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The effect of observing averted gaze on attention: Object-based

effects and individual differences

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This thesis is submitted in part fulfilment of the degree of Doctor of Philosophy, completed at the Centre for Cognitive Neuroscience, School of Psychology, University of Wales, Bangor.



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Abstract

Orienting to the direction of another persons gaze is pivotal in social development. As well as alerting one to peripheral events, this behaviour helps the observer engage in 'Joint Attention', which can facilitate the representation of another person's mental state. The effect of observing averted gaze cues on visuospatial attention was investigated in a series of experiments. Replicating prior work, taskirrelevant gaze and arrow cues resulted in reaction time advantages to targets at cued locations, compared with targets at uncued locations. Female participants revealed consistently larger cueing effects than male participants did, for gaze and arrow cues (Experiments 1 to 5). Further, gaze-cueing magnitude was inversely correlated with score on the autism-spectrum quotient (AQ; Baron-Cohen et al. 2001). That is, participants with few autistic-like traits were cued more by other people's gaze. Furthermore, peripheral cues revealed no gender differences (Experiments 6 and 7), suggesting that the sex difference is unique to attention shifts evoked via central cues. Low scorers on the AO were also found to display larger gaze and arrowcueing effects when the target appeared on a coherent object, compared with scrambled displays, while high AO participants displayed the opposite trend (Experiments 8 and 9). This was interpreted as evidence for differences in local/global processing bias, as a function of position along the autism spectrum. A final issue of the integration of gaze and head orientation was addressed. Head orientation was manipulated by rotating the face 90 degrees in the picture plane. The eyes in the face looked up or down, yet cueing was found to the left or right, as if the head had been presented upright (Experiments 11 to 13). The findings of these

studies have implications for the study of attention and social interactions, and for the role of individual processing style in such cueing effects.

Chapter 1 – Introduction

How people understand and predict the behaviour of others is a central issue in psychology and related fields. The investigation of the underlying mechanisms of social interactions has recently allowed the fields of cognitive psychology and cognitive neuroscience to influence and contribute to the study of social cognition, which has traditionally taken developmental and social psychological approaches. Hence, a new discipline has emerged, 'social cognitive neuroscience' (Adolphs, 1999, 2003a, 2003b; Ochsner & Lieberman, 2001). The studies described in this thesis utilize evidence from these diverse fields to formulate hypotheses concerning the generalised tendency to orient towards the direction of gaze of a conspecific. However, the methodology used throughout is based on a cognitive psychology paradigm used to study spatial orienting of attention. This introductory chapter will highlight the issues surrounding the study of gaze-following and describe the way in which the paradigms adopted can approach these issues.

The Perception of Social Behaviour

The efficient detection of the presence of others, and high-level encoding of the behaviour of others is of great survival value. Within a social group, action recognition and intention evaluation is vital to the establishment of beneficial social interactions. Human individuals have a tendency to attribute high-level mental states to others, even when only greatly impoverished information is available. For example, observing the eye region alone allows people to infer quite complex affective states (Baron-Cohen, Wheelwright, Hill, Raste, & Plumb, 2001; Baron-Cohen, Wheelwright, & Jolliffe, 1997). Even the observation of simple geometric shapes in motion can lead to spontaneous 'mental state attribution' (Heider & Simmel, 1944). This demonstrates that the human information processing system is highly tuned for the extraction and interpretation of meaningful behaviour, emotions and intentions of others around them.

The ability to naturally imitate other's behaviour is an example of evidence for a direct route between the observation of another's behaviour and the performance of that behaviour (Gallese, 2001; Gallese & Goldman, 1998). Neurophysiological evidence for such a direct link comes from the discovery of 'mirror neurons' (di Pellegrino, Fadiga, Fogassi, Gallese, & Rizzolatti, 1992), which are located in the ventral premotor cortex (region F5) of the macaque monkey. Like canonical F5 neurons, these cells respond when the animal performs a goal-directed action, but also responds when the animal observes the same action performed by another monkey or experimenter. There is evidence that similar neural mechanisms are active in humans when observing other people's reaching actions and when imitating them (Rizzolatti, Fogassi, & Gallese, 2001). The ability to automatically represent another's action as if you are actually performing it yourself suggests that humans have a certain degree of 'shared representation' between each other in social situations (Chartrand & Bargh, 1999), which may flow unintentionally from observation to performance (Byrne, 1999). Imitation, action observation and mirror neurons provide a framework for investigating the emergence of cultural transmission of behaviour (Morrison, 2002), the development of language (Rizzolatti & Arbib, 1998; Vihman, 2002) and empathy (Preston & de Waal, 2002).

As noted above, a vital issue when representing another's behaviour is the ability to encode the intentions of the observed agent. For example, another area of the macaque brain which has been identified as important for social perception is the superior temporal sulcus (STS). This area encodes biological motion (Jellema, Baker, Wicker, & Perrett, 2000; Perrett, Smith, Mistlin et al., 1985) and properties of observed faces such as the direction of attention (Allison, Puce, & McCarthy, 2000; Perrett, Hietanen, Oram, & Benson, 1992; Perrett, Smith, Potter et al., 1985). Jellema et al. (2000) investigated STS cells that were responsive to action observation. As well as finding direction-sensitive and action-specific cells, these investigators also found a subset of cells (n = 7) to be active when observing actions only when the agent's attention was directed to the hand performing the action. That is, these cells were only active when the action was perceived to be intentional. Actions are easier to perform with concurrent monitoring with gaze: that is, watching your action makes feedback of ongoing behaviour more accurate (Jeannerod, 1997). So, when you see an action being performed by an agent who is not watching their action, you may conclude that the agent does not care for the action's outcome, that it is irrelevant to their primary goal. However, a monitored action is much more likely to be goal-directed, and therefore intentional. This finding suggests that the information about another's gaze direction is integrated with signals arising from action observation. Gaze monitoring is therefore integral to behaviour evaluation.

Establishing 'Joint Attention', using another's direction of attention to attend the same object or feature of the environment (Emery, 2000; Emery, Lorincz,

Perrett, Oram, & Baker, 1997), is another vital mechanism in the person perception system. The development of joint attention has been shown to correlate with language acquisition (Baldwin, 1995; Lutchmaya, Baron-Cohen, & Raggatt, 2002b) and the development of 'Theory of Mind' (Charman et al., 2001). The perception of social gaze, and its relation to other cognitive mechanisms such as attention, and individual differences in cognitive processing style relating to social stimuli, are the foci of this thesis. The following sections highlight issues surrounding this subject, and introduce the experimental approach.

Perception of Averted and Mutual Gaze

How people perceive, encode and decode other peoples gaze behaviour, and how the gaze behaviour of others affects ones own gaze behaviour is the subject of diverse scientific investigation (Argyle & Cook, 1976; Emery, 2000; Kleinke, 1986; Langton, Watt, & Bruce, 2000). Before examining the effect of observing another's gaze on the attention of the observer, it is necessary to review the literature of gaze perception to discuss theories which suggest that gaze perception might subserve high-level mechanisms such as theory of mind (Baron-Cohen, 1995a, 1995b). A highly specialized mechanism may be involved in the perception and interpretation of social gaze, which may be separate from other mechanisms underlying the recognition of social stimuli, for example, face recognition (Hoffman & Haxby, 2000).

Eye contact has a great effect on the receiver. For example, prolonged eye contact increases Galvanic Skin Response (GSR) as compared to observation of

averted eye gaze in adults (Nichols & Champness, 1971), suggesting arousal, or anxiety levels naturally increase when being stared at. Direction of observed eye gaze also modulates person perception: participants are quicker to make gender classification based on a face, if the eyes are looking at the participant (Macrae, Hood, Milne, Rowe, & Mason, 2002). Faces are more efficiently encoded in and retrieved from memory if presented with direct eye gaze compared to closed eyes, in both adults and 7-year-old children (Hood, Macrae, Cole-Davies, & Dias, 2003). The evaluation of the emotion of another person is also highly modulated by direction of gaze. Adams and Kleck (2003) showed that people are faster to categorise avoidance-oriented emotions (fear and sadness) when the face displaying that emotion was gazing away from the participant, but that the categorisation of approach-oriented emotions (anger and joy) was facilitated by direct gaze in the observed face. The ability to infer complex emotional states of a person when only the eyes are visible was demonstrated in normal adults by Baron-Cohen, Wheelwright and Jolliffe (1997), where viewing eyes alone enabled the distinction to be made, for example, between 'scheming' and 'arrogant' as easily as when viewing the entire face. Adults with autism-spectrum disorders performed worse on such tests, suggesting that such people have difficulty reading the 'language of the eyes'.

People are highly sensitive to being attended to (i.e. gazed-at) by others. The subjective feeling of being 'looked-at' is a common experience, suggesting that people may have a predisposition to the detection of the gaze of others. Such a predisposition may be supported by a dedicated module, an 'Eye Direction

Detector', for example (Baron-Cohen, 1995a). An adult's ability to determine whether another person's gaze is direct or averted is very accurate. Gibson and Pick (1963) showed that the participant's threshold for accepting truly deviated gaze as direct gaze is just 2.8°. Visual gaze discrimination may be achieved based on very low-level features, and may be a highly adapted automatic process. For example, patients with schizophrenia often have disrupted person-perception abilities (Frith & Frith, 1999), yet are not significantly worse than controls at determining the direction of gaze of another (Franck et al., 1998), or at deciding whether they are being directly looked at or not (Franck et al., 2002). This suggests that any higherorder difficulties that such patients experience are not a result of an impaired eye direction detection mechanism.

The morphology of the human eye may render it as a special visual stimulus "in the sense that useful information can be recovered from it with robust simple processing mechanisms" (Langton et al., 2000, p. 52). Compared to other primates, humans have a relatively small dark region (the pupil and iris) and large regions of white sclera either side of the iris (see Emery, 2000). This makes the discrimination of gaze direction much easier in humans than in other animals. Indeed the use of the high contrast between the colour of the iris and sclera seems to be specific to the overlearnt spatial relationship between dark and light within a normal eye, since when participants observe eyes with inverted polarity (i.e. dark sclera, light iris), gaze perception is severely disrupted (Ricciardelli, Baylis, & Driver, 2000; Sinha, 2000). That is, participants fail to report that the face is looking in the direction of the (now white) pupil, which is the same shape and size as before, but often report the direction of the (now dark) sclera. Ando (2002) showed that a similar effect is found when participants are presented with a face with direct gaze, but either the left or right section of sclera is presented as grey. This luminance-induced shift of apparent direction of gaze again demonstrates how reliant the gaze perception system is on the availability of unperturbed perception of the eye region. When accurate information about the pupil position is not available to direct visual perception, due to shadow, occlusion or distance, then other means of decoding the direction of attention must also be integrated into the perception of social attention, such as head and body posture (Emery, 2000; Langton, 2000; Perrett et al., 1992).

The integration of information regarding pupil position in the orbit with other cues to the direction of attention has been the topic of some debate. For example, the perception of head orientation is also very good in humans, who show a discrimination threshold of 1.9° for heads turned to the left or right (Wilson, Wilkinson, Lin, & Castillo, 2000). People are rather efficient at encoding the direction of eye gaze and head orientation, but the relative contribution of either stimulus to the overall impression of another's direction of attention is an important question. Perrett et al. (1992) noted that gaze direction is a more reliable source of information about the direction of another's attention than is head direction. Hence, an individual would benefit from a system which inhibits signals from cells coding head direction when a head is seen pointing up, but where the eyes are pointing *down*. Since attention in this scenario is 'down', perceived head direction should not be able to influence the perceived direction of attention. Indeed, when the eyes are visible, inhibition is applied to cells coding incongruent head and body postures, suggesting a hierarchically organised joint attention mechanism (Perrett et al., 1992).

However, this neural organisation seemingly fails to command eye-gaze dominance over head direction in behavioural studies of perceived attention direction. Langton et al. (2000) noted that an eye region presented in a face pointing forward gave the impression of direct gaze, while the same eye region (cut and pasted using photo-editing software) presented in a face pointing to the participant's left, gave the impression of leftward gaze (see also Gibson & Pick, 1963, and Wollaston, 1824, as cited in Langton et al.). Furthermore, when deciding the direction of head orientation, participants RTs were slowed when the eyes looked in the opposite direction, but the same was true when responding to the direction of gaze: incongruent head direction also interfered with response latency (Langton, 2000). These behavioural data contradict neural evidence, and suggest that eye and head direction are "equal partners" in the encoding of the direction of attention of others (Langton et al., 2000, p. 56).

Neural Correlates of Gaze Perception

The perception of direct and averted gaze has also been investigated with brain imaging techniques and electrophysiology in monkeys and humans to elucidate the neural mechanisms that may underlie the perception and interpretation of gaze behaviour. An area in the fusiform gyrus of the occipital lobe is known to be selectively active when viewing faces (Kanwisher, 2000). However, observing eye gaze seems to activate separate areas of the brain to those involved in face perception (Hoffman & Haxby, 2000). The superior temporal sulcus (STS) seems to be selectively active for the observation of eye gaze in humans (George, Driver, & Dolan, 2001; Hooker et al., 2003; Pelphrey, Singerman, Allison, & McCarthy, 2003; Puce, Allison, Bentin, Gore, & McCarthy, 1998; Wicker, Michel, Henaff, & Decety, 1998). Other areas involved in the analysis of social stimuli include the amygdala, even in the absence of emotional context (Kawashima et al., 1999), and medial prefrontal regions involved in theory of mind, suggesting that observing eye-gaze can activate higher-level neural mechanisms, when a theory of mind task is involved (Calder et al., 2002).

The involvement of temporal cortex in eye gaze perception accords with the findings from single-cell recordings in monkeys. Superior temporal cortex is involved in the analysis of biological motion (Oram & Perrett, 1994; Perrett, Smith, Mistlin et al., 1985), and the macaque STS harbours cells sensitive to head, gaze and body orientation (Perrett, Smith, Potter et al., 1985), which combine to enable the encoding of direction of attention (Perrett et al., 1992). Thus, STS is a vital area in the network involved in social perception (Allison et al., 2000). Indeed, while eye-gaze activates distinct areas to that of face perception or emotional processing (Calder, Lawrence, & Young, 2001; Hoffman & Haxby, 2000), the circuits involved in these processes are affected by contextual effects of eye-gaze direction.

Evidence for the effect of observed gaze on face processing comes from the 'N170', a negative ERP peak in the EEG signal that occurs 170 ms after onset of a face stimulus. Taylor, Itier, Allison and Edmonds (2001) found that the latency of

this component was shorter when the eyes in the face were visible, reflecting a facilitation of face-processing due to the presence of eye stimuli (see also Puce, Smith, & Allison, 2000). This finding has been replicated with the magnetoencephalographic equivalent, the 'M170' (Taylor, George, & Ducorps, 2001; Watanabe, Kakigi, & Puce, 2001). George et al. (2001) showed that direct gaze resulted in a positive relationship between activity in fusiform gyrus and amygdala (involved in emotional evaluation of stimuli), while averted gaze was associated with inferior parietal activation (associated with shifts of spatial attention, see also Wicker et al., 1998). Similarly, the responses of the left amygdala to angry or fearful faces are modulated by gaze direction (Adams, Gordon, Baird, Ambady, & Kleck, 2003). That is, a direct gazing face elicits greater neural response in the amygdala when it is expressing fear, while a face with averted gaze elicits more activation when it expresses anger.

The perception of eye gaze seems to be lateralized to the right hemisphere (e.g. Wicker et al., 1998), like face processing (e.g. Young, Hay, & McWeeny, 1985). Indeed, Ricciardelli, Ro, and Driver (2002) manipulated the direction in which either eye in a stimulus face could look, such that both eyes could look in the same direction, or in different directions. When judging where a face was looking, participants were more guided by the left eye (i.e. the eye appearing in the left visual field), than the right eye. A further link between hemispheric laterality of face processing and gaze perception is provided by studies of split-brain (Kingstone, Friesen, & Gazzaniga, 2000; Ristic, Friesen, & Kingstone, 2002) and neglect patients (Vuilleumier, 2002). However, these lateralized networks may be distinct from networks subserving shifts of attention evoked by other cues. This issue will be dealt with in more depth in a later section on averted gaze as a cue to attention.

The Development of Joint Attention

The interest in others' eyes emerges early in development. Young infants smile more at faces with visible eyes (Spitz & Wolf, 1946, as cited in Argyle & Cook, 1976) and even human neonates prefer to gaze at a face with the eyes visible (Batki, Baron-Cohen, Wheelwright, Connellan, & Ahluwalia, 2000). At fivemonths, infants can already discriminate between very small horizontal deviations (5°) of eye gaze (Symons, Hains, & Muir, 1998). Sensitivity to receiving eye contact therefore emerges very early in life, while individual differences in the amount of eye contact made are also detectable by the age of 12 months, where males make less eye-contact than females (Lutchmaya, Baron-Cohen, & Raggatt, 2002a). A strong biological component to the development of eye contact behaviour is suggested due its early emergence, and the finding of a significant quadratic relationship between pre-natal testosterone levels and the amount of eye contact made (Lutchmaya et al., 2002a). However, the ability to *explicitly* determine whether an adult is making eye contact, or where an adult is looking may not develop until the age of 3 years (Doherty & Anderson, 1999).

Gaze following, however, is the behaviour of central relevance to this thesis. Orienting ones own attention (overtly, through eye movements or head turns, or covertly through a shift of spatial attention) to the direction of another's gaze is the subject of intense research in infant development. Scaife and Bruner (1975) found that infants reliably follow caregivers' head turns within the first year of life, while Hood, Willen and Driver (1998) showed that observing shifting eye-gaze in a face presented on a computer screen resulted in facilitated saccades to the direction of gaze in infants as young as 3 months old. The capacity to use another persons eye gaze as a cue to attention therefore develops very early in life.

However, the depth to which the infant 'understands' another person's gaze behaviour is unclear (see Moore & Corkum, 1994, for review). For example, Moore, Angelopoulos, and Bennett (1997) found that 9-month-old infants who had already developed gaze-following could follow gaze based on the observation of static stimuli. However, infants who had not developed spontaneous gaze following needed to see the motion of the head-turn in order to learn to follow gaze – learning from static models was not found. Furthermore, if a gaze-cue is produced by a lateral translation of the stimulus face independently of the pupils, such that the pupils are stationary, but the facial movement results in averted gaze, 4- to 5-month-old infants orient to the direction of *motion*, rather than to the opposite side of space cued by gaze.

The ability to follow gaze may initially develop from a simple motionfollowing response, and since interesting objects tend to appear when the infant orients in the direction of observed gaze, the behaviour is positively reinforced. Nevertheless, from arguably simple origins, gaze following has a remarkable influence in the development of higher level representations of other minds. For example, orienting to the object of a caregiver's attention might allow the speedy acquisition of nouns, through the pairing of an observed object and its vocalised name (Baldwin, 1995). Indeed, gaze following at 6 months has been shown to correlate with vocabulary size at 18 months (Morales et al., 2000; Morales, Mundy, & Rojas, 1998). The development of joint attention at 20 months can predict theory of mind abilities at 44 months (Charman et al., 2001), again demonstrating the importance of gaze following in the development of social cognition. The development of joint attention behaviour is also associated with an increase in frontal lobe activity, crucial for higher-order representations (Mundy, Card, & Fox, 2000).

The establishment of a dyadic joint attention relationship may be a behaviour that originally develops from stimulus-response relationships and reinforcement, but is a higher-level interpersonal skill that requires at least some level of 'theory of mind'. To take Emery's (2000) definition, 'Joint attention requires that two individuals... are attending to the same object... based on one individual using the attention cues of the second individual' (p. 588). This definition demands that attention is directed to the appropriate feature of the environment, whereas gaze following is perhaps simple orienting to the appropriate hemifield. 'Shared attention' is a higher state of dyadic relationship whereby both individuals are attending the same object, as with joint attention, but both are aware of each other's attentional state (Emery, 2000). The subtle differences between gaze following, joint attention and shared attention are also highlighted by work with non-human primates. For example, Chimpanzees have been shown to display behaviours that suggest they possess the ability to comphrend psychological states such as understanding that a conspecific might have a different visual perspective, or have access to different knowledge than themselves (Tomasello, Call, & Hare, 2003). These animals, like human infants, follow gaze direction to appropriate objects in the environment, (Tomasello, Hare, & Agnetta, 1999). Furthermore, Myowa-Yamakoshi, Tomonaga, Tanaka, and Matsuzawa (2003) showed that chimp infants (aged 10 - 32 weeks) have a preference for attending to direct human gaze. This result mirrors that of Batki et al. (2000) in 36 hour old human infants. Rhesus (Deaner & Platt, 2003; Emery et al., 1997) and macaque monkeys (Ferrari, Kohler, Fogassi, & Gallese, 2000), on the other hand, show gaze following and some aspects of joint attention but cannot use such cues to solve simple object-choice problems (Anderson, Montant, & Schmitt, 1996). These data suggest that joint attention abilities vary between species, with some primates using social gaze to higher levels than others. In some ways, these differences mirror stages in human infant development, and also stages at which some people develop difficulties with social cognition due to a developmental disorders such as autism, adult onset disorders such as schizophrenia, or difficulties in person perception caused by brain damage.

Pathologies of Social Cognition

The developmental disorder 'autism' is characterized by a triad of symptoms that describe poor social, communicative and imagination skills in people with autism (Baron-Cohen, 2000). Children with autism often fail first-order tests of 'theory of mind' (e.g. understanding that "Mary thinks the marble is in the basket"), with performance on second-order tests (e.g. understanding that "Mary thinks that John thinks the marble is in the basket") being very poor compared to normals and children with Down's syndrome (Baron-Cohen, 1989). Social interactions are also different to those of normally developing children, with fewer attention sharing behaviours with caregivers and other children in children with autism (Sigman, Mundy, Sherman, & Ungerer, 1986). Rather, shifts of attention are more often made between two (non-social) objects, rather than shifts between people (Swettenham et al., 1998). Imitation, another index of learning through experience sharing is also impaired in children with autism (Charman et al., 2001; Charman et al., 1997; Stone, Ousley, & Littleford, 1997). Along with general learning, language and IQ deficits, children with autism present a highly impaired cognitive profile. Asperger's syndrome is another diagnosis which is based on the observation of autistic traits. However, people with Asperger's are generally less impaired, with normal or superior IQs. As such, people with Asperger's syndrome are considered by some theorists to lie on the extremes of the normal population of autistic traits, rather than in a distinct category outside the normal population (e.g. Baron-Cohen, 2000).

While the 'theory of mind' hypothesis can explain the social impairments, a fuller framework is necessary to explain the presence of 'islets of ability', or even superior performance in certain tests of cognitive ability (Baron-Cohen, 2000; Happé, 1999). For example, weak central coherence is another feature of people with autism's cognitive profile. That is, people with autism often fail to see the 'whole picture', be it a perceptual pattern, or the correct pronunciation of a homograph given its semantic context (e.g. 'In her eye there was a big tear' vs. 'In her dress there was a big tear', see Happé, 1999, p. 219). People with autism are also less 'susceptible' to visual illusions (Happé, 1996). Furthermore, superior spatial

abilities (map use, recall and learning of paths) have been noted in people with autism (Caron, Mottron, Rainville, & Couinard, 2004), as well as a bias to the processing of local features in a variety of tasks (Mottron, Belleville, & Menard, 1999; Mottron, Burack, Iarocci, Belleville, & Enns, 2003). Children with autism have been found to display normal or superior attentional processing in visual search and selective attention (Brian, Tipper, Weaver, & Bryson, 2003; O'Riordan, Plaisted, Driver, & Baron-Cohen, 2001).

With regard to gaze processing in people with autism, the evidence is clear that the eye gaze of others is treated very differently by people with autism than by people without autism. When observing a face, normals tend to scan the eve and mouth region in a highly consistent manner (Mertens, Siegmund, & Grusser, 1993). In contrast, people with autism often dislike and avoid eye-contact (see Baron-Cohen, 1988). When the task demands exploring the eye region of a face, GSR increases, while neural activity in the fusiform gyrus and amygdala is much greater in people with autism compared with controls, suggesting eye-region avoidance is an arousal modulation strategy on the part of people with autism (Gernsbacher, Davidson, Dalton, & Alexander, 2003). Such behavioural traits are mirrored in people with social phobia, in whom scanning of faces rarely includes the eye region (Horley, Williams, Gonsalvez, & Gordon, 2002). Normal children make immediate eye contact with the agent of an ambiguous action, but not so readily if the action is unambiguous, while children with autism make little eye contact whatever the action's semantic context (Phillips, Baron-Cohen, & Rutter, 1992). Furthermore, adults and children with autism are poor at attributing emotions to people based on

the eye region, something that normals are proficient at (Baron-Cohen, Campbell, Karmilloff-Smith, Grant, & Walker, 1995; Baron-Cohen, Wheelwright, Hill et al., 2001; Baron-Cohen, Wheelwright, & Jolliffe, 1997).

Joint attention is also impaired in people with autism (Charman et al., 1997; Roeyers, Van Oost, & Bothuyne, 1998). However, like normals, better joint attention skills are associated with larger vocabularies, and fewer social and communicative difficulties in people with autism, illustrating the vital importance of joint attention in the social development of children with autism, as well as normal children (Charman, 2003). However, orienting to the direction of another's gaze can occur at normal levels in children with high-functioning autism (where IQ is within the normal range), perhaps based on the same low-level motion cues from which joint attention develops in normally developing children (Chawarska, Klin, & Volkmar, 2003; Leekam, Hunnisett, & Moore, 1998; Swettenham, Condie, Campbell, Milne, & Coleman, 2003).

Theory of mind impairments also often accompany the cognitive and affective deficits encountered in schizophrenia. For example, failing to correctly attribute the agent of an action is a feature of the positive symptoms of schizophrenia (Frith, Blakemore, & Wolpert, 2000). People with schizophrenia tend to misattribute actions of others to themselves, whereas normal participants are proficient at telling the difference between their gloved hand performing an action on a TV screen, and the experimenters gloved hand performing the same action (Daprati et al., 1997). Self-other confusion is characteristic of mentalising problems associated with schizophrenia (Langdon et al., 1997), and when processing facial affect, people with schizophrenia recruit premotor areas as opposed to the amygdala, suggesting that a mirror system is hyper-active in people with schizophrenia as they process other people's mental states (Quintana, Davidson, Kovalik, Marder, & Mazziotta, 2001). Such overactivation of a facial mirror system may contribute to the blurring of boundaries between potential mentalistic agents in the environment. Despite this, the accuracy of eve direction determination is good in people with schizophrenia, where performance does not differ significantly from that of normals (Franck et al., 1998; Franck et al., 2002). Unfortunately, there are no cueing studies currently published that assess whether gaze following is also unimpaired in people with schizophrenia. Turner syndrome, where females with an incomplete X chromosome present a wide range of symptoms, also show impaired theory of mind abilities. Nevertheless, like people with autism, intentionality and emotional processing is disrupted, but simple gaze-cueing is spared (Lawrence et al., 2003). Somewhat conversely, other authors have suggested that the arguably lower-level ability of determining gaze direction is impaired in people with Turner syndrome (Elgar, Campbell, & Skuse, 2002). The currently unclear picture of gaze processing in disorders other than autism will benefit from further work, which could potentially prove as valuable as studies centred on autism.

Averted Gaze as a cue to attention

The study of joint attention and visuospatial orienting has taken relatively independent routes, from the early papers on joint attention (Scaife & Bruner, 1975) and the development of the highly influential 'Posner' cueing paradigm in the field

of spatial attention (Posner, 1980; Posner & Cohen, 1984). However, gaze-cues have recently been adopted as a method of elucidating information about the mechanisms of attention, and of normal adult social cognition (e.g. Driver et al., 1999; Friesen & Kingstone, 1998). Essentially, gaze-cueing studies are adaptations of the Posner cueing paradigm, in which participants fixate the centre of a screen, and are required to detect the onset of a target stimulus presented in the periphery. Before the target appears, however, a 'cue' may lead to a shift of attention to the cued location. The effect of the cue is to bias attentional processes to the location of the cue to the detriment of processing of uncued locations ('biased competition', Desimone & Duncan, 1995). Hence, performance is improved (i.e. quicker RTs and equal or perhaps fewer errors) in tasks requiring the detection, localisation or identification of targets presented at the cued location, compared with targets appearing at uncued locations.

The form of the cue, and its meaning was manipulated by Posner and colleagues (Posner, 1980; Posner & Cohen, 1984; Posner, Snyder, & Davidson, 1980). For example, two peripheral boxes would be presented, followed by the onset of a brief flash, that could occur at the left box or right box. If the target appeared at the cued location soon (< 300 ms) after the flash, responses were faster, compared with responses to targets appearing at the uncued locations (Posner & Cohen, 1984). This was true, even though the peripheral stimulus predicted the target location on only 10% of trials. Targets appearing after 300 ms at the cued location were processed less efficiently due to the activation of inhibition of return (IOR), whereby reactive inhibition is applied to cued loci, seemingly to facilitate visual search of

new locations (Posner & Cohen, 1984). Central cues were also used to study attention, and were found to produce different patterns of cueing. Firstly, nonpredictive arrows failed to produce these speedy, automatic shifts of attention (Jonides, 1981). However, when an informative central arrow (or informative number, see Posner et al., 1980) was used as a cue, shifts of attention were found. That is, when an arrow that predicts target location on 80% of trials is presented, attention is 'voluntarily' shifted in the direction of the arrow, and hence target processing is facilitated when targets appear in cued, compared to uncued locations. In this case, the attention shift is slower to emerge, and does not reveal the behavioural effects of IOR. These types of attention shifts are seen as 'endogenous' since the cue must be interpreted before attention can be *voluntarily* directed.

However, the possibility that centrally presented *uninformative* cues can result in attention shifts with exogenous (i.e. involuntary) components is of great interest to the study of attention. While Jonides (1981) revealed null effects of nonpredictive arrows, both Shepard, Findlay and Hockey (1986) and Eimer (1997) have successfully shown that non-predictive arrows do indeed cue attention. However, participants in the studies of Eimer (1997) and Shepherd, Findlay and Hockey (1986) viewed the same stimuli to be either predictive and non-predictive in different blocks. However, recent studies have shown consistent shifts of attention in the direction of a non-predictive arrows in participants who were only ever told to ignore the cue (Hommel, Pratt, Colzato, & Godijn, 2001; Pratt & Hommel, 2003; Ristic et al., 2002; Tipples, 2002). Since the cues are non-predictive (unlike those used by Posner, 1980) participants are assumed not to engage in strategic control over attention. These studies therefore suggest that these effects have automatic components, meaning that the functional difference between peripheral and central cues is somewhat less clear-cut than earlier studies had suggested. Furthermore, it suggests that studies where predictive central arrows are used to investigate voluntary attention in isolation perhaps cannot rely on the assumption that attention is being directed through solely voluntary processes in their studies (e.g. Corbetta & Shulman, 2002).

The usefulness of the Posner cueing paradigm to researchers into social cognition is now well established. Indeed, it was the gaze-cueing studies of the late 1990s (Driver et al., 1999; Friesen & Kingstone, 1998; Hood et al., 1998) that has inspired the new interest in investigating the involuntary effects of other central cues to attention, such as arrows. Hence, most recent studies into non-informative central cues have used gaze cues to investigate shifts of attention. Indeed, some researchers have proposed that these new findings are so important, that the past twenty years of attention research may require a theoretical overhaul in light of the new data on gaze-cueing, taking particular account of the arguably greater ecological validity that gaze-cueing studies have over the peripheral cueing studies (Kingstone, Smilek, Ristic, Friesen, & Eastwood, 2003).

The gaze-cueing paradigm, as described above, is adapted from the Posner paradigm, in that most studies present participants with a blank screen at the start of each trial. A fixation cross is presented in the centre of the screen, on which participants must fixate throughout each trial, so that only covert attention shifts are

executed. This facet of the design immediately differs from studies on joint attention, which is normally achieved through overt orienting in the natural environment. Then, a photograph (or schematic depiction) of a face is presented in the centre of the screen, which then looks to the left or right. The onset of the gaze cue is often made by presenting no pupils at the start of trials, then presenting them in the averted gaze position (Driver et al., 1999; Friesen & Kingstone, 1998), rather than have the participants observe the gaze moving from central to averted gaze. Then, a target may appear on the screen, either at the cued or uncued (opposite) location. Performance (reaction time and accuracy) is then measured from the speeded responses made by participants to the target. For example, participants may be required to detect the onset of, localise, or identify (discriminate) the target. With a range of stimulus onset asynchronies (SOAs) between the onset of the gaze-cue and the onset of the target, participants are consistently faster when the target appears on the cued (i.e. looked at) side of space, compared to the opposite side of space, while making equal amounts of errors in either condition (Driver et al., 1999; Friesen & Kingstone, 1998). This measure is a standard index of attentional facilitation at cued locations.

Driver et al. (1999) found that cueing magnitude was smaller when the face producing the gaze-cue was presented immediately (i.e. a face, with averted gaze, Experiment 1) than when the face was presented with no gaze for 900 ms prior to cue onset (Experiment 2). Hence, participants had 900 ms to process the face, before cue onset. In this way, greater processing recourses may have been available for processing the gaze-cue, leading to stronger shifts of attention in the direction of averted gaze. Furthermore, Driver et al. tested RTs to discriminate targets appearing to the left or right of the face, 100, 300 or 700 ms after cue onset. Varying the SOA provides information about the timecourse of the allocation of attention following gaze-cue onsets. Driver et al. found that cueing effects (the RT to invalid targets minus RT to valid targets) increased across SOA, suggesting that the effect (of around 15 – 20 ms) is slow to emerge and is relatively long-lasting. Notably, Driver et al. did not observe IOR at the later SOAs, instead they observed larger facilitatory effects. In this way, the results do mirror the effects of predictive and non-predictive arrow cues. However, the discrimination task used by Driver et al. may also explain the timecourse of the effect. For example, discrimination tasks often fail to reveal IOR even in peripheral cueing studies. However, IOR has been found to emerge in peripheral cueing studies involving target identification tasks, at longer SOAs (e.g. 700 ms, where Driver et al. found the largest gaze-cueing effect) (Cheal, Chastain, & Lyon, 1998; Lupianez, Milan, Tornay, Madrid, & Tudela, 1997; Terry, Valdes, & Neill, 1994). This suggests that it was the nature of the gaze-cue, not the target identification task, which was responsible for the failure to observe IOR.

Friesen and Kingstone (1998) also failed to find IOR in gaze-cueing studies across three tasks (detection, localization and discrimination). With their schematic face stimuli, the discrimination task revealed very similar timecourse effects as Driver et al. (1999), with cueing being weak at a 105 ms SOA, then increasing over 300 and 600 ms SOAs. A further SOA of 1005 ms revealed no cueing effect, but still no IOR. The null effect of cueing at the 1005 ms SOA was also found in two other tasks, target detection and localization. However, cueing was found to be quite robust at the earliest (105 ms) SOA in these detection and localisation tasks. This shows that, unlike the early work with predictive arrows, the effect of eye-gaze cueing is indeed quick to emerge, in the appropriate task conditions. This finding supports the idea that attention shifts toward the direction of gaze are speedy, automatic and strong.

The notion of automaticity of the effect of these gaze-cues is further supported by the findings of the third experiment by Driver et al. (1999). In this experiment, targets would appear in the gazed-at location on only 20% of trials, rather than 50%. By informing participants of this manipulation, Driver et al. could evaluate whether strategic control of attention could be exerted in the presence of a counter-predictive gaze-cue. While cueing effects were found at the early SOAs, a null effect was found at the later SOA of 700 ms, which when the eye-gaze had been non-predictive had revealed the largest effects. This suggests that the early-mid timecourse of the gaze-cueing effect is not modulated by knowledge about the predictivity of the cue. However, strategy can lead to the later suppression of the urge to orient to the direction of gaze, such as to nullify the effect of attention towards the direction of gaze. The cueing effects at short SOAs, however, demonstrate that the effect is automatic, similar to the effects of non-predictive peripheral cues which, in some paradigms, correctly cued attention in only 10% of trials (Posner & Cohen, 1984).

The approaches discussed above have enabled several other authors to investigate attention using gaze-cueing paradigms. The possible advantage of using

a gaze-cue over peripheral cues is that the location or stimulus being cued is unchanged in cued and uncued conditions, whereas in peripheral cueing studies, the stimulus properties must change somewhat to produce the cue (a flicker, enlargement or luminosity variation). For example, the line-motion illusion is a phenomenon whereby a line, presented on a screen is perceived to 'move', as if being drawn across the screen, from the locus of peripherally cued attention, to the other end of the line. In fact, all points on the line are drawn simultaneously. Bavelier, Schneider and Monacelli (2002) showed that the illusion could be induced by the observation of averted gaze, directed to one end of the line or the other. This adds support to the notion that this is a pure attentional effect, rather than due to lower-level visual effects of peripheral stimulation (but see Downing & Triesman, 1997).

Finding the origin of the attentional effects of observing averted eye-gaze is therefore of great value to a wide range of researchers. How gaze-cueing compares to peripheral and other types of cues is important for the development of future paradigms and the expansion of knowledge in attention, perception and social cognition. The neural basis of gaze perception, discussed in a previous section, is an important issue. Kingstone et al. (2000) found that gaze-cueing effects arise in splitbrain patients, but only for gaze-cues appearing in the visual hemifield represented by the hemisphere dominant for the processing of faces. This is because in splitbrain patients, the corpus callosum is severed, and information presented on one side of space cannot cross to the ipsilateral hemisphere, as normal. However, in these patients, cueing effects were only found at an early (100 ms) SOA, with effects surprisingly not sustaining to 600 ms, unless the cue was predictive (75%) of target location. Arrows, on the other hand produce cueing when presented in either hemifield in the same patients (Ristic et al., 2002). However, these effects lasted across both SOAs, suggesting an overall stronger effect, perhaps because the arrows used by Ristic et al. were more salient cues to attention than the gaze-cues. Nevertheless, the contrast between gaze- and arrow-cues in split-brain patients is suggestive of a special neural pathway underlying the reflexive gaze orienting effect. On the other hand, orienting to the direction of arrows might rely on a general/nonspecific pathway. While the STS and superior parietal lobe have been implicated in gaze-cueing, there have been few studies investigating the neural mechanisms of non-predictive arrow observation (but see Kato et al., 2001), but many using *predictive* arrow cues to encourage observers to strategically shift attention (see Corbetta & Shulman, 2002, for review).

Vuilleumier (2002) provided more evidence for a special neural system underlying eye-gaze cueing. Patients with lesions to temporo-parietal regions of the right hemisphere often present with unilateral neglect, an attentional deficit for processing stimuli presented on the left (contralesional) side of space (Rafal, 2000). In its severe form, neglect can lead to a complete ignorance of the left side of space in spite of an intact visual field. However, 'extinction' is a more common residual deficit, whereby contralesional stimuli are not reported only when a competing ipsilesional stimulus is present. This may be because of greater competitive weight being applied to the ipsilesional stimulus, to the additional detriment of processing of the contralesional one (e.g. di Pellegrino, Basso, & Frassinetti, 1997). In the Vuilleumier study, patients with neglect were found to show improved detection of contralesional stimuli if the competing ipsilesional stimulus was a face, gazing to the contralesional side. This suggests that if an ipsilesional stimulus is a contralateral gaze-cue, then extinction is ameliorated. It is a surprising result, since any concurrent ipsilesional stimulation might be expected to impair performance in extinction patients. The finding was not repeated for arrow stimuli, suggesting that only social cues of biological origin can ameliorate neglect. However, later experiments showed that only gaze-cueing, but not arrow cueing was found in the same patients. Firstly, it is therefore unclear as to whether a contralesional arrow would still have no effect in patients who do display both arrow and gaze-cueing effects. Secondly, this is an interesting contrast between the findings of Kingstone and colleagues (Kingstone et al., 2000; Ristic et al., 2002), who found stronger cueing by arrows, compared to gaze-cues in split-brain patients. It is clear, therefore, that further neuropsychological testing is needed to elaborate on these as yet inconclusive data regarding the preservation and laterality of gaze and arrow cueing in brain damaged patients.

The relationship between gaze and symbolic cues has been directly compared in paradigms with normal adults (Downing, Dodds, & Bray, 2004; Friesen, Ristic, & Kingstone, 2004). Downing et al. showed that arrows and eyes are not unique: laterally averted tongues produce very similar effects to those of Driver et al. (1999) in a similar paradigm. Furthermore, Fischer, Castel, Dodd, and Pratt (2003) found that centrally presented numerical stimuli also reflexively shift attention: to the left if the number presented is small and to the right if the number is large relative to the size of the stimulus set. This suggests that such cues can modulate attention based on solely internal spatial representations of number. The Downing et al. study, however, also compared counter-predictive gaze and tongue cues, which are equally potent cues when non-predictive. In a replication of Driver et al. (1999, Experiment 3), small cueing effects were found with gaze cues. Conversely, tongue cues were easily overcome, and participants were able to orient to the opposite (targetexpected) side of space. This suggests that while numbers, tongues, arrows and eyes are equally effective at directing attention, eye-gaze cues alone have been found to be strong enough to prevent strategic orienting of attention to the opposite side of space. Perhaps the similar magnitude of simple cueing effects is due to a ceiling effect, whereby magnitude differences between gaze and arrow cues can only be elucidated with non-standard paradigms.

Further, Friesen et al. (2004) presented anti-predictive gaze and arrow cues. Crucially, however, four target locations and eye directions were used (up, down, left or right). In such a paradigm, it was possible to observe the reflexive and voluntary components of attention when directed by anti-predictive central cues. That is, for a rightward gaze or arrow, the right target position would be reflexively cued, but the left would be voluntarily attended, since it was the most likely target location. The other two target locations served as equiprobable baseline target locations. For gaze cues, compared to uncued loci, cueing was found at both cued and predicted loci, with the balance of attentional focus fluctuating across SOA (the general trend was for only the gazed-at location to be facilitated at early SOAs, then both the gazed-at and the expected target location to be equally cued at later SOAs).
However, anti-predictive arrow cues produced cueing at pointed at and predicted loci only at the early (105 ms) SOA, with sustained advantages only for predicted targets at all other SOAs. This suggests that in gaze cueing studies, voluntary and reflexive attention is engaged in parallel, but the reflexive component in arrow cueing is much weaker, and is easily overcome by the engagement of top-down strategic control.

Another study by Friesen and colleagues (Friesen & Kingstone, 2003a) sought to further investigate the relationship between voluntary and reflexive attention shifts, by evoking peripherally cued and gaze-cued attention shifts in the same design. By placing four circles around fixation, and having the gaze-cue appear unpredictably in one, the same stimulus would serve both as a peripheral onset cue and gaze-cue, looking to one of the other three circles. The target signal was the offset of one of the four circles. Friesen and Kingstone found IOR, an index of exogenous cueing, at the onset location of the gaze-cue at appropriate SOAs (555 ms). However, the onset of the gaze-cue simultaneously produced facilitation for targets at gazed-at loci, despite being produced by a face which received reactive inhibitory processing. Finding this co-occurrence of two cueing effects suggested to Friesen and Kingstone that the two orienting mechanisms are functionally independent. This suggested that inhibition of return had not be found in gaze cueing studies because cueing following peripheral onsets is subserved by separate neural mechanisms to the cueing produced by gaze-cues. For example, the superior colliculus and parietal lobe are implicated in peripheral cueing (Rafal, Posner,

Friedman, Inhoff, & Bernsrein, 1988), but cortico-cortical interactions may be necessary for gaze-cueing (Kingstone et al., 2000).

The relationship between overt and covert orienting of attention in gazecueing studies is also a vital issue for the field of attention, with debates about the role of eve-movements in the attention system being a constant issue for research. However, the naturalistic orienting to the direction of another's gaze involves overt orienting (actually looking to where another is looking), so in studying the behavioural effects of observing gaze, some authors have chosen not to instruct participants to inhibit eye movements (e.g. Driver et al. 1999). Saccades, instead of manual responses to peripheral targets, have also been shown to be facilitated by the observation of a congruent gaze-cue (Friesen & Kingstone, 2003b). Intuitively, an eve-movement response might be a more potent measure of the effect of other people's gaze behaviour on our own attention mechanism. That is, a gaze should potentate a similar saccade program to the same feature of the environment, in the same way that hand actions evoke similar motoric states in observers (di Pellegrino et al., 1992; Rizzolatti et al., 2001). Firstly, gaze-evoked microsaccades are found to be executed in the direction of observed gaze before the target onset, when participants are instructed to withhold saccadic response until the presentation of the target. However, the magnitude and frequency of these small eye-movements were found to poorly account for the facilitation in orienting to gaze direction in a study by Mansfield, Farroni and Johnson (2003).

Ricciardelli, Bricolo, Aglioti, and Chelazzi (2002) showed that when instructed to make an immediate eye-movement to the left or right, based on the colour of a small central square, the concurrent presentation of an incongruent gaze stimulus resulted in many more erroneous (i.e. anti-saccadic) eye movements. That is, if the eyes looked to the opposite side of space to which the colour cue informed the participant to look, then there was a tendency to unintentionally imitate the observed gaze. If the gaze stimulus was presented between 150 ms before and around 50 ms after the instruction to saccade, this pattern of errors was most apparent, while gazes presented at SOAs beyond +75 ms failed to influence accuracy in this way. Importantly, however, Ricciardelli et al. showed that this effect was weaker for arrows, suggesting that this is an imitative response, special to eyegaze. The failure of arrows to produce this effect was in spite of facilitated saccade RTs when the observed instruction and symbolic cue agreed than when they were incongruent. That is, while Ricciardelli et al. demonstrated attentional cueing, like other authors, imitative behaviour was only revealed when observing averted eye gaze. This adds support to the idea that eyes are special, despite the seemingly similar attentional effects obtained with arrow cues.

Other studies have attempted to investigate other aspects of attention with gaze-cues. For example, Hietanen and Leppanen (2003) varied the emotional expression of the face that produced the gaze cue. Since different facial expressions may alert the observer to the mental state of the person, the gaze-cue may be more or less potent a cue to peripheral targets, depending on gaze-affect interactions. For example, observing a fearful face looking to the left might indicate that a negative

and to-be-avoided object or event has occurred to the left. It would be advantageous for the observer to orient to the direction of gaze even more quickly and strongly than normal to evaluate the possible threat. However, Hietanen and Leppanen failed to show such modulation of timecourse or strength. Similarly, Mathews, Fox, Yiend, and Calder (2003) showed that fearful faces did not result in larger cueing effects. However, participants scoring above the median on an anxiety measure did show greater cueing towards the direction to which a fearful face looked, suggesting an interaction between gaze-cueing, facial emotion and individual differences in state and trait anxiety measures.

The use of gaze-cues to study differences between clinical groups which often fail theory of mind tests (e.g. children and adults with autism or people with Turner syndrome) is also of interest to understanding the underlying mechanisms of joint attention. For example, children with autism show gaze-cueing from the age of 2 years, despite their problems with joint attention and mental state decoding (Chawarska et al., 2003; Leekam et al., 1998; Swettenham et al., 2003). Women with Turner syndrome, who present with problems with social interactions (e.g. emotion and intention understanding), were found to also follow gaze (Lawrence et al., 2003). However, the studies with children with autism have used moving eyes or head, which provide an additional naturalistic cue to attention that children encounter in the environment. It is possible that when tested in a standard static gaze-cueing paradigm, children with autism may not reflexively follow gaze. The studies reviewed above highlight the importance of studying attention using averted gaze stimuli as cues: new data on gaze cueing suggest that theoretical frameworks that have been devised to explain the mechanism of selective visual attention need to incorporate non-predictive central symbolic cues and social cues. Furthermore, using cueing techniques such as those described above can allow us to gain insight into how we process the social cues of others. The issues investigated in this thesis reflect this, as individual differences in spatial attention are studied with gaze-cues (Chapter 2) and symbolic cues (Chapter 3), with the issues of object-based (Chapter 4) and object-centred (Chapter 5) representations being approached using gaze-cues. Hence, the interaction between social-cognitive functioning and core issues in current attention research is the central theme. The following section discusses further the approach and scope of the thesis.

Scope of the Thesis

Psychological Sex differences and the 'Extreme Male Brain'

If orienting toward the direction of another's gaze reflects special, 'social' processing, rather than some lower-level system that orients attention based on simple geometric properties, then the magnitude of cueing should depend upon the strength of signal from a 'social module'. The 'Extreme Male Brain' hypothesis of autism (Baron-Cohen, 2000, 2002, 2003) suggests that the male information processing system is generally less well adapted to understanding the mental states of others than the female brain. In its extreme state, the male brain is expressed in people with autism, the majority of whom are male (Rutter, 1978), as 'mindblindness' (Baron-Cohen, 1995b). Weaker joint attention in people with autism may be one example of inactivity of a module for social stimuli (Baron-Cohen et al., 1995; Charman et al., 1997; Roeyers et al., 1998). Compared to normal children, children with autism make fewer attention shifts, and of shorter duration, to people. Instead, children with autism show a preference for orienting to non-social objects in the world (Swettenham et al., 1998). McGuinness and Symonds (1977) presented mechanical objects and human figures stereoscopically, so that two images occupied the same area of the visual field. Normal adult males reported seeing more objects than human figures, with the opposite bias in females. In fact, an interest in mechanical objects reflects another feature of the hypothetical extreme male brain, since it indicates proficiency in understanding systems ('systemising'). Indeed, fathers and grandfathers of children with autism are twice as likely to have been engineers, compared with fathers of normally-developing children (Baron-Cohen, Wheelwright, Stott, Bolton, & Goodyear, 1997). Children with autism are also more proficient at understanding mechanical events and sequences than normally developing children are (Baron-Cohen, Leslie, & Frith, 1986).

Many studies have shown gender differences on a wide range of cognitive skills. Males outperform females in spatial tasks, such as the water-level test, where a tilted glass of water is presented, and the subject is required to judge where the water-level would be if the glass had been placed upright (Robert & Ohlmann, 1994). This is an example of better processing of physical systems in males. Other examples are mental rotation (e.g. Geary, Gilger, & Elliott-Miller, 1992) and lineangle judgement (Collaer & Nelson, 2002). Females have been found to perform better in episodic memory tasks, involving face recognition (Yonker, Eriksson, Nilsson, & Herlitz, 2003), and object recognition (McGivern et al., 1998). With reference to face processing, the ERP component N170, which has been associated with processing of faces, occurs later in males (Taylor, Itier et al., 2001). Furthermore, males are more vulnerable to prosopagnosia, a disorder where familiar faces cannot be recognised following brain damage (Mazzucchi & Biber, 1983). However, while some behavioural studies show an overall advantage for females in face recognition, the effect seems to be moderated by same-gender advantages (Wright & Sladden, 2003), especially in females (Lewin & Herlitz, 2002).

Many of the sex differences described above are also present in childhood and infancy. This relates very well to the idea that the developmental disorder of autism is an extreme expression of an overall cognitive style that is found more often in males than females. Male adults spend much less time attending to the eye region of other people in a myriad of situations (see Argyle & Cook, 1976, p 148). This difference seems to have a strong biological component, since the amount of eye contact made at 12 months is inversely correlated with pre-natal levels of the male sex hormone testosterone (Lutchmaya et al., 2002a). Furthermore, even female neonates are found to spend more time looking at a human face than at an infants mobile, while males show the opposite preference (Connellan, Baron-Cohen, Wheelwright, Batki, & Ahluwalia, 2000). If these sex differences are present from birth, and have a strong biological component, then the effects of such differences in cognitive style could potentially continue into adulthood, just as males continue to outperform females in spatial cognition, females should continue to show greater joint attention abilities. Hence, the series of experiments in Chapters 2 and 3 investigate the performance of males and females in eye-gaze cueing and symbolic cueing paradigms. Furthermore, the autism-spectrum quotient (the 'AQ', Baron-Cohen, Wheelwright, Skinner, Martin, & Clubley, 2001) was administered to some participants in order to evaluate the link between autism-like traits in the normal population, and any gender differences.

Object-based attention

In most gaze-cueing or joint attention studies, the target appears on a blank screen, in empty space. In many circumstances however, attention orients to engage with objects in the scene. When we observe another person suddenly orient attention to a particular location, it is assumed that some event/object evoked this attention shift. As such, joint attention requires not only the encoding of gaze direction, but of the object of another's attention. That is, in order to establish a high-level representation of another's attentional state, and subsequently a representation of mental state, one must be able to orient not only in the general direction of observed gaze, but to the correct object of attention (Emery, 2000; Emery et al., 1997). This aspect of joint attention may explain why the development of language and vocabulary is correlated with the development of joint attention skills (Baldwin, 1995), since working out which object a caregiver is referring to would enable an infant to more easily infer the name of objects in the environment. A poor joint attention system may lead to relatively slow (or poor) encoding of the object of another's attention, hence making noun acquisition a more lengthy developmental process.

If joint attention mechanisms can influence covert attention shifts, then greater cueing towards coherent objects, compared to incoherent or non-objects may be predicted. Since meaningful objects are more likely to guide the orienting behaviour of a conspecific, the incentive to engage in joint attention with another person should be greater when the person is clearly attending a real object. Furthermore, using gaze-cues that orient to an object in the world provides adds to the ecological validity of this paradigm, which may provide greater power with which to describe joint attention behaviour (Kingstone et al., 2003).

Object-based orienting of attention has been studied extensively with the use of peripheral cues. For example, the attentional processes of excitation and inhibition have been found to spread across an object's surface (Egly, Driver, & Rafal, 1994; Jordan & Tipper, 1999; Reppa & Leek, 2003). Other studies have shown that the inhibition that can be activated via a sudden onset peripheral cue (i.e., inhibition of return: Posner & Cohen, 1984) is larger if attention was oriented to an object rather than empty space (Jordan & Tipper, 1998). Thus, these studies showed that cueing one part of an object resulted in larger attentional cueing (or inhibition) to targets appearing in different parts of the same object than to equidistant targets that were part of different objects. At present it is unknown whether larger gaze evoked shifts of attention are observed when the eyes look towards an object. The notion that gaze shifts trigger joint attention states, where the observer engages attention with the same object the viewer looks at, predicts increased cueing when coherent objects are cued. Another issue of interest when devising the studies presented in Chapter 4 were the findings that symbolic stimuli such as arrows also reflexively trigger attention shifts in very similar ways to gaze-cues (Eimer, 1997; Hommel et al., 2001; Tipples, 2002). Arrows, while over-learnt stimuli that are often behaviourally relevant, are nevertheless not an indication of the direction of attention of an agent. Therefore, arrow cues do not trigger joint attention states, and hence they enable one to test whether gaze cues have any special status when attention is oriented towards an object. If gaze cues are 'special', object-based effects will be observed with gaze but not with arrow cues. In contrast, if arrows and gaze produce similar object-based cueing effects, this would demonstrate a further similarity between the cue types, despite the subtle differences found between eye and arrow stimuli in other paradigms (Ricciardelli, Bricolo et al., 2002; Ristic et al., 2002).

Object-centred attention

The way that the perception of eye-gaze and faces is integrated in such cueing paradigms is of great interest. In the human brain, the superior temporal sulcus seems to be involved in the perception of gaze (Wicker et al., 1998), while separable areas of the inferior occipital lobe and fusiform gyrus are involved in the processing of face identity (Hoffman & Haxby, 2000). The manner in which the face of an agent may be integrated with eye gaze perception can be investigated by studying how the perception of eye-gaze is modulated by perceived head orientation. The role of head orientation in the perception of social attention has been investigated in behavioural paradigms (Gibson & Pick, 1963; Hietanen, 1999, 2002; Langton, 2000), and in neurophysiological studies (Perrett et al., 1992; Perrett, Smith, Potter et al., 1985).

The notion that the processing of inverted faces is less fluent than that of upright faces is well established (Bartlett & Searcy, 1993; Yin, 1969). Notably, the 'Thatcher Illusion' (Thompson, 1980), demonstrated that changes to the configuration of face parts (i.e. flipping of the mouth and eyes) are easily noticed in an upright face, yet when presented in an inverted face, the manipulation is difficult to perceive. Langton and Bruce (1999) showed that head-direction cues were ineffective in cueing attention when presented upside down. Furthermore, Kingstone et al. (2000) showed that gaze-stimuli presented to the face-processing dominant hemisphere of split-brain patients were effective cues to attention when presented in an upright face, or as eyes alone, but not when presented in the context of an upsidedown face. These studies demonstrate that there is some interference in the representation of social attention when the face producing that cue is inverted. However, the cause of this is unclear - an inverted face is difficult to encode, hence the features within it (i.e. eve-gaze) may not be fully processed, resulting in attenuated cueing due to an impoverished representation of averted social attention. A second possibility is considered, however, which forms the basis for the studies in Chapter 5. When observing a gaze-cue in an inverted face, there may be two frames of reference active. Firstly, a spatial frame could cue attention to the actual direction of gaze based in spatial coordinates. However, a competing frame could simultaneously be active which codes the face in terms of object-centred coordinates. The influence of this frame could be to bias attention to the opposite

side of space – to the direction of gaze had the face been presented in its normal upright orientation. The experiments reported in the final experimental chapter of this thesis aimed to test this hypothesis not by opposing these two frames, but by separating them, by presenting faces oriented 90 degrees from upright, rather than 180 degrees.

The influence of object-centred representations in attention is well demonstrated by studies on visual neglect. Driver and Halligan (1991) studied a patient with right temporo-parietal damage, resulting in neglect of left space. Samedifferent judgements about two objects were impaired in this patient if the distinguishing feature of the objects (when different) appeared in the left side of space. However, if the objects were rotated 45 degrees about their principal axis, such that the distinguishing feature was now on the right side of space (hence in the 'good' visual field), performance was still poor. Similarly, Tipper and Behrmann (1996) presented a barbell stimulus upon which targets could be presented. Target detection was poor when targets were presented on the left part of the barbell, compared to when targets appeared on the right, due to hemispatial neglect. However, if the patient viewed the barbell rotate 180 degrees through space prior to target presentation, then performance was poor for targets on the right side of space, occupied, of course by the left side of the object (see also Behrmann & Tipper, 1994; 1999; Tipper, Driver, & Weaver, 1991). These studies demonstrate that attention can operate in multiple frames of reference.

Some studies have also looked at object-centred representations using faces. A subset of head orientation-selective cells in the superior temporal sulcus were found by Hasselmo, Rolls, Baylis, and Nalwa (1989), to encode head orientations in an object-centred frame of reference, independent of invariant viewer-based representations. Perrett et al. (1985) found similar cells that responded to upright and isomorphically oriented faces. While these cells were coding for rotated faces, they were more active, and sooner (10-60 ms shorter latency) when viewing an upright face. These data suggest that rotated faces can be coded in terms of their normal orientation (i.e. upright) in a head-centred frame of reference.

There is also behavioural evidence for head-centred representations of faces presented in unusual orientations affecting the processing of targets. Hommel and Lippa (1995) showed that responses to targets presented on a face rotated 90 degrees clockwise or anticlockwise, were indeed influenced by the orientation of the face. That is, when judging whether a visual target appeared in the upper, or lower part of the display, with left and right key-presses, response facilitation was found when the targets appeared in locations congruent with required response, in a head-centred frame of reference. For example, if targets, appearing in the upper part of the display required a left key-press, then the response would be facilitated to a target appearing over the left eye in a face appearing rotated clockwise. In contrast, a target appearing in the upper part of the display would result in a slow left-key response if the face appeared rotated anticlockwise, since the target would appear over the right eye, and would thus be incongruent in head-centred terms.

These head-centred effects were small, in comparison to standard stimulusresponse compatibility (S-RC) effects (7 ms, Hommel & Lippa, 1995), however, they were successfully replicated by Proctor and Pick (1999). These effects suggest that the intrinsic head-centred representations of faces can affect the coding of stimuli on the face. That is, the left side of the face is coded, at least in part, as the left side however it is oriented in space. It is possible, therefore, that the attention system may also access intrinsic head-centred information about a gaze-cue that is presented in the context of a rotated face. Further evidence from stimulus-response compatibility experiments suggest that gaze-cues automatically activate motor responses to the congruent side of space. For example, Zorzi, Mapelli, Rusconi, and Umiltà (2003) showed that responding to the colour of the irises of presented gaze stimuli were faster if the responding hand (e.g. green iris means respond with right hand, blue means respond with left hand) was the same as the direction of the observed eyes. Ansorge (2003) showed that this S-RC relationship remained when the face was rotated 90 degrees, as in Hommel and Lippa's (1995) study. Ansorge took this finding to suggest that these S-RC effects arise independent of attention, since a face, rotated 90 degrees, gazing up or down could only ever cue attention up or down. However, it is possible that the highly flexible mechanisms of attention, which access several interacting reference frames (Tipper, Jordan, & Weaver, 1999; Tipper, Lortie, & Baylis, 1992; Tipper & Weaver, 1998) could also access this headcentred frame, and allow attention shifts to the right or left as if the face had been presented upright. The final experimental chapter of this thesis investigates this possibility.

Overview

In summary, the studies presented in the following experimental chapters will approach the question of whether, as predicted by Extreme Male Brain theory, normal adult males may show weaker attention shifts in response to eye-gaze cues as compared with normal adult females (Chapter 2). Such gender differences are examined in several gaze-cueing conditions (Experiments 1-4), before the possibility that gender differences may emerge in other forms of attentional cueing (arrows, and peripheral cueing), is investigated in Chapter 3. Chapter 4 examines the influence of target context on cueing magnitude, by presenting targets on either coherent or incoherent visual objects. The influence of score on the autism-spectrum quotient on cueing towards these different types of visual display is also examined. The final experimental chapter demonstrates that averted gaze can influence attention in multiple reference frames (Chapter 5), such that attention is cued to the actual direction of the gaze of an isomorphically rotated face, but also toward the direction that the eyes would have been looking, had the face been presented upright. As such, this thesis attempts to answer questions regarding the nature of gaze-evoked attention shifts, and to examine individual differences in gaze-cueing.

Chapter 2 – Sex differences in eye-gaze cueing of attention

Following the direction of another person's gaze, 'joint attention', has been found to emerge as early as 3-months in human infants (Hood et al., 1998; Scaife & Bruner, 1975) and is seen as a very important step towards establishing strong patterns of social interaction (see Moore & Dunham, 1995). Observing averted gaze has also been found to direct spatial attention reflexively in adults (Driver et al., 1999; Friesen & Kingstone, 1998; Hietanen, 1999; Langton, 2000; Langton & Bruce, 1999, 2000). The orienting of attention based on observed gaze direction is thought to reflect the activation of neural systems dedicated to the decoding of social stimuli (Allison et al., 2000; Emery, 2000; Hoffman & Haxby, 2000; Kingstone et al., 2000; Wicker et al., 1998).

If orienting toward the direction of another's gaze reflects 'social' processing, then the strength of cueing should depend upon the strength of signal from this 'social module'. The 'Extreme Male Brain' hypothesis of autism (Baron-Cohen, 2000, 2002, 2003) suggests that the male information processing system is less well adapted to understanding the mental states of others than the female brain. Males tend to do better in tests of spatial reasoning and problem solving, but as infants and adults, are less sensitive to eye-gaze and faces, preferring to attend to non-social stimuli (Connellan et al., 2000; Lutchmaya et al., 2002a; McGuinness & Symonds, 1977; Taylor, Itier et al., 2001).

These sex differences relate very well to the idea that the developmental disorder of autism is an extreme expression of an overall cognitive style that is found more in males than females. If these sex differences are present from birth, and have

a strong biological component, then the effects of such differences in cognitive style may continue into adulthood, just as males continue to outperform females in spatial cognition, females should continue to show greater joint attention abilities and tendencies, which rely on social cognition. Hence, the following series of experiments investigate the performance of males and females in eye-gaze cueing paradigms. The prediction is that a) males will show reduced cueing from eye gaze cues compared with females, and b) will show greater modulation of cueing as a function of whether the pupils are seen to move or not, due to a potential male bias towards processing low-level cues such as motion.

Experiment 1 – 'Pupils appear' gaze-cue

The first experiment in this series was a replication of (Driver et al., 1999, Experiment 2), with the small exception that participants were explicitly asked to maintain central fixation throughout trials. Hence, an overall replication of the findings of Driver et al. was predicted. It was also predicted that males would be cued less than females, in accordance with Extreme Male Brain theory (Baron-Cohen, 2000, 2002, 2003). This would also serve as a baseline for the second and third experiments in this chapter. Hence, participants observed either a female or a male face, with patches over the eyes which disappeared to reveal pupils looking to the left or right. After a variable SOA, a target was presented randomly to the left or right, which the participant was required to identify as quickly as possible.

Method

Participants.

Forty adults participated in the study (20 males, mean age = 21.5 years, SD = 3.97 years; 20 females, mean age = 21.8 years, SD = 2.93 years).¹ Participants were recruited via the School of Psychology Participant Panel, or from the university student population. Participants received payment or course credit. All were naive to the purpose of the study.

Apparatus and Materials.

The stimuli were presented to participants on a PC (800MHz, Pentium III processor), using E-Prime 1.0 experimental procedure software (Schneider,

¹ All experiments reported in this thesis recruited participants between the ages of 18-35.

Eschman, & Zuccolotto, 2002). The faces were created with Poser software (Curious Labs, Inc), and manipulated in Adobe Photoshop 5.0 (Adobe Systems, 1998). The male face measured 11 x 18 cm, each eye was 2 x 0.8 cm, and the pupils were 0.9 x 0.8 cm. The female face measured 10.9 x 16.5 cm, eyes measuring 1.8×0.7 , with the pupils at 0.8 x 0.7 cm. The letters ('T' and 'L') were both 1.0 x 1.6 cm, and presented 12.5 cm from the centre of the screen. Participants were positioned such that their eyes were 60 cm from the centre of the screen, with a chinrest.

Design.

'Sex of Participant' and 'Gender of Viewed Face' were the two betweensubjects factors, with participants divided equally between groups. Two withinsubject factors also contributed to the design. Firstly, 'Validity' was a two-level factor, whereby 'Valid' trials were when the direction of the pupils pointed to the location of the target. 'Invalid' trials were trials where the target was presented in the opposite hemifield to the direction of gaze. The second within-subject factor was SOA, whereby the presentation of the target followed the gaze-cue after a variable amount of time: 100, 300 or 700 ms. The within-subject factors were therefore the same as those used by Driver et al. (1999).



Figure 1: Illustration of the timecourse of a 'valid' trial in Experiment 1. See Figure 3 for an example of the male face used in the experiments in this chapter.

Procedure.

Participants were instructed to fixate the fixation cross, which appeared for 670 ms in the centre of the screen. The face then appeared in the centre of the screen for 900 ms. Participants were urged to maintain fixation at the centre of the screen, and to ignore the non-predictive gaze direction. The gaze-cue then appeared (pupils positioned either in the right or left corners of the eyes), followed by a target letter to the left or right, after a variable SOA (see Figure 1). The participant was required to respond with a key-press as quickly and as accurately as possible to the presentation of the target. Up or down identification key-press responses were required (keys 'h' and 'spacebar', for responses to 'T' and 'L', respectively) to ensure these responses were orthogonal to the left-right target loci (Driver et al., 1999). Each trial type could occur randomly with equal probability. Each participant completed 288 experimental trials presented over three blocks, taking approximately 30 minutes.

Results

Data treatment involved removing errors (3.26%), slow (> 1000 ms) and fast responses (< 250 ms), and all trials with responses two standard deviations above

and below the mean, for each participant (7.03 %).² Errors did not differ across conditions, as evidenced by mixed-factor analysis of variance (ANOVA). A Mixedfactor ANOVA, with 'SOA' and 'Validity' as within-subject factors, and 'Gender of Face' and 'Sex of Participant' as between-subject factors, was performed on the RT means for each condition. A significant effect of 'Validity' was found, F(1,36) =16.4, p < .001, confirming the cueing effect of gaze (see Table 1 and Figure 2). 'SOA' also reached significance, F(2,72) = 63.2, p < .001, with reaction times (RT) decreasing at longer SOAs. There was a main effect of 'Gender of Face', F(1,36) =9.20, p = .004, with responses to the female face being quicker (501 ms vs. 552 ms). Further, the 'Gender of Face' by 'Sex of Participant' interaction was significant, F(1,36) = 8.91, p = .005. This interaction is due to the females responding much quicker to female face (480 ms) than male face (581 ms) stimuli, whereas the two groups of males responded with similar RTs when viewing either face (523 vs. 522 ms).

² This method of RT data trimming, as used by other authors (Hietanen & Leppanen, 2003) may be seen as rather conservative, in that many data (7%) are excluded. However, analysis of untrimmed medians produced very similar results (see Appendix I).

Sex of	Gender of Face	Validity	SOA		
Participant			100 ms	300 ms	700 ms
Males	Male Face	Valid	543 (17.1)	515 (17.8)	497 (18.4)
		Invalid	550 (18.9)	526 (18.2)	508 (18.0)
	Female Face	Valid	543 (15.1)	510 (14.3)	513 (18.2)
		Invalid	552 (18.5)	519 (14.4)	497 (15.3)
Females	Male Face	Valid	592 (21.1)	560 (26.8)	566 (21.3)
		Invalid	606 (18.0)	580 (22.7)	582 (20.6)
	Female Face	Valid	499 (14.0)	471 (14.6)	455 (12.3)
		Invalid	504 (15.0)	482 (12.8)	467 (11.4)

Table 1: Mean RT (ms) and standard errors for each group and condition in Experiment 1.



Figure 2: Graph illustrating reaction times at each SOA, for valid and invalid trials, for either gender in Experiment 1.

To further investigate the timecourse of cueing in the experiment, planned contrasts were performed at each SOA. A significant cueing effect was found at 100 ms, t(39) = 2.72, p = .010; and at 300 ms, t(39) = 3.57, p = .001; but not at 700 ms SOA, t(39) = 1.57, p = .124. No other main effects or interactions were significant, including the hypothesised 'Validity' by 'Sex of Participant' interaction, F(1,36) =

2.63, p = .113. However, in order to test a priori predictions, independent-samples ttests were performed on the RT benefit (invalid-valid) scores of male and female participants, to investigate whether gender differences were present, despite the nonsignificant ANOVA result. Cueing was found not to be significantly larger in females at 100 or 300 ms SOA, t's (38) < 1. However, at 700 ms, cueing was found to be significantly larger in females than in males, t(38) = 2.36, p = .024, supporting the hypothesis regarding sex differences (see Figure 2).

Discussion

This replication of Driver et al. (1999) resulted in similar results to the original study. That is, even though participants knew that the direction of the eyes was not predictive of target location, participants' responses were still faster to targets presented in the same hemifield as where the face looked. However, the timecourse of this effect was different to that found by Driver et al. (1999). Significant cueing was found at the early SOAs, but not at the 700 ms SOA. Firstly, this questions the assertion by Driver et al. that the effects of averted gaze observation on attention are slow to emerge. Friesen and Kingstone (1998) demonstrated consistent cueing effects at short SOAs, but only in target detection and localisation paradigms: cueing was weak at the 100 ms SOA when participants were required to identify the target (like the Driver et al., 1999 study). The lack of a significant cueing effect at the longer SOA in the present experiment, is perhaps more surprising. However, this seems to be because there were equal numbers of males and females in this sample - as one can see from Figure 2, males show no cueing at 700 ms, whereas cueing is still strong in the female subjects.

It has been suggested that visuospatial orienting to the direction of eye gaze is driven by neural mechanisms which are dedicated to the processing of social information. These mechanisms are primarily associated with ventral visual stream areas such as the STS (Allison et al., 2000; Wicker et al., 1998), which affect the attention system slowly, but their influence is strong and long lasting, hence no IOR is found until very long SOAs (Frischen & Tipper, in press). However, this result seems to suggest that the strength of the signal from eye gaze to the parietal attention system is weaker in males, resulting in a degradation of facilitatory cueing by 700 ms.

Experiment 2 – 'Pupils Move' gaze-cue

This experiment was designed to evaluate the effect of observing a more naturalistic social cueing episode on the attention system. The importance of mutual gaze in social situations is well documented (Argyle & Cook, 1976), as is motion to the development of joint attention in infants (Farroni, Johnson, Brockbank, & Simion, 2000; Moore et al., 1997). However, studies investigating the attentional effects of gaze-cues have tended to avoid using moving pupils (e.g. Driver et al. 1999), since motion may act as an additional cue to attention, based on rather different orienting mechanisms (i.e. those guided by perceptual features such as lowlevel motion). Hence, in this experiment, participants viewed a face looking at them at the start of each trial, then the pupils would move to the left or right. Thus, the final gaze-cue was comparable to Experiment 1, but both motion and mutual attention preceded this cue.

The influence of motion and mutual gaze may be investigated in terms of the Extreme Male Brain hypothesis. Again, males will be cued less by eye-gaze, but it is a possibility that as well as the attenuated social processing, a bias towards processing of mechanical events in the environment (superior 'folk physics', Baron-Cohen, 2002), may lead to a greater effect of motion of pupils in males than in females. Indeed, as Baron-Cohen (1995a, see also Driver et al. 1999) notes, the eye direction detector (EDD) can operate fully based on low-level information alone, while the higher-level mechanisms involved in shared and joint attention might require access to richer forms of information about the meaning of another's eye gaze behaviour. If the motion of the pupils does indeed result in improved cueing in

males, then such a result could help to explain why children with autism show strong cueing effects from moving pupils at similar SOAs (Chawarska et al., 2003; Leekam et al., 1998; Swettenham et al., 2003).

Method

Participants.

Forty adults participated in the study (20 males, mean age = 21.6 years, SD = 5.01 years; 20 females, mean age = 21.7 years, SD = 4.69 years). Participants were recruited via the School of Psychology Participant Panel, or from the university population. Participants received either payment or course credit. All were naive to the purpose of the study.

Apparatus and Materials, Design and Procedure.

The apparatus and materials were the same as for Experiment 1, with the exception that centrally positioned pupils were used instead of grey patches in the precue face. The design of the experiment was also identical to that of Experiment 1. The procedure of the experiment was identical to that of Experiment 1, with the exception that the precue face now consisted of centrally fixated pupils (rather that grey patches), which, when the gaze-cue was presented, moved from the centre to the corner of the eyes (see Figure 3).





Figure 3: Illustration of a 'valid' trial in Experiment 2.

Results

Errors (3.45%) and RT outliers (5.57%) were removed. Mean RTs were submitted to a mixed-factor ANOVA. Within-subjects factors were 'Validity' and 'SOA', with 'Sex of Participant' and 'Gender of Face' as between-subjects factors. The ANOVA revealed significant effect of Validity, F(1,36) = 21.7, p < .001, with faster responses in Valid trials. A significant effect of SOA was also found, F(2,72)= 101, p < .001. No other main effects or interactions were significant, including the 'Validity' by 'Sex of participant' interaction, F(1,36) = 1.99, p = .167. In order to fully investigate the timecourse of the cueing effects, planned contrasts were performed on the effect of validity at each SOA, finding significant cueing at 100 and 700 ms SOAs; t(39) = 3.38, p = .002 and t(39) = 3.93, p < .001, respectively. Cueing at 300 ms SOA was not significant, t(39) = 1.37, p = .178. In accordance with the hypothesis concerning sex differences, independent-samples t-tests were performed on the RT benefit scores. Females displayed significantly more cueing than males at 300 ms SOA, t(38) = 2.49, p = .017, (-3 ms vs. 12 ms). Cueing did not differ at 100 ms SOA, *t*(38) < 1, or 700 ms SOA, *t*(38) < 1 (see Table 2 and Figure 4).

Sex of	Gender of Face	Validity	SOA		
Participant			100 ms	300 ms	700 ms
Males	Male Face	Valid	528 (26.1)	507 (28.2)	478 (24.7)
		Invalid	537 (28.1)	508 (25.8)	492 (25.6)
	Female Face	Valid	522 (15.0)	512 (16.8)	497 (12.8)
		Invalid	535 (15.9)	504 (14.2)	503 (12.4)
Females	Male Face	Valid	523 (23.5)	494 (24.6)	476 (25.7)
		Invalid	535 (24.5)	507 (26.5)	499 (23.3)
	Female Face	Valid	524 (13.1)	495 (9.86)	477 (10.1)
		Invalid	526 (13.0)	505 (11.7)	485 (12.2)

Table 2: Mean RT (ms) and standard errors for each group and condition in Experiment 2.



Figure 4: Graph illustrating reaction times at each SOA, for valid and invalid trials, for either gender in Experiment 2.

Discussion

Again, cueing toward the direction of gaze was found. However, in this experiment cueing was found at the early (100 ms) and late (700 ms) SOAs. The overall trend was for cueing to be attenuated at 300 ms SOA. This decrease was mainly due to weak cueing in males. Hence, it seems that females followed essentially the same pattern of cueing as in Experiment 1, with males in general displaying smaller cueing effects. However, in this experiment, it is at the 300 ms SOA where the sex difference is most clear. It is possible to speculate that the suppression of cueing at 300 ms is due to reactive inhibition (Inhibition of Return, Posner & Cohen, 1984) preventing the reorienting of attention to a location previously cued by the sudden onset of motion of the pupils, which is absent in the pupils appear condition. The fact that males' cueing toward the direction of gaze recovers (but is still numerically weaker than in females) by the 700 ms interval perhaps indicates that the disruption of the social processing system caused by the motion in the scene is resolved, allowing males' attention systems to be driven by observed averted eye-gaze. A similar mechanism may perhaps be active in children with autism, who follow moving pupils (Chawarska et al., 2003; Swettenham et al., 2003). This further illustrates the greater strength of social orienting in females as compared to males. At this point, it is unclear as to whether this intriguing cueing timecourse is due to the motion of the pupils, or the introduction of mutual gaze at the start of trials. Hence, Experiment 3 was designed to investigate the effect of eyegaze cueing with mutual gaze at the start of trials, but without the possible confound of pupil motion towards the direction of gaze.

Experiment 3 – 'Face translation' gaze-cue

In this experiment, the eyes were presented looking straight ahead, then looking to the left or the right. However, in order to avoid the possibility that the physical motion of the pupils would result in orienting towards the direction of motion, the gaze-cue was presented in a face that had been translated one pupil's width to the left or right. Therefore, the pupils remained static throughout a trial, and the physical motion in the display was produced by the whole head moving one pupil's width right or left. This head motion was of course in the opposite direction to the direction of eye gaze (see Figure 5). This method of producing a gaze-cue has been used before with infants (Farroni et al., 2000), and successfully in neglect patients (Vuilleumier, 2002).



Time Figure 5: Illustration of the timecourse of an 'invalid' trial in Experiment 3.

Method

Participants.

Forty adults participated in the study (20 males, mean age = 25.4 years, SD = 11.3 years; 20 females, mean age = 19.5 years, SD = 1.15 years). Participants were recruited via the School of Psychology Participant Panel, or from the university

population. Participants received payment or course credit. All were naive to the purpose of the study.

Apparatus and Materials.

The apparatus and materials were the same as for Experiment 2, with the exception that the gaze-cue face was presented one pupils width off-centre; that is, if the gaze-cue is 'left', then the face would be presented to the right of centre, and visa-versa for the 'right' gaze cue. Hence, the male face would be presented 0.9 cm off-centre, and the female face 0.8 cm off-centre, in order to allow the static maintenance of the pupil position on the screen.

Design and Procedure.

The design and procedure of the experiment was identical to that of Experiment 2, with the exception that the gaze-cue face now was presented a pupil's width towards the opposite side of the screen to that which the eyes pointed.

Results

Errors (3.71%), and RT outliers (7.23%), were removed. Mean RTs for each condition were submitted to mixed-factor ANOVA, with 'Validity' and 'SOA' as within-subject factors, and 'Sex of Participant' and 'Gender of Face' as between-subject factors (see Table 3 and Figure 6). A significant effect of Validity was found, F(1,36) = 28.1, p < .001, with faster responses in Valid trials (527 ms vs. 517 ms). The main effect of SOA was significant, F(2,72) = 68.9, p < .001, with faster responses at long SOAs.

Sex of	Gender of Face	Validity	SOA		
Participant			100 ms	300 ms	700 ms
Males	Male Face	Valid	533 (21.4)	518 (21.0)	504 (18.2)
		Invalid	542 (19.9)	522 (20.2)	507 (16.1)
	Female Face	Valid	536 (29.4)	500 (28.3)	500 (25.6)
		Invalid	533 (24.6)	518 (23.7)	504 (25.3)
Females	Male Face	Valid	536 (17.4)	511 (19.0)	499 (18.9)
		Invalid	545 (17.2)	536 (19.7)	521 (19.3)
	Female Face	Valid	541 (14.6)	516 (12.5)	504 (14.7)
		Invalid	541 (15.1)	535 (13.2)	519 (14.1)

Table 3: Mean RT (ms) and standard errors in each group and condition in Experiment 3.



Figure 6: Graph illustrating reaction times at each SOA, for valid and invalid trials, for either gender in Experiment 3.

Crucially, the interaction of 'Validity' by 'Sex of Participant' was significant, F(1,36) = 5.96, p = .020. This interaction was investigated with independent samples *t*-tests. Cueing in males was found to be significantly less than in females at the 700 ms SOA, t(38) = 2.70, p = .010. Cueing was weaker in males at the other two SOAs, but did not reach significance in either contrast: 100 ms SOA, t(38) < 1; 300 ms, t(38) = 1.65, p = .108. A further interaction of 'Validity' by 'SOA' was found to be significant, F(2,72) = 3.99, p = .023. Planned contrasts revealed that this interaction was due to significant cueing at 300 and 700 ms SOAs, t(39) = 5.05, p < .001; t(39) = 3.64, p = .001; but non-significant cueing at 100 ms SOA, t(39) < 1.

Discussion

This experiment was conducted to investigate the possibility that the differences between the timecourse of cueing effects in Experiments 1 and 2 were due to the addition of mutual gaze in Experiment 2 rather than due to the introduction of motion. The cueing timecourse found in Experiment 3 is very similar to the findings of Driver et al. (1999, Experiment 2), suggesting that the particular way in which the cue was made, resulted in no substantial difference to the timecourse of cueing. Furthermore, in this experiment, cueing in males was greatest at 300 ms SOA, whereas this SOA in Experiment 2 revealed the weakest cueing effects in males. Finally, the 700 ms SOA mirrored the findings of Experiment 1, with cueing in females significantly greater than in males. In fact, the sex differences were strongest in this particular experiment, as the ANOVA results showed. The similarities of the cueing patterns in this experiment as compared to Driver et al. (1999) and Experiment 1 of this thesis suggest that the presentation of mutual gaze at the start of trials had little effect on the cueing patterns. Hence, motion of pupils, but not mutual gaze seems to have resulted in the weak cueing effect at 300 ms in Experiment 2. Indeed, in further analyses, contrasts performed at each SOA, across the three experiments showed that cueing was only modulated at the 300 ms SOA as a function of experiment, F(2,108) = 3.42, p = .036, with less cueing in the moving

pupils experiment (Experiment 2; 4 ms cueing), than in Experiment 1 (13 ms cueing) and Experiment 3 (16 ms cueing). Cueing at the 100 or 700 ms SOAs was not modulated across experiments.

Experiment 4 – Anti-predictive face translation gaze-cue

The automaticity of gaze-cueing has been effectively demonstrated by Driver et al. (1999, Experiment 3). Participants were correctly informed that targets were likely to appear in the opposite direction to that which the pupils pointed. Despite this information, participants were still cued to the direction of gaze. This suggests that participants were unable to engage top-down control of attentional orienting in order to fully suppress the automatic orienting of attention to the direction of gaze.

The findings of Experiments 1 to 3 suggest a strong gender difference in the orienting of attention to the direction of another's gaze. If the male attention system is less influenced by the gaze of others, males should be able to engage top-down mechanisms of attentional control more effectively than females when given instructions concerning target location that encourage them to suppress the representation of observed eye gaze direction. Since the most reliable gender difference was found in the Experiment 3 of this chapter, Experiment 3 of Driver et al's (1999) study was replicated, using this 'Head Moves' method, specifically to see if gender differences could again be found. The specific experimental hypothesis was that males can actively suppress the effect of the pupils, and orient to the expected target location, while females will orient to the direction of the pupils, due to the stronger signals from the gaze-processing mechanism to the attention system.

In using the paradigm used in Experiment 3 from this thesis, however, this design has an advantage over that of Driver et al. (1999) in approaching the argument of automaticity of the gaze-cueing effect. Experiments that show cueing of
attention to the direction of eye gaze is automatic do so by informing participants that the target will usually appear in the opposite side of space to the direction of the eye-gaze cue (Downing et al., 2004; Driver et al., 1999; Friesen et al., 2004). Participants are therefore required to explicitly encode the gaze-cue, in order to attempt to subsequently orient to the opposite side of space (to the expected target location). In contrast, in the current procedure, participants are instructed to completely ignore the eye-gaze (like Experiments 1 to 3). Rather, they are told to orient attention in the direction in which the head moves, as the target will be presented on that side of space on 75% of trials. Hence, the present experiment uses 75% invalid cues: that is, only 25% of targets appear at the gazed-at location. However, the importance of the direction of gaze is never mentioned to participants.

Orienting towards to opposite side of space to the direction of a cue is a much more demanding task as to orienting in the same direction as a cue. For example, making a voluntary saccade to the opposite direction of a cue (an antisaccade) evokes a latency delay of around 80 ms, in comparison to a pro-saccade in the direction of the cue (Hallett, 1978). Covert orienting (as in these experiments) might also be influenced in this way. Hence, using a predictive cue (motion of the head) in participant instructions encourages pro-orienting, rather than anti-orienting of attention in the presence of a gaze cue. In using this paradigm, which produces strong gaze-cueing (in females, Experiment 3, this chapter), gaze is again rendered irrelevant to the task by the task instructions. The preservation of cueing effects will strongly suggest that these gaze-effects are automatic. The lack of cueing effects will suggest that when gaze is unrelated to task, participants can indeed utilize top-down control over attention in the presence of another's averted gaze. If the reason that males are cued less by gaze-cues is due to greater top-down control, then males might be expected to be better at voluntarily orienting to the target-expected side of space. If males' gaze-cueing mechanism works in essentially the same way as females', but simply weaker at encoding gaze direction, then males and females should produce similar patterns of cueing, but with cueing simply attenuated in males.

Method

Participants.

Forty university students participated in the experiment. Twenty males (mean age = 27.0, SD = 4.5 years) and 20 females (mean age = 22.6 years, SD = 4.2 years) with normal or corrected to normal vision participated, for which they received £5. All were naive to the purpose of the study.

Design and Procedure.

The design and procedure were the same as for Experiment 3, with the exception that only 25% of trials had congruent pupil direction and target location, 75% of the trials therefore being validly predicted by head movement direction. Participants were informed that the direction in which the head moves usually indicated the probable target location. In this experiment, there were four experimental blocks, with 384 trials in total (96 validly cued by pupil position, 288 invalidly cued). The addition of 96 extra trials, in comparison to Experiment 3 was

to compensate for the reduction of the number of valid trials following the change in the target location probability.

Results

Incorrect responses (4.08%) and RT outliers (7.25%) were removed from analysis using the same methods as in Experiments 1-3. A mixed-factor ANOVA was performed on the mean scores, with 'SOA' and 'Validity' as within-subject factors, and 'Sex of Participant', and 'Gender of Face' as between-subject factors. The main effect of 'Validity' was non-significant, F(1,36) = 1.08, p = .306. The main effect of SOA was significant, F(2,72) = 41.9, p < .001, with faster RTs at longer SOAs. No interactions were significant, although 'Sex of Participant' by 'Gender of Face' approached significance, F(1,36) = 3.80, p = .059, with responses being quicker when the gender of the participant corresponded with the gender of the face used in the experiment. Males observing a male face were quicker than those observing a female face (484 ms vs. 535 ms), while females observing a female face were quicker than those observing a male face (473 ms vs. 517 ms). This same-gender advantage for overall reaction time mirrors that of Experiment 1, suggesting an overall increase in arousal in groups observing a face of their own gender (see Table 4). However, this interaction was absent in Experiments 2 and 3, so firm conclusions are difficult to draw.

Sex of Participant	Gender of Face	Validity	SOA		
			100 ms	300 ms	700 ms
Males	Male Face	Valid	495 (24.8)	484 (22.7)	470 (23.4)
		Invalid	497 (23.5)	489 (21.5)	469 (22.3)
	Female Face	Valid	553 (28.7)	534 (26.1)	517 (28.7)
		Invalid	558 (27.9)	535 (24.7)	513 (27.0)
Females	Male Face	Valid	524 (33.6)	522 (35.1)	499 (31.4)
		Invalid	534 (32.4)	521 (32.9)	502 (31.7)
	Female Face	Valid	486 (11.0)	470 (15.6)	451 (10.3)
		Invalid	491 (11.8)	484 (17.9)	455 (11.8)

Table 4: Mean RT (ms) and standard errors for each group and condition in Experiment 4.



Figure 7: Graph illustrating reaction times at each SOA, for valid and invalid trials, for either gender in Experiment 4.

As before, cueing effects at each SOA were investigated with t-tests. A trend was found at 100 ms SOA, t(39) = 1.88, p = .068, such that targets congruent with pupil location were responded to quicker (515 ms vs. 520 ms, see Figure 7). No other contrasts approached significance. So, although cueing was not significant overall, at the 100 ms SOA, some evidence of cueing to the direction of gaze was found. Independent-samples t-tests revealed no differences between cueing magnitude between males and females at any SOA (ts < 1). However, again gazecueing was larger in females than in males at each SOA, and further contrasts revealed that the only cueing effect to approach significance was at 100 ms SOA in the female group, t(19) = 1.91, p = .072, all other ps > .20.

Discussion

This experiment investigated the possibility that males will be more successful in employing a strategy which demands that they should actively orient to the opposite direction of gaze. Overall, no cueing effects were found. The 100 ms SOA produced marginally significant gaze-cueing, but there was no evidence of the predicted sex differences (although the small cueing effects that were present, were again larger in females). This suggests that although the gaze-cues did not produce large cueing effects, the pupils of the face could not be completely ignored (Downing et al., 2004; Driver et al., 1999; Friesen et al., 2004).

In the present study, participants were informed that a target was most likely to appear on the side of the screen congruent with head movement direction. While participants were also unable to orient to this location at any SOA, they also did not display orienting of attention to the opposite side of space, which was gazed at by the stimulus face. The trend for cueing at the early (100 ms) SOA suggests that gazecueing was the dominating influence over the attention system at this point in time. However, gaze-cueing degraded across later SOAs, indicating that participants were able to successfully suppress the influence of gaze-direction such as to produce a null effect of attentional cueing towards looked-at and likely target locations (see also Driver et al. 1999). The results from Experiments 1-3 suggest that males have a weaker gazeprocessing system, which therefore has only a weak influence on the attention system (compared to that of females). Alternatively, males might be better equipped to suppress the influence of the non-predictive cues in Experiments 1-3. Either of these reasons could explain the sex difference. However, if the latter were true, then males should have been able to use the additional information about probable target location to orient to the direction of motion in this experiment. If males have better inhibitory control over centrally cued attention, then they should have displayed cueing to the likely target position. While not conclusive evidence, these data therefore lend more support to the argument that weaker attention shifts in males are due to weaker processing of the cue, rather than due to active inhibition of the cue. However, the use of other target locations (e.g. above and below fixations) would potentially have revealed whether cueing was present at cued and likely target locations, as compared with baseline (neutral) target locations (see Friesen et al., 2004).

The Autism-Spectrum Quotient (AQ)

With respect to the 'Extreme Male brain' hypothesis of autism, from which the experimental predictions were made, a link to the symptomology of the autism spectrum disorders was made by administering a questionnaire to a subset of the participants. The use of the AQ was introduced after testing had commenced, hence the lack of a full data set in these experiments. Since only a subset of participants from Experiment 1, 2 and 3 (a total of 24 males, 19 females) completed the questionnaire, strong conclusions are difficult to draw. Nevertheless, despite the lack of a full data set, it is of interest to mention.

The questionnaire was the fifty-item 'Autism-Spectrum Quotient (AQ)', developed by Baron-Cohen et al. (2001). This questionnaire lists 50 statements, and requires the participant to indicate whether he/she 'definitely agrees', 'slightly agrees', 'slightly disagrees', or 'definitely disagrees' with the statement. The AQ assesses five traits, which pertain to social and cognitive functioning styles often found to be in the extreme ranges in people with autism-spectrum disorders. Therefore, ten questions were aimed at assessing each of the following traits: 'social skill', 'attention switching', 'attention to detail', 'communication', and 'imagination'. The questionnaire is scored out of 50 points, with high scores meaning that more traits that are autistic-like are reported.

Two aspects of the questionnaire data are of note: First, males tended to score higher (M = 18.6) than females (M = 15.2). This difference was almost significant, t(41) = 1.98, p = .054. This confirms the sex differences observed by

Baron-Cohen (2001), and supports the potential link between autism and the extreme male brain hypothesis. The second observation of note is that there was a significant negative correlation between score on the AQ and cueing at the 700 ms SOA (r = -.259, n = 43, p = .047, see Figure 8). That is, those individuals scoring higher on the autism quotient, tended to produce less cueing towards the direction of gaze. This suggests that those who rate themselves as poor communicators, having poor social skills, and so on, also show weaker reflexive gaze following. While conclusions drawn from the AQ data are limited, due to the small sample size, this new research approach may prove to be a useful explanatory tool in the study of individual differences in normal social cognition (Baron-Cohen, Richler, Bisarya, Gurunathan, & Wheelwright, 2003; Baron-Cohen, Wheelwright, Skinner et al., 2001).



Figure 8: Scatterplot of cueing effects at the 700 ms SOA in the 43 participants who completed the AQ in Experiments 1-3. When the two male outliers (at the bottom of the chart) are removed, the correlation is slightly weaker, but still approaches significance, r = -.247, n = 41, p = .059.

General Discussion

The experiments presented in this chapter demonstrate consistent sex differences in attentional cueing following the presentation of a central averted eyegaze cue. Hence, in replicating the basic effect of attention orienting towards the direction of another's gaze (e.g. Driver et al. 1999), a gender difference is revealed that is entirely predicted by the Extreme Male Brain theory of autism and psychological sex differences. It seems that males do not process eye gaze as efficiently as females do, and therefore do not orient to the direction of gaze as strongly. This effect was due to a larger difference between RTs to targets presented in cued and uncued loci in females compared to males. Note that in Experiments 1 to 3, participants were informed that gaze direction did not predict subsequent target location. Therefore, the task goal involved ignoring the irrelevant gaze cue. In this sense, males can be considered more efficient, being able to ignore gaze shifts. In contrast, females encode gaze in such an automatic and efficient manner that they cannot ignore this irrelevant social stimulus.

When eye-gaze was anti-predictive of target position (Experiment 4), cueing was not found. This supports previous results that suggested that participants cannot completely ignore the direction of the gaze cue, as had participants been able to ignore gaze, cueing towards the direction of head motion would have been found. Importantly, even with instructions that encouraged orienting in the direction of motion in the scene, away from gaze, participants could not use this information to orient to the target-expected side (Driver et al. 1999). This is in contrast to arrows and laterally averted tongues, which are easily overridden (Downing et al., 2004; Friesen et al., 2004). The weaker gaze-cueing effects in this experiment (in comparison to Driver et al., Experiment 3) may be due to the way in which the gazecue was produced. By translating the face towards the likely location of the target (on 75% of trials), it was possible to retain the instruction of 'ignore the gaze-cue', but adding the instruction that the 'target will usually appear in the direction in which the head moves'. This suggests that the propensity to orient to the direction of non-predictive gaze can be suppressed more efficiently if another feature of the environment can be used to direct attention. Overall, Experiment 4 of this thesis is a demonstration of the failure of strategic control of spatial attention in the presence of anti-predictive central gaze, and is hence another demonstration of the strength of irrelevant gaze-cues to affect behaviour.

Across experiments 1-3, female participants produced very similar patterns of cueing (see Figure 9). In general, cueing increased over SOA, while in males, weaker cueing was observed. Furthermore, the timecourse of the (small) cueing effects in males was numerically different in each experiment. When the pupils appeared from behind occluders (Experiment 1), cueing decreased over time; when the pupils moved (Experiment 2), cueing decreased, and then recovered over time; when the head moved to produce the gaze-cue (Experiment 3), cueing was greatest at the 300 ms SOA. This suggests that not only do males have a weaker gaze processing system, but that the behavioural effects of observing averted gaze is much more influenced by the manner in which the gaze is produced.



Figure 9: Graphs of cueing effects magnitudes for each experiment in Chapter 1.

Indeed, across the four experiments, it was only at the 100 ms SOA in Experiment 2, where motion of the pupils produced the gaze-cue, where males were cued numerically more than females (see Figure 9). This suggests that this more 'mechanical' method of cueing, with low-level visual motion, initially drives males' attention systems more than females', an observation which is again in accordance with Extreme Male Brain Theory (Baron-Cohen 2000, 2002, 2003). In females, the manner in which the gaze is produced has little effect on the cueing pattern, suggesting that the final pupil position is encoded in similar ways across experiments.

These results show that sex differences found in infancy, regarding processing of social information, continue to influence cognition in adulthood. Of course, males are perfectly able to work out where someone is looking, and intentionally follow their gaze. However, the lack of a strong system that *automatically* orients attention to the locus of another's attention could have profound effects on the development and cognitive style of the male brain. For example, males develop vocabularies slower than females (Lutchmaya et al., 2002b), and the development of language is correlated with the development of Joint attention (Baldwin, 1995; Morales et al., 2000; Morales et al., 1998). Joint attention is also a precursor to theory of mind (Charman et al., 2001). Hence, the female brain, with its greater propensity to orient to direction of gaze, is at an advantage for interpreting subtle social cues while interacting with other people. Such processing biases in the female brain may facilitate the accurate representation of the mental states of others.

Chapter 3 – Effects of gender on attentional cueing

following symbolic and peripheral cues

The sex differences described in Chapter 2 suggest a link between weaker social attention abilities and smaller gaze-cueing effects in males. However, this conclusion may be somewhat premature. Non-predictive arrows have been shown to be effective cues to attention (Eimer, 1997; Hommel et al., 2001; Ristic et al., 2002; Shepherd et al., 1986; Tipples, 2002). Although non-biological stimuli, arrows are centrally presented symbolic stimuli that are developed for the purpose of interpersonal communication, so it is possible that females are also cued more by these stimuli, than males are. The question of whether males fail to produce attention shifts according to centrally presented arrows is therefore of great interest, in order to contextualise the results of Chapter 2.

If orienting to the direction of another person's eye gaze is functionally different to the 'symbolic cueing' seen with arrows, for example, then no gender difference would be obtained with arrow cues - males and females should display attention shifts of equal magnitude. This result would add to other findings of subtle differences between the effects of eyes and arrows (Friesen et al., 2004; Ricciardelli, Bricolo et al., 2002; Ristic et al., 2002; Vuilleumier, 2002), and would strongly suggest that the reason that females show more orienting towards the direction of another's gaze is due to their greater processing of social stimuli (Baron-Cohen, 2002). In sharp contrast, the persistence of a gender difference when cueing with arrows would suggest that the difference between males and females in these experiments is more general than just differences in processing of biological stimuli. The following experiment investigates the way symbolic cues affect male and female attention systems. The final two experiments of the chapter assess shifts of attention in males and females, following peripheral cues, in paradigms based on those of Posner and Cohen (1984). The mechanisms underlying shifts of attention following peripheral onset cues are thought to involve very different orienting mechanisms, hence no sex differences are predicted. However, in light of the findings of Chapter 2 with gaze-cues, the way that male and female attention systems operate in a variety of other experimental situations is an important area of investigation. Experiment 5 – Arrows as symbolic cues

Method

Participants.

Forty university students (twenty males, mean age = 22.7, SD = 5.1 years; twenty females, mean age = 21.2 years, SD = 3.7 years) participated in this experiment in return for payment or course credit. All had normal or corrected to normal vision, and were naïve to the purpose of the experiment.

Apparatus.

The arrow consisted of a line (5.5 cm), and arrowheads (1.0 x 2.0 cm) drawn with 0.3 cm thickness.

Design and Procedure.

Design and Procedure were identical to Experiment 1, except that an arrow cue was used (see Figure 10).



Time

Figure 10: Illustration of a 'valid' trial in Experiment 5.

Results

Errors (3.44%) and RT outliers (6.92%) were removed from analysis. Mean RTs for each participant in each condition were submitted to mixed-factor ANOVA (see Figure 10). The factors 'Validity', 'SOA', and 'Sex of Participant' contributed to the analysis, which revealed a significant effect of 'Validity', F(1,38) = 15.3, p < .001, with faster responses to validly cued targets (522 ms vs. 529 ms). 'SOA' also reached significance, F(2,76) = 88.7, p < .001, with faster responses at later SOAs (548 ms vs. 520 ms vs. 507 ms). The between-factor variable, 'Sex of Participant', interacted with 'Validity', F(1,38) = 4.70, p = .037, with the benefit for RT to valid targets being larger in females (11 ms), than in males (3 ms). This interaction was investigated further with independent *t*-tests on the cueing effects at each SOA. Cueing was not different at the 100 ms SOA, t(38) = -1.15, p = .258. At the 300 ms SOA, females were cued more (19 ms) than males (2 ms), t(38) = 3.27, p = .002. At the 700 ms SOA, the difference in cueing effects was marginal, t(38) = 1.73, p = .092 (Females = 14 ms; Males = 2 ms).



Figure 11: Graph of mean RTs in each condition, for either gender.

The only other effect to reach significance, was the 'Sex of Participant' by 'Validity' by 'SOA' interaction, indicating a different time-course of cueing in the different gender groups, F(2,76) = 4.77, p = .011 (see Figure 11). The source of this interaction was due to the amount of cueing in females changing across SOAs, but the male participants' cueing effects not changing over time. This was shown by performing ANOVAs on the two sex groups independently. The 'Validity' by 'SOA' interaction was significant in females, F(2,38) = 6.43, p = .004, but not in males, F(2,38) < 1.

One other feature of the data is of note. While the main effect of 'Sex of Participant' did not reach significance F(1,38) = 1.66, p = .205, this difference of 29 ms (Males = 511 ms, Females = 540 ms) in the overall reaction time to identify targets may have influenced the cueing effects. For example, slower RTs may reveal magnified cueing effects, and contributed to the gender difference. To investigate this possibility, the forty participants were reclassified, irrespective of gender, as 'Fast' (mean RT = 471 ms, n = 20) and 'Slow' (mean RT = 579 ms, n = 20). The two new groups' RTs were significantly different, F(1,38) = 54.4, p < .001. In a new ANOVA with 'RT group' replacing 'Sex of Participant' as the between-subjects factor, 'RT group' did not interact with 'Validity', with both groups showing equivalent cueing effects, F(1,38) < 1, p > .9. Cueing effects were also equal across SOA, F(2,76) < 1, p > .9. This shows that faster responses overall did not result in attenuated cueing, and that the sex differences in arrow-cueing are not due to males generally being quicker to respond to targets.

Discussion

These data demonstrate that observing a non-predictive central arrow cue has little effect on males' attention systems. This failure of central arrow cues to evoke orienting of attention in male subjects is very similar to the failure of gaze cues to evoke strong attention shifts in this population. In contrast, females again show significantly larger cueing effects than males. In fact, the sex difference appears even stronger in this arrow cueing experiment than in the gaze cueing studies of Experiments 1 to 3. This shows that the sex difference described in Experiments 1 to 3 generalises to symbolic cues such as arrows, and is not confined to sociobiological stimuli such as averted eye gaze. Experiment 6 – Peripheral cueing with discrimination task

This experiment used the same target identification task and presentation timecourses as the symbolic cueing Experiments 1-5. However, no face or arrow was present to produce a cue. Rather, the cue was the transient enlargement (perceived as a flash) of one of two peripheral squares presented at the possible target locations. This method of attentional cueing produces robust facilitatory effects at early (e.g. < 300 ms) SOAs. In a detection task, this effect rapidly disappears due to 'inhibition of return' (IOR), evidenced by an increase of RT to validly cued targets presented more than 300 ms after cue onset (Posner & Cohen, 1984). Inhibition of Return is thought to reflect a mechanism that facilitates visual search, by preventing attention from remaining at a previously attended location (see Klein, 2000, for review).

Inhibition of Return has not been found in standard eye-gaze cueing experiments (e.g. Driver et al. 1999). The reason for this may be that while gazeand peripheral-cues share many properties, IOR is thought only to follow peripheral cueing, while gaze-cues are central cues. Friesen and Kingston (2003a) demonstrated that peripheral cues and central gaze-cues have independent effects on behaviour, suggesting they do not share common mechanisms. Gaze-cueing is thought to be underpinned by primarily cortical networks (Wicker et al., 1998), while orienting following peripheral cues is thought to be controlled by phylogenetically older structures such as the superior colliculus (Rafal et al., 1988). It is therefore predicted that the sex differences found in Chapter 2 and Experiment 5 will not generalise to reveal sex differences in peripheral cueing tasks. Hence, cueing magnitude and timecourse will not differ between males and females when attention is cued by the onset of a peripheral stimulus.

In using a discrimination task for this experiment, it is noted that studies of peripheral cueing have not always found IOR with a discrimination task (e.g. Terry et al., 1994), while other authors have demonstrated that IOR takes longer to emerge in such tasks (Cheal et al., 1998; Lupianez et al., 1997). However, since this study aims to assess the relative magnitude and timecourse of attentional cueing in males and females, the direction of any cueing effect is not of central interest.

Method

Participants.

Forty university students (twenty males, mean age = 25.0 years, SD = 4.8 years; twenty females, mean age = 22.6 years, SD = 4.9 years) volunteered for this study. All had normal or corrected-to-normal vision, and were naïve to the purpose of the experiment. Participants gave informed written consent and received either payment or course credits for their participation.

Apparatus and Materials.

A fixation cross was presented at the centre of the screen ($0.9 \times 0.9 \text{ cm}$), with two placeholder boxes, indicated by black lines (.3 cm thick), of dimensions 5.8 x 5.8 cm. The centres of these boxes served as target locations, and were 12.5 cm from the centre of the screen. The peripheral cue was achieved by doubling the thickness of the lines, internally, to 0.6 cm. Participants were positioned 60 cm from the screen with a chinrest.



Figure 12: Illustration of the timecourse of a 'valid' trial in Experiment 6. *Design.*

There were two within-subjects factors. Firstly, 'Validity' of the peripheral cue and 'SOA' were manipulated within-subjects, with the target appearing either 100, 300 or 700 ms after the onset of the peripheral cue, as with Experiments 1-5. 'Sex of Participant' was a between-subjects factor.

Procedure.

Participants were instructed to fixate the fixation cross, which appeared for 670 ms in the centre of the screen. The peripheral squares then appeared for 900 ms. The peripheral cue was then presented for 100 ms on the left or right of the screen, followed by a target letter to the left or right, after a variable SOA (100, 300 or 700 ms). The remainder of the procedure is identical to that of the gaze-cueing experiments (see Figure 12).

Results and Discussion

Errors (2.64%) and outliers (6.68%) were removed. Remaining data contributed to cell means, which were submitted to a mixed-factor ANOVA. The main effect of 'Validity' was significant, F(1,38) = 49.6, p < .001, with faster responses to validly cued targets (506 ms vs. 523 ms). The main effect 'SOA' was significant, F(2,76) = 16.3, p < .001, with slower responses to targets at the early SOA (524 ms) than the later SOAs (both at 510 ms). The interaction between 'Validity' and 'SOA' also reached significance, F(2,76) = 4.62, p = .014. Contrasts performed on the validity effect scores (invalid-valid) revealed that this interaction was due to significantly more cueing at the 300 ms SOA (22 ms cueing) than the 700 ms SOA (11 ms cueing), t(39) = 2.72, p = .010.

There were no main effects or interactions involving the between-subjects factor 'Sex of Participant'. Specifically, 'Validity' by 'Sex of Participant' was not significant, F(1,38) < 1, cueing effects were the same in either gender (Males: 525 ms vs. 509 ms, 16 ms cueing; Females: 521 ms vs. 503 ms, 18 ms cueing). The 'Validity' by 'SOA' by 'Sex of Participant' interaction was also not significant, F(2,76) = 1.06, p = .352 (see Figure 13). Nevertheless, independent-samples t-tests were performed on the data to establish whether the cueing effect size was different in males versus females at each SOA. Cueing was not significantly different between the genders, at any SOA. At 100 ms SOA, t(38) < 1; at 300 ms SOA, t(38) < 1.



Figure 13: Graph of mean RTs for each condition in Experiment 6, for either gender.

This experiment investigated peripheral cueing in males and females, in order to evaluate whether, like gaze-cues, non-predictive peripheral cues have little effect on the male attention system. Cueing magnitude and time-course was found to be equivalent in males and females, in contrast to the effect of non-predictive central gaze and arrow cues. Thus, consistent facilitatory effects were present in both sex groups. This is taken as evidence that males' and females' attention systems treat sudden onset peripheral cues in similar ways.

However, it should be noted that IOR was not observed in this experiment. It is noteworthy that the facilitatory cueing does appear to be declining from 300 ms SOA to 700 ms SOA, and hence IOR may have emerged at longer intervals in this study. However, to confirm that there are no sex differences in IOR effects evoked by peripheral cues, the next study examined peripheral cueing effects when detection of targets was required. This detection task is known to produce robust IOR effects in the range of SOAs investigated here.

Experiment 7 – Peripheral cueing with detection task

This experiment was similar to Experiment 6, except that instead of letters requiring identification, a black square served as the target, which the participants were required to detect with a single key-press. This target detection procedure allows the evaluation of exogenously cued attention in the two sexes with a design that will be more likely to reveal the behavioural effects of IOR. Hence, in accordance with the findings of Experiment 6, no difference with cueing magnitude or time-course is expected between males and females – both are expected to display significant facilitation at the early SOA and significant inhibition at the later SOA.

Method

Participants.

Forty university students participated in the experiment. Twenty males (mean age = 27.0, SD = 4.5 years) and 20 females (mean age = 22.6 years, SD = 4.2 years) with normal or corrected to normal vision participated, for which they received £5. All were naive to the purpose of the study. All had participated in Experiment 4 immediately before participation.

Apparatus.

Apparatus was the same as Experiment 6, except the target was a black square, measuring 0.9 x 0.9 cm.

Design.

A mixed-factor design was employed, with 'Validity' and 'SOA' (in this procedure, SOAs were either 200 or 800 ms) as within-subjects factors.³ 'Sex of participant' was a between-subjects factor.

Procedure.

The procedure was the same as Experiment 6, except that a simple spacebar response was required to the presentation of the target, with no response required on catch trials (n = 20). The eighty probe trials were split equally between trials with left or right cues, left or right targets, at early (200 ms) or late (800 ms) SOAs (see Figure 14).



Figure 14: Illustration of a 'valid' trial in Experiment 7.

Results and Discussion

Trials with incorrect responses (.40%), RTs less than 150 ms,⁴ more than

1000 ms or more than 2 SD above or below the mean (4.6%) were removed.

Participants' means for each condition were submitted to a mixed-factor ANOVA,

³ The intended SOAs were 100 and 700 ms, but programming error led to an additional 100 ms SOA.

⁴ A smaller lower RT cut-off was used in the target detection paradigms reported in this thesis, since RTs are generally faster in such tasks (Experiments 8-13).

with 'Validity' and 'SOA' as within-subject factors, and 'Sex of Participant' as a between-subject factor (see Figure 15).



Figure 15: Graph of mean RTs in each condition for males and females.

A significant effect of 'SOA' was found, F(1,36) = 28.1, p < .001, with faster responses to targets presented at 800 ms SOA than at 200 ms SOA (376 ms vs. 351 ms). A significant interaction of 'SOA' by 'Validity', F(1,36) = 35.1, p < .001, was investigated by planned contrasts, which showed faster responses to Valid target locations at 200 ms SOA, t(39) = 2.85, p = .007, and slower responses to Valid target locations at 800 ms SOA, t(39) = -4.48, p < .001 (see Figure 15). Hence, significant facilitation was found at 200 ms, followed by significant inhibition at 800 ms SOA. No interaction with 'Sex of participant' approached significance, most importantly, 'SOA' by 'Validity' by 'Sex of Participant', F(1,36) < 1, illustrated that 'Sex of Participant' did not interact with the magnitude of the cueing or time-course effects. Facilitation was the same at 200 ms in either gender, as was inhibition at 800 ms (independent *t*-tests, $t \le 1$). Therefore, this experiment demonstrates again that peripheral onset cues have the same effect on attention in males and females. The additional finding to that of Experiment 6 is that the IOR component of exogenous orienting was found to be equivalent in males and females.

The Autism Spectrum Quotient

Seventy-nine participants completed the AQ after Experiments 5 and 6. Males (n = 39; one male did not complete the AQ in Experiment 5) scored an average of 17.8, and females (n = 40) scored 15.6, supporting the observation of Baron-Cohen et al. (2001). This difference again approached significance, t(77) =1.77, p = .081. No correlations between cueing magnitude and AQ score were significant at any SOA, in either experiment. While no significant correlations were found between cueing and AQ score in these studies, it is difficult to conclude that no effect is present, due to the small sample sizes. Nevertheless, males still produced significantly less cueing to the direction of arrows (Experiment 5). It is possible that while overall sex differences in symbolic cueing exist, the AQ may only be sensitive enough to reveal a relationship between symbolic cueing and prevalence of autismlike traits when the cue is a social stimulus such as eye gaze. For this reason, the AQ will be used throughout this thesis as an indicator of participant processing style.

General Discussion

This chapter aimed to contextualise the results of Chapter 2, where consistent sex differences were found in gaze-cueing paradigms. These sex differences do not generalise to peripheral cues to attention, since cueing was found to be equivalent in males and females in Experiments 7 and 8. This lack of sex differences with these cues is not surprising, since orienting via peripheral cues is thought to be controlled by very different orienting mechanisms to that of joint attention evoked by eye gaze. A cortical network involving the superior temporal sulcus and the inferior parietal lobule is thought to encode another's gaze direction and direct attention shifts (Pelphrey et al., 2003; Wicker et al., 1998). In contrast, a subcortical system is thought to be involved in exogenously driven attention shifts, with the superior colliculus interacting with parietal cortex (Klein, 2000; Rafal et al., 1988).

Reflexively following the direction of an arrow also seems to be much weaker in males than in females (Experiment 5), suggesting a global sex difference in the way symbolic cues are treated by the attention system. Initially, these results seem to be at odds with the prediction of an Extreme Male brain hypothesis, since it is difficult to see how inefficiency in processing faces, emotions and eye gaze might be related to smaller attention shifts evoked by arrows.

The similarities between gaze- and arrow-cueing are striking. In this study, they share the same timecourse, same magnitude and same gender difference. Similarly, Ristic et al. (2002) suggested that following eyes and arrows have similar developmental time-course, by demonstrating that both effects develop by ages 3-5. Despite these similarities, there is growing evidence for separate underlying mechanisms. Firstly, arrows presented in ipsilesional space, cueing contralesional stimuli do not ameliorate extinction in the same way that gazing faces do (Vuilleumier, 2002). Furthermore, while arrows produce comparable attentional effects to eve-gaze, only gaze cues potentiate corresponding eye-movements in observers (Ricciardelli, Bricolo et al., 2002), and may have different neural mechanisms (Kingstone et al., 2000; Ristic et al., 2002). Indeed, Hooker et al. (2003) showed that interpreting eye gaze as a directional cue results in more STS activation than interpreting an arrow (see also Kingstone, Tipper, Ristic, & Ngan, 2004). If STS is less active for the observation of arrows, then differential activity in STS is an unlikely candidate for the origin of the gender differences reported here. It is possible instead, that while the mechanisms underlying arrow and gaze-orienting are clearly separate in some respects, the gender difference arises from where the mechanisms do overlap. One possibility that further work could investigate is that the difference is centred more in the semantic system in males and females, in the way that meaning is automatically extracted from the central cue.

Chapter 4 – Object-based gaze-cueing

The tendency to orient to the locus of another's attention is clearly of great benefit to an individual. As well as using other conspecifics orienting behaviour to alert the individual to important objects or events in the environment, the ability to accurately encode another's direction of attention may allow at least a coarse representation of the mental state of the observed individual to be constructed by the observer. That is, gaze following may reflect early representations of other minds, leading to the development of a full 'theory of mind' (Baron-Cohen, 1995b; but see Moore & Corkum, 1994). Gaze following has been found to emerge in infants as young as 3-months old (Hood et al., 1998; Scaife & Bruner, 1975). Recent studies in adults have shown that observing averted gaze results in a reflexive shift of covert attention (Driver et al., 1999; Friesen & Kingstone, 1998; Hietanen, 1999; Langton & Bruce, 1999).

One intriguing difference between developmental studies on joint attention (where "two individuals are attending to the same object, based on one individual using the attention cues of the second individual", Emery, 2000, p. 588), and those using averted gaze as a cue to attention, is that in gaze-cueing paradigms, no object is present until target presentation. In development, infants are able to orient to the correct object of another's attention after around 12 months, before which, the first object along the line of sight tends to capture attention (Butterworth, 1991). Objects are also important in joint attention episodes when one considers evidence that suggests that language development is correlated with the development of joint attention (Baldwin, 1995). A weak joint attention system, which fails to consistently orient to the correct object, may impede the pairing of a visual object to its' name, and hence slow vocabulary acquisition.

The importance of objects to orienting behaviour is also clear from the visuospatial attention literature. For example, the attentional processes of excitation and inhibition have been found to spread across an object's surface (Egly et al., 1994; Jordan & Tipper, 1999; Reppa & Leek, 2003). Thus, these studies showed that cueing one part of an object resulted in larger attentional cueing (facilitation or inhibition) to targets appearing in different parts of the same object than to equidistant targets that were part of different objects. Other studies have shown that the inhibition that can be activated via a sudden onset peripheral cue (i.e., inhibition of return: Posner & Cohen, 1984) is larger if attention was oriented to an object rather than to an area of space filled with random patterns with no apparent global form (Jordan & Tipper, 1998). If objects are the unit of attentional selection, then gaze-cueing should also evoke object-based cueing effects, such that greater cueing should be observed towards objects, as compared to towards displays that contain comparable density and complexity of visual information, yet constitute no coherent visual object. Hence, manipulating the nature of the cued object, upon which targets could appear, is the focus of this chapter.

The object category to be presented at target location was felt to be potentially important when considering the context of social interactions that surround gaze cueing effects. If the objects upon which targets could appear are also faces (Experiment 8), then participants would be observing a highly complex visual
scene (see Figure 16, top panel), in which three (potentially) mentalistic agents (participant, cue face and cued face) are involved in a mutual attention-sharing episode. If observing this scene strongly activates a social orienting mechanism, then gaze-evoked attention shifts should be much larger than towards displays of scrambled face parts. If the observation of a social interaction is assigned somewhat more importance than a non-social interaction, then a central cue other than eye-gaze would not evoke such a difference in cueing. Although arrows are stimuli that are designed to communicate direction, they are nevertheless devoid of the sociobiological importance of a gaze-cue. Therefore, if social interactions drive orienting to social stimuli, then greater cueing to faces will only be observed when a face produces a gaze-cue. If object-based attention acts regardless of the nature of the cue, then greater orienting to faces (as compared to scrambled face parts) will be observed whether a gaze or an arrow produces a cue.

A further concern of this study was the possibility that different individuals might have different orienting biases, related to their overall cognitive processing style. That is, some individuals will be strongly biased to orienting towards social stimuli, while others will not show this bias. Such orienting biases are evident in the autism and sex differences literature (Chapters 2 & 3). For example, compared to normally developing children, infants with autism spend little time orienting to people (Swettenham et al., 1998). Instead, non-social objects are attended longer by infants with autism. Poor social skills and communication are central to the impairments presented by people with autism. Indeed, while normal children understand that gaze behaviour of others allows one to infer the intentions and desires of mentalistic agents, children with autism seem to utilize gaze on a more superficial level (Baron-Cohen et al., 1995). Furthermore, children with autism often have poor joint attention skills (Charman, 2003; Charman et al., 1997). Overall, the poor theory of mind skills in people with autism (e.g. Baron-Cohen, 1989) has led Baron-Cohen (2002) to suggest that people with autism have a general profile of poor 'empathising' skills.

The other significant aspect to the cognitive profile of people with autismspectrum disorders is the observation that many people with autism have good attention to details, islets of ability and obsessions. A wider-reaching framework, incorporating both triadic and non-triadic features is needed to fully describe and explain autism (Frith & Happé, 1994). Weak 'central coherence' in perception and processing style has been posited as a deficit in processing global form, with a preserved or superior ability to process local features (Frith, 1989; Frith & Happé, 1994; Happé, 1999). Indeed, people with autism have been shown to have a perceptual bias toward the processing of local details of visual stimuli (Mottron et al., 1999; Mottron et al., 2003), superior conjunctive visual search (O'Riordan et al., 2001), and more fluent perceptual processing (Brian et al., 2003).

As an alternative to weak central coherence, Baron-Cohen (2002) suggests that a bias towards the processing of local features reflects the stronger tendency to 'systemise', to attempt to understand and build systems. Indeed, children with autism are better at understanding mechanical events than normally-developing controls (Baron-Cohen et al., 1986), and are more likely to have fathers or grandfathers who had been engineers, perhaps reflecting the genetic basis underlying such traits (Baron-Cohen, Wheelwright, Stott et al., 1997). Hence, people with autism have a cognitive style that is associated with good systemising, but poor empathising skills. The more direct relevance this theory has to this study is, however, its relationship to diversity in cognitive style in the normal population. Indeed, 'empathising' and 'systemising' are predicted to vary within the normal population, and the majority of evidence for this comes from sex differences in empathising and systemising abilities. The 'extreme male brain theory' of autism (Baron-Cohen, 2000, 2002, 2003) suggests that exceptional systemising, and very poor empathising skills are the hallmarks of the extreme male brain, and of autism. Indeed, the vast majority of people with autism-spectrum disorders are male (Rutter, 1978). Poor systemising, but good empathising skills describe the cognitive style associated with the extreme female brain. While the gender of the brain describes only cognitive style (and is not necessarily fixed to the biological sex of the person), normal sex differences in infancy and adulthood reflect the idea that empathising and systemising vary within the normal population.

Sex differences are apparent from very early in life, since female neonates spend more time looking at a human face than at a mobile, while male neonates show the opposite preference (Connellan et al., 2000). Furthermore, more eye contact is made by female infants than by male infants at 12-months-old (Lutchmaya et al., 2002a). Later in life, these biases are equally striking. Many studies have shown gender differences on a wide range of cognitive skills (see Geary, 1998, for review). Males outperform females in spatial tasks, such as the water-level test (Robert & Ohlmann, 1994), mental rotation (Geary et al., 1992) and line-angle judgement (Collaer & Nelson, 2002), reflecting superior processing of physical systems in males. Females have been found to perform better in episodic memory tasks, involving face recognition (Yonker et al., 2003). Also, males are more vulnerable to prosopagnosia, a disorder where familiar faces cannot be recognised following brain damage (Mazzucchi & Biber, 1983). Hall (1978) found that males were less sensitive to visual and auditory non-verbal cues to emotion as compared with females. Further, Chapters 2 & 3 of this thesis demonstrated that in a standard gaze-cueing paradigm based on that of Driver et al. (1999), males show weaker attentional effects of non-predictive eye-gaze and arrow cues, as compared to females (Bayliss, di Pellegrino, & Tipper, in press).

These sex differences in sensitivity to, and processing fluency of, social and physical stimuli support the extreme male brain hypothesis of autism. The idea that the male population, in general, have more autistic-like traits than females is borne out by scores on the autism-spectrum quotient (AQ), developed by Baron-Cohen et al. (2001), on which males score higher than females (see also Chapters 2 & 3). If people have different levels of autistic-like traits, then a number of predictions might be made about the present study. If 'social' cueing occurs when a face cues another face through averted eye-gaze, then the cueing effect might be expected to be larger in participants who have few autistic traits. When a scrambled display is cued, this pattern might be expected to be absent, or even reversed, since the scrambled displays have the local details of objects, yet form no global pattern, perhaps favouring the orienting biases of people with many autistic traits. Hence, the AQ

was given to participants in order to evaluate any possible differences between people scoring high and low scores on the questionnaire.

A further possibility is also explored in this study. Experiment 8 investigates orienting towards social stimuli (faces), compared to scrambled displays. Any differences in orienting magnitudes towards the two types of stimuli could be inferred as being due to the fact that faces are sociobiological stimuli, and scrambled objects are not. Conversely, object coherence could determine cueing magnitude regardless of object category. In order to evaluate these opposing hypotheses, Experiment 9 used an identical procedure, but with whole tools, compared with scrambled tool parts as target object context. If object category is important in the modulation of cueing magnitude, then different results would be predicted for Experiment 9, as compared with Experiment 8. Any differences between participants with high and low AQ scores in Experiments 8 and 9 would be especially interesting, since while one would predict that low AQ participants would be cued very strongly towards faces by an eye-gaze cue, one might predict that high AQ participants would be strongly cued by an arrow towards tools. However, if object coherence alone determines cueing magnitude, then identical results will be obtained in the two experiments. Nevertheless, how AQ score might modulate cueing magnitude across these two procedures is somewhat an open question.

Experiment 8 – Faces and scrambled face parts as target context

Method

Participants.

Twenty-five naïve participants (mean age = 20.3 years; 5 males) took part for payment or course credit. They were recruited from the University population and the School of Psychology participant panel. All participants had normal or correctedto-normal vision.

Apparatus.

The stimulus set consisted of three male and three female faces, which could have the pupils in the centre, in the left or in the right of the eyes. These faces were used as the gaze-cues and the target placeholders on some trials. The faces were divided into several parts, which were rotated and reorganized randomly such as to create six 'Scrambled Face' objects, upon which targets could appear during half the trials. The dimensions of the faces varied from 10 cm x 9 cm to 13 cm x 13.5 cm. Pupil size was approximately 0.8×0.8 cm. Six differently designed arrows were also created. Arrows varied between 4.8×2 cm and 7×3 cm. The area that the target covered was matched to the size of the visible regions of skin of the six faces, measuring from 6×9 cm to 8×11 cm. Targets were presented as red patches over the faces, or over the scrambled face parts (see Figure 16). In this way, the targets would be perceived as changes to the stimuli, rather than as new objects appearing in the scene. Such semitransparent patches have been used before in cueing paradigms (Tipper, Grison, & Kessler, 2003). Red patches were used as target stimuli since they could be perceived as representing a biologically plausible state (i.e. blushing), which can occur during social interactions.

a) Eye-gaze cue, target appearing on a face a) Eye-gaze cue, target appearing on a face b) Arrow cue, target appearing on a face c) Eye-gaze cue, target appearing on scrambled face parts c) Eye-gaze cue, target appearing on scrambled face parts c) Arrow cue, target appearing on scrambled face parts c) Arrow cue, target appearing on scrambled face parts c) Arrow cue, target appearing on scrambled face parts c) Arrow cue, target appearing on scrambled face parts c) Arrow cue, target appearing on scrambled face parts c) Arrow cue, target appearing on scrambled face parts c) Arrow cue, target appearing on scrambled face parts c) Arrow cue, target appearing on scrambled face parts c) Arrow cue, target appearing on scrambled face parts c) Arrow cue, target appearing on scrambled face parts c) Arrow cue, target appearing on scrambled face parts c) Arrow cue, target appearing on scrambled face parts c) Arrow cue, target appearing on scrambled face parts c) Arrow cue, target appearing on scrambled face parts c) Arrow cue, target appearing on scrambled face parts c) Arrow cue, target appearing on scrambled face parts c) Arrow cue, target appearing on scrambled face parts

Time

Figure 16: Illustration of the timecourse of conditions in Experiment 8. The displays were preceded by the presentation of a fixation cross in the centre of the screen, for 658 ms. Panels a) and b) illustrate 'valid' trials, since the target appears at the cued locations. Panels c) and d) are examples of 'invalid' trials.

Design.

The within-subject factor 'Cue Type', was whether the cue was an arrow or a

face with averted gaze. 'Target Object Type' was whether the central arrow or face

was flanked by faces or scrambled face parts. Finally 'Validity' was included, where

direction of the cue (left or right) was congruent with target location in 'Valid' trials,

and incongruent on 'Invalid' trials. Other facets to the design were not included in analyses, but are noted below. In Gaze-Face trials, the flanking faces were always of the opposite gender to the cueing face. Because of the inclusion of this, it was necessary to balance this manipulation by arbitrarily splitting the scrambled faces into two groups – a set of three that could only appear when the centre face was male, another three that could appear when the central face was female. A similar arbitrary process was applied to the arrows, by also treating the six arrows as two sets of three.

Procedure.

Participants were instructed to respond to the presentation of a target by hitting the spacebar as soon as they detected the onset of the red patch. They were also informed that the direction of the central cue did not predict target location, and that they should ignore it, while maintaining central fixation throughout each trial. On each trial, a fixation cross was presented on a blank screen for 658 ms. This was followed by the presentation of the central cue (either an arrow or a gazing face) in its neutral position (eyes central, or arrows without arrow heads). Simultaneously, two pictures would appear to the left and right of the centre. These pictures would either be faces looking towards the centre, or two areas of scrambled face parts. The faces were looking at each other. In this way, the impression of observing an unfolding social interaction was felt to be even more salient to participants. For this reason, gaze towards the centre was preferred to the alternatives: no eye gaze in peripheral faces would have given an unnatural feel to the scene, and straight-ahead gaze might have resulted in additional attentional capture towards the peripheral faces, compared with the scrambled displays. This display would remain for 1504 ms before the central cue appeared. This cue was achieved by the movement of the eyes, or the appearance of arrow-heads. The target would then appear on one of the peripheral objects, after 376 ms (see Figure 16). This display remained until response, or until 2491 ms had elapsed. A blank screen was then presented for 1269 ms after each trial. Participants completed a practice block of 15 trials, followed by 4 blocks of 84 trials. One seventh of trials were catch trials, where no target was presented, leaving 288 trials for analysis. The stimulus set for each trial was selected randomly. At the end of the experiment, all but one participant completed the autism-spectrum quotient questionnaire (Baron-Cohen, Wheelwright, Skinner et al., 2001).

Results

Reaction Time Data.

In total, there were few errors (0.4% of trials). A further 5.3% of trials were removed as RT outliers (where RT was shorter than 150 ms, longer than 1000 ms, and was more than 2 *SD* above or below the participant's cell mean). The remaining data contributed to means for each participant in each condition, which were submitted to Repeated Measures ANOVA, with 'Validity' (Valid or Invalid), 'Cue Type' (Arrow or Eyes) and 'Target Object Type' (Face or Scrambled face parts) as factors (see Figure 17 and Table 5).



Figure 17: Graph of mean RTs (ms) for each condition in Experiment 8.

The main effect of 'Validity' was highly significant, F(1,24) = 31.1, p < .001, with RTs to valid targets being quicker than to invalid targets (318 ms vs. 331 ms). The 'Cue Type' by 'Target Object Type' interaction reached significance, F(1,24) = 4.91, p = .036, because when the cue was an arrow, RTs were faster when targets appeared on a face (321 ms) than when targets appeared on scrambled face parts (327 ms). When gaze was the cue, this trend was not apparent, with RTs of 325 ms and 324 ms to targets on faces and scrambled face parts, respectively. As this interaction is unrelated to hypotheses, and did not involve 'Validity', it will not be considered further. The non-significant main effect of 'Target Object Type', F(1,24) = 1.99, p = .17, shows that, independently of cueing effects, RTs to targets appearing on either target type were equivalent, demonstrating that targets appearing on both the coherent and scrambled displays were equally discriminable. This suggests that

extracting the target from the background is equally demanding in both conditions. The effect that was of direct interest to the hypothesis was the three-way 'Cue Type' by 'Target Object Type' by 'Validity', which did not approach significance, F(1,24)< 1. However, the 'Target Object Type' by 'Validity' interaction was significant, F(1,24) = 5.45, p = .028. This was due to a greater effect of 'Validity' (i.e. more cueing) in trials where targets appeared on faces (314 ms vs. 332 ms; 18 ms cueing), than when scrambled face parts were presented as target placeholders (320 ms vs. 330 ms; 10 ms cueing). These two results suggest that cueing magnitude was only modulated by 'Target Object Type'. However, 'Cue Type' had no reliable influence on cueing magnitude, since the 'Cue type' by 'Validity' interaction did not approach significance, F(1,24) < 1 (see Figure 17).

Analysis of AQ score.

Analysis of the AQ scores in this sample revealed a mean of 15.5 (SD = 5.9) out of 50 (n = 24; one questionnaire was not completed). Given that most (19 out of 24) of the respondents were female, this mean score is very similar to that found in the original study, when testing normal females (M = 15.4, n = 98; Baron-Cohen et al. 2001, p. 8). It was hypothesised that those who scored highly on this questionnaire may display less attentional cueing towards social stimuli (i.e. targets appearing on a face) than those with low scores on the AQ. Based on the distributions of scores reported by Baron-Cohen et al. (2001), the cut-off scores were chosen to allow approximately 40% of the sample into either group. The groups were 'high' (M = 21.9, SD = 3.1, n = 9), those who scored 18 or more. Participants with a score of 13 or lower were included in the 'low' group (M = 10.4, SD = 2.4, n = 11). These groups' scores differed significantly, t(18) = 9.49, p < .001. Four participants with intermediary scores (one with 16, and three with 15) were excluded from either group.

Statistical analysis, similar to that described above, was performed on the remaining 20 participants' data, with 'AQ group' as an additional between-subjects factor. Again, 'Validity' reached significance, F(1,18) = 24.1, p < .001, with faster RTs to validly cued targets (308 ms vs. 321 ms). In this analysis, the pattern of results of larger cueing to targets presented on a face than to targets presented on a display of scrambled face parts was not found. That is, the 'Target Object Type' by 'Validity' interaction did not approach significance, F(1,18) = 1.14, p = .30, with 15 ms cueing to targets on a face, and 12 ms to targets on a display of scrambled face parts.



Figure 18: Graph illustrating cueing effect magnitudes for each AQ group, for either target object type, in Experiments 8 and 9.

			Coherent Objects		Scrambled Objects	
			Gaze cue	Arrow cue	Gaze cue	Arrow cue
	Low AQ	Valid	315 (10.1)	307 (8.6)	315 (10.5)	318 (10.9)
Experiment 8	(n = 11)	Invalid	333 (12.3)	329 (10.4)	326 (11.1)	329 (14.6)
(Faces)	High AQ	Valid	303 (17.3)	296 (15.3)	303 (18.2)	298 (15.8)
	(n = 9)	Invalid	312 (16.2)	305 (15.5)	310 (17.3)	314 (15.9)
	Low AQ	Valid	305 (11.1)	310 (13.1)	312 (12.9)	315 (13.1)
Experiment 9	(n = 13)	Invalid	326 (13.6)	326 (13.6)	323 (14.2)	329 (15.0)
(Tools)	High AQ	Valid	350 (22.3)	352 (22.0)	347 (24.3)	349 (22.6)
	(n = 9)	Invalid	364 (21.0)	365 (23.7)	367 (23.2)	367 (24.5)

Table 5: Mean reaction times (ms) for each AQ group in Experiments 8 and 9, across all conditions. Standard errors in parenthesis (ms).

However, there was a significant 'Target Object Type' by 'Validity' by 'AQ group' interaction, F(1,18) = 6.20, p = .023 (see Figure 18 and Table 5). This interaction was due to greater cueing to targets presented on a face in the 'Low' AQ group, but greater cueing to targets presented on the scrambled face parts in the 'High' AQ group. Note that again, there were no interactions with 'Cue Type', indicating that the observed individual differences were due to target object properties, not to cue properties.

Discussion

This experiment aimed to evaluate whether the magnitude of orienting to the direction of observed gaze direction could be modulated by the context in which the target could appear. It was found that cueing to targets appearing on faces was larger than cueing to the same targets appearing on scrambled face parts. This effect was found for both gaze-cues and arrow cues, suggesting that cue properties had little effect on cueing magnitude. This was contrary to the hypothesis that proposed that any modulation of cueing towards faces or non-faces would only be evident when the cue was averted gaze, produced by a face. The results therefore suggest that observing a social interaction between cue and target, when both are faces, does not result in more cueing than observing an arrow pointing to a face. These data therefore again demonstrate the strikingly similar behavioural effects of nonpredictive gaze and arrow-cues on attention, which have been observed before (Bayliss et al., in press; Ristic et al., 2002; Tipples, 2002). Importantly, there was no main effect of 'Target Object Type', demonstrating that presenting targets on coherent objects versus scrambled object parts results in very similar raw performance. Unpublished pilot data demonstrated that comparing RTs to targets appearing on objects versus in empty space resulted in a large RT advantage for targets appearing on objects, and hence it was felt that a stimulus set which controlled for this should be used in the present study. Scrambled objects were deemed appropriate because detection of the target should be as demanding in both coherent and scrambled conditions, and also allowed the investigation of the

influence of observing local features forming no coherent object in terms of a 'systemising' account of individual differences.

The response patterns of participants scoring high on the autism-spectrum quotient (Baron-Cohen, Wheelwright, Skinner et al., 2001) were very different to those with low scores. Participants reporting few autism-like traits (low AQ) displayed an exaggerated cueing pattern to that described above: twice as much cueing towards targets appearing on faces, than to targets appearing on scrambled face parts. High scorers (reporting more autistic-like traits) showed the opposite trend, with slightly greater cueing to targets appearing on scrambled face parts. Again, these group differences were not different when comparing gaze with arrow cues.

This suggests that greater cueing towards faces from a central cue only occurs in people whose cognitive style is biased to the processing of social information. This finding mirrors that of Swettenham et al. (1998), who showed that children with autism made fewer attention shifts towards people than normally developing children did. Similarly, Connellan et al. (2000) showed that female neonates attended a face for longer, compared to a mobile decorated with scrambled face parts, while male neonates showed the opposite trend. The similarity between these findings and those of Experiment 8 is clear - processing style is highly influential in determining the depth to which social information is processed.

In summary, it appears that when socially relevant stimuli such as faces are objects towards which attention is oriented, differences between high and low scorers on the AQ can be detected. However, to be confident that the individual differences reflect differences in orienting to social stimuli such as faces, a further test is required. Hence, in replacing the face target holders with tools, Experiment 9 allowed the examination of whether object coherence or social relevance is the important factor in determining the magnitude of attentional shifts away from a central, non-predictive cue.

The procedure for Experiment 9 was identical to that of Experiment 8, except that the objects that would act as target placeholders were powertools, not faces, and the scrambled displays were now made up of tool parts. Tools were considered an appropriate contrast to the faces used in Experiment 8 for several reasons. Firstly, tools are non-social objects. Thus, if the results from Experiment 8 were due to the use of social stimuli, rather that an effect of presenting a coherent object of any category, then one would predict no repeat of the 'Validity' by 'Target Object Type' interaction that was found in Experiment 8. Secondly, while faces as an object category seem to selectively activate occipito-temporal regions in the ventral visual stream, such as the fusiform face area (FFA) and superior temporal sulcus (STS) (Allison et al., 2000; Hoffman & Haxby, 2000), the observation of tools tends to reveal patterns of activation in the dorsal visual stream, such as the parietal lobe (Chao & Martin, 2000). Thirdly, tools are similar to faces in that they are complex objects made up of several different parts, yet have very different processing demands, and hence may reveal different individual differences to those of Experiment 8. Indeed, one may predict that participants with high AQ scores may now be cued more to tools than low AQ scorers, since Baron-Cohen (2003) suggests

that people further along the autism spectrum have superior 'systemising' abilities, and hence are drawn to physical systems such as mechanical objects (Baron-Cohen et al., 1986; Baron-Cohen, Wheelwright, Stott et al., 1997). Experiment 9 - Tools and scrambled tool parts as target context

Method

Participants.

Twenty-five naïve participants (mean age = 23.7 years; 5 males) took part for payment. They were recruited from the student population of the University of Wales, Bangor. All participants had normal or corrected-to-normal vision.

Apparatus.

Instead of faces, six pictures of tools were used (a multi-tool, a vacuum cleaner, a drill, two planers and a circular saw). Sections of each tool were cut and rotated to create scrambled images of tool parts. Targets were presented as red, transparent patches on the main body of the tools, and the shape of these patches were used as the shape on the scrambled tool parts displays (see Figure 19).

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a) Eye-gaze cue, target appearing on a tool



Time

Figure 19: Illustration of the time-course of conditions in Experiment 9. The displays were preceded by the presentation of a fixation cross in the centre of the screen, for 658 ms. Panels a) and b) illustrate 'invalid' trials, since the target appears at the uncued locations. Panels c) and d) are examples of 'valid' trials.

Design and Procedure.

The design and procedure were identical to that of Experiment 8, with the

exception that the levels of the 'Target Object Type' variable were now 'Tools' or

'Scrambled Tool Parts'.

Results

Reaction Time Data.

In total, there were few errors (0.2% of trials). A further 4.0% of trials were removed as RT outliers (where RT was shorter than 150 ms, longer than 1000 ms, and was more than 2 *SD* above or below the participant's cell mean). The remaining data contributed to means for each participant in each condition, which were submitted to repeated measures ANOVA, with 'Validity' (Valid or Invalid), 'Cue Type' (Arrow or Eyes) and 'Target Object Type' (Tool or Scrambled tool parts) as factors (see Figure 20). The only main effect to reach significance was 'Validity', F(1,24) = 76.4, p < .001, with faster RTs to valid targets (324 ms vs. 339 ms). No other main effects or interactions approached significance (all *F*-ratios < 1.9), including the 'Target Object Type' by 'Validity' interaction, which was central to the hypothesis, F(1,24) < 1, with the validity effect being the same whether the target appeared on a tool (323 ms vs. 339 ms; 16ms cueing) or on a scrambled display of tool parts (324 ms vs. 339 ms; 15 ms cueing).

Analysis of AQ score.

The 25 participants scored an average of 14.8 (SD = 5.8) on the AQ questionnaire. Thirteen participants scored 13 or less, and were assigned to the 'Low AQ' group (M = 10.3, SD = 2.3), and the nine scoring 18 or more were assigned to the 'High AQ' group (M = 21.2, SD = 3.9). The two groups' scores were significantly different, t(20) = 8.29, p < .001. Two participants scoring 15, and one scoring 14 were not included in either group. These 22 participants' data were reanalysed as in Experiment 8, with 'AQ group' as an additional between-groups

factor. ANOVA revealed a significant effect of 'Validity', F(1,20) = 60.8, p < .001. The only other interaction to reach significance, just as in Experiment 8, was the 'Target Object Type' by 'Validity' by 'AQ group' interaction, F(1,20) = 4.72, p =.042. Again, this was due to the 'Low AQ' group showing greater cueing to coherent objects (Tools; 19 ms cueing) than to Scrambled Tool Parts (13 ms cueing), while the 'High AQ' group showed the opposite pattern, being cued more to Scrambled Tool Parts (19 ms cueing) than to Tools (14 ms cueing, see Figure 18).



Figure 20: Graph of Mean RTs for each condition, for Experiment 9.

Discussion

The purpose of this experiment was to contextualise the results observed in Experiment 8, where non-informative arrow and gaze-cues produced greater attentional effects when targets appeared on faces, as compared to scrambled face parts. This second experiment showed that the magnitude of cueing was not modulated by whether the targets appeared on a different object category, tools, as compared to scrambled tool parts. This suggests that cueing is only modulated when the target appears on a social/biological stimulus such as a face. However, the results of the autism-spectrum quotient (Baron-Cohen, Wheelwright, Skinner et al., 2001), suggest an alternative interpretation may be appropriate.

Experiment 8 showed that only low AQ scorers (i.e. those who rated themselves as possessing few autism-like traits) contributed to the effect of greater cueing towards faces than to scrambled face parts. High AQ scorers (possessing more autism-like traits), showed instead a trend for greater cueing towards the scrambled displays. While Experiment 9 demonstrated no overall difference in cueing towards tools, compared to scrambled displays, this too was shown to be a product of two different orienting biases in either AQ group (see Figure 18). Low scorers again were cued to the coherent objects (tools) more than to the scrambled displays, though this difference was smaller than in Experiment 8. The high AQ group again showed the opposite trend, with more cueing to the scrambled displays than to the coherent object.

These results show that cueing towards tools is not greater in high AQ participants, as might be predicted if one considers that good folk physics (Baron-Cohen, 2000) and superior systemising skills (Baron-Cohen, 2002) are associated with people with high AQ scores (hence sharing more traits with people with autism-spectrum disorders). The fact that very similar results were found in Experiments 8 and 9, suggests that participants with high AQ scores orient strongly

towards scrambled displays, irrespective of object category. The following analysis investigated whether any differences in group performance were present between participants in Experiments 8 and 9.

Combined Analysis of the Effect of AQ group in Experiments 8 and 9.

In order to evaluate the high and low AQ groups orienting effects over both experiments, the data from 'High AQ' and 'Low AQ' scorers were analysed in a combined ANOVA. As before, 'Validity', 'Cue Type' and 'Target Object Type' were within-subjects factors. The levels of 'Target Object Type' factor were 'Coherent Object' (i.e. a face or a tool), or 'Scrambled Object' (i.e. scrambled face or tool parts). Between-subjects factors were 'AQ group' and 'Experiment'.

'Validity' was highly significant, F(1,38) = 77.5, p < .001. The 'Cue Type' by 'Experiment' interaction approached significance, F(1,38) = 3.95, p = .054, due to faster RTs when the cue was an arrow in the Experiment 8 (312 ms vs. 314 ms), but faster RTs when the cue was averted gaze in Experiment 9 (336 ms vs. 339 ms). This interaction did not involve 'Validity', and was not involved in predictions, so is not considered further. The overall 'Target Object Type' by 'Validity' interaction did not reach significance, F(1,38) = 1.44, p = .24. However, the critical three-way interaction of 'Target Object Type' by 'Validity' by 'AQ group' was highly significant, F(1,38) = 9.69, p = .004. The 'Low AQ' group showed more cueing towards targets appearing on coherent objects (20 ms) than on scrambled objects (11 ms), while the 'High AQ group' showed the opposite pattern of more cueing towards targets appearing on scrambled objects (15 ms) than on coherent objects (12 ms). No other effects approached significance. Follow-up ANOVAs showed that there was a 'Target Object Type' by 'Validity' interaction in the 'Low AQ' group, F(1,22) = 8.30, p = .009, whereas there was a trend in the opposite direction in the 'High AQ' group, F(1,16) = 2.75, p = .117 (see Figure 18 and Table 5). This analysis demonstrates that the modulation of cueing by target object type and AQ group was consistent across Experiments 8 and 9.

General Discussion

This study investigated the effect of manipulating target object context on the magnitude of attentional cueing via the observation of non-informative directional arrows or eye-gaze. Consistent cueing effects were found in all conditions, replicating several studies, with nonpredictive gaze cues (e.g. Driver et al., 1999; Friesen & Kingstone, 1998), and nonpredictive arrow cues (Eimer, 1997; Hommel et al., 2001; Ristic et al., 2002; Shepherd et al., 1986; Tipples, 2002).

The manipulation of target object context (i.e. whether the target appeared as part of a coherent visual object, or a meaningless scrambled display) was made, in part, as an attempt to reveal differences between eyes and arrows as cues to attention. It was predicted that since in naturalistic situations eye-gaze allows the sharing of experience in shared or joint attention, the presence of objects in the display would allow the stronger activation of joint attention mechanisms. Such mechanisms were not predicted to be so strongly active when observing an arrow. However, arrows and eyes had identical effects on cueing magnitude in this paradigm. It is interesting that gaze and arrow cues had such similar effects on attention. The similarities between gaze and arrow cueing in the normal population are indeed striking. The two cues have produce the same magnitude of effect (Tipples, 2002), across a similar timecourse, both effects appear by age 3-5 years (Ristic et al., 2002), both reveal a gender difference such that normal females are more strongly cued by gaze and arrow cues than males are (Bayliss et al., in press). While symbolic cueing appears to rely on separate neural substrates to gaze-cueing (Kingstone et al., 2000; Kingstone et al., 2004; Ristic et al., 2002), it is only when

cues are anti-predictive that behavioural differences have so far been found. That is, when the participant is aware that the target will usually appear at the location opposite to the cued location, top-down strategic control of attention is unable to suppress the effect of eye-gaze cues, but can override the automatic cueing effect of symbolic cues (Downing et al., 2004; Friesen et al., 2004). Interestingly, Pellicano and Rhodes (2003) have recently demonstrated that conflicting arrows disrupt normal children's ability to infer mental states such as desire and intention from eye-gaze cues. That is, when an arrow points to a different object to that which is looked at by a cartoon character, the character is often thought to want the object indicated by the arrow, not the eye-gaze. This suggests that similarities between eye and arrow cues exist both for high- and low-level functions that these cues have. The origin of any differences between the encoding and function of eyes and arrows is clearly of importance to further research in this area.

Greater cueing towards faces, compared to scrambled displays was found (Experiment 8). While this result overall did not generalise to tools (Experiment 9), this null effect was due to opposing patterns of cueing magnitude in high AQ and low AQ participants. In both experiments, the high AQ participants showed more cueing towards scrambled displays than to coherent visual objects. Although this trend failed to reach significance, it was in stark contrast to the pattern showed by low AQ participants. Low AQ participants showed more cueing towards coherent objects than to scrambled displays, with this trend being more exaggerated in Experiment 8 (faces). Firstly, the low scorers on the AQ will be considered. These participants rate themselves as having relatively good social, communication, imagination and attention switching skills, but relatively poor attention to details. These participants displayed greater cueing towards coherent visual objects than to scrambled displays. This effect was numerically larger when the coherent visual object was a face (Experiment 8) than a tool (Experiment 9), as might be expected in a group biased towards social interactions. The overall pattern that 'Low AQ' participants were cued more to real objects than to meaningless objects has implications for other research. For example, Jordan and Tipper (1998) showed a similar result in a peripheral cueing study, however they did not examine the critical variable of individual differences. Therefore the general claim that objects have much more behavioural relevance than incoherent random patterns, might not be true for all individuals.

The 'High AQ' participants, on the other hand, show very different patterns of cueing. In both experiments, there was no evidence for greater cueing towards the coherent objects, but trends for greater cueing towards scrambled object parts. The results from Experiment 8 were predicted, since 'High AQ' participants rated themselves as having poorer social skills, their orienting bias may be comparable to that of male infants (Connellan et al., 2000; Lutchmaya & Baron-Cohen, 2002; Lutchmaya et al., 2002a), where females oriented preferentially to social stimuli, but males oriented more to non-social scrambled, or mechanical displays. In contrast, the finding of a bias towards processing mechanical stimuli in males led to the prediction that orienting to tools, in Experiment 9, would be larger than scrambled displays in 'High AQ' participants. Instead, the same trend for greater orienting to the scrambled displays was found. This result suggests that the scrambled displays were not necessarily 'meaningless' displays, but rather were displays containing high levels of detail that is appealing to the systematising cognitive style of high AQ individuals. As noted before, 'High AQ' participants tend to have good 'attention to details' (Baron-Cohen et al., 2003; Baron-Cohen, Wheelwright, Skinner et al., 2001). This bias for attending to details is similar to the local bias in object processing in participants with diagnoses of autism-spectrum disorders (Happé, 1996; Jolliffe & Baron-Cohen, 1997; Mottron et al., 1999; Mottron et al., 2003). Hence, tools, as a 'complex' object perhaps contained less complexity for a system biased to the processing of objects in terms of local details than a scrambled display, with no obvious global grouping pattern.

Clearly, the two groups displayed very different cueing patterns in this study. However, whether the two groups are displaying differences between object-based and non-object (i.e. location) based attentional orienting is perhaps questionable. That is, do participants with low AQ scores show cueing towards the coherent objects because their attention system is biased towards the processing of objects rather than location? The normal bias for attending to the global form in visual displays would certainly support this assertion. However, the scrambled displays could also be considered to be objects: the way they were constructed was such that the features formed a symmetrical rectangular shape *within which* features were incoherently organised. Perhaps the object of attentional selection was the whole object in all cases. In fact, the rectangular shape defined by the boundaries of the scrambled features might have served as a highly salient object. Despite this, differences between groups were found. Therefore the contrast between low and high AQ participants is not necessarily between location vs. object-based representations, but rather is a contrast between coherent and incoherent object representations.

With regard to the sample of mainly female undergraduates (40 of the 50 participants), it is likely that the sample was skewed towards the non-autistic end of the normal distribution of the autism-spectrum (Baron-Cohen, 2002, 2003; Baron-Cohen, Wheelwright, Skinner et al., 2001). Since much of the evidence for individual differences in social and spatial cognition comes from the sex difference literature (e.g. Geary, 1998), the use of a predominantly female sample may be problematic. However, Baron-Cohen (2002; 2003) suggests that while sex differences exist, and perhaps contribute to the variation of autism-traits in the normal population, a normal distribution of traits exist in either gender. Indeed, scores on the AQ are distributed normally in both male and female population (see Baron-Cohen, Wheelwright, Skinner et al., 2001). It is therefore felt that these experiments effectively compare normal non-autistic participants whose scores fall on either side of the population mean. By randomly recruiting participants of either sex, a gender ratio similar to that of many psychology experiments was recruited, since many psychology studies are conducted on psychology students, who are predominantly female. In this way, this study demonstrates that in a given random

sample, individual differences exist in a standard cognitive psychology paradigm (cueing of spatial attention), with the same sampling method as used by researchers not investigating individual differences. It is highly likely that equal numbers of males and females would have revealed even stronger group differences (see Chapter 2), since more males would have increased the numbers of high AQ participants. However, the differences might have then been indistinguishable from a general sex difference. Instead, taking the approach of testing the AQ score of each participant allowed the evaluation of the idea that autistic-traits truly vary in the normal population, somewhat independently of gender. Inevitably, therefore, the experiments in this chapter are more descriptive of low AQ participants' behaviour. However, according to Baron-Cohen's (2001) study, social science students score lower than average on the AQ. This therefore implies that many research samples (in studies where individual differences are not investigated) might be skewed in this way.

In conclusion, these experiments demonstrate that the use of central nonpredictive cues can produce object-based attentional effects. However, orienting to coherent visual objects was only larger in participants rating themselves as having few autistic-traits. This finding highlights the importance of considering such individual differences in attentional cueing studies. This design, which differed from many symbolic cueing studies by manipulating the object on which targets may appear, adds flexibility to central cueing paradigms in terms of ecological validity. It is notable that gaze cues were not observed to be more effective than arrow cues in low-AQ than high-AQ participants, illustrating the similar effects of arrows and eyegaze on attention in these two groups. Rather, these experiments have revealed for the first time that it is the nature of the objects towards which attention is oriented, that is more likely to reveal the effects of different information processing styles. Chapter 5 – Object-centred gaze-cueing

The way that gaze and face perception is integrated is of great interest. In the human brain, the superior temporal sulcus seems to be involved in the perception of gaze (Wicker et al., 1998), while separable areas of the inferior occipital lobe and fusiform gyrus are involved in the processing of facial identity (Hoffman & Haxby, 2000). The manner in which the face of an agent may be integrated with eye gaze perception can be investigated by studying how the perception of eye-gaze is modulated by perceived head orientation. The role of head orientation in the perception of social attention has been investigated in behavioural paradigms (Gibson & Pick, 1963; Hietanen, 1999, 2002; Langton, 2000), and in neurophysiological studies (Perrett et al., 1992; Perrett, Smith, Potter et al., 1985).

Perrett et al. (1992) suggested that cells in macaque superior temporal sulcus, coding for gaze and head orientation, are involved in the perception of social attention. Further, it was found that gaze direction was the dominant factor in determining neural response in these STS cells. That is, head orientation is only influential when the eyes are obscured, while if the eyes are visible, then inhibition is applied to cells coding head orientation. Thus, perception of social attention is organised hierarchically. However, Langton et al. (2000) suggest that head and gaze interact as more "equal partners" (p. 56). For example, Langton (2000) found that manipulating head orientation was able to influence the perception of eye-gaze direction. When reporting the direction of gaze (left or right), participants' RTs were slower when the head orientation was incongruent with the direction of gaze. Furthermore, direction of gaze interfered with the perception of head orientation in

the same way. All these studies have looked at the influence of head orientation on the perception of social attention, or the effect of head and eye-gaze on attention. While they did not rotate the head to orientations that do not also directly act as a cue to social attention, some studies have used inverted faces to explore these effects.

The notion that the processing of inverted faces is less fluent than that of upright faces is well established (Bartlett & Searcy, 1993; Yin, 1969). Notably, the 'Thatcher Illusion' (Thompson, 1980), demonstrated that changes to the configuration of face parts (i.e. flipping of the mouth and eyes) are easily noticed in an upright face, yet when presented in an inverted face, the manipulation is difficult to perceive. Langton and Bruce (1999) showed that head-direction cues were ineffective at cueing attention when presented upside down. Furthermore, Kingstone et al. (2000) showed that gaze-stimuli presented to the face-processing dominant hemisphere of split-brain patients were effective cues to attention when presented in an upright face, or as eyes alone, but not when presented in the context of an upsidedown face. These studies demonstrate that there is some interference in the representation of social attention when the face producing that cue is inverted. However, the cause of this is unclear – an inverted face is difficult to encode, hence the features within it (i.e. eye-gaze) may not be fully processed, resulting in attenuated cueing due to an impoverished representation of social attention signals. A second possibility is considered, however, which forms the basis for these experiments. When observing a gaze-cue in an inverted face, there may be two frames of reference active. Firstly, a spatial frame could cue attention to the actual

direction of gaze based in retinotopic coordinates. However, a competing frame could simultaneously be active which codes the face in terms of object-centred coordinates. The influence of this frame could be to bias attention to the opposite side of space – to the direction to which the eyes would have been looking, had the face been presented upright. The experiments reported in this chapter aimed to test this hypothesis not by opposing these two frames, but by separating them, by presenting faces oriented 90 degrees from upright, rather than 180 degrees. Further, since this notion suggests that gaze-cueing might be directed via multiple frames of reference, the influence of both object-centred (Experiments 11, 12 & 13) and spatial frames of reference (Experiments 10 & 13) are investigated here. The idea that attention acts within multiple frames of reference suggests that these frames might be organised hierarchically, and the relative influence of these frames would depend on the task demands of ongoing behaviour (Tipper, Howard, & Houghton, 1999; Tipper, Jordan et al., 1999; Tipper et al., 1992; Tipper & Weaver, 1998). One aspect of research into attentional orienting via multiple reference frames is the findings that location-based and object-based inhibition of return effects appear to be additive (Jordan & Tipper, 1998, 1999). A similar effect may occur in standard gaze-cueing studies (using upright faces), such that the observed facilitatory effects are due to the addition of both frames of reference acting in the same direction.

Some studies have revealed object-centred effects using faces (Hasselmo et al., 1989; Hommel & Lippa, 1995; Proctor & Pick, 1999). That is, the left side of the face is coded, at least in part, as the left side however it is oriented in space (Young, Hellawell, & Welch, 1992). It is possible, therefore, that the attention system may

also access intrinsic head-centred information about a gaze-cue that is presented in the context of a rotated face. For example, a face, with eyes looking left, but presented rotated 90 degrees anticlockwise will still cue attention to the left, even though the eyes are actually looking *down*. If this effect is revealed, it would serve as evidence for the influence of purely *internal* object-centred representations affecting the distribution of spatial attention. That is, the objects that have been used to study object-centred attention (shapes, barbells and boxes joined by lines) have all been relevant to task demand, since the target (and/or cue) appears on the object (Behrmann & Tipper, 1994, 1999; Driver & Halligan, 1991; Tipper & Behrmann, 1996; Tipper et al., 1991; Tipper & Weaver, 1998). In using a gaze-cueing study, where the face is irrelevant, and the targets appear in empty space (not on the object), attention would have to be directed away from (not within) the object with respect to the internal representation of a normally oriented (upright) face. In previous studies, attention has always been oriented within the objects of interest.

In a study on the role of movement in the development of joint attention in infants, Moore et al. (1997) found that observing a model's head moving from faceon to profile (looking to the left, or right) was an effective cue to attention for infants. However, observing a 'head-tilt' movement (such that the ear of the model moves toward the shoulder) was an ineffective cue to attention. By extension, one may assume that the observation of a static face, oriented in this way, would not act as a cue to attention in adults. This assumption may allow one to study the effect of eye-gaze on attention, while varying the object-centred properties of the cue, by presenting the head in different, socially neutral orientations other than upside-down.
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Figure 21: Upper panel: Illustration of timecourse of stimulus presentation in Experiment 11. Middle panel: Illustration of target locations cued by gaze in a rotated face. Lower panel: Graphs of the results predicted by the three hypotheses investigated in this thesis.

Figure 21 illustrates the general paradigm used in this chapter, and the three possible results anticipated by the hypotheses. Firstly, gaze-cueing, unlike peripherally cued IOR effects, could arise from the activation of single reference frames. Therefore, hypothesis A is that gaze is cued in purely spatial frames of reference. If this is the case, then the cueing effects found in Experiment 10 (with an upright face) will be roughly equal in magnitude with a rotated face, but to the upper and lower hemifields to which a rotated face would look. Alternatively, only the object-centred frame of reference might be active. In this case, only orienting to the direction in which the face would have been looking had it been presented upright will be observed, with equal magnitude as a truly upright face (hypothesis B). Finally, hypothesis C suggests that, like in IOR, at least two frames of reference can influence attentional orienting at the same time. In this case, the maximal shift of attention will be towards the corner of the screen that is cued both in location-based and object-centred space, with shifts of attention of intermediary magnitudes to the corners of the screen cued only in a single frame of reference. Hence, Experiment 10 investigates the standard cueing effects to corners of the screen that are not in direct line of gaze, and thus serves as a baseline to Experiment 11, which investigates the role of two frames of reference on gaze-cueing. Experiments 12 and 13 are further extensions of this theme.

Experiment 10 – Targets in corners (upright head)

The first experiment in this chapter acted as a baseline for the subsequent study (Experiment 11), as Experiment 10 investigated cueing by an upright face to locations not directly looked at, but to targets appearing in the corners of the screen. Hence, while the eyes looked left or right, cueing should be observed for an entire hemifield, not just for locations in direct gaze. The magnitude of this cueing effect could be considered an additive effect of spatial and object-centred cueing effects. In this way, when the direct test of the object-centred hypothesis is approached in Experiment 11, the relative influence of either frame of reference can be compared.

Method

Participants.

Ten participants (mean age = 20.0 years; 2 males) volunteered for this experiment, from the School of Psychology subject panel. All were naïve and had normal or corrected-to-normal vision.

Apparatus.

The face measured 13 x 13.5 cm and was presented in the centre of the screen. The pupils were 0.8×0.8 cm in eye regions measuring 2×1.2 cm Targets measured 1.5×1.5 cm and were presented 16 cm from fixation, at angles subtending 36 degrees from the horizontal axis.

Design.

Within-subjects factors were 'Validity' (whether the target appeared in the cued or uncued hemifield), and SOA (either 100 or 900 ms).

Procedure.

Participants were told that the direction of the eyes did not predict the target location, and that they should respond as quickly as possible after detecting a target. Spacebar was used as the response key. The 212 trials (including 20 catch trials) were presented randomly over 3 blocks. The procedure took approximately 30 minutes to complete. Each trial began with the presentation of a fixation cross on a blank screen for 670 ms. Then the central face, with pupils absent was presented for 900 ms. Next, the pupils would appear, either in the right or left side of the eyes. Then, after either 100 or 900 ms SOA, a target would appear in one of the four target locations (see Figure 21).



Time Figure 22: Illustration of an invalid trial in Experiment 10.

Results

RT outliers were removed (3.6%), there were no errors. Means for each participant, in each condition, were analysed with repeated-measures ANOVA (see Figure 23). The main effect of 'Validity' was significant, F(1,9) = 10.6, p = .01, with faster responses when the target appeared in the gazed-at hemifield (333 ms vs. 339 ms). The main effect of SOA, was also significant, F(1,9) = 53.6, p < .001, with faster responses in trials with a 900 ms SOA, compared to those with a 100 ms SOA (321 ms vs. 351 ms). No other effects or interactions were significant.



Figure 23: Graph of mean RTs in each condition.

Discussion

This experiment was designed in order to evaluate the hypothesis that averted gaze may cue an entire hemifield, rather than just a restricted area, in line with horizontal gaze. In support of this hypothesis, attentional cueing was found towards the upper and lower regions of the cued hemifield. The magnitude of this effect was smaller than normally found, however (6 ms, where 10-20 ms is normally found).

Experiment 11 – Targets in corners (rotated head)

This experiment was designed to investigate the effect that a gazing face may have on the attention system if the face is positioned rotated 90 degrees from the vertical, rotated either clockwise or anticlockwise. Hence, the face is seen on its side, looking up, or down. However, in object-centred co-ordinates, the gaze would still be to the 'left', or 'right' of the head. There are several possible sets of results that might be anticipated from this study. Firstly, cueing could be abolished in all cases, since the unusual view of the face may hinder the encoding of the gaze as a directional cue. This possibility was minimised by presenting the rotated face without gaze for an extended period before cueing. A second possibility is that spatial locations will be cued based on spatial correspondence with the eyes only. Hence, a face rotated, looking down, will lead to fast RTs to targets appearing in the lower hemifield. These results would support the work of Perrett and colleagues (Perrett et al., 1992; Perrett, Smith, Potter et al., 1985) who suggested that when gaze information is available, the position of the head and body are rendered uninfluential through inhibition. From a developmental perspective, this is also a favourable hypothesis, since the face is looking up or down, it would be maladaptive orient anywhere else other than up, or down. Indeed, Ansorge (2003) explicitly makes the assumption that attention must *only* be shifted up or down when observing averted eye gaze in a face looking up or down, when the face is rotated 90 degrees left or right.

However, the work of Langton (2000) suggests that head orientation can prove a highly influential partner to averted gaze as a cue to attention. The use of head orientations that do not act as cues to attention, enables this paradigm to test the hypothesis that any head orientation can influence gaze perception, due to the influence of object-centred representations. Therefore a third possibility is considered where object-centred representation lead to cueing toward the hemifield to which the eyes would have been looking had the face been presented upright. Hence, Experiment 10 was repeated, but with the face presented oriented 90 degrees clockwise or anticlockwise. The two SOAs (100 and 900 ms) were used to investigate the possibility that head-centred orienting effects might take longer to emerge than pure spatial cueing effects.

Method

Participants.

Twenty-five adults (mean age = 23.0, eight males) volunteered to participate in this experiment. Recruited from the School of Psychology's undergraduate pool, all had normal or corrected-to-normal vision.

Apparatus.

The apparatus was the same as in the previous experiment, with the exception that the face was never presented upright. Rather, it was presented on its side, rotated 90 degrees clockwise or anti-clockwise about the central point between the eyes.

Design and Procedure.

The design was similar to that of the previous experiment, with the following changes. First, the variable of 'Head Rotation' was included as a within-subjects

factor. The total number of trials was doubled (to 424) to account for the addition of this two-level factor, and trials were presented over four blocks.

Results

Errors (0.1%) and RT outliers (4.0%) were excluded from analysis. Remaining data contributed to means for each participant, in each condition, and were submitted to a 4 (Target Type) x 2 (SOA) Analysis of Variance. The main effect of 'Target Type' approached significance, F(3,72) = 2.38, p = .077. Planned contrasts were performed within this factor. RTs to the three cued conditions were compared to baseline target trials. RTs in trials where the target was cued by eye gaze in both the object-centred and location-based frames of reference, were faster than RTs to baseline target positions (356 ms vs. 361 ms), t(24) = 3.70, p = .001. This 5 ms effect is therefore similar to the cueing effect sizes to targets in the corners of the screen produced by the upright face in Experiment 10. RTs to targets presented at object-centred cued loci were quicker than to uncued targets (358 ms vs. 361 ms), the contrast approaching significance, t(24) = 1.93, p = .066. RTs to targets appearing in location-based positions were not different than to uncued targets (358 ms vs. 361 ms), t(24) = 1.08, p = .29. The main effect of 'SOA' was also significant, F(1,24) = 94.5, p < .001, with faster RTs after 100 ms SOAs (376 ms vs. 341 ms). Although there seems to be a trend for greater cueing at the 900 ms SOA (see Figure 24), the interaction between 'Target Type' and 'SOA' did not reach significance, F(3,72) < 1.



Figure 24: Graph of mean RTs to targets in each of the conditions in Experiment 11.

Discussion

This experiment investigated whether intrinsic information about face orientation could affect the allocation of attention when observing averted gaze. A face was presented that could be oriented either 90 degrees clockwise or anticlockwise, such that it was facing the participant, but on its side. The pupils in the eyes would then appear in either the left or the right side of the eye. Because the face was rotated, the eyes were actually either looking up or down, depending on whether the eyes were in the left or right side of the eyes, and whether the face was rotated clockwise or anticlockwise. It was hypothesised that cueing may occur to the upper or lower hemifield if gaze following was based solely on spatial co-ordinate encoding (i.e. participants would orient to the actual direction of gaze). An alternative hypothesis considered whether the gaze was also encoded in the context of the head, such that the gaze was to the left or right side of the head. If gaze encoding was in terms of both spatial and head-centred coordinates, then a particular pattern of results was predicted. That is, cueing would be most robust when spatial and head-centred frames coincided. Intermediate levels of cueing should be observed for each individual frame of reference (spatial or object-centred). This later patter of data was observed, suggesting that eye-gaze is encoded in location and object-centred frames of reference.

Experiment 12 – Head-centred gaze-cueing

Experiment 11 provides the first evidence that gaze cueing can be encoded in a head-centred frame of reference. However, it is clearly necessary to confirm and generalise this observation to a new study. This experiment was an improved version of Experiment 11 in several ways. Firstly, for simplicity, one SOA was used. Secondly, targets were now only presented at left and right locations, such that a pure measure of head-centred cueing could be obtained when the head was oriented 90 degrees from the upright. Thirdly, the face was also presented upright on one third of trials, in order to compare any object-centred cueing effects to a standard spatial plus object-centred cueing effect from an upright face. Finally, the face was presented for 1.5 seconds before cue onset in allow participants more time to process the face prior to cue and target onset. The previous two experiments were completed before the introduction of the use of the AQ questionnaire. However, for the final two experiments of this chapter, participants did complete the AQ in order to investigate any possible group differences. That is, smaller object-centred cueing effects might be expected in 'High AQ' participants if object-centred cueing from eve gaze relies on deep processing of the face, which may be more developed in 'Low AQ' participants.

Method

Participants.

A total of sixty-one adults participated in the experiment. Twenty-five (mean age: 19.4 years; two males) were assigned to the 'manual detection' group. Thirty-six participated in the 'eye-movement' group, but eleven were excluded due to poor

calibration (n = 6), high pre-target saccades (n = 2), erroneous saccades to targets (n = 1), and computer error (n = 2). The mean age of the remaining 25 participants (five males) was 19.3 years. Participants received course credit or payment, were naïve to the purpose of the experiment, and had normal or corrected-to-normal vision. Informed consent was gained in accordance with the guidelines of the School of Psychology, Bangor.

Apparatus.

Target locations were 12.5 cm from the centre of the screen, in line with the eyes of the stimulus face when presented in the upright orientation. Participants sat with their heads on a chin-rest approximately 60 cm from the screen. In order to record eye position and saccade data for participants in the 'eye movement' group, the EyeLink v.1 eye-tracking system (SensoMotoric Instruments, SR research) was used. The system uses infrared scleral reflectance to measure pupil diameter to determine angle of gaze with two cameras mounted on a headset securely placed on the participants head. Sampling rate was 250 Hz, for vertical and horizontal dimensions.

Design.

The face could appear in one of three orientations: rotated 90 degrees anticlockwise, rotated 90 degrees clockwise, and also upright. The pupils could then appear in either the left or right of the eye in the upright condition, or upper or lower part of the eye in the face when oriented 90 degrees. The target could appear on the cued or the uncued side of space in head-centred coordinates (left or right of the screen). Whether participants responded with a key-press or saccade was manipulated between-subjects.

Procedure.

Participants were told that neither the direction of gaze, nor angle of head orientation predicted target location. Participants in the 'manual detection' group were asked to maintain fixation throughout each trial, and to respond to the target as quickly as possible with a press on the spacebar. Participants completing the 'eye movement' task were asked to maintain fixation until onset of the target, then look as quickly as possible to the target. The two factors produced six trial types, each repeated 40 times over the course of the experiment. After a practice block of twelve trials, four experimental blocks of trials were completed. In each block, sixty experimental and eighteen catch trials (no target, no response) were presented in a random order.

On each trial, a fixation cross was presented for 658 ms, followed by the presentation of the face, in the appropriate orientation, for 1504 ms, before the presentation of the gaze-cue. The pupils were gazing for 517 ms before the presentation of the target (see Figure 25). In the 'manual detection' task, after response, or 1974 ms, a blank screen was presented for 1269 ms. In the 'eye-movement' task, the blank screen would appear 600 ms after target onset. Responses on catch trials and misses were followed by an error beep. The 'manual detection' task 45

minutes, due to the apparatus set-up, and drift correction procedures for calibration after every sixth trial.



Figure 25: Illustrations of the three rotation conditions. Upper panel a) shows an invalid clockwise trial, b) shows a valid anticlockwise trial (note the true direction of gaze in both a) and b) is down). The lower panel illustrates an invalid trial normal 'upright' condition. Targets could also appear on the right.

Results

For the 'eye-movement' task group, saccadic RTs were defined as the time between onset of the target and the onset of the first saccade of at least 2.0 degrees of visual angle. Trials were excluded if a saccade of more than 5.0 degrees occurred during the cue period or if the response was in the incorrect direction (2.2%). The 5.0 degrees amplitude was approximately the same size as the eye region of the stimulus face. In visual scan-path experiments, faces evoke robust, specific patterns, involving looking at the right and left eyes. After just 2.5 seconds of exposure of a face, participants begin to engage in a phasic left-right shift of gaze of around 5.0 degrees in eccentricity (Mertens et al., 1993). Other data from this laboratory suggests that with a large face stimulus, with long exposure durations at fixation, more restrictive thresholds are impractical, despite the experimenters' instructions to maintain fixation (Frischen & Tipper, in press). Responses quicker than 50 ms or slower than 600 ms were removed, followed by the removal of trials where RT was more than 2 SD outside the participants mean RT (4.2%). For the 'manual detection' group, errors (0.1%) and outliers (4.8%) were removed, using the same filtering method, but with 150 and 1000 ms as cut-offs, due to the slower RTs found with manual detection tasks. Remaining trials contributed to each participants mean for each condition type (see Figure 26).



Figure 26: Graph of RTs for each response condition for trials where the face was oriented 90 degrees from upright.

The critical issue in this study was whether head-centred cueing effects could be observed. Therefore, analysis centred on the head rotated 90 degrees conditions. To analyse the effect of cues presented in a rotated face, a mixed-factor ANOVA, with within-subjects factors of 'Head Orientation', 'Validity', and the Betweensubjects factor of response mode, was undertaken. The main effect of 'Response' was significant, due to faster saccades (217 ms) than manual responses (332 ms), F(1,48) = 82.5, p < .001. Critically, the main effect of 'Validity' was highly significant, F(1,48) = 13.1, p < .001, with quicker RTs to valid (272 ms) than to invalid targets (277 ms). No interactions approached significance. Furthermore, planned comparisons showed that both the manual detection, F(1,24) = 7.87, p = .010, and the saccade task, F(1,24) = 5.28, p = .031, revealed significant cueing effects. Analysed separately, the Upright face produced the standard cueing effect, F(1,48) = 21.6, p < .001. Intriguingly, this cueing effect was weaker in the saccade task than in the manual detection task, F(1,48) = 7.88, p = .007 (see Table 5). Saccades were faster than manual responses, F(1,48) = 75.1 p < .001.

 Table 5: RTs (ms) in the Upright face conditions, with standard errors in parenthesis.

 Valid

 Valid

	Valid	Invalid
Manual Response	321 (10.2)	337 (10.4)
Saccade Response	216 (7.5)	221 (8.1)

Discussion

This study attempted to evaluate the hypothesis that a vertical (up or down) uninformative eye gaze cue, could act as an attentional cue to the left or right, if the cue is placed in the context of a face rotated 90 degrees anticlockwise or clockwise. The experiment reported here shows clear support for the hypothesis. Cueing was reliable when the face was rotated, even though the eyes never looked towards the target, only up or down. This suggests that viewing a face rotated in this way may involve coding of the object in terms of its normal orientation. Furthermore, if an object contains a cue to attention, the direction of attention shift can be in the direction of the cue according to the canonical view of the object. This therefore confirms the finding of Experiment 11, in observing consistent cueing of attention in object-centred space from an eye-gaze cue.

Hence, while these effects are numerically small, this experiment has demonstrated again that orienting to the direction of gaze can be influenced by the orientation of the observed face. The more surprising finding is the lack of consistent cueing in the upright face condition in the 'saccade to target' task. Initially, larger effects were expected since observing another persons averted gaze results in the immediate tendency to overtly orient to the direction of observed gaze (Ricciardelli, Bricolo et al., 2002). Eve movements as response modality have been shown to effectively demonstrate cueing effects in similar paradigms (Friesen & Kingstone, 2003b; Frischen & Tipper, in press). However, the data from Friesen and Kingstone suggest that smaller cueing effects are indeed found in saccade studies (21 ms in a manual localisation task, 12 ms in a saccade task, p491). However, both these cueing effects are similar in regard to the percentage increase in performance when responding to cued targets (4.9% quicker in manual RT; 4.8% quicker in saccade RT, see Friesen and Kingstone, 2003b). In Experiment 12, participants are 4.6% guicker to manually respond to cued targets than uncued targets, but only 2.1%quicker in the saccade task. This is in spite of rather comparable head-centred cueing effect in either experiment (1.6% advantage in the manual detection, 2.0% advantage in the saccade response task). This is surprising, but demonstrates the robustness of these head-centred effects, even in a paradigm that failed to reveal the normal magnitude of simple orienting to the actual direction of seen eye-gaze.

Experiment 13 – Head-centred and spatial gaze cueing

The previous experiment showed that attention could facilitate detection of target stimuli that were not directly gazed-at, but cued in a head-centred frame of reference. That is, cueing effects were found for left and right target loci even when the eyes in the observed face were looking up or down, but in a face oriented 90 degrees clockwise or anti-clockwise. This experiment aimed to assess the robustness of these effects in a design that acts as a stronger test of the hypothesis. Hence, the procedure for this experiment was largely similar to that of the previous experiments, but returned to the issue of spatial cueing from a rotated face, which was addressed in part in Experiment 11. Hence, the face producing the gaze-cue would only ever be presented rotated clockwise or anti-clockwise, never in the upright position (like Experiment 11). This condition was removed as it allowed extra trials to be included in the rotated conditions, while keeping the length of the experiment similar. Furthermore, the absence of the visual stimulus in the upright position meant that the participants were provided with no 'upright' model of the stimulus face. This is an improvement, as participants may have been encouraged to utilize the rotated gaze-cues in head-centred coordinates in Experiment 12, where they were presented with the face upright on one third of trials. A second new aspect to the design was that, as in Experiment 11, four target locations were used, but instead were positioned at left and right locations, probing head-centred cueing effects (like Experiment 12), and in upper and lower parts of the screen, probing pure spatial cueing effects. This is again an improvement on the previous design for two reasons. Firstly, if spatial cueing is observed for actual direction of gaze, then

the head-centred cueing effects may be weaker if they are due to consciously mediated processes. That is, participants may be less inclined to intentionally rotate the face if half the targets do appear along the vertical axis. Secondly, only 25% of targets appear at locations validly cued in head-centred space. Hence, participants have little motivation to utilize the cue in any strategic manner, to orient to the direction of head-centred gaze. For these reasons, the persistence of the head-centred gaze effects in this paradigm will further the evidence that these effects are robust, and the result of automatic processes of spatial normalization of faces and gazecueing.

Method

Participants.

Twenty-five adults (mean age = 20.1 years; 3 males) participated in return for course credit or payment. All were naïve to the purpose of the experiment, and had normal or corrected-to-normal vision. Informed consent was gained in accordance with the guidelines of the School of Psychology, Bangor.

Apparatus and Stimuli.

The apparatus was the same as in previous experiments, except that no upright face was used, and targets could appear above and below the centre of the screen, as well as to the right and left.

Design.

There were three within-subjects factors, 'Head Orientation', was 'Clockwise' or 'Anti-clockwise'. 'Frame of Reference' was a two-level variable, with 'Spatial' and 'Object-centred factors. This variable refers to whether target appears on the vertical axis, in line with or opposing eye-gaze ('spatial'), or on the horizontal axis ('object-centred'). The final factor was 'Validity', whether the target appeared in a cued or uncued location.



Time

Figure 27: Illustration of presentation sequences for Experiment 13. The upper panels illustrate a target appearing in a spatially valid (i.e. directly looked at) location, following a cue from a clockwise face. The lower panel illustrates a target appearing in an invalid location in object-centred terms, from a cue in an anti-clockwise face. Targets could also appear on the left or upper locations of the display.

Procedure.

Participant instructions were the same as in the previous experiment (see

Figure 27). Four experimental blocks followed a practice block of twelve trials.

Eighty experimental and twelve catch trials were presented in each block.

Results

Errors (0.28%) and 4.8% of trials were excluded as outliers according to the same methods as previous experiments. Mean RTs were submitted to ANOVA, with 'Head Orientation', 'Frame of Reference', and 'Validity' as factors (see Figure 28). The main effect of 'Validity' was significant, F(1,24) = 32.5, p < .001, with quicker RTs to valid targets than to invalid targets (329 ms vs. 340 ms), showing that overall cueing effects were found. RTs were overall faster to targets appearing on the vertical axis compared to targets on the horizontal axis (332 ms vs. 340 ms). The main effect of 'Frame of Reference' was significant, F(1,24) = 25.1, p < .001. The interaction of 'Validity' and 'Frame of Reference', F(1,24) = 12.3, p = .002, was significant, due to a greater effect of 'Validity' in the spatial frame of reference (18.2 ms cueing), than in the Object-based frame of reference (6.5 ms cueing). Planned contrasts revealed that cueing in the direction of gaze was significant (Spatial cueing), t(24) = 5.17, p < .001. Crucially, cueing to the direction of gaze in head-centred coordinates, was also highly significant, t(24) = 3.24, p = .003.



Figure 28: Graph of RTs for each condition in Experiment 13.

Discussion

This experiment replicated the findings of the previous experiments by demonstrating head-centred cueing effects to targets appearing on the horizontal axis. This demonstrates the robustness of this head-centred effect. The effect is, as shown by this experiment, present even when the participant never sees the face in the upright position, and in a paradigm which probes directly looked-at locations as well as locations cued in head-centred space. That is, cueing was found to looked-at targets (i.e. those targets appearing on the vertical axis) as well as those on the horizontal axis. This finding adds evidence for the argument that both these effects are the result of automatic processes. Furthermore, this finding shows that both spatial and head-centred cueing can be produced simultaneously by the same gazecue, which demonstrates the dynamic interaction between two frames of reference acting on the attention system (Tipper & Behrmann, 1996; Tipper & Weaver, 1998).

Analysis of AQ scores

Only participants from Experiment 12 and 13 completed the AQ, with a mean AO score of 16.1 (n = 75). Twenty-four participants scoring in the middle range (14-17) were excluded from the analysis. This left 28 participants in the 'High AQ' group (mean AQ = 21.6), and 23 in the 'Low AQ' group (mean AQ = 9.9, group scores differed, t(49) = 11.9, p < .001). In order to compare the two experiments, the factor 'Frame of Reference' was included, which used scores from the upright face condition in Experiment 12, and from targets appearing on the vertical axis in Experiment 13 as the 'Spatial' level of this factor. The 'Object-Centred' level of this factor was the RTs in head-rotated condition in Experiment 12, and targets appearing on the horizontal axis in Experiment 13. A 'Validity' by 'Frame of Reference' by 'AQ group' by 'Experiment' mixed ANOVA revealed no significant main effect or interactions involving AQ group. This indicates that unlike Chapters 2, 3 and 4, this paradigm did not reveal evidence of individual differences. However, further work, with greater statistical power may reveal differences. That is, the experiments in this chapter recruited many participants scoring mid-range scores. With larger sample sizes, a difference may emerge. One would predict that 'Low AQ' groups might show stronger object-centred orienting that 'High AQ' groups. However, the small magnitude of the standard effect might also have made group differences, observed in previous chapters, more elusive.

General Discussion

These findings imply, in accordance with Langton (2000) and Hietanen (1999; 2002), that head orientation can influence the interpretation of eye gaze. However, the original finding here, is that the head orientations that were used were not cues to the direction of attention. This suggests that head orientation is influential under all circumstances, not just when it implies the direction of social attention. This view may explain findings of disrupted cueing towards the direction of gaze in a face presented upside-down (Kingstone et al., 2000; Langton & Bruce, 1999), since the directions cued in viewer- and head-centred frames are in direct opposition. The face that is presented in rotated conditions, is certainly not 'looking' to the left or right, but consistent shifts of attention to the left or right are found in observers. The inhibitory model of Perrett et al. (1992) would also not predict the effects presented here, since the head position should be rendered irrelevant to the attention system.

The data presented here are the first evidence for a gaze-cue producing attentional facilitation for targets appearing in locations which are not directly gazed-at (Bayliss, di Pellegrino, & Tipper, 2004). This finding has a number of important implications for theory and future research. Firstly, it demonstrates that gaze-cues can be affected by object-centred properties of the face. That is, facilitatory effects were found at locations that would have been gazed-at if the face had been presented upright. This presents interesting questions concerning the origin of the effect – it may rely on mental rotation of the observed face, followed by an updating of the face at the onset of the gaze-cue, or a more direct access mechanism

acting with reference to stored representations of canonical faces. Which of these alternatives is correct remains unclear at this time, and is worthy of future work. Secondly, with the finding that other symbolic cues (e.g. arrows) effectively act as cues to attention even when non-predictive (Eimer, 1997; Ristic et al., 2002; Tipples, 2002), it is unknown whether the effects reported here can generalise to any symbolic cue embedded in any unusually oriented object. Thirdly, since theory of mind is implicated in eye-gaze observation and gaze-cueing, why should a gaze-following system allow orienting to anywhere else other than that which is directly gazed-at? If gaze-following enables one to access the internal attentional state of another, and thus to infer the object of attention, and make an internal model of the mental state of the observed person, then the orienting behaviour described here seems maladaptive. This maladaptivity suggests that this effect emerges automatically⁵ through the processing of the face in object-centred frames, relatively uninfluenced by higher-level mechanisms of person perception, such as theory of mind.

Thus, it seems the interpretation of gaze-cues is always affected by the context in which they are presented. Hence, implicit face processing must occur during the interpretation of eye-gaze. This is certainly the case in other work where there is neural evidence for the integration of intentional (Jellema et al., 2000) and

⁵ These data make a strong case for automaticity of these attention shifts. In contrast with most gazecueing studies, the pupil position was less intuitively involved in the experimental manipulation. None of the participants in these experiments reported 'working out' the purpose of the rotated face conditions, during casual debriefing. Conversely, very few participants (in this experiment, and in others) are surprised to learn that we expect to find cueing from an upright face. It is therefore felt that these data contribute positively to the notion that these gaze-cueing effects occur with automatically without conscious strategies.

emotional (Wicker, Perrett, Baron-Cohen, & Decety, 2003) states of the observed agent on the coding of eye-gaze. The data reported here showing head-centred effects where the eyes are coded in the context of the face implies that the computation may involve an automatic mental rotation, or spatial normalization, of the rotated face to the canonical upright position (Lawson, 1999). Such a discovery has implications for a wide range of issues from object-based models of attention to social interaction driven by social gaze.

Chapter 6 – General Discussion

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The influence of observing averted gaze on attention was investigated in a series of experiments. The standard effect of attentional cueing to the direction of non-predictive gaze (e.g. Driver et al., 1999; Friesen & Kingstone, 1998) was replicated throughout this thesis, as was cueing towards the direction of non-predictive arrows (Eimer, 1997; Hommel et al., 2001; Ristic et al., 2002; Shepherd et al., 1986; Tipples, 2002). The first two experimental chapters used adaptations of the Driver et al. study to reveal that these cueing effects are much weaker in males than in females, providing evidence for differences in cognitive style between the sexes with regard to the processing of social stimuli. However, arrows also elicited much smaller shifts of attention in males than in females, suggesting that the sex differences, predicted by Extreme Male Brain theory (Baron-Cohen, 2000, 2002, 2003) are pervasive throughout symbolic cueing paradigms. This view was supported by the failure to reveal sex differences in paradigms using sudden onset peripheral cues, based on the procedures of Posner and Cohen (1984).

The third experimental chapter investigated the role of object-based attention in these cueing studies, and compared participants who scored high and low scores on the AQ (Baron-Cohen et al. 2001), which in Chapter 2, had been found to be related to cueing magnitude, such that high scores tended to display weaker gazecueing effects. Gaze and arrow cueing was found to be larger when the target appeared on a complete and coherent object, as compared to a scrambled display. However, this trend was only true for participants with low scores on the AQ (i.e. rating themselves as having few autism-like traits). This trend was reversed for participants with high scores, who tended to display more cueing towards scrambled displays. This suggests that even in the normal population, group differences can be found between those with many and few autistic-like traits, in relatively simple cueing paradigms. The differences seemed to be due to different biases in the processing of local features and global objects. That is, the 'complete object/scrambled parts' trends were consistent across the object categories of faces and tools, suggesting that it was the form (coherent vs. scrambled), not the category (faces vs. tools) that dictated cueing magnitude in the two groups. Hence, the data support the notion that individuals with many autism-traits have a stronger bias toward orienting to complex patterns than low-autistic trait individuals do, who themselves tend to orient more strongly when the target appears on a complete object. This finding agrees with the findings of authors who compare the localglobal biases in children and adults with diagnoses of autism (e.g. Mottron et al., 1999; Mottron et al., 2003).

The final experimental chapter investigated object-centred attention with the use of eye-gaze cues. Many studies have shown that head and eye position are integrated to form an impression of direction of another person's attention, which can influence the strength of attention shifts in the direction of gaze (Hietanen, 1999, 2002; Langton, 2000; Langton & Bruce, 2000). However, in manipulating the isometric orientation of the face in which the gaze-cue is presented, pure object-centred effects of gaze direction could be investigated. Indeed, faces presented oriented 90 degrees gazing up or down were found to not only cue attention up and down, but also to the left or right, as if the face had been presented upright. This finding is at odds with theories which suggest that eye gaze direction dominates the

interpretation of the direction of social attention (Perrett et al., 1992), but also prompts an update of theories which suggest that cues to the direction of social attention derived from encoding head orientation are integrated dynamically with those derived from gaze information (Langton et al., 2000). Rather, gaze interpretation is also influenced by head orientation in terms of object-centred frames of reference, since head orientation is influential even when it is not itself directly a cue to attention. These findings have implications for the understanding of joint attention, individual differences and attention research, and are discussed below.

Implications for the study of individual differences in the normal population

The finding that males display much smaller shifts of attention when presented with an irrelevant gaze or arrow cue may provide insight into the relative cognitive styles and biases of the two genders. At present there is little evidence that adult males are less sensitive to the geometric properties of gaze, or less efficient at reference resolution through working out to which object another person is attending. Furthermore, how males and females respond to a gaze-cue that is *predictive* of target location also remains untested. Using predictive cueing is standard in the voluntary attention literature (e.g. Corbetta & Shulman, 2002), yet has been overlooked in eye-gaze cueing paradigms (although one split-brain patient in the Kingstone et al., 2000 study needed a predictive cue to produce cueing effects, predictive cues have not been investigated thoroughly). Hence, investigating the intentional use of gaze in males and females would be an interesting avenue for research. In the studies reported here, however, participants attempting to complete the task successfully (speeded, accurate target discrimination or detection) are at a disadvantage if they consciously encode eye gaze direction. Hence, the circumstances under which a female advantage is revealed in the magnitude of gaze cueing effects are not entirely defined. Nevertheless, conclusions can be made from the data in Chapters 2 and 3 about how joint attention might develop differentially in males and females, when other findings are taken into account.

Essentially, the findings of Chapter 2 suggest that males are more able to successfully ignore the gaze of another person when task instructions demand it. Stronger executive control over allocation of attention is a possible alternative explanation of sex differences in attention. For example, one feature of an Extreme Male brain is poor attention switching abilities, and children with autism are often found to be frustrated by distractions. Perhaps weaker automatic shifts of attention from observed eye gaze is a symptom of this cognitive bias, rather than due to a weaker social attention module. The faces that cue attention in this thesis are distracters to ongoing task (in Chapter 2 the task is target identification), and since the task is relatively difficult and demanding, it might be the case that the high task demands preclude the orienting of attention in males. Indeed, an increase in task demand is associated with a reduction in the interference effect from irrelevant distracters (Lavie, 1995). Hence, the difference between males and females in gazecueing might be absent in an easier task (e.g. target detection). However, further research by Lavie and colleagues has recently shown that the interference effect of peripherally presented face distracters is constant as task difficulty increases, suggesting that faces are special distracters in that they affect task performance

however difficult the task is (Lavie, Ro, & Russell, 2003). While this suggests that in my experiments, the faces should have the same effect on behaviour whatever the task demand, one cannot rule out the possibility of sex differences in Lavie et al.'s data (unfortunately, male/female ratios are not reported). It is possible that only females were consistently distracted by faces (and hence faces are processed automatically and easily by females), but males might have shown a different pattern (i.e. no interference effect in high-load conditions).

As there is no direct evidence that males process distractor faces differently to females, an explanation in terms of a capacity limitation or greater top-down control of attention in males is not favoured. Furthermore, data from Experiment 4 of this thesis shows that males are not much better at *actively* using another's gaze in an anti-predictive manner (i.e. orient to the opposite side of space) when compared to female performance. This therefore again suggests that inhibition of gaze signals are not different in males and females, since if males had stronger executive, topdown control of automatic orienting to gaze and arrows, then orienting to the opposite side of space should be relatively easy. Instead, the data suggest that stronger shifts of attention in females to the direction of gaze and arrows are due to stronger signals from gaze- and social-signal encoding networks, as compared with males.

This conclusion has a number of implications that relate well to theories such as the Extreme Male Brain theory of autism, but cannot attempt to investigate the 'wilful' use of eye gaze. In naturalistic conditions, other people's gaze *always* means something, but in the experiments presented here, gaze is simply a distraction to the ongoing task. The behaviour of males in these experiments, when gaze is a simple distraction, is still very important. It seems that the gaze-processing circuits are relatively uninfluential in such circumstances. Male infants are biased toward the processing of mechanical stimuli, in preference to social stimuli (Connellan et al., 2000; Lutchmaya & Baron-Cohen, 2002; Lutchmaya et al., 2002a). If males generally lack this bias towards social stimuli, then it might be expected that when social stimuli are unrelated to the task, they are afforded less processing recourses by the male cognitive system than by the female cognitive system. In some ways, this is unsurprising. However, the participants in Chapters 2 and 3 were not infants, but adult male and females. It seems, therefore, that these processing biases persist into adulthood. Furthermore, cueing magnitude was inversely correlated with prevalence of autistic-like traits on the AQ (Baron-Cohen et al. 2001). This showed that a basic attention cueing paradigm could reveal individual differences along the autism-spectrum, even in adults without autism.

A more immediate, empirical implication of the finding that males are not cued strongly by non-predictive central symbolic cues, is that researchers using such cues should at the very least report the gender of the subjects (often omitted from brief reports), but also consider including gender as a factor in statistical analysis and perhaps also match group numbers. For example, a greater number of males in an experiment may lead to a null effect, independent of experimental manipulations. Not considering gender might lead to inferences being made which are, in fact, gender specific. That is, robust effects may only seem robust due to the oversampling of females, while conversely, the undersampling of males may preclude the discovery of other effects that are generally too weak due to the greater proportion of females as compared with males.

Further work would be able to elucidate the differences between male and female's treatment of cues to social attention, by comparing the sexes on simple gaze direction determination measures. The prediction would be that while males show weaker spontaneous gaze-following, gaze discrimination would be unimpaired, as with patients with schizophrenia in studies by Franck and colleagues (Franck et al., 1998; Franck et al., 2002). Future research should also compare the behaviour of adult males with females, infants, people with Asperger's syndrome and autism across common attention paradigms. For example, do male and female infants reveal similar differences in gaze-cueing tasks (e.g. Hood et al. 1998)? What is the role of motion in the gaze-following behaviour of children with autism? Since normal children require motion cues in order to develop joint attention abilities, eventually following static cues (Moore et al., 1997), do children with autism follow the same initial developmental pattern, but later fail to use gaze-cues fully? Children with autism are cued by gaze direction, but the role of motion may prove to be vital (Chawarska et al., 2003; Leekam et al., 1998; Swettenham et al., 2003). The relationship between the scores on the AQ and cueing magnitude suggests that it is possible that clinical groups' cueing patterns in these cueing experiments might be predicted by some measure of autistic trait prevalence, such as the AQ.
If the strength of automatic gaze-following varies along the autism-spectrum. then it may well also vary along other continua relating to clinical symptoms of other disorders involving a disruption of social functioning. For example, social phobics do not scan the eye region when evaluating emotional expressions (Horley et al., 2002), suggesting that social phobics might not follow eye gaze as readily as non-phobics. Conversely, people with above average levels of state and trait anxiety are cued more by fearful faces (Mathews et al., 2003). These two findings suggest that the magnitude of cueing might be modulated by levels of anxiety, and emotional expression of the cue face. For example, hypervigilance in anxious people might lead to a greater attention to other people's behaviour, whereas social phobics might suppress attention to other people's behaviour in order to avoid any contact. Mood can have a great impact on attention, with detection performance at peripheral locations improving with arousal (Shapiro, Egerman, & Klein, 1984), so it is highly likely that different gaze-cueing patterns should also be observed in people with different arousal levels, as modulated by the emotional expression of the face producing the gaze-cue. The importance of using some measure of anxiety in investigating such potential effects is not to be understated, since in experiments where anxiety levels are not measured, modulation of cueing is not found (Hietanen & Leppanen, 2003).

Establishing what information is gleaned by different populations (with different cognitive styles) from the observation of averted gaze, might also be a worthy area of further work. For example, in Chapter 4, target context was manipulated, essentially manipulating the 'common' object in a joint attention relationship. While gaze and arrow cues again acted in similar ways in these experiments, the paradigm nevertheless has potential to reveal individual differences in a wide range of populations. However, a foremost issue concerns whether individuals who show less cueing to real objects (high AQ participants) are also less selective in their attention shifts towards stimuli cued by gaze cues. That is, experiments where one participant must resolve and report correctly the object to which another is attending, among the presence of several strong distracters (i.e. sharing several attributes), might prove an effective test of individual differences in these domains. Indeed Hanna and Brennan (2003) found that incidental gaze information was used unconsciously by participants in such reference resolution paradigms. The use of such paradigms with patient groups might provide a more naturalistic index of automatic use of eye-gaze information in different populations, and enable the more direct implication of joint attention differences between individuals.

The finding that males show smaller cueing effects in gaze and arrow paradigms, reflects the fact that males generally display more autistic traits than females do (see Table 6). However, another aspect of the cognitive profile of people with autism is a bias toward the processing of local details. The data from Chapter 4 of this thesis support the view that local/global biases can be seen in the normal population, as a function of position on the autism spectrum. Greater gaze and arrow induced shifts of attention towards objects were found in low AQ scorers, providing evidence of a bias toward being cued to global patterns, whereas the opposite trend in high AQ participants indicated a small bias toward orienting to local features of complex patterns. This also therefore has implications for the study of object-based attention in individuals.

One final issue to be discussed in this section is the scores by males and females over the entire thesis, and whether the sex difference reported by Baron-Cohen et al. (2001) is observed in a separate normal sample. The AQ scores of 246 participants (84 males, 162 females) who completed the AQ after completing experiments reported in this thesis (experiments 1, 2, 3, 5, 6, 8, 9, 12 & 13) were investigated. Scores on the AQ and subsets are summarised in Table 6, with independent-samples t-test results. An overall mean score of 16.2 was found (SD = 5.60, SE = .36). As well as an overall gender difference, males' and females' scores differed in three of the five subsets, with females scoring more than males on only one subset (attention to details). This pattern is very similar to that found by Baron-Cohen et al. (2001).

results.						
	AQ Score	Social Skills	Attention Switching	Attention to Details	Communica tion Skills	Imagination Skills
Males $(n = 84)$	17.7 (.6)	2.3 (.2)	4.9 (.2)	4.6 (.2)	3.0 (.2)	2.7 (.2)
Females $(n = 162)$	15.5 (.4)	2.1 (.2)	4.1 (.2)	4.9 (.2)	2.1 (.1)	2.2 (.1)
t(244) =	3.00	.55	2.84	98	3.74	3.24
<i>p</i> =	.003	.59	.005	.33	.001	.001

Table 6: Mean AQ scores (SE in parenthesis) for males and females, with independent-samples t-test results.

Further analysis showed that 38.7% of scores were of less than 14, with 37.4% of scores being higher than 17. This shows that while the cut-off scores used

in Chapters 4 and 5 were a little conservative, in that 23.9% of participants were excluded from either group (the aim was to exclude 20%), these cut-offs were not inappropriate, producing two equally-sized groups over the thesis. Therefore, this overall replication of the Baron-Cohen et al. (2001) study provides a further validation of the AQ as a brief, self-administered index of autistic traits in the normal population. In relating scores on this questionnaire to the magnitude of cueing effects, the experiments reported here add weight to the validity of the questionnaire in terms of its' applicability to the investigation of individual differences in cognitive style.

Implications for the study of attention

One of the fundamental differences between gaze and peripheral cueing experiments, is that peripheral cues always involve a change to the appearance of the cued stimulus (somewhere on the object), whereas central cues do not. Using central cues to study object-based and object-centred attention might therefore be considered advantageous, as the possible target locations (cued and uncued locations) are physically the same stimuli in cued and uncued trials. Clearly the two techniques (peripheral and central cues to attention) are greatly informative about the nature of the mechanisms of attention, but central cues have not often been used to study object-based attention (but see Goldsmith & Yeari, 2003, for a study using predictive central cues). The individual differences noted in Chapter 4, where cueing was larger towards complete objects in participants scoring low on the AQ, and larger towards scrambled displays in participants scoring higher scores, suggest that different orienting biases exist in different people. However, there may be something special about the mechanisms underlying the distribution of attention via central cues. Perhaps object-based attention, evoked through peripheral cueing will not differ between AQ groups.

Hence, further work could use a paradigm similar to that of Experiments 8 and 9, but with peripheral cueing, with objects and scrambled displays acting as target place holders. Indeed, Jordan and Tipper (1998), used scrambled displays to successfully demonstrate inhibitory effects of object-based attention with peripheral cueing. If peripheral cueing does not reveal individual differences, then this would be evidence of a difference between the effect of peripheral and central cues on attention. That is, only the mechanisms of attention that underlie central cueing are sensitive to individual processing style, while the mechanisms underlying attention shifts evoked by peripheral visual stimulation are invariant along the autismspectrum within the normal population (see Chapters 2 & 3). This again would mirror the findings of the peripheral cueing studies in this thesis (Experiments 6 & 7), where no sex differences were found, in contrast to gaze and arrow cueing. It is possible that the reflexive orienting following a peripheral cue, generated in subcortical areas such as the superior colliculus, is not influenced by individual cognitive style, whereas the automatic orienting following a central cue to attention, relying on higher cortical areas can be partly a function of individual orienting biases.

The only aspect of this thesis in which individual differences did not emerge, was the experiments investigating object-centred cueing effects from a gazing face (Chapters 5). In retrospect, this is perhaps unsurprising, since two opposing hypotheses that might be made from the findings of Chapters 2-4. Firstly, orienting to the true direction of gaze should be a sign of an efficient and accurate joint attention / gaze following mechanism (Perrett et al. 1992). This hypothesis would predict that low AQ participants would not show object-centred cueing from faces gazing up or down when orientated 90 degrees from the vertical, in the picture plane. Conversely, the findings of Chapters 2-4 suggested that high AQ participants might not process or encode eye-gaze and symbolic cues (Chapter 2-3), or process objects like faces (Chapter 4) as deeply as low AQ scorers. Hence, high AQ scorers might not process the face on it's side fully, and subsequently fail to apply a mental rotation process to it's internal representation, resulting in no object-centred shifts of attention. However, *both* groups showed consistent shifts of attention based on headcentred representations.

Alternatively, there may be a more empirical reason behind the failure to reveal individual differences along the autism-spectrum. Chapters 2 and 3 revealed sex differences in attention as measured by a target identification task, and Chapter 4 revealed local/global differences by manipulating the context in which the target appeared. The targets presented in Chapter 5 required a simple response, and were not as rich and engaging as the targets in Chapters 2 - 4. As noted before, task demand and target processing may be a critical factor in revealing individual differences in gaze-evoked shifts of attention. While Chapter 5 did not reveal further differences between low and high AQ participants' attention systems, the findings do have important implications for object-centred attention.

Again, the use of a symbolic cue embedded in the object (eye-gaze in a face) is rather different to other studies of object centred attention, in which targets or cues appear as parts of the object (Driver & Halligan, 1991; Hommel & Lippa, 1995; Tipper & Behrmann, 1996). Unlike these studies, the task-relevant feature in Experiments 11-13 (the target) was presented outside the confines of the object, rendering the object (the face) *completely* irrelevant to the task. This therefore adds support to the argument that objects are automatically encoded relative to the orientation in which they are normally viewed, even when task irrelevant. Further work might focus on other cues embedded in objects, such as arrows, and objects other than faces, to investigate the generalisability of this effect.

Summary and Conclusions

The experiments presented in this thesis used central gaze and arrow cues to measure shifts of spatial attention evoked by non-predictive symbolic cues. Previous studies have shown that observing these centrally presented cues can produce attentional cueing even when task-irrelevant (Driver et al., 1999; Eimer, 1997; Friesen & Kingstone, 1998; Langton & Bruce, 1999; Shepherd et al., 1986; Tipples, 2002). The standard paradigm of Driver et al., revealed a consistent gender difference such that females were cued more by gaze and arrow cues. This was interpreted as evidence that males fail to use symbolic cues to attention automatically due to males generally being further along the autism-spectrum. This conclusion accords with the Extreme Male Brain hypothesis of autism (Baron-Cohen, 2000, 2002, 2003), and supports the view that sex differences in the processing of social stimuli, which emerge in infancy, persist into adulthood (Connellan et al., 2000; Lutchmaya & Baron-Cohen, 2002; Lutchmaya et al., 2002a, 2002b). Further evidence for such processing biases came with the finding that gaze and arrow cueing was larger towards coherent visual stimuli in people with low AQ scores, with high AQ scorers displaying greater shifts of attention toward scrambled stimuli. Since this finding was independent of gender, it acts as converging evidence for individual differences along the autism-spectrum in the normal population, again demonstrating the applicability of the gaze-cueing paradigm to a variety of research questions. A further series of experiments related to the issue of head-orientation and its effect on gaze-perception. It was found that gaze was encoded in terms of head-centred coordinates, even though the head orientations used were irrelevant, and not themselves cues to attention. This finding extended evidence that attention shifts to the direction of gaze are influenced by the encoding of head orientation, and also has implications for the study of spatial attention in general.

In conclusion, this thesis sought to integrate findings from developmental and social psychology, and apply the theoretical approaches of these fields, to the study of spatial attention. Using paradigms adopted from standard spatial attention paradigms, this thesis has contributed to knowledge about individual differences in how cues to social attention are interpreted and how object-based information and object-centred frames of reference can be integrated into the attention system's treatment of such cues. The use of gaze and other central cues to attention has the potential to be as powerful as the use of peripherally presented cues to attention have proved in the exploration of the mechanisms of human spatial attention.

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Appendix I – Median analysis of Experiment 1

Untrimmed median scores were submitted to mixed-factor ANOVA, with 'SOA' and 'Validity' as within-subject factors, and 'Gender of Face' and 'Sex of Participant' as Between-Subject Factors, was performed on the data. A significant effect of 'Validity' was found, F(1,36) = 15.6, p < .001, confirming the cueing effect of gaze. 'SOA' also reached significance, F(2,72) = 64.5, p < .001, with reaction times (RT) decreasing at longer SOAs. There was a main effect of 'Gender of Face', F(1,36) = 8.73, p = .005, with responses to the female face being quicker. Further, the 'Gender of Face' by 'Gender of Participant' interaction was significant, F(1,36) = 9.80, p = .003. This interaction is due to the females responded with similar RTs.

With this analysis, the hypothesied 'Validity' by 'Sex of Participant' interaction did reach significance, F(1,36) = 4.90, p = .033. To further investigate the timecourse of cueing in the experiment, planned contrasts were performed at each SOA, pairing Valid with Invalid scores. Significant cueing was found at 100 ms, t(39) = 2.24, p = .031; and at 300 ms, t(39) = 3.62, p = .001; but not at 700 ms SOA, t(39) = 1.25, p = .218. In order to test a priori predictions, independent-samples t-tests were performed on the RT benefit scores of male and female participants, to investigate whether gender differences were present. Cueing was found not to be significantly larger in females at 100 or 300 ms SOA, t(38) < 1; t(38) < 1, respectively. However, at 700 ms, cueing was found to be significantly larger in females than males, t(38) = 2.22, p = .033.
Therefore, with an analysis of untrimmed median scores, the effects reported in Experiment 1 were found, with the only difference being that the overall 'Sex of Participant' by 'Validity' interaction now did reach significance. There is currently no standardised method of trimming RT means, so while this median analysis reveals results which more strongly support the hypothesis underlying Chapter 2 of this thesis, there is no statistical reason that the author is aware of to revert to median analysis for subsequent analyses. In fact, trimming techniques may be preferable to median analysis because while median analysis negates the impact of outliers on the average score, this technique does not improve the likelihood that the assumption of normality (required by ANOVA) will not be violated. This is due to the natural positive skew in a traditional RT distribution. Hence, trimmed means provide a method of producing reliable data that will be more likely to be appropriate for ANOVA without adjusting for violations of underlying statistical assumptions (Howell, 1997). According to z-tables, removing scores 2 *SD* above and below the mean should exclude approximately 4.56% of scores (Gravetter & Wallnau, 1996).

No.	Item	Definitely Agree	Slightly Agree	Slightly Disagree	Definitely Disagree	
1	I prefer to do things with others rather than on my own					
2	I prefer to do things the same way over and over again					
3	If I try to imagine something, I find it very easy to create a picture in my mind					
4	I frequently get so strongly absorbed in one thing that I lose sight of other things					
5	I often notice small sounds when others do not					
6	I usually notice car number plates or similar strings of information					
7	Other people frequently tell me that what I've said is impolite, even though I think it is polite					
8	When I'm reading a story, I can easily imagine what the characters might look like					
9	I am fascinated by dates					
10	In a social group, I can easily keep track of several different people's conversations					
11	I find social situations easy					
12	I tend to notice details that others do not					
13	I would rather go to the library than a party					
14	I find making up stories easy					
15	I find myself drawn more strongly to people than to things					
16	I tend to have very strong interests, which I get upset about if I can't pursue					
17	I enjoy social Chit-chat					1
18	When I talk, it isn't always easy for others to get a word in edgeways					
19	I am fascinated by numbers					

Appendix II – The AQ

No.	Item	Definitely	Slightly	Slightly	Definitely	
		Agree	Agree	Disagree	Disagree	
20	When I'm reading a story, I find it					
	difficult to work out the characters'					
17	intentions					
21	I don't particularly enjoy reading					
	fiction					
22	I find it hard to make new friends					
23	I notice patterns in things all the time			-		
24	I would rather go to the theatre than a					
	museum					
25	It does not upset me if my daily	2				
	routine is disturbed					
26	I frequently find that I don't know					
07	how to keep a conversation going					
27	I find it easy to read between the					
- 29	Innes when someone is taking to me			-		
28	y used a picture, rather than the small					
	details					
20	Lam not very good at remembering					
49	phone numbers					
30	I don't usually notice small changes in					0
50	a situation, or a person's appearance					i
31	I know how to tell if someone					
10460	listening to me is getting bored					
32	I find it easy to do more than one thing					
	at once					
33	When I talk on the phone, I'm not sure					
	when it's my turn to speak)				
34	I enjoy doing things spontaneously					
35	I am often the last to understand the					
	point of a joke					
36	I find it easy to work out what					
	someone is thinking or feeling just by					
	looking at their face					
37	If there is an interruption, I can switch					
	back to what I was doing very quickly					

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No.	Item	Definitely Agree	Slightly Agree	Slightly Disagree	Definitely Disagree	
38	I am good at social chit-chat					
39	People often tell me that I keep going on and on about the same thing					
40	When I was young, I used to enjoy playing games involving pretending with other children					
41	I like to collect information about categories of things (e.g. types of car, types of bird, types of train, types of plant, etc.)					
42	I find it difficult to imagine what it would be like to be someone else					
43	I like to plan any activities I participate in carefully					
44	I enjoy social occasions					
45	I find it difficult to work out people's intentions					
46	New situations make me anxious					
47	I enjoy meeting new people					
48	I am a good diplomat					
49	I am not very good at remembering people's date of birth					
50	I find it easy to play games with children that involve pretending					1-2