EB was familiar, and only half of those used locations within or around the psychology department building. Moreover, EB may have been familiar with the locations in real life but she had not seen the pictures themselves. Furthermore, EB's ability to fixate the person with the very first eye-movement she made was consistent across all stimuli and therefore cannot wholly be attributed to the effects of familiarity. In addition, MO had no such advantage, having no connection to the stimulus locations nor the people depicted. While we cannot draw strong conclusions from the data of only one participant, his example at least shows how accurately and rapidly it is possible to detect people in peripheral vision and make fixations directly to them, without any extra cues from movement nor any prior knowledge of the scene.

These analyses of outlying participants have supported the contention that the social attention tasks designed here were able to indicate the presence of genuine social attentional biases. The presence of strong preferences for social information in the PL task indicate that social attention can be a powerful director of visual attention. The difference scores used to access the type of strategies used in the SCD task show that social attention and the use of expectation can guide visual search for a change, even in participants whose baseline ability to detect change is poor. This finding helps to discount the possibility that domain-general attentional problems, like poor attention switching, would have confounding effects on these tasks, which aim to discover processes specific to attention to social stimuli. Finally, the pattern of response of one case across the FD and PL tasks indicates that the inclusion of temporal measures may be important in revealing the subtle workings of social attention.

6.4 Case Study

The final method for investigating the current data, to expose patterns of responding across tasks and individual differences, is a brief case study of one participant with ASD for whom clinical notes have been made available, with the permission of both the participant himself and his parents.

PG is a male, born in 1988 after a normal pregnancy at 39 weeks gestation. He had a normal birth weight, but was blue and lacked muscle tone and was cared for in a special care baby unit for two weeks. He suckled normally following this period and smiled at 6 weeks. His mother was concerned about his development because of his early post-natal problems, but specific worries over language and behaviour began in 1991 when PG was 37 months old. Early signs of a problem included indiscriminate affection to family and strangers and problems following social conversational rules. He had few friends and became transfixed by flashing lights, often so excited that his body would go rigid and his hands would flap.

PG's educational history includes a period at a mother-toddler group where he did not seem to fit in with the other children. At a private nursery there were concerns about his hearing. Thereafter he was mostly in mainstream education, but a statement of special educational needs, issued when he was 4 years old, meant that he was supported in class and given speech therapy. A period of eighteen months, when aged 5 years, was spent in a very small class with children with physical disabilities. In this environment, PG regressed somewhat, particularly losing some verbal communicative ability. PG was also bullied by his classmates in subsequent mainstream primary and secondary schools. He finally progressed to a college for young adults with ASD aged 16 years old, from which he was recruited for this research project, and where he was observed to be a happy and well-integrated pupil.

PG's diagnosis of pervasive developmental disorder/autism spectrum disorder was made at 11 years old, based on assessment with the ADI-R (Lord, Rutter, & Le Couteur, 1994) and

ADOS (Lord *et al.*, 1999), and observation in school and at home and following referral to a Pervasive Developmental Disorder Service. As stated above, there were concerns about his development for some years before that.

The ADI-R assessment showed problems in communication and markedly circumscribed interests. He did, at that time, have some reciprocal social interactive skills, including having one or two friends at school and an increasingly interactive relationship with his family members. His scores were 11/28 for reciprocal social interaction, 15/25 for communication and 10/12 for repetitive behaviours. All of these are above the recommended cut offs of 10, 8 and 4 respectively.

The score sheet for the ADOS assessment is unfortunately not available. However the clinical notes present a picture consistent with the ADI-R results. PG was co-operative but reserved and anxious. He had abnormal verbal communication, both in the manner and content of his speech and his ability to engage in flowing conversation. He was keen to interact but often unable to do so appropriately, or prevented by anxiety. He took things very literally and showed limited imagination. The examiner concluded that he *"presented as an anxious boy with some pragmatic communication and social developmental difficulties... [his] developmental difficulties could be usefully considered as falling within the diagnosis of Pervasive Developmental Disorder/Autism Spectrum Disorder. He does however show a number of social skills and social interest such that... he would not reach a core diagnosis of autism".*

In addition to these assessments for autism, an EEG was carried out following some evidence of 'attacks' in which PG would shake with his head rolled back. PG said he did this because he was bored. The EEG was normal.

At the time of PG's participation in the current research he was 18 years old. His original diagnosis had been confirmed upon admittance to his college, though these records were not available to the researcher. As part of the current series of experimental studies, he completed an autism quotient questionnaire, on which he scored 31/50. A cut off of 32 is recommended as indicating AS, but the rate of false negatives in this self-report questionnaire is not clear (Baron-Cohen, Wheelwright, Skinner *et al.*, 2001). In addition, a lifelong Social Communication Questionnaire was completed by PG's mother. This measure is intended as a way to evaluate communication skills and social functioning in people who have ASD, and it can also be used a measure of individual symptom level. This produced a score of 30/39, well above the recommended cut-off of 15 for ASD, and in fact above the higher cut-off of 22 for autism (Rutter, Bailey, & Lord, 2003).

A comparison of the researcher's observations of PG now with his clinical notes makes it apparent that though he has made progress, his profile remains largely the same. His communication is still lacking social awareness and his grammar and vocabulary are both poor. This is reflected by his low scores on the verbal measures of the Wechsler abbreviated Scales of Intelligence (Wechsler, 1999), which produced a standardised verbal IQ of 78. PG also has a limited range of interests, which can be obsessive. His visuo-spatial skills are more developed, producing a performance IQ of 95, and this ability was also noted in his original ADOS assessment. PG's social skills are still poor but he makes an effort to interact with his peers and staff at school, as well as with the researcher. He was an enthusiastic participant in the current set of studies, often asking the researcher whether she had *"any new tests for me?"* though within an experimental sessions, he could be a little reluctant to start a new task, or dubious about his abilities, often sighing very deeply and saying things like "*Well, I'll do my best*".

PG took part in the social change detection and the preferential-looking task. Unfortunately, due to a reluctance to be recorded, his responses to the FD task are not available. His performance on the social change detection task, as has already been noted [see section 6.3j page 208], was poor, in that his responses to all trials were very slow, though accuracy was normal. This is unexpected in light of the visuo-spatial skills noted in his original assessment and reflected in his relatively high performance IQ. Change detection in a complex scene has been compared to visual search (Rensink, 2000b), which may be enhanced in ASD (O'Riordan, Plaisted, Driver, & Baron-Cohen, 2001; Plaisted, O'Riordan, & Baron-Cohen, 1998b), and though we do not have data on PG's visual search ability, it is possible that in autism the link between change detection and visual search ability would not hold.

PG benefited normally from the use of expectations to improve his scores on spectacles trials relative to filler trials, and of a social bias to improve his response time to eye-gaze direction trials relative to spectacles trials. The presence of this social bias could link to PG's attempts to interact socially. He has a clear desire to interact with other people though his attempts may be inappropriate or clumsy and this seems to be typical of the able individuals with ASD who took part in all of our studies. Perhaps some individuals with high-functioning ASD can orient appropriately to social elements of their environment, but fail to translate this attention into socio-cognitive abilities, for example using what they see to further direct their attention, or make a social judgement.

PG's viewing time in the preferential-looking task indicates a very low attentional preference for the Person depicted. He spent only 7.9% of his viewing time looking at the Person on average, and 7% of that was spent looking at the Body (group means: Person = 26.3%, Body = 13.7%, Face = 12.7%). He showed only a small preference for the person-present scene as a whole (PG mean = 46.5%; group mean = 56.2%), driven by a large amount of time spent looking at the background of that scene (PG mean = 38.7%, group mean = 29.9%). This reduced looking to the Person is reflected in his first fixation scores, of which only 15% went to the Person, and only 5% (1 fixation) to the Face (group means: Person = 35%, Face = 9.8%). However, he did show a strong preference for the entire person-present scene at the first fixation, directing 70% of fixations into that scene (group mean = 71.9%).

These data indicate that, for PG, the person-present scene did hold some early interest. Although first fixations mostly landed on the background of the scene, the only difference between the person-present and person-absent scenes across all stimuli was the presence of a person in one and not the other. Therefore, it seems that the presence of a person in one scene did have an influence on PG's initial fixations However, the contrast between the high percentage of first fixations in the person-present scene and the low proportion of viewing time spent in that scene, suggests that PG quickly lost interest in the person-present scene and moved his gaze elsewhere. One possible explanation for these results is that the presence of the person captured his attention but could not hold it. Perhaps PG felt that he should try to be interested in the person but because this was not genuine, his attention quickly strayed? Another possibility is that PG spent time fixating on Background items but still covertly attended to the Person.

PG's data from the gender-discrimination condition show a normal proportion of first fixations to the Person (PG mean = 42.1%; group mean = 49.1%), suggesting that he had no trouble identifying a Person from peripheral vision. The absence of first fixations on the Person in the free-viewing condition must have been driven by a lack of preference rather than an inability to detect the human figure depicted. In this condition, there is also a normal level of fixation on the Person over time, (PG mean = 38.7%; group mean = 46.2%) and a high level of fixation on their Face, (PG mean = 31.1%; group mean = 23.9%). PG was clearly capable of identifying people from peripheral vision when called upon to do so, and of sustaining his fixation on them. For this participant at least, there is no evidence of aversion to looking at people.

PGs results seem largely consistent with the group-level conclusions drawn at each stage of this investigation. He is capable of social attention behaviours, spontaneously using social attention to quickly identify changes to eye-gaze direction from a complex scene, relative to his own performance on non-social changes. He shows no aversion to social stimuli and there is evidence that his visual system is capable of identifying these stimuli quickly and accurately from peripheral vision. However, his behaviour in the free-viewing condition of the PL task suggests that he does not prioritise social information for attention, and the preference he shows for social information is weak and does not persist over time.

6.5 Discussion

6.5a Summary of Social Attention Task Goals

The cross-task analyses undertaken here were designed to reveal two things: links between the tasks, possibly in terms of an underlying construct which underpins all of the novel social attention tasks developed here; and differences between individual participants in their approach to these experiments. These two aspects of the analysis in turn contribute to our understanding of both the concept and manifestation of social attention. Therefore, at all times, the tasks have been assessed as measures of social attention, though this was never an explicit goal conveyed to the participants. The analyses have been limited by the small sample of participants whose data was available for all or for the majority of the tasks, and therefore conclusions are necessarily restricted. Nevertheless this exploratory analysis offers new ways of assessing performance by atypical and typical populations and embracing individual differences in research.

The first task was a free-description task in which participants' descriptions of social scenes were analysed for their content – in particular the proportion of references to people and social information. The second task was a social change detection task in which participants had to identify the difference between a pair of images. This difference could either be a filler-change to a small object, a social change to eye-gaze direction or a non-social, but still person-centred, control change to someone's spectacles. The third task was a preferential-looking task in which participants viewed, side-by-side, a scene depicting a person and a scene depicting an empty room or garden.

All of these tasks had a number of key elements in common: they used colour photographs of static but complex visual scenes and attempted to capture spontaneous attention processes by minimising task instructions. It was therefore plausible to suppose that an analysis of these three tasks might reveal a degree of commonality between them and perhaps even evidence of a single underlying 'social attentiveness' construct. On the other hand, there were important differences between tasks. Each one assessed social attention with a different measure: verbal descriptions; response time and change detection accuracy; and eye-movements and fixations. In addition, the kind of social information under scrutiny was varied. Though all depicted people in a naturalistic context, the assessment of social attention was in regard to different levels of social information: attention to person- and non-person centred, but explicitly social information; attention to social versus non-social aspects of people; and attention to people in general. These differences between tasks indicate that it is equally plausible to suggest that different components of what we call social attention were at play in each task.

6.5b Evidence for Links between Tasks

The analysis of the three tasks fulfilled the latter expectation, of differences between tasks. Relationships were found but they were not consistent. An initial investigation of correlations between task scores suggested that for TD participants only, there was a link between social attention as measured by viewing time on a person compared to background items, and social attention measured by the proportion of phrases in a description devoted to social information. Both variables index social attention over a period of time, rather than priority for social information. This suggests a link between the free-description and preferential-looking task, which were both measures of spontaneous social attention over a period of time, though this link was not apparent in the ASD group.

The subsequent principal components analysis did not support this link between the free-description and preferential-looking task. Instead, it implied that preferential-looking scores were related to social change detection, while free-description scores related only to each other. The preferential-looking and social change detection task were both purely visual or visuo-motor tasks without a verbal component and this could explain the relationship between them. However the absence of a correlation between verbal IQ and any task questions this hypothesis. Another way in which the preferential-looking and social change detection tasks differ from the free-description task is that they place the participant under greater pressure. In the change detection task the participant has a limited amount of time to make a response while in the preferential-looking task the participant's attention is competed for by a pair of stimuli. In contrast, the free-description task places no pressures on time nor does it present competing stimuli. This conclusion ties in with recent work suggesting that autistic perceptual atypicalities are particularly notable in complex tasks which present multiple stimuli or require multiple levels of response (Kemner & van Engeland, 2005).

A distinction between tasks based on the type of information being attended to is also consistent with our analysis. As stated, though there were some indications of links between tasks, they did not correlate highly with each other. This suggests that in some ways each task measured a different aspect of social attention. The most obvious candidate for this difference is the type of information targeted for attention in each task. Our findings indicate that attention to people, to specifically social aspects of people, and to social aspects of the environment which are not person-centred could be subject to different levels of priority and may not be dictated by a single attention bias. In addition, there may be an effect of individual differences in personal hierarchies of social information available for attention, which could also vary with the task at hand.

6.5c Evidence for Individual Differences

The preferential-looking task has proved the most able to detect differences between people with and without ASD. This is reinforced in this sub-sample by the fact that the preferential-looking task summary scores were the only ones to produce significant differences between diagnostic groups. The preferential-looking task, followed by the change detection task, seems most effective in detecting subtly different patterns of responding between ASD and TD participants, but Figures 6.2 and 6.3 reveal why this may not always result in significant group differences. The range of responding among people with ASD, suggests that social attentiveness can be extremely variable among individuals with high-functioning autism and Asperger's syndrome. It had been hoped to be able to relate this variation in responding to symptom profiles but these were not available for most participants. There were no correlations between task responses and autism quotient scores. However one case study showed that social attentiveness, at least in his case, may correspond to difficulties in social communication.

Hierarchical cluster analyses suggested that the task scores could be used to successfully distinguish between people with and without ASD, with TD participants grouping into fairly exclusive and clear clusters. While it was not possible to compare clusters according to descriptive data such as IQ, chronological age and autism quotient, the absence of any correlations between these and task scores suggests that this comparison might not have yielded interesting results. Instead, it is suggested that social attentiveness acts largely independently of intelligence, adult age or degree of self-reported autistic traits.

6.5d Conclusions

The cross-task analyses undertaken here have exposed some of the limitations of our understanding of social attention. Despite the caution imposed by the use of a small participant sample, we can see that different measures of social attention do not always relate to each other. This conclusion is strengthened by the fact that, if anything, the use of a small participant sample should increase the likelihood of finding spurious relationships between variables, rather than the opposite, a phenomenon known as 'over-fitting' (Tabachik & Fidell, 1996). Social attention may appear differently in a single individual depending on the circumstances in which it is measured. For example, an individual may attend to social information presented in isolation and without time pressure but not under constrained or competitive circumstances. Moreover, they may attend to people, without attending to or processing their social aspects, or they may attend to social information present in the environment, but not to people. It is therefore important to acknowledge in each new assessment of social attention that particular methodological decisions may have a great impact on how participants respond. The differences (and similarities) between tasks here support the suggestion that contradictions among results from existing studies may have been produced by differences in methods and indeed stimuli used.

This analysis provides evidence of the need to acknowledge the wide range of abilities encompassed by the autistic spectrum: abilities in 'impaired' domains such as social interaction as well as intellectual or visuo-spatial skills. Though individuals with autism are apparently united by the social nature of their condition, these skills run on a continuum like every other behavioural aspect of the disorder, and this must be acknowledged. In particular, participants differing in age or ASD diagnosis may show different capacities and preferences, and the two may not always be aligned.

7. Discussion

7.1a Aims of the Investigation

The current investigation aimed to further understanding of social attention, by assessing the spontaneous distribution of attention to social elements of a static but complex visual stimulus. These social elements were often defined as being person-centred information, but the investigation also showed that there are other types of social information available to us, that can be thought of in terms of a hierarchy, from most to least socially informative. Tasks measured social attentional preferences in typically developed (TD) adults and those with autism spectrum disorders (ASD), for explicitly social person-centred and non-person centred information, and attention to people in general. As well as looking at gross attentional preferences over a period of time, attempts were made to measure subtle aspects of social attention distribution, such as the priority given to social stimuli and persistence in sustaining attention to social stimuli over time. This investigation provides an important insight into social attention, in our understanding of the psychological construct, in describing the nature of different types of social information, and in revealing the manifestation of social attention in typical adulthood and in autism.

It is valuable to explore social attention in autism because a number of developmental theories have placed social attention atypicalities at the centre of their accounts of autism (Klin *et al.*, 2003; Mundy & Neal, 2001; Schultz, 2005). Though no specific behavioural predications were made in these theoretical accounts regarding the presence of problems with social attention in adults with ASD, it is important to know whether social attention plays a role in the maintenance of autism as well as in its development. If a person with ASD had consistent problems attending to social information throughout their life, this would create day-to-day difficulties in the social arena, and hinder attempts to reduce impairments, as well as having been a causal factor in the origin of autism in infancy and childhood.

Little is known about the social attention of adults with ASD. On one hand, research has produced evidence of social attention difficulties in adulthood (Klin *et al.*, 2002b). This research is limited in its ability to pin-point the root of social attention atypicalities in ASD because it presents moving images with multi-sensory input. Problems processing this kind of complex stimulus may result from general impairments in autism in sensory integration (Iarocci & McDonald, 2006) and movement perception (Milne *et al.*, 2005) rather than social attention problems. Moreover, evidence of social attention impairments in children with ASD indicates a relationship between social attention skills and developmental level, IQ and language ability (Leekam *et al.*, 1998; Leekam *et al.*, 2000; Loveland & Landry, 1986; Mundy & Sigman, 1990; Mundy *et al.*, 1994). This suggests that social attention deficits might have been overcome in adolescents and adults, particularly those with normal IQ. Nevertheless, the overriding prediction adopted for this research was that the well-documented difficulties with social attention in children with autism would also be apparent in adulthood.

As well as searching for the presence of a social attention impairment in adults with ASD, it was important to understand the nature of the problem if it exists. Research with children with autism has illustrated how social attention problems may only be apparent in some circumstances. For example, social attention is considered to be impaired in real life in children with ASD, as evidence from studies of social orienting (Dawson *et al.*, 1998; Leekam *et al.*, 2000) and shared attention (Bruinsma *et al.*, 2004) shows. In contrast, experimental evidence from children with ASD suggests that they may show normal attention to pictures of simple, isolated social stimuli, namely faces (Bar-Haim *et al.*, 2006; van der Geest, Kemner, Verbaten *et al.*, 2002), though there is also evidence to the contrary (Pelphrey *et al.*, 2002; Spezio *et al.*, 2007). Studies of the response to eye-gaze cues to attention also demonstrate the influence of different task contexts, by showing that children with autism can respond to eye-gaze cues presented in isolation, on a computer screen (Charwarska *et al.*, 2003; Kylliainen & Hietanen, 2004; Senju *et al.*, 2004; Swettenham *et al.*, 2003), but do not follow eye-gaze direction cues in real life (Leekam *et al.*, 1997; Leekam *et al.*, 1998; Leekam *et al.*, 2000).

The evidence illustrates how social attention behaviours in autism may vary between tasks. Consequently, we cannot accept that evidence of a social attention impairment in autism in a task which places sensory integration and movement processing burdens on participants, is the final word (Klin *et al.*, 2002b). Likewise, evidence for normal fixation of social stimuli which are presented in isolation (Bar-Haim *et al.*, 2006; van der Geest, Kemner, Verbaten *et al.*, 2002), giving participants no alternative focus for their attention, does not address whether attention to social information can occur to the exclusion of other non-social stimuli. It is therefore important to try to understand how social attention functions in adults with ASD in the absence of multi-sensory information and motion processing requirements, and when social stimuli are presented as part of a naturalistic scene.

This investigation can also help to reveal how social attention functions in typical adults. In studies of visual attention in TD adults, research has often focused on the relative influence of high-level and low-level properties on the location of attention. For example, one would ask whether the location of attentional focus is primarily influenced by the low-level properties of the stimuli presented, such as colour and brightness. The alternative is that high-level characteristics, such as the semantic role of the stimulus or the personal interests and expertise of the viewer, have the greater effect. Recent work has begun to indicate that high-level information has a significant effect on attention (Henderson, Weeks Jr, & Hollingworth, 1999; Kirchner *et al.*, 2003; Werner & Thies, 2000), and some studies suggest that social information in particular invokes an enhanced level of attentional capture (Herschler & Hochstein, 2005; Herschler & Hochstein, 2006; Ro *et al.*, 2001). However, there is also evidence that social stimuli such as faces, and people, are not subject to any unique processing or attentional advantage (Brown, Huey *et al.*, 1997; Palermo & Rhodes, 2003; Rousselet *et al.*, 2003). This work therefore contributes to our understanding of high-level influences on attention and explores attention to social stimuli in particular, as a potentially unique form of high-level input.

In making comparisons between TD and ASD groups and particularly with the design of new methods, the research explores the meaning of the term 'social attention' and the different kinds of social information available in real life. Three tasks were created to fulfil the goals of furthering understanding the nature of social attention and its manifestation in typical adults and those with ASD. Each task targeted responses to slightly different kinds of social information, in paradigms newly applied to this population and this topic. The tasks differed both in their methodological approach and in the precise elements of social attention which they purported to assess. Consequently, the tasks produced subtly differing pictures of social attention in ASD.

7.2 Reviewing Task Conclusions

7.2a Reviewing Task Conclusions: Free-Description Task

The first task that was developed was an exploratory description of social attention as measured by verbal descriptions of a scene. This free-description task presented participants with scenes containing social information, such as an individual expressing an emotion or people engaged in an interaction. A coding scheme was developed which distinguished between non-social descriptions of persons and descriptions of person-centred and other social information, though it was not possible to construct these two categories to be mutually-exclusive. This content analysis of the verbal descriptions of each scene did not reveal group differences in social attentiveness. For both groups the majority of their scripts described people, and about a quarter of all phrases referred specifically to social information, such as emotion, interactions and relationships. There was also a similar distribution of topics through descriptions for each participant group. The task was designed to be a highly naturalistic and unconstrained investigative probe of social attention, which would help to define the potential targets of social attention, and also explore the tendency to describe those targets in different participant groups.

The free-description task was not an experimental assessment of social attention: there was no control condition; social and human description categories were overlapping; and it lacked a precise and sensitive measure of the distribution of attention over time. However, the lessons learned from this early exploration of social attention provided valuable methodological guidance for later components of the investigation. They demonstrated the importance of careful selection of non-social control conditions, and showed that this selection process should consider a wide range of potential targets for social attention and match stimuli carefully for content of scenes. Moreover, measures of social attention should be chosen to provide a subtle assessment of social attention preferences, but avoid placing demands on domain-general skills such as verbal intelligence. The study also gave the first indication in this thesis that a social attention bias could be present in adults with autism. Nevertheless, the methodological limitations of this study meant that further exploration was required, and subsequent studies benefited from the lessons learned in this early exploration of social attention.

7.2b Reviewing Task Conclusions: Social Change Detection task

The social change detection task used a change detection paradigm with a flicker method. Since focused attention is required for the detection of changes presented in this way, speed and accuracy of change detection is an index of attention to those changes. This study compared changes to a highly social aspect of a person (their eye-gaze direction) with changes to a non-social aspect of a person (their spectacles). Control stimuli were carefully selected to ensure that use of a expectation-based search strategy, in which repeated changes were detected more quickly due to learnt expectation of their presence, could not have distinguished between these two types of changes. In fact, only a predisposition to monitor social changes to a person would facilitate detection of eye-gaze direction changes over changes to spectacles. Under these constrained circumstances and using response time measures of social attention, it was predicted that differences would be found between the participant groups, but this was not the case. Both groups showed a similar change detection advantage for eye-gaze direction changes over changes to spectacles as measured both by response time and accuracy.

This finding corresponds with evidence for an ability to correctly follow eye-gaze direction cues (Charwarska *et al.*, 2003; Kylliainen & Hietanen, 2004; Senju *et al.*, 2004; Swettenham *et al.*, 2003) and interpret meaning from the eyes in autism (Back *et al.*, 2007). Our finding significantly extends this work, showing an attentional preference for the eye area when it is presented as part of a complex visual scene. This is a crucial development, since studies which present eyes or other social stimuli in isolation cannot reveal whether attention would be focused on those stimuli if others were available in the display.

Our results also contribute to findings of normal fixation of the eye-area presented in the context of the whole face (Bar-Haim *et al.*, 2006; van der Geest, Kemner, Verbaten *et al.*, 2002) by further demonstrating that attention to the eye-area is socially motivated. Participants who merely looked at this part of the face would have detected changes to eyes and to spectacles with equal accuracy and speed. The advantage in detecting changes to eye-gaze direction indicates that attention to the eye-area was coupled with a particular interest on the part of the viewer in whether the eyes would move. In other words, as well as attending to the eye-area, both participant groups were alert to the possibility of a change of eye-gaze direction. Attention to the eyes served the social purpose of monitoring changes in eye-gaze direction.

A general group difference was found in accuracy, not only to experimental but also to filler changes to items such as objects in the scene. This reduced accuracy in the group with

ASD did not extend to those trials on which no change was present. In these cases the TD participants were no more likely to produce a false positive, pressing Yes when there was no change. This shows that participants with ASD were not merely more cautious in identifying changes – they did not simply press the Yes button less often. It is possible that the ASD group made more errors due to greater problems with the motor response required. Finally, it is also possible that the search for a change was implicitly a task requiring shifts of attention between items – though the task was not designed to assess this domain-general process. If so, this adds to evidence for a deficit in shifting attention in autism (Courchesne, Townsend *et al.*, 1994; Harris, Courchesne, Townsend, Carper, & Lord, 1999; Townsend *et al.*, 1996; Wainwright-Sharpe & Bryson, 1993; Wainwright & Bryson, 1996).

7.2c Reviewing Task Conclusions: Preferential-Looking Task

The third and final novel task to be developed to investigate the nature of social attention in autism was a preferential-looking task which employed an eye-tracking methodology. The combination of this task and method permitted a direct assessment of preferential attention to social stimuli, to the exclusion of non-social stimuli, with a measure which gave detailed records of attention at high temporal and spatial resolution. Social scenes were paired with non-social scenes, creating direct competition for attention within each trial. Eye-tracking provided a measure of priority by allowing us to look at the placement of the very first fixation in a trial and the latency of the eye-movement preceding this fixation and a measure of persistence in the distribution of individual fixations over time. The preferential-looking task was the most detailed assessment of social attention and therefore had the potential to uncover subtle deficits in social attention in autism, not picked up by preceding tasks. Most notably, this task gave access to the operation of social attention at the level of the very first fixation when presented with a new stimulus.

The preferential-looking task found that overall, the participants with ASD looked as much at a social scene as the TD group, suggesting that the two groups have a comparable preference for social information. However this conclusion was tempered by the finding that, when comparing viewing to different parts of the person (body and face), a borderline main effect of group indicated that the TD group looked more at both of these domains that the ASD group. The strongest group effects were found for the location of first fixations, indicating that the ASD group did not prioritise social information to the same extent as the TD participants. The ASD group's preference for social information did not appear to be as persistent over time as that of the TD group - plots of the data suggest that the participants with ASD moved their focus away from social elements of the display earlier in the viewing period than the TD group. This final task, therefore, revealed slight but significant group differences on three aspects of social attention: preference, priority and persistence.

7.2d Reviewing Task Conclusions: Cross-task Analyses

The three novel experiments presented in this thesis produced differing pictures of social attention both as a construct, and as manifested in the behaviour of people with and without ASD. A series of cross-task analyses were performed to investigate relationships between tasks and patterns of responding among individuals. The former set of analyses indicated that our tasks, which all purported to assess different aspects of the same construct, were not closely related. Links between tasks were not consistent across different kinds of statistical investigation. Moreover, there were no clear links between tasks and measures of intellectual function, age or a measure of autistic symptoms. This is despite the fact that, if anything, our small sample size could have been expected to produce stronger rather than weaker relationships between variables.

The analysis which focused on individual differences likewise demonstrated that the same participant, from either diagnostic group, could perform very differently in each assessment of social attention. This variability among individuals and between tasks made it difficult to characterise different types of individual according to their social attentiveness. Taken together, the analyses focusing on tasks and individuals indicate that the kind of social information presented, the format of its presentation and the constraints placed on the viewer may interact with personal attentional biases in a complex way. We have talked about the concept of a hierarchy of social stimuli, each level conveying a different amount of social information and therefore being subject to different degrees of attentional preference. These results suggest that different individuals might hold different hierarchies of social information, leading to variable performance across tasks. Above all, these findings indicate that a simple conceptualisation of social attention as a single construct is not appropriate, either for the study of autism or typical attention.

7.2e Reviewing Task Conclusions: Summary

The social change detection and preferential-looking tasks combined suggest that people with ASD may exhibit social attention atypicalities only in specific circumstances and in response to particular kinds of information. The social change detection task showed that people with ASD are influenced by a bias to attend to socially informative aspects of a scene. This bias was also present in evidence that people with ASD showed a preference to attend to a social scene, depicting a person, over a non-social scene. However, in the preferential-looking task, the social bias did not make people with ASD look at the person as much as TD people did, it did not operate from the first fixation and it did not persist over time. In this task, social information was embodied by the presence of a person, though this single individual was not actively social engaged nor socially informative. Furthermore, the free-viewing condition of the task did not impose a goal on participants, and even in the gender-discrimination condition the goal (correctly identify the person's gender) could be achieved without looking at the person from the first fixation or for the full three second viewing period.

The subtle differences between the two participant groups in the preferential-looking task, particularly when compared with the social change detection results, suggests that people with ASD may attend to social information, but only when there is a reason to do so. The human figures depicted in the preferential-looking task caught attention early on (at the second fixation people with ASD were as likely as their TD peers to look at the person depicted) but, perhaps because they were not exhibiting any obvious or useful information, people with ASD then looked elsewhere. In contrast, the people depicted in the social change detection task were changing in a socially meaningful manner, which made them more interesting targets for attention.

According to this interpretation, individuals with ASD look at other people in order to gain some information, which may be social (as in our social change detection task) or useful in other ways (as in our gender-discrimination condition). TD individuals, in contrast, seem to look at other people regardless of whether they are changing, or offering some social information. This indicates that a principal difference in the manifestation of social attention in people with and without autism may be the motivation for such attention, which may also interact with the types of information available. However, as has also been noted, discussing gross group differences ignores the possibility that individual preferences also play a role in directing attention and that these may interact with the different types of social information on display.

7.3 Theoretical Contributions to our Understanding of Autism

7.3a Theoretical Contributions: Heterogeneity in Autism Spectrum Disorders

Above all, the participants with ASD involved in this research have exceeded our expectations of their capacity, and indeed preference, for attention to social aspects of a complex visual scene. This has been seen in a variety of experimental contexts with varying degrees of task instruction, and naturalism. Subtle group differences indicate that our participants did not have a social preference to the same extent as their TD peers, revealed by the relative time spent looking at a person compared to background items. They also showed less attentional priority for social information and less persistence in attending to social information over time. These subtle differences in social attentiveness in the participants with ASD can be interpreted in the context of possible developmental changes in social attention abilities, and in reference to the specific circumstances of our experimental assessments of attention.

The minimal impairments in social attention in the ASD group may represent the residue of a more significant deficit in social attention which was present at a younger age. As many theorists concede *"early risk markers (such as... reduced propensity to orient to faces) may not be simple analogues of later signs of autism, but rather behaviours that reduce a child's opportunities to learn from social experiences, thus initiating an atypical pattern of development that eventually leads to further manifestations of autism."* (Zwaigenbaum *et al.*, 2005 p.144). It is possible that social attention deficits provide a root cause of autism without being so greatly manifest in adulthood. Alternatively, the specialised education of our sample – including training in social skills such as the use of eye-contact - combined with life-experience, may have resulted in greater social competence, including improvements in social attention. While no age or IQ effects were found in the course of these investigations, work specifically looking for a developmental progression in social attentiveness in autism could reveal that this can improve over the lifespan. This suggests that social attention atypicalities may play a greater role in the origins of autism than in maintenance of the disorder.

This hypothesis corresponds with evidence from children of links between joint attention and age, developmental level, IQ and language (Leekam *et al.*, 1998; Leekam *et al.*, 2000; Loveland & Landry, 1986; Mundy & Sigman, 1990; Mundy *et al.*, 1994) and the possibility of change in the cognitive capacities of children with autism (Pellicano, 2006), though this capacity for change may not persist in adolescence (Ozonoff & McEvoy, 1994). In this light, these data present a positive picture of what the outcome of education and life experience can be for someone with autism, in terms of their fundamental social skills. A burgeoning ability to attend to socially important elements of the environment could provide a basis for more sophisticated social skills, such as monitoring a conversation, or judging the emotional state of another. On the other hand, perhaps it is only in childhood that there is adequate flexibility to move from mere attention to people to a greater social cognitive ability.

An alternative explanation of our findings is that, in this high-functioning group with largely normal-range IQ scores, social attentiveness was never significantly different from the norm, even in childhood. Though we were unfortunately unable to distinguish between participants with Asperger's syndrome and high-functioning autism, it is possible that individuals with Asperger's syndrome might not have had severe social problems, as this can be considered a more mild variant of autism (Frith, 2004). These participants might have had good basic social attention skills throughout their lives, which helped them to attain the high level of intellectual and social ability, relative to others with ASD, seen today. This would correspond with data showing intact theory of mind and other isolated social abilities in people with Asperger's syndrome (Bowler, 1992; Ozonoff, Rogers, & Pennington, 1991; White, Hill, Winston, & Frith, 2006). In fact, intact theory of mind has also been found in people with high-functioning autism (Bowler, 1997; Ozonoff, Pennington, & Rogers, 1991), raising the possibility that the different sub-groups in our ASD sample might not have had distinct responses to our social attention tasks.

Our inability to secure detailed diagnostic measures in our sample inhibits the drawing of conclusions about a link between measures of social attention and autistic diagnosis. Cross-task analyses did not show clear links between autism quotient and social attention, but there was significant variation both within and between samples. Psychologists must acknowledge the heterogeneity of the autistic population in their research designs and attempt to incorporate measures of symptom presentation and individual analyses in research.

If some people with ASD have normal social attention skills throughout life, the question of how these individuals fail to develop other, more sophisticated social skills arises. This hypothesis casts doubt on whether social attention preferences can be invoked as a root cause of autism, and suggests that it may be only one factor in the development of social cognitive abilities in typical and autistic development. One possibility is that able individuals with autism lack social skills due to an absence of motivation to interact with others, or due to anxiety about the unpredictable actions of others. Klin and colleagues suggest that people with ASD can develop social knowledge, but that this is impaired because it is not rooted in experience (Klin *et al.*, 2003). Without proper developmental data on how social attention changes over time in both the typical and autistic population we cannot come to a firm conclusion on this issue.

7.3b Theoretical Contributions: Perceptual Processing in Autism Spectrum Disorders

Another possible explanation for the lack of social attention disturbance in our participants with autism arises from the nature of the stimulus content and experimental methods employed. Throughout, the intention was to investigate social attention in the context of complex, but static visual scenes. This type of stimulus was selected for two main reasons. First, many experiments purporting to investigate social attention present social stimuli in isolation (Bar-Haim *et al.*, 2006; Dalton *et al.*, 2005; Pelphrey *et al.*, 2002; Spezio *et al.*, 2007; van der Geest, Kemner, Verbaten *et al.*, 2002) or are an unrealistic depiction (van der Geest, Kemner, Camfferman *et al.*, 2002). Others, also presenting social stimuli in isolation, may appear to have some relevance for our understanding of social attention, but additionally assess a higher socio-cognitive skill such as response to social cues (Charwarska *et al.*, 2003; Kylliainen & Hietanen, 2004; Senju *et al.*, 2004; Swettenham *et al.*, 2003) or judgement of mental states (Back *et al.*, 2007; Baron-Cohen, Wheelwright, Hill *et al.*, 2001). It is possible that the social attention abilities apparent in some tasks arise from the simplistic presentation of social stimuli out of context, while socio-cognitive deficits exist only at the higher level of responses required by the latter studies. It was therefore crucial to present social stimuli in a realistic context and without imposing social cognitive demands on participants.

Second, evidence is building for deficits in autism in motion perception (Bertone & Faubert, 2005; Bertone *et al.*, 2003; Gepner & Mestre, 2002; Gepner, Mestre, Masson, & De Schonen, 1995; Milne *et al.*, 2005; Milne *et al.*, 2002; Milne *et al.*, 2006) and sensory integration (Iarocci & McDonald, 2006; Rogers & Ozonoff, 2005). It has been suggested that one existing assessment of social attention in autism (Klin *et al.*, 2002b) produced group differences on the basis of motion perception deficits rather than social attention deficits (Kemner & van Engeland, 2003). We therefore felt it was crucial to eliminate movement and multi-modal sensory input from our stimuli in order to make an assessment of social attention without making demands on other processing skills.

Interpreted within this framework, the next step is to investigate whether our results indicate that the presence of motion and multi-sensory input in real-life interactions de-rail the social attention process of people with ASD. Our tasks reveal broadly normal social attention behaviours in people with ASD, at all but the most meticulous level of analysis. People make about three fixations per second, and it was at the level of the individual fixation that we found the only prominent differences between our participant groups. Of course, in the real world, social information is largely presented across sensory modalities, and with movement. The investigation of social attention in the absence of sensory integration and motion processing in our tasks is concordant with the theory that people with ASD have a preference, even a desire for social information, but that their processing of this information is impaired. While our data are in accordance with this theory, they do not address the role of stimulus complexity directly. In future, it will be very important to examine this possibility.

7.3c Conclusions: Social Attention in Autism Spectrum Disorders

There are different ways of explaining the results of three novel tasks, developed here to assess spontaneous attention to social elements of a visual scene. Any explanation is also compromised by the evidence of great variability in participants' responses to different tasks. However, we can draw a general conclusion from these results and their relation to other studies: able adults with autism can show a spontaneous preference for social information. Nevertheless, the subtle differences found between groups in these experiments, at the level of the individual fixation, could translate into greater impairments in the real world, where social information is presented fleetingly and responses must be formulated with great rapidity.

Further research must investigate how the social attentional preference of individuals with and without ASD develops over time, and with developmental and intellectual level. The role of motivation in directing attention and building personal preferences should also be assessed: it is possible that able individuals with autism are motivated to attend to others, and thereby interact with them, but lack the ability to do so appropriately, or that they are only motivated to attend to social information when there is a practical reason to do so. Future research should also investigate how the stimulus complexity introduced by motion and multi-sensory input interacts with social attention preferences. Finally, if social attention is intact in adults with autism, it must be investigated whether this fundamental skill can be exploited to enhance more sophisticated socio-cognitive abilities.

7.4 Theoretical Contributions: Social Attention in Typical Adults

The studies presented here aimed to understand social attention by searching for abnormalities in social attention in adults with ASD. However, in doing so, we were also able to advance the study of social visual attention in typical development. All the methods used were novel assessments of social attention, capable of providing new information about the way in which social attention in the visual domain functions in typical adults. In particular, these data can help to elucidate the role of high-level information versus low-level properties of the visual scene in directing attention, and the interaction of preferential attention to social aspects of the environment with perceptual capacities. The studies reported here not only inform our understanding of typical social attention but can also make a contribution to our knowledge of vision in general.

Research has investigated responses to eye-gaze direction cues (Frischen *et al.*, 2007) and attention to the eyes when presented in an isolated face (Walker-Smith *et al.*, 1977). The change detection task was devised to assess attention to eye-gaze direction when presented in a complex and naturalistic scene. Changes to eye-gaze direction were compared with non-social changes to spectacles. The latter were appearance/disappearance changes to a whole object, and involved a larger area of the scene, with a tendency to being higher contrast, than the changes to eye-gaze direction. All of these low-level differences could have created an advantage for detecting spectacles changes over eye-gaze direction changes. However the data clearly showed that eye-gaze direction changes were detected both faster and more accurately than changes to spectacles. This suggests that high-level social attention preferences had a greater influence on directing attention to different parts of the scene than low-level factors. The finding corroborates evidence of other high-level influences on change detection ability, such as enhanced detection of changes to items of central importance, (Rensink *et al.*, 1997), detection of contextually inappropriate items more rapidly than items which belong in a scene (Henderson *et al.*, 1999; Hollingworth & Henderson, 2000), and the influence of individual expertise on change detection (Werner & Thies, 2000).

Mitroff and Simons (2002) have suggested that changes presented as part of a natural scene are detected according to the salience of the changing object, rather than the salience of the change. Pre-attentive mechanisms, like the social attention bias proposed here, should not improve change detection. Instead, change detection ability is embedded in the properties of the changing object, and not the manner in which it changes. However our data question that interpretation, since eye-gaze direction changes are located in the same place as changes to spectacles and yet are detected more rapidly and accurately. Though control changes were not to the eyes themselves but to spectacles - changes to eye colour were considered but these are almost impossible to detect except when the face is in extreme close-up - the social meaning of the eye-gaze direction change was embedded in the nature of the change, to gaze direction, rather than the object, the eyes. This suggests that a pre-attentive social bias is capable of affecting change detection, and that this bias is sensitive to the nature of the change, not just the identity of the changing object. Clearly further investigation would be required to adapt the social change blindness study to explicitly address this question.

The preferential-looking task provides further evidence that typical adults' attention is directed by high-level aspects of a scene over and above low-level influences. Participants were able to fixate a scene depicting a person within just 150ms of its presentation and this bias was present, among a small number of data points, from as little as 100ms. Between 15 and 20% (across two experiments) of first fixations landed directly on the face, an area taking up only 0.4% of the display on average. The relationship between the distance of the face from the fixation cross and proportion of first fixations on the face, indicated that the high-level influence on distribution of eye-movement cannot completely overcome the limitations of the visual system. Faces farthest from the initial site of foveation received fewer first fixations. Nevertheless, complex, social elements of the scene were identified extra-foveally with great rapidity and accuracy.

In those cases where a first fixation was not made to the face, participants often fixated on the body instead. This is a larger area than the face, both in our stimuli (bodies covered 8% of the display on average) and in reality. The body may also have a low-level advantage over the face since, depending on the clothing being worn, they may have stronger low-level properties such as high-contrast borders and bright colour. Bodies did seem easier to detect than faces, resulting in a larger number of first fixations on this area (between 26% and 35% in our two experiments). However, when an external goal was introduced, with a task instruction to identify the gender of the person depicted, first fixations to the face increased, but not first fixations to the body – though this finding was not repeated in the comparison of TD and ASD groups. The gender-discrimination condition illustrated that typical adults can be highly efficient in detecting faces in peripheral vision and making saccades directly to them. However, it is impossible to tell from this study what extent the body played in helping to direct saccades to the face. It is possible that the body was detected in peripheral vision, and participants used their existing knowledge of the relative positions of faces and bodies to direct a fixation to the face, without actually having identified the face itself. Thus, low-level features may still have a role in directing fixations, but these interact with and are largely superseded by high-level attentional goals.

In addition to demonstrating top-down control over eye-movements within milliseconds of stimulus onset, the preferential-looking task also showed us how people use complex information to identify gender. In the gender-discrimination condition, time spent looking at the face and body increased compared to the free-viewing condition, indicating that both elements are useful in judging gender. Though a great deal of past research has focused on face-processing, these findings suggest that perception of the body could be an interesting area for future study. Recent work has suggested that body posture may play an important role in judging emotion, (Meeran *et al.*, 2005) and this could also be the case for judgements of identity and gender.

7.5 Methodological Evaluations

7.5a Methodological Evaluation: Free-Description Task

One of the goals of this investigation into social attention in people with ASD was to create a task, or series of tasks, which would provide a measure of spontaneous social attention in a high-functioning sample of adults and adolescents with ASD. The free-description task was a way of making an initial exploratory probe into the nature of social attention in our groups. However, it could be modified to create a suitable paradigm for measuring social attention experimentally. Most importantly, the task lacked a non-social control component. In this sense, the task was similar to the social attribution task created by Klin and colleagues to assess mentalising and social reasoning in people with ASD (Klin, 2000). Since then, the same group have created a parallel physical attribution task which provides a control assessment of linguistic and reasoning skills in a non-social domain (Klin & Jones, 2006). It would be possible to refine the free-description task to incorporate a similar matched set of images depicting scenarios which invite physical descriptions – for example images of people engaged in a sporting activity, or of machinery or interesting landscapes – though matching the two stimulus sets for scene complexity would be challenging.

After the incorporation of non-social control stimuli, the free-description task could be further improved to provide a more instructive measure of social attention. First, the measurement process used here, dividing descriptions into statements, did not provide an opportunity to make a temporal assessment of social attention: it is possible that the participants with ASD were slower to direct their attention to social elements of the scene, or that in producing their descriptions they paused for longer to process the stimulus. This limitation could be overcome by using a more elaborate transcription procedure, or by combining the descriptive measure with eye-tracking. A new challenge would be to temporally match verbal descriptions with eye-movement data, but the resultant data set would combine participants' statements and eye-movements to provide two simultaneous measures of attention, each reinforcing the other. This would also provide a way of assessing mapping between covert attention (indexed by description content) and overt attention (indexed by eye-movements).

The use of a linguistic measure in this task still limits its application to less-able or younger populations. Verbal IQ was correlated with overall amount of descriptions produced, and consequently had a relationship with the distribution of participant responses into different topics. The task is therefore unsuitable for use with a group with low verbal ability, or without a well-matched comparison group. This reduces the adaptability of the free-description task for use with other populations: other methods may be more suitable for the assessment of spontaneous and naturalistic social attention in young children and those with intellectual impairments or language difficulties.

7.5b Methodological Evaluation: Social Change Detection Task

The social change detection task makes a more substantial contribution to the range of assessments of social attention available. Indeed change detection methods have been employed already to reveal developmental changes in attention (Fletcher-Watson *et al.*, submitted; Shore *et al.*, 2006) and also to investigate attentional processes in atypical populations including people with mental retardation, dyslexia, schizotypy and Williams syndrome (Carlin *et al.*, 2003; Rutkowski *et al.*, 2003; Snowden *et al.*, 2004; Tager-Flusberg *et al.*, in press). Change detection has also been used to investigate other forms of social attention, in studies which compare changes to objects being looked at by the person depicted in the scene, versus changes to objects not being looked at (Langton *et al.*, 2006; Mitchell & Freeth, 2007). The stimuli and presentation programme developed for our own social change detection study are also now being used as part of a battery of tests assessing social skills in young children with acquired brain injury (Porter, 2007). These studies all demonstrate how versatile change detection is as a way of comparing the attentional preferences of difference categories of people.

However, change detection methods do also have their limitations, perhaps in particular in the study of social attention. Our study was limited by the use of just one change-type, to eye-gaze direction, which in effect acted as a proxy for all kinds of social information. This contrasts with the other two experimental tasks used, which included a variety of person-centred information as being social. It would be challenging to extend a change detection task to include more kinds of social information for two reasons. First, each change-type introduced needs to be present in enough trials to be analysed individually, since it is not possible to equate across different kinds of social information *a priori*. For example, one might not expect the same accuracy or response time in identifying changes to a person's hand gesture as to their facial expression, though both are social in nature. Second, each social change-type needs to be matched with an equal number of a non-social control changes, in order to provide a baseline comparison which is equally susceptible to the use of expectation-based search strategies.

These two requirements mean that a social change detection study which attempted to investigate a range of different social changes would have to incorporate a very large number of trials. This can be prohibitive when working with an atypical or young population, who may find it hard to concentrate on a lengthy task. Atypical participants are also often hard to recruit in large numbers, and require matched typically-developing comparison participants, making long or multiple testing sessions inadvisable. Instead, a wide range of different types of social information such as gesture, facial expression, posture and eye-gaze direction can be more easily investigated with a method which does not rely on change detection speed or accuracy as an index of attention.

7.5c *Methodological Evaluation: Preferential-Looking Task*

Eye-tracking is just such a method, since "*eye movements provide an unobtrusive, sensitive, real-time behavioural index of ongoing visual and cognitive processing*" (Henderson, 2003, p.498). The circumstance of using an eye-tracker notwithstanding, participants can view stimuli in a relatively naturalistic situation. This flexibility is increasing as eye-trackers themselves improve: remote trackers can be successfully used even with very young infants (Frank *et al.*, submitted). Eye-tracking also facilitates the collection of interesting data without the need for elaborate experimental designs and complex task instructions. For example, Yarbus' seminal work on scene viewing revealed how simple differences in the questions asked before viewing a scene radically altered scan paths across that scene (Yarbus, 1967).

Eye-tracking has been widely used to investigate social attention and face perception in autistic populations (see Boraston & Blakemore, 2007 for a review). New studies are now also employing eye-tracking to investigate the attention of people with Williams syndrome (Riby & Hancock, 2007; Tager-Flusberg, 2007) and to reveal the development of face preferences in infancy (Frank *et al.*, submitted). Eye-tracking can also be combined with other experimental techniques (e.g. Spezio *et al.*, 2007) to help elucidate the link between where we look and our conscious awareness of that information. One suggestion here is that eye-tracking could be used in conjunction with a modified free-description task, as described earlier. The use of eye-tracking with a preferential-looking task permits stimuli of different kinds of interest to be directly pitted against each other in competition for the attention of the participant, eliminating problems with tasks which present social or non-social stimuli in isolation.

One weakness of eye-tracking methodologies is that the link between eye-movements and attention is not fully understood. Some argue that drawing conclusions about the focus of attention from the location of fixation is invalid since covert attention can shift independently of eye-movements (Luck & Vecera, 2002). However, there is a powerful relationship between eye-movements and covert attention (Findlay, 2004) and some studies also suggest a neurological link (Nobre, Gitelman, Dias, & Mesulam, 2000). Therefore it is reasonable to consider eye-movements a valid index of attention (Henderson, 2003). In particular, for the purposes of interpreting the work presented here, covert attention is not considered to be capable of focusing far from the site of current fixation, so for our relatively large domains of interest it is safe to assume that fixation within a region also corresponds to covert attention in the same region.

Another weakness, seen in our own data, is that the latency of eye-movements in particular can be difficult to interpret. Eye-movements may have very short latencies for opposing reasons: when the individual quickly locates an object of interest and moves their eyes towards it; or when the individual makes an eye-movement without an awareness of the visual display, because that eye-movement has been planned before the stimulus appeared. These latter 'anticipatory' eye-movements have short latencies but indicate a lack of attentional goal. Likewise, very long latencies can occur when the participant finally finds something he or she wants to look at, when no attentional goal has been identified and so the eyes move at random, or when the participant is engaged in processing the site of current foveation for a long time. It may only be within a central range of latencies that one can attempt to map a relationship between attentional preference and saccade latency.

Despite these uncertainties in interpreting eye-movement data, the method remains a valuable way to investigate attentional and perceptual processes. Its flexibility means it can be combined with existing paradigms and even other data recording systems (Dalton *et al.*, 2005; Jemel, 2007). The specific preferential-looking paradigm employed here is broad enough to be used with a wide range of ability levels, having little intellectual requirement. It could be adapted to investigate preferences to a wide range of stimuli, as in a study which compared images of animals to natural landscapes (Kirchner *et al.*, 2003) or research on infants comparing faces with direct and averted gaze (Farroni *et al.*, 2002). The technique permits a relatively naturalistic assessment of spontaneous attention, while making detailed recordings to permit a rich analysis.

7.5d Methodological Evaluation: Cross-task Analyses

The cross task analyses presented in this thesis represent a first step in acknowledgement of the heterogeneity of populations, and an attempt to delve further into the nature of a concept which has, to date, been poorly defined: social attention. These analyses employed a range of statistical techniques to address the combined issues of variation between tasks and individuals. A more in-depth investigation was also carried out in the form of a case study of one participant with ASD. These analyses were imperfect in that the sample size restricted the use of some statistical techniques which could have been enlightening, such as discriminant function analysis, regression and non-hierarchical cluster analysis. The small sample size also meant that conclusions were necessarily restrained and post-hoc testing such as significance tests on clusters was not possible. Furthermore, detailed symptom profiles were not available for most participants, nor did they represent a distribution of people across the autistic spectrum: most had a diagnosis of Asperger's syndrome. This limits the generalisability of these findings and their contribution to a wider understanding of autism.

Nevertheless, this chapter represents an example of how researchers in all disciplines should acknowledge and address the limitations of straightforward significance testing, and challenge the assumptions of their research field. In particular, these results demonstrate that future investigations of social attention in both typical and autistic populations should explore different types of social information, and attention under different circumstances. We cannot assume that a high level of attention to a person depicted in a picture will relate to an ability to detect changes to a specific aspect of a person, for example. Research should also, wherever possible, incorporate measures of symptom presentation in research with people with ASD. This not only provides a way of looking for sub-groups within the autistic spectrum, but in relating task performance to symptoms it increases the relevance of psychological research for clinicians, educators, parents and people with ASD themselves.

7.6 Limitations

As has been indicated above, the studies presented here are subject to three significant limitations. First, the participant group was a relatively homogenous sample of adolescents and adults with ASD: they almost all had normal-range IQs, and though symptom profiles were not available, none showed evidence of debilitating impairments. The role of social attention in autism is emphasised in developmental accounts (Klin *et al.*, 2003; Mundy & Neal, 2001; Schultz, 2005) which acknowledge the potential for change over time and with intellectual level and degree of symptom presentation. Working with participants who represent, to some extent, the end-state of child development, and a peak of intellectual functioning within autism, limits the relevance of our data for such developmental theories.

On the other hand, the sample could also be considered to be somewhat heterogeneous, in its inclusion of people with both Asperger's syndrome and high-functioning autism. In most samples, it was not possible to distinguish between these two diagnoses. Despite calls to eliminate the distinction between Asperger's syndrome and high-functioning autism (Leekam, 2007; Mayes & Calhoun, 2003) it would have been valuable to make this distinction. A comparison between individuals in each autistic sub-group could have reinforced the argument to abandon the separated diagnostic category of Asperger's syndrome, or have demonstrated a new way in which the two groups could be distinguished.

Attempts were made to incorporate measures of symptom severity and analysis of individual differences in order to overcome the limitation of sample-type. However, only one experiment incorporated an attempt to measure autistic traits and this used only a self-report questionnaire (Baron-Cohen, Wheelwright, Skinner *et al.*, 2001). This autism quotient score was not found to make a contribution to task performance in the cross-task analyses. Despite this limitation, the work presented here demonstrates a valuable approach to the analysis of experimental data from atypical populations and furthermore represents an interesting snapshot of social attention in adulthood which provides a positive picture of one possible social outcome of a childhood diagnosis of autism.

A second limitation of the current work is the focus on the use of static, uni-modal stimuli. While this focus was well-justified [see section 1.11, page 32], and provides an assessment which fills a gap between apparently contradictory evidence of social attention impairments in autism (e.g. Klin *et al.*, 2002b vs. van der Geest, *et al.,* 2002), it does not explicitly address the role of stimulus complexity in autistic social attention. It is possible that the complex processing required to succeed in real-life social interactions provides a significant obstacle to limited social attention abilities, such as may be found in autism. Nonetheless, the current investigation can add to the stimulus complexity debate, even though our studies do not directly address the role of motion or sensory integration, by showing how attention is preferentially given to social elements of a scene by people with ASD, even when they are presented in a realistic context with non-social stimuli also available for attention. This kind of stimulus complexity, at least, does not significantly hamper the social attention of people with ASD, except at the most delicate level of analysis.

Finally, our results are limited in their relation to each other. The overall conclusion drawn from these data is that social attention preferences do operate spontaneously in people with ASD, except when analysed at a level of fine detail – the individual fixation. In this case, we have revealed subtle differences in the exact distribution of attention between social and non-social elements of a scene, in the priority given to social information, and in the persistence of social attention over time. However, the cross-task analyses did not reveal consistent relationships between these three tasks, raising the possibility that they do not measure comparable aspects of social attention. One way in which tasks differed was in the type of social information presented: it is possible that social information can not only be considered in a hierarchy, but that this hierarchy differs between individuals.

If tasks had been related to standard measures of social attention (e.g. gaze following) or social function (e.g. false belief) we might have a different understanding of the meaning of these data. Unfortunately, standard measures of social attention as used with children are not suitable for an able, adult sample and socio-cognitive measures were not originally expected to relate to the hypothesis at hand. In fact, social cognitive abilities were intentionally excluded from assessment, since the study aimed to investigate social attention in isolation from other social skills. Inclusion of such measures might not have produced clearer relationships between tasks, and the small sample size for the cross-task analyses prohibits many analyses. This is one option for future assessment of social attention, and such a study would help to define the nature of social information as well as making links between the different social problems of people with autism. For the time being, the explanation given is believed to be the most parsimonious interpretation of these data, and fits with a conceptualisation of social attention as a developing skill which may be largely normal in autistic adulthood.

7.7 Future Directions

It will be important to build on the work introduced in this thesis, to further understand the developing relationship between social function and perceptual abilities in autism and in typical development. The methods designed here can be adapted to investigate social attentiveness over the lifespan in both able and less-able groups with ASD, to reveal whether social attention relates to later autistic symptom severity and intellectual function, or whether good language and high IQ can allow an individual to learn social attention later in life. The paradigms developed here could also be adapted to research social attention in other groups. A first step would be to adapt the existing change detection and preferential-looking tasks for use with children with ASD, and investigate whether there is evidence of greater impairment in social attention at younger ages. Preferential-looking tasks, using a remote eye-tracker, would also be appropriate for use with non-verbal and low-functioning individuals, so that social attention could be mapped across age and ability levels.

Moreover, adapting the stimuli presented in a preferential-looking task could also provide a way of assessing attentional hierarchies. For example, the social scenes presented could show a person with an emotional expression or someone with a neutral expression, a group of people interacting or a person alone, and a person facing or a person turned away from the viewer. Pitting these different levels of social stimulus against a non-social scene in direct competition for attention would help to reveal how different kinds of social information capture, and hold, attention. The greater the preference for the social scene, the more that kind of social information captures attention. This kind of design could even be used to map personal social attention preferences for different individuals.

There is some suggestion of an interaction between top-down attentional control and sensory processing atypicalities (Blakemore *et al.*, 2006) and between social and motion processing problems (Abreu & Happe, 2005). It is therefore important to systematically investigate the role of stimulus complexity in attention and perception in both the social and non-social domain. It is possible that cues which enhance typical attention – such as movement and multi-modal sensory information – inhibit processing in autism. This is one explanation for the discrepancy between our data and the results of Klin and colleagues (2002b). It would be most valuable to investigate stimulus complexity by using both social and non-social information and presenting stimuli in a naturalistic manner. An experiment could present social and mechanical stories (e.g. Baron-Cohen, Leslie, & Frith, 1986) as sequences of still frames compared with a continuous moving film, to investigate the role of motion processing. These could be accompanied by no soundtrack, music, an inappropriate and an appropriate verbal soundtrack, to assess the influence of multi-modal sensory information on attention.

Another way of examining the interaction between sensory processing and social attention would be to present participants with a series of cues to attention in different modalities, and with or without social meaning. For example, a person pointing, speaking or touching the participant could be compared with visual, aural and tactile cues provided by objects. These could be varied according to whether they were presented exogenously, drawing attention to themselves or endogenously, to direct the participant's attention elsewhere. Likewise the nature of the target in the endogenous condition – something non-socially rewarding like a cookie, socially rewarding like a person smiling and clapping, or something neutral like a colourful picture - could be varied to investigate the role of motivation and reward in social attention.

Once again, taking a developmental perspective will be vital – does a processing problem or a lack of motivation for social attention lie at the root of autism? Do processing and social impairments develop in parallel, or interact to compound each other? Can we intervene in one area, and consequently have positive effects on the other? One way of answering these questions would be to combine eye-tracking with neuro-imaging techniques, to discover whether participants looking at the same stimulus are responding in the same way.

Finally, the continued investigation of typical social attention is crucial to provide a comparison for research into autism. How do social attention preferences function in different sensory modalities and presentation circumstances? How do high-level biases interact with perceptual limitations? In development, when does a perceptual model of the salient aspects of the world begin to turn into a semantically-defined set of preferences, and does the latter fully replace the former? Likewise, research in autism may have unexpected consequences for our understanding of typical development.

7.8 Conclusions

The introduction to this thesis suggested that by the end of the investigation we would have fulfilled three aims. First, whether adults with ASD show intact or impaired social attention in response to static, naturalistic scenes, and how this differs from TD social attention. Second, how social attention functions in typical adults, specifically revealing the relative influence of high and low-level information on attentional focus. Third, the suitability of the construct of social attention to be invoked as a crucial factor in development and maintenance of autism and as an explanation for experimental findings.

In response to the first aim, our data uncover a social attention bias in autism, which directs attention even when social information is presented as part of a complex scene, when non-social information is also available for attention. Differences in social attention between participants with ASD and TD individuals were only found at the level of the individual fixation, indicating that in adulthood social attention in autism is largely normal. This preference is likely to be the consequence of a developmental process in which social attention is linked to intellectual and language skills, and perhaps to life-experience, offering an optimistic perceptive on autism, and suggesting that very basic social skills could be capitalised upon to scaffold social cognitive abilities. However, the subtle differences found between our two groups could have profound effects in real life, where social information is presented fleetingly and responses must be made rapidly. The autistic social attention mechanism may be further obstructed in real-life by the need to process moving and multi-modal stimuli, and this is a question ripe for further investigation.

Typically-developed adults demonstrated powerful social attention preferences, which seemed to have an influence on attention distribution over and above the effect of low-level scene features. In particular, change detection was enhanced for social information, despite non-social changes having a number of low-level advantages over social changes. However, the location of fixations within a scene also show that high-level attentional preferences and stimulus properties are subject to some perceptual limitations. Participants' ability to make saccades directly to social stimuli is limited by the distance of that stimulus from fixation, and high-contrast, colourful, large bodies may be used to direct saccades to faces. Nevertheless, there was no evidence that participants' attentional preferences for social information were overwhelmed by the presence of non-social stimuli with strong low-level visual characteristics. Taken together, in response to the second aim of this thesis, we can see that high-level input does have a significant influence on attention in typical adults, but that the limitations of the perceptual system must also be taken into account.

This program of research has developed three new methods for assessing social attention, which are also ripe for adaptation to be used with different populations. This contribution to the range of tools available for the study of high-level influences on attention is very valuable. Our examinations of the manifestation of social attention in TD adults and those with ASD have revealed that our vocabulary for examining 'social' skills and behaviours may be woefully inadequate. The studies presented here investigated attention to both person-centred and non-person social information, and to a hierarchy of more or less socially informative aspects of people. If we are to understand the nature of social attention, and its role in both typical and autistic development, we must refine our terminology to reflect the range of social input available and to acknowledge individual differences in attentional preference. Future assessments of social attention, and cognition, should acknowledge and compare the influence of social motivation and perceptual processes, and should draw a distinction between different social targets. Therefore, in response to the third aim of this thesis, it seems that the existing construct of social attention is not adequate to explain either the development or the maintenance of autism. This is not because social attentional difficulties do not play a part in autism, but because the term 'social attention' has been shown to encompass a range of behaviours and social stimuli which it cannot adequately describe.

8. Appendix 1: Supplementary Information for Chapter 2

8.1 Appendix 1a

8.1a Free Description Task

In this task, participants were asked to describe 12 colour photographs (presented individually on a computer screen) in as much detail as they could, as if describing them to someone outside the room. There was no time pressure and task instructions were designed to impose as little restriction on the speaker as possible. Those participants who said very little were encouraged (after the first two images only) to say a little more using phrases such as "*Anything else? Can you say any more?*" Descriptions were recorded on a minidisk player.

The goal of this task was to use recordings of people describing photographic images to assess their social attention. Six measures were produced and analysed:

References to people per script, as a proportion of total references

Social references per script, as a proportion of total references

Proportion of total references to people made in each half of each description

Proportion of total social references made in each half of each description

Proportion of repeated statements.

Proportion of repeated statements devoted to social information

The following represents a copy of the coding scheme as given to coders. Note that Steps 1 and 2 were performed by the experimenter in all cases.

8.1b Initial Coding Scheme and Instructions

In this task, participants were asked to describe 12 colour photographs (presented individually on a computer screen) in as much detail as they could, as if describing them to someone outside the room. Your job is to rate the content of these descriptions according to the different kind of information provided. The term 'description' refers to the section of text describing a particular photograph. The term 'script' refers to the full set of descriptions provided by a participants.

Step 1: Transcribe entire script, excluding introductory experimenter comments but including incidental participant comments and pauses. Divide the script into descriptions of each photograph.

Step 2: Divide the script into "phrases" at points where the principal subject of the information imparted changes.

Step 3: Count the total number of phrases per description and per script

Step 4: Divide each image description at the approximate halfway point. NB: if the image description has an odd number of phrases, always divide to leave more phrases in the first half.

Step 5: Label phrases which include information about people or people-centered information by marking in red (full definitions overleaf). Record the total number of these 'Human' references per description and per script. Record the number of Human references in the first half and second half of each description

Step 6: Label phrases which include social information or exhibit social motivation, by marking with an underline (full definitions overleaf). Record the total number of these 'Social' references per description and per script. Record the number of Social phrases in the first half and second half of each description.

Step 7: Record the number of repetitions in which *no new information* is revealed but the phrase merely repeats previously described information and mark them in italics (original and repeated phrases). Count how many of these are social references and record totals per description and per script.

Definitions of Human and Social references are provided in the table below. This table includes definitions which aim to encompass almost every type of information a phrase could convey in the context of this task. Phrases which fall outside the compass of the instructions above need not be coded or counted, however their definitions are provided to help you understand what information falls within the definition of Human references and Social references, and what information is excluded.

Category	Category definition	Example phrases	Excluding...
Layout	Comment on image layout	"Behind her" "facing left" "the focus of the picture" "it's not all in the picture"	"she's looking at him" "she's smiling at the camera"
Location	Comment on location (non-theoretical). Includes reference to time of day, seasons etc..	"they're outside" "it's a street" "looks like the afternoon" "it's a hot country"	"Looks like New York" "maybe it's a school" Anything debateable or theoretical
Physical	Person description: appearance, age etc	"he's tall" "she's about 5 years old" "he's dressed casually" "he's wearing a t-shirt" "it's a brass band"	"a blue t-shirt" "he looks like a professor" Any descriptions which are debateable or theoretical Any descriptions of clothes
Object	Object description – colour, size etc	"a yellow thing" "some kind of sign" "blue jeans with a belt"	"he's wearing a shirt" "he's holding something" Phrases describing the action performed on an object, not the object itself
Action	Apparent action description (non-theoretical)	"he's pointing" "they're hugging" "she's crying" "he's standing"	"she's congratulating the other girl" "she's thinking" also exclude "*wearing*"
Story	Hypothetical inspired by image	"she looks like she just fell over" "they're having a demonstration" "he looks like a professor" "they're at a university" "they're having a graduation"	"it's a crowd of people" "it's a brass band" "they're outside an old building"

Emotion	Description of person's emotion	"she's unhappy" "she's a bit over-excited" "he looks full of rage"	"she's crying" Physical descriptions of actions or expressions
Mentalising	Description of person's thoughts or character or role	"he's sort of saying 'oh well, never mind" "he looks aggressive" "she's the band leader"	"he's sad" "she's crying"
Relationship	Description of personal relationship between people	"she looks like his mother" "there's a mother and a baby" "his best friend"	"she's the band leader"
Photo	Comment on photo quality/photographer	"it's really blurry" "it isn't a professional photo"	"it's not all in the picture" "we can't see all of him"
Social 'super' category	Phrases including social information or requiring social knowledge.	Most emotion, story, mentalising, interacting and relationship comments. "He's in charge" "it's a graduation I think". Also some object descriptions: "formal clothing" "indian costumes"	"I think they're in a hot country" "he might be pointing at something"
Human 'super' category	Phrases referring directly to people, their actions, their posture, their characters, emotions and thoughts	Most physical and action phrases as well as some social phrases (above). Almost anything including a personal pronoun: he, she, they, etc..	"It's a torch he's got" "they're all in a line going off into the distance" "it's a big crowd". These don't describe individuals or impart specific information about people.
Repetition	Any phrase repeating previous information with nothing added	"she's looking really upset" "yeah she's really sad"	"she's crying" "she looks really unhappy" "she's got her mouth open wailing"

8.1c Sample Script (TD participant)

The following is a full script from the typically-developing participant, provided as an example of the kind of content provided by participants. This script was selected since it provides a large amount of content (though some scripts were very much shorter) and the coded version includes examples of all types of information relevant to our hypotheses.

Picture 1

ok it's a picture of a man with a white shirt on wearing a grey suit... he's appears to be pointing at something... is in a very crowded place... there are people behind him um there's... a woman to the left of him with a blue t-shirt on holding up some sort of poster and there's also... I think it's another woman... to the right but she's wearing a bandanna covering most of her face up... and she's er holding a really big sign saying... you can make out the words "to he belong with the cops"... um... there's a it's a really really really crowded place you can't really make out many of the people... all the people in the picture as far as I can see are black people erm... all facing the same direction... it looks like some sort of protest... possibly the guy at the front is leading the protest

Picture 2

ok the next picture is of a couple... they appear to be having a dance lesson... the... it's a couple a male and a female the female is wearing a black top with spots on it and a long skirt with a white boots... it's a blue skirt um... they appear to be in some sort of community centre maybe... I don't know whether it's a dance lesson or some sort of function that they're at... the guy's wearing a red and blue check shirt with dark jeans on um there are few balloons... maybe leading you to the conclusion that it's some sort of celebration

<u>Picture 3</u>

ok the next photograph is of five people appearing to be in some sort of discussion... maybe some sort of confrontation as the main guy... well he appears to be the main guy wearing a kingkong t-shirt appears to be quite serious... maybe some sort of debate? um... they're in a very sunny place all wearing shorts and t-shirts there are four men in the picture and one woman um... I'm not really sure whereabouts they are somewhere really hot on... th- everyone's outside um... (laughs) I don't know what else to say... I'm not... you can't really tell what's going on... but it appears to be two men in confrontation... and then the rest of the people look to be bystanders?

<u>Picture 4</u>

the next picture is of a... couple... a man is playing some sort of flute or wind instrument... he's wearing and green t-shirt a blue jacket and jeans with a belt he has spectacles on the woman is wearing a blue t-shirt... with... dark trousers and a belt again w- th- some sort of shirt wrapped round her shoulders... she appears to be listening to the music that the man's playing and they're in some sort of old market place ... it looks like some sort of outdoor market... but they're in one of the stands which seems to be selling quite a lot of musical instruments and brightly coloured things erm... that's about it

<u>Picture 5</u>

k- the next picture is of a brass band... there are a lot of people in the picture maybe 15 20 people all playing brass instruments they seem quite happy... it's some sort of celebration everyone's wearing a red uniform um... with brass buttons on it... and gold trim... a- there's a one woman who doesn't appear to be playing any instrument she's at the f- more or less the centre of the picture and is waving her arms around and appears to be singing maybe rather than playing an instrument as everyone else is doing

Picture 6

the next picture is of... two guys quite young guys maybe in their early twenties w- one of the guys has his arm round the other one... they appear to be friends of some sort... one guy is wearing a gilet and a check shirt... he has dark hair... both of th- very er- smiling and happy sort of people the one on the right hand side of the picture has got a pink and red t-shirt with a picture of beer on the front and he's wearing a hat... the o- its- looks to be some sort of student maybe sort of picture on some sort of night out ok?

Picture 7

the next picture is again of two men again both happy however... these are old men maybe in their late forties? um... I think they've just won some sort of award the- er- one of them's holding up a trophy they both look very happy erm and they have some sort of scoreboard behind them leads me to the conclusion that it's some sort of... sporting event the man on the right of the picture has a cream shirt on with blue trim and the man on... the other side has a check shirt on they both seem very happy

Picture 8

ok the next picture is of four... females maybe at some sort of fancy dress party erm they look as if they're getting ready for a night out actually or they're actually on a night out erm there are four girls one of them is... wearing a dress with a white top underneath and she has spectacles on two of the girls one e- is doing the other girl's hair they seem to be s- in some sort of bedroom there's quite a lot of clothes all over the place erm all smiling very happy... the girl at the front of the picture is wearing erm very it's a blue dress she has really long wavy blond hair and they just look as if they're getting ready to go somewhere

Picture 9

ok the next picture appears to be at some sort of graduation everyone's wearing caps and gowns everyone looks very happy people have got pieces of paper in their hands erm... it's looks to be in a very sort of an old formal... well it's outside the picture has been taken but it's outside quite an old formal sort of building erm... there's a lot of ivy and stuff and there's quite a lot of movement in the picture it's s- quite a blurred picture... one of the women is l- like seems to be congratulating another one and they're all very formally dressed t- the one who those who don't have caps and gowns who appear to be congratulating those who do are all wearing suits... it's very s- sort of like a black tie sort of dress (long pause) ok

Picture 10

ok the next picture is what may or may not be a mother and a baby it's any- it's a woman with some sort of young child... the woman has spectacles on and is wearing a white t-shirt and a gold chain she's smiling and looking down at the baby who she's holding in her arms... maybe it's not a baby it's actually some sort of- it's a toddler... the toddler looks seems to be very pouty I think if it's a he maybe he's a bit distressed and the woman's trying to comfort him um she's... obviously it's nothing too serious as the woman is still smiling and it seems just that the toddler may have fallen over or something? cause he's doesn't look too happy

Picture 11

ok the next picture is of a little girl it's just the little girl's face she's got blond wavy hair and is wearing a white jumper and the picture's been taken outside she doesn't look very happy at all and is actually looks as if she's screaming or crying... you can't really tell what's happening as it's just the little girl on her own but she doesn't look very happy

Picture 12

ok the next picture is... of three girls... stood in a line all wearing jeans and sort of t-shirts... it's taken outside... I'm not sure what's going on... it's seems to be taken early evening... I don't know whether it's some sort of sporting event or som- some sort of social occasion... but they're not formally... dressed... maybe on some sort of sporting camp or something? um... there are two oh no three men in the background all dressed in indian sort of costumes... they all have like feathers on and... you can't really tell what's going on in the picture... ok?

8.1d Sample Coded Script

The following gives a copy of the preceding sample script, which has now been coded according to the definitions provided above. Each description ends with the total number of phrases produced in that segment, plus the number of phrases in Human and Social categories, and the number of repetitions. Please note that each description in this script would have been split into two halves for the experimental analysis, and totals provided for each half of the description separately. This information has been left out here to simplify this example.

Red text indicates information which falls into the 'Human' category. Underlined text indicates information which falls into the 'Social' category. *Italicised text* indicates information which is repeated.

Picture 1

ok it's a picture / of a man / with a white shirt on / wearing / a grey suit... / he's appears to be pointing at something... / is in a very crowded place... / there are people / behind him um / there's... a woman / to the left of him / with a blue t-shirt on / holding up / some sort of poster /and there's also... / I think / it's another woman... / to the right / but she's wearing a bandanna covering most of her face up... / and she's er holding / a really big sign saying... you can make out the words "to he belong with the cops"... um... / there's a it's a really really really crowded place / you can't really make out many of the people... / all the people in the picture as far as I can see are black people erm... / all facing the same direction... / it looks like some sort of protest... / possibly the guy at the front is leading the protest

Total phrases = 27; Human = 12; Social = 2; Repetitions = none

Picture 2

ok the next picture is of / *a couple...* / they appear to be having a dance lesson /... *the... it's a couple* / a male and a female / the female is wearing / a black top with spots on it / and a long skirt / with a white boots... / it's a blue skirt um... /they appear to be in some sort of community centre maybe /... I don't know / *whether it's a dance lesson* / or some sort of function that they're at /... the guy's wearing / a red and blue check shirt / with dark jeans on / um there are few balloons /... maybe leading you to the conclusion / that it's some sort of celebration

Total = 20; Human = 7; Social = 7; Repetitions = 1 social

Picture 3

ok the next photograph is of / five people / appearing to be in some sort of discussion /... maybe some sort of confrontation / as the main guy... / well he appears to be the main guy wearing / a king-kong t-shirt / appears to be quite serious... / maybe some sort of debate? um.../ they're in a very sunny place / all wearing shorts and t-shirts / there are four men in the picture and one woman um /... I'm not really sure whereabouts they are / somewhere really hot on... th- / everyone's outside um... (laughs) / I don't know what else to say /... I'm not... / you can't really tell what's going on... / but it appears to be two men in confrontation... / and then the rest of the people look to be bystanders?

Total = 20; Human = 8; Social = 7; Repetitions = none

Picture 4

the next picture is of / a... couple... / a man is playing / some sort of flute or wind instrument... / he's wearing / a green t-shirt a blue jacket and jeans with a belt / he has spectacles on / the woman is wearing / a blue t-shirt... with... dark trousers and a belt again w- th- some sort of shirt / wrapped round her shoulders... / she appears to be listening to the music that the man's playing / and they're in some sort of old market place ... / it looks like some sort of outdoor market... / but they're in one of the stands / which seems to be selling quite a lot of musical instruments and brightly coloured things erm... / that's about it

Total = 16; Human = 7; Social = 1; Repetitions = none

Picture 5

k- the next picture is of / a brass band... / there are a lot of people in the picture / maybe 15 20 people / *all playing* / *brass instruments* / they seem quite happy... / it's some sort of celebration / everyone's wearing / a red uniform um... / with brass buttons on it... / and gold trim... / a- there's a one woman who doesn't appear to be playing any instrument / she's at the f- more or less the centre of the picture / and is waving her arms around / and appears to be singing maybe rather than playing an instrument / *as everyone else is doing*

Total = 17; Human = 10; Social = 2; Repetitions = 1 people

Picture 6

the next picture is of... / two guys / quite young guys / maybe in their early twenties w- / one of the guys has his arm round the other one... / they appear to be friends of some sort... / one guy is wearing / a gilet and a check shirt... / he has dark hair... /both of th- very er- smiling and / happy sort of people / the one / on the right hand side of the picture has got / a pink and red t-shirt with a picture of beer on the front / and he's wearing a hat… / the o- its- looks to be some sort of student maybe sort of picture / on some sort of night out / ok?

Total = 18; Human = 11; Social = 4; repetitions = none

Picture 7

the next picture is again of / two men / *again both happy* / however… these are old men maybe in their late forties? um… / I think they've just won some sort of award / the- er- one of them's holding up a trophy / *they both look very happy erm* / and they have some sort of scoreboard / behind them / leads me to the conclusion that / it's some sort of… sporting event / the man / on the right of the picture / has a cream shirt on with blue trim / and the man on… / the other side / has a check shirt on / *they both seem very happy*

Total = 18; Human = 9; Social = 5; repetitions = 2, both social

Picture 8

ok the next picture is of / *four… females* / maybe at some sort of fancy dress party erm / *they look as if they're getting ready for a night out actually* / or they're actually on a night out erm / *there are four girls* / one of them is… wearing a / dress with a white top underneath / and she has spectacles on / two of the girls one e- is doing the other girl's hair /they seem to be s- in some sort of bedroom / there's quite a lot of clothes all over the place erm / all smiling / very happy… / the girl / at the front of the picture is wearing erm / very it's a blue dress / she has really long wavy blond hair / *and they just look as if they're getting ready to go somewhere*

Total = 19; Human = 11; Social = 5; Repetitions = 1 social, 1 people.

Picture 9

ok the next picture / appears to be at some sort of graduation / everyone's wearing caps and gowns / everyone looks very happy / people have got pieces of paper in their hands erm…

/ it's looks to be in a very sort of an old formal… well it's outside the picture has been taken / but it's outside quite an old formal sort of building erm… / there's a lot of ivy and stuff / and there's quite a lot of movement in the picture / it's s- quite a blurred picture… / one of the women is I- like seems to be congratulating another one / and they're all very formally dressed / t- the one who those who don't have caps and gowns / who appear to be congratulating those who do / are all wearing suits… / it's very s- sort of like a black tie sort of dress / (long pause) ok

Total = 17; Human = 7; Social = 6; Repetitions = none

Picture 10

ok the next picture is / what may or may not be a mother and a baby / it's any- it's a woman / with some sort of young child… / the woman has spectacles on and is wearing / a white t-shirt and a gold chain / she's smiling and / looking down at the baby / who she's holding in her arms… / maybe it's not a baby it's actually some sorf of- it's a toddler… / the toddler looks seems to be very pouty / I think if it's a he maybe he's a bit distressed / and the woman's trying to comfort him um she's… / obviously it's nothing too serious / as the woman is still smiling and / it seems just that the toddler may have fallen over or something? / cause he's doesn't look too happy

Total: 17; Human = 14; Social = 6; repetitions = none

Picture 11

ok the next picture is of / a little girl / it's just the little girl's face / she's got blond wavy hair and is wearing / a white jumper and / the picture's been taken outside / *she doesn't look very happy at all* / and is actually looks as if she's screaming or crying… / you can't really tell what's happening / as it's just the little girl on her own / *but she doesn't look very happy*

Total = 11; Human = 7; Social = 2; repetitions = 1 social

Picture 12

ok the next picture is... / of three girls / stood in a line / all wearing jeans and sort of t-shirts / it's taken outside... / I'm not sure what's going on... / it's seems to be taken early evening... / I don't know whether it's some sort of sporting event or som- some sort of social occasion... / but they're not formally... dressed... / maybe on some sort of sporting camp or something? um... / there are two oh no three men / in the background / all dressed in indian sort of costumes... / they all have like feathers on and... / you can't really tell what's going on in the picture... ok?

Total = 15; Human = 6; Social = 4; repetitions = none

8.2 Appendix 1b

8.2a Free Description Task – Final Coding Scheme

The coding scheme originally developed for the free-description task was adjusted slightly before the experimental comparison of TD and ASD groups. Six new sub-categories were added to ensure that every kind of utterance produced could be categorised under the coding scheme. In all other respects the coding scheme and coders' instructions used for the final experiment were identical to those used while developing the method. The new sub-categories are marked in grey in the table below.

Category	Category definition	Example phrases	Excluding...
Intro/outro	Opening/closing statement, lacking descriptive value	"Ok, this one is of..." "number 4" "that's that for this one"	"it looks like a party..." any opening statement which imparts information
Layout	Comment on image layout	"Behind her" "facing left" "the focus of the	"she's looking at him" "she's smiling at the camera"

		picture" "it's not all in the picture"	
Location	Comment on location (non-theoretical). Includes reference to time of day, seasons etc..	"they're outside" "it's a street" "looks like the afternoon" "it's a hot country"	"Looks like New York" "maybe it's a school" Anything debateable or theoretical
Physical	Person description – appearance, age etc	"he's tall" "she's about 5 years old" "he's dressed casually" "he's wearing a t-shirt" "it's a brass band"	"a blue t-shirt" "he looks like a professor" Any descriptions which are debateable or theoretical Any descriptions of clothes
Object	Object description – colour, size etc	"a yellow thing" "some kind of sign" "blue jeans with a belt"	"he's wearing a shirt" "he's holding something" Phrases describing the action performed on an object, not the object itself
Action	Apparent action description (non-theoretical)	"he's pointing" "they're hugging" "she's crying" "he's standing"	"she's congratulating the other girl" "she's thinking" also exclude "*wearing*"
Story	Hypothetical inspired by image	"she looks like she just fell over" "they're having a demonstration" "he looks like a professor" "they're at a university" "they're having a graduation"	"it's a crowd of people" "it's a brass band" "they're outside an old building"
Emotion	Description of person's emotion	"she's unhappy" "she's a bit over-excited" "he looks full of rage"	"she's crying" Physical descriptions of actions or expressions
Mentalising	Description of person's thoughts or character or role	"he's sort of saying 'oh well, never mind" "he looks aggressive" "she's the band leader"	"he's sad" "she's crying"
Interacting	Description of a non-physical interaction between people	"they're arguing about something" "she's congratulating her"	"he's sort of saying 'oh well, never mind" "she's hugging him"

		"they're dressing up"	
Relationship	Description of personal relationship between people	"she looks like his mother" "there's a mother and a baby" "his best friend"	"she's the band leader"
Photo	Comment on photo quality/photographer	"it's really blurry" "it isn't a professional photo"	"it's not all in the picture" "we can't see all of him"
Personal	Personal comment	"he reminds me of my boyfriend" "I don't like the look of him"	"I think he looks a bit upset"
Doubt	Expression of doubt	"I'm not really sure about that" "It's really hard to tell what's going on"	"Maybe they're having a discussion" "They could be married"
Fillers	Phrases imparting no real information	"this is like some kind of thing" "or something like that"	Anything imparting information
Justifications	Phrases justifying opinions but imparting no new information of their own	"judging by what they're wearing" "by looking at their faces"	"they're married because he's wearing a wedding ring"
Social 'super' category	Phrases including social information or requiring social knowledge	Most emotion, story, mentalising, interacting and relationship comments. "He's in charge" "it's a graduation I think". Also some object descriptions "formal clothing" "indian costumes"	"I think they're in a hot country" "he might be pointing at something"
Human 'super' category	Phrases referring directly to people, their actions, their posture, their characters, emotions and thoughts	Most physical and action phrases as well as some social phrases (above). Almost anything including a personal pronoun: he, she, they, etc..	"It's a torch he's got" "they're all in a line going off into the distance" "it's a big crowd". These don't describe individuals or impart specific information about people.

Repetition	Any phrase repeating previous information with nothing added	"she's looking really upset" "yeah she's really sad"	"she's crying" "she looks really unhappy" "she's got her mouth open wailing"

NB: New categories, not used in the original coding scheme used in the preliminary study, are highlighted.

9. Appendix 2: Supplementary Information for Chapter 3

9.1 Example Stimuli from the Social Change Detection Task

9.1a Examples of 'Twinned' Stimuli

Figures 9.1 and 9.2 show cases in which a social change to eye-gaze direction and a non-social change to spectacles were introduced in two copies of the same image, used in two separate trials in the task. This strategy meant that stimuli could be matched perfectly for image content and complexity. In both figures, the change to eye-gaze is shown in the upper half and the change to spectacles is shown in the lower half. The altered image is always on the right.

Figure 9.1: Twinned stimuli showing changes to both eye-gaze direction and spectacles

Figure 9.2: Twinned stimuli showing changes to both eye-gaze direction and spectacles

9.1b Examples of 'Matched' Stimuli

Figures 9.3 and 9.4 show cases in which a social change to eye-gaze direction and a non-social change to spectacles were introduced two different scenes, used in two separate trials in the task. While stimuli were matched across stimulus groups for the number of eyes, faces and people visible, it was not possible to match for general stimulus complexity. However, this matching strategy avoided the potential complications of repeating all stimuli twice, once with each kind of experimental change. In both figures, the change to eye-gaze is shown in the upper half of the figure and the original image is on the left, while the altered scene is on the right.

Figure 9.3: Matched stimuli showing changes to eye-gaze direction and spectacles

Figure 9.4: Matched stimuli showing changes to eye-gaze direction and spectacles

9.1c Examples of 'Filler' Stimuli

Figures 9.5 to 9.7 show examples of 'filler' stimuli in which changes were introduced to non-social aspects of scenes. Efforts were made in filler stimuli to create potential for experiment change – images were selected to show people's eyes, and people wearing spectacles, even though these did not change in filler stimuli. Most filler images had changes to objects which were not connected to the people depicted, as in Figure 9.5. However, 15 out of 38 filler changes were to objects which were connected to the people depicted, as in Figure 9.6. Only four of these changes were in the face-region and most were to clothing or objects being held by the people depicted. This was due to the absence of alternative image-aspects suitable for change. In all three figures, the original image is on the left, while the altered scene is on the right.

Figure 9.5: A filler stimulus with a change to a non person-centred item (the cross in the background).

Figure 9.6: A filler stimulus with a change to a person-centred item (the right-hand girl's pendant).

Six filler stimuli had two changes introduced, and these therefore made up twelve trials in the experiment. These were included to provide suitable fillers for the twinned stimuli depicted in Figures 9.1 and 9.2. In the example below, the original images are on the left, while the altered scenes are on the right

Figure 9.7: A filler stimulus with two different changes (to the horizon and the film camera).

A CD of supplementary material is enclosed in this thesis. This shows all experimental images used in the final experiment in Chapter 3, and also a selection on filler images. These can be viewed on a computer to give a larger and clearer depiction of the changes as seen by participants in the study.

10. Appendix 3: Supplementary Material for Chapters 4 and 5

10.1 Example Stimuli from the Preferential-Looking Task

These are example stimuli as used in Set 2 (Chapter 4) and throughout Chapter 5. The stimulus on the left contains a PP scene which is re-used as a PA scene on the right.

Figure 10.1: Sample stimuli for the preferential-looking task

11. Appendix 4: Supplementary material for Chapter 6.

11.1 Cross-Task Analyses: Original Variables and Summary Score Calculations

11.1a Free-Description Task Variables

The following variables were recorded in the Free-Description task:

1. Number of phrases recorded: total per script. Also divided into the total per script placed in the first half of a description and in the second half of a description: in the event of an odd number of phrases, the first half of the description always included one more than the second half.
2. Number of repetitions of social information: total per script
3. Number of repetitions of non-social information: total per script
4. Proportion of phrases describing people: percentage per script. Also calculated as the proportion of phrases describing people in each half of a description.
5. as #4, for social information
6. Proportion of 1st placed phrases describing People information: percentage per script
7. Proportion of 2nd placed phrases describing People information: percentage per script
8. as #6 for social information
9. as #7 for social information

The following summary statistics were used for analysis of the Free-Description task in relation to other tasks:

- FD descriptors: Proportion of phrases describing social information: percentage per script
- FD Priority: Proportion of 1st placed phrases describing social information: percentage per script
- FD composite: Score of one every time an individual result exceeds the mean, across all participants, for the following variables (see above): number of social repetitions,

percentage of phrases describing people, percentage of phrases in the first half of each description describing people, percentage of phrases describing social information, percentage of phrases in the first half of each description describing social information, percentage of first and second phrases describing people or social information. This created a score out of nine for each participant: the greater the score, this higher the level of social attentiveness.

11.1b Social Change Detection Task Variables

The following variables were recorded in the Social Change Detection task:

1. Accuracy for non-experimental 'filler' trials with a change: % correct
2. Accuracy for non-experimental 'filler' trials with no change: % correct
3. Accuracy for experimental 'spectacles' trials: % correct
4. Accuracy for experimental 'eye-gaze' trials: % correct
5. Response time for non-experimental 'filler' trials with a change: mean across all trials
6. Response time for non-experimental 'filler' trials with no change: mean across all trials
7. Response time for experimental 'spectacles' trials: mean across all trials
8. Response time for experimental 'eye-gaze' trials: mean across all trials
9. Expectation advantage: mean response time to filler changes minus mean response time to spectacles changes
10. Social advantage: mean response time to spectacles changes minus mean response time to eye-gaze changes

The following summary statistics were used for analysis of the Social Change Detection task in relation to other tasks:

- Expectation advantage: as #9 above
- SCD advantage: as #10 above
- Baseline response time: as #5 above

11.1c Preferential-Looking Task Variables

The following variables were recorded in the Preferential-Looking task:

1. Viewing time for each Scene: person-present and person-absent. % of total viewing time
2. Viewing time for each Domain: Person, Body, Face, Face-remainder, Eyes, Object, Viewing-cone. % of total viewing time.
3. Domain-relative viewing time for each Domain: Person, Body, Face, Face-remainder, Eyes, Object, Viewing-cone. % of total viewing time divided by size of domain as a % of total stimulus size.
4. First fixations for each Scene: person-present and person-absent. % of all first fixations.
5. First fixations for each Domain: Person, Body, Face, Face-remainder, Eyes, Object, Viewing-cone. % of all first fixations.
6. First saccade latency for first fixations in each Scene: person-present and person-absent. Mean across all trials
7. First saccade latency for first fixations in each Domain: Person, Body, Face, Face-remainder, Eyes, Object, Viewing-cone. Mean across all trials
8. Relative first saccade latency for first fixations in each Scene: person-present and person-absent. Overall first saccade latency minus first saccade latency for that Scene.
9. Relative first saccade latency for first fixations in each Domain: Person, Body, Face, Face-remainder, Eyes, Object, Viewing-cone. Overall first saccade latency minus first saccade latency for that Domain
10. Repeat all measures, #1-9, for the gender-discrimination condition

The following summary statistics were used for analysis of the Preferential-Looking task in relation to other tasks:

- PL Viewing time: Percentage viewing time in Person minus Percentage viewing time in PP background

- PL First fixations: Percentage first fixations in Person minus percentage first fixations in PP background
- PL Composite: Participants scored one every time their individual result exceeded the mean for the following variables: percentage viewing time looking at the body, percentage viewing time looking at the face, percentage viewing time looking at the eyes, percentage of first fixations on the body, percentage of first fixations on the face, percentage of first fixations on the eyes. They also received a score of one for every individual result less than the mean for the following variables: first saccade latency to the body, first saccade latency to the face, first saccade latency to the eyes. All of these variables were drawn from the free-viewing condition and therefore the final score, out of nine, reflects spontaneous attention to social information.

12. References

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