Social versus mechanical cues of attention

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PREFACE

This dissertation is the result of my own work and includes nothing which is the outcome of work done in collaboration except when specifically indicated in the text.

My thesis is not substantially the same as any that I have submitted for a degree or diploma or other qualification at any other University. I further state that no part of my thesis has already been or is being concurrently submitted for any such degree, diploma or other qualification.

This dissertation does not exceed 20,000 words for the Degree Committee of Clinical Medicine and Clinical Veterinary Medicine.

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Abstract

The ability to detect and respond to social cues that cause a shift of attention is essential to communicating with other individuals. Prior studies reported gaze shifts and arrows reflexively orient attention (Driver et al., 1999; Friesen & Kingstone, 1998; Ristic, Friesen, & Kingstone, 2002), more strongly in women vs. men (Bayliss, di Pellegrino, & Tipper, 2005), with a weaker effect in high Autism Quotient (AQ) scorers (Bayliss et al., 2005), and perhaps differently in individuals with Autism Spectrum Conditions (ASC) (Ristic et al., 2005; Vlamings, Stauder, van Son, & Mottron, 2005). Using a novel computer task, social cues (faces and hands) were compared to non-social cues (cars, arrows and squares) to determine whether there were variations in the effects of these stimuli on orienting attention in: 1. male (n = 30) vs. female students (n = 30) 2. high vs. low scorers on the AQ, Empathy Quotient (EQ) and Systemizing Quotient (SQ) (Baron-Cohen, Richler, Bisarya, Gurunathan, & Wheelwright, 2003; Baron-Cohen & Wheelwright, 2004; Baron-Cohen, Wheelwright, Skinner, Martin, & Clubley, 2001) and 3. individuals with Autism Spectrum Conditions (ASC). Student population data revealed that there were faster shifts of attention to the social vs. the non-social stimuli, and that within the social stimuli, faces led to faster orienting than did hands. No sex differences were found. There were clear associations with AQ to stimuli type, suggesting that attention shifts to the social vs. non-social stimuli can be explained by AQ. These results support the idea that there are individual differences in the tendency to orient attention to social stimuli, and these differences might be explained by the presence of autistic-like traits.

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Introduction

'Social communication' refers to the ability to relate to and interact with others and requires the capacity to integrate and interpret complex visual and behavioural cues from other agents (Adolphs, 1999). Such cues come from the face (Emery, 2000) (such as different facial expressions or eye movements); from 'body language,' (de Gelder, 2006) (for instance, doubling over in pain can indicate how one is feeling); and from the voice (Murray & Arnott, 1993) (e.g., intonation can express emotional state). Finally, in order to be able to communicate, it is essential to integrate these multiple cues into the social context which surrounds the person (Golan & Baron-Cohen, 2006).

Individuals with Autism Spectrum Conditions (ASC) have impairments in social communications skills (APA, 1994). They have difficulty reading cues from faces such as interpreting information from the eyes (Baron-Cohen et al., 1999) and producing appropriate gestures during conversations (APA, 1994). However, non-social objects often captivate their attention (Baron-Cohen, Leslie, & Frith, 1986; Baron-Cohen & Wheelwright, 1999). For example, individuals with ASC will fixate on an object for many hours and prefer games or occupations that are orderly and follow rules (i.e. train sets, computers or physics).

One skill that is essential to communicate with other individuals is the ability to detect and respond to social cues that cause a shift in attention. Typically, the gaze movements of others will automatically shift an individual's attention, even if they do not predict where a target will be located (Driver et al., 1999; Friesen & Kingstone, 1998).

This effect was reported to be more robust in women than in men (Bayliss et al., 2005). This reflexive shift of attention and sex difference was reported with non-biological stimuli such as arrows (Bayliss et al., 2005; Tipples, 2002). Many studies have reported that eye and head movements reflexively orient attention, but no prior study has demonstrated whether other biological stimuli such as pointing gestures, will induce the same effect.

Studies with the ASC population have produced inconclusive results regarding whether these individuals have reflexive shifts of attention to gaze movements and arrows (Ristic et al., 2005; Senju, Tojo, Dairoku, & Hasegawa, 2004; Swettenham, Condie, Campbell, Milne, & Coleman, 2003). No studies have examined whether non-agentive stimuli, which are often favoured by this population, may induce a greater reflexive shift of attention compared to social stimuli.

The aim of the current experiment was to examine how different aspects of the environment (social vs. non-social) differ in their power to induce reflexive shifts of attention. We further tested if there would be: 1. sex differences and 2. differences in the ASC population compared to typically developing individuals. The first of these comparisons (test of sex differences) fell within the timeframe of this thesis. The second of these (test of autism group differences) is ongoing work, but preliminary data are reported.

Mechanisms of Attention

The seminal experiments utilizing a cue to orient attention followed by a target were by Posner (1978; 1980). Participants were told to respond when they saw a target that could appear on the left or right side of a central fixation point. Their attention was cued to a certain side by a flash of light or they were told that the target was most likely on one side. Based upon the paradigm of these cueing experiments, two significant attention classifications have been defined.

First, covert attention is when a person shifts attention, but not necessarily by moving their eyes, whereas overt attention is a shift of attention *with* eye movement. Prior work has reported that watching shifts in eye gaze can induce both covert and overt orienting (Friesen & Kingstone, 2003; Ricciardelli, Bricolo, Aglioti, & Chelazzi, 2002). However, viewing arrows did not produce overt shifts of attention (Ricciardelli et al., 2002). Friesen and Kingstone (2003) directly examined overt and covert orienting in response to viewing faces with averted and direct gaze. The authors reported *no* enhancement of gaze triggered orienting in either condition (overt vs. covert). These findings together suggest that gaze cues can produce overt and covert attention shifts.

The second mechanism defined was endogenous vs. exogenous shifts of attention. Endogenous (or top-down) orienting of attention is when there is a controlled or voluntary shift of attention. Exogenous is involuntary, automatic (or bottom-up) shifting of attention, such as that induced by a flash of light (Posner, 1980). Exogenous orienting of attention peaks at cue-target onset asynchronies (SOAs) of around 100-150ms (Müller & Findlay, 1988). Endogenous peaks later at SOAs around 300-400 ms (Müller & Rabbitt, 1989).

Exogenous orienting is further characterized by an effect called Inhibition of Return (IOR) (for a review, see Klein (2000)). IOR is when there is a reflexive shift of attention towards a stimulus and once attention is removed, there will be delayed return of attention to the site of the stimulus. IOR typically occurs when SOAs are longer than 300ms (Posner & Cohen, 1984). No studies have reported IOR in response to gaze shifts, i.e. no studies have found reaction times to be greater for the targets appearing at the gazed at location vs. the non-gazed at location. Friesen and Kingstone (2003) directly tested for IOR in response to gaze shifts and did not find that IOR was produced at gazed at locations. However, Frischen and Tipper (2004) reported that longer gaze cueing (2,400ms SOAs) will produce an inhibitory effect. This finding suggests that there may be IOR responses to gaze shifts but the inhibition emerges on a much longer time scale. No other experiments have used SOAs of that length.

Two aspects of attention, Joint Attention and Shared Attention, rely specifically on gaze movements. Joint Attention is when two people are focused on the same entity (Emery, 2000). Shared Attention is when two individuals are focused on the same entity and are aware that they are sharing the same focus of attention with the other person (Emery, 2000). Based upon the notion that there are different aspects of attention, Baron-

Cohen (1994) proposed a modular system for gaze communication. In his model there are four modules or neurocognitive mechanisms: an Eye Direction Detector (EDD), an Intentionality Detector (ID), a Shared Attention Mechanism (SAM), and a Theory of Mind Mechanism (ToMM). EDD represents gaze direction. In response, Perrett and Emery (1994) proposed a Direction of Attention Detector (DAD) which was responsible for processing all possible attention cues (eyes, head or body) and a Mutual Attention Mechanism (MAM) which detects mutual gaze. One of the major differences between the two models is that Baron-Cohen (1994) emphasized the special role eyes have in shifting attention, whereas Perrett and Emery (1994) suggested that it was not the eyes alone which were responsible for shifting attention. This debate is relevant to the present study since this examines the difference among social stimuli (faces vs. hands) in shifting spatial attention.

The ability to attribute mental states to others is referred to as possessing a theory of mind (ToM) and is key for social communication. Using cues from another person's body language, including their eye movements, it is possible to predict another's intentions, desires or emotions. This ability is impaired in individuals with autism, which is discussed further in section 'Autism Spectrum Conditions'. ToM and the different mechanisms of attention provide a framework to understand studies that used faces and eye-gaze cues to trigger attention.

Cues for social communication

Faces

Faces are unique environmental stimuli that provide crucial cues for social interactions. Within the face, the movement and manipulation of different features (eyes, mouth) enable individuals to express emotional states and intentions. Whether the ability to process faces is innate and unique to humans has been the focus of much research (Johnson, Dziurawiec, Ellis, & Morton, 1991). Non-human primate and developmental research offers insight into these questions and provides a background for understanding adult human face processing.

Behavioural studies have shown that non-human primates have a unique preference for faces. Infant pigtailed macaques prefer normal feature faces to scrambled faces (Lutz, Lockard, Gunderson, & Grant, 1998). And, like humans, macaques (Pascalis, de Haan, & Nelson, 2002), have a specialization for face recognition within their own species versus those of other non-human primates and human faces (Dufour, Pascalis, & Petit, 2006). Evidence that there is an innate ability in humans to process faces comes from the findings that infants prefer to look at face-like stimuli as compared to scrambled faces or a blank face without facial features (Goren, Sarty, & Wu, 1975; Johnson et al., 1991). Connellan, Baron-Cohen, Wheelwright, Batki, and Ahluwalia (2000) reported female neonates will look longer at faces as compared to a mechanical mobile, whereas male neonates will concentrate more on the mobile. This suggests an innate sex difference to faces. This finding will be discussed in greater detail in the section 'Sex Differences'.

Further evidence that faces are a special and salient stimulus for both humans and non-human primates comes from neurological research. The notion that there could be a face specific region in the human brain was first developed because of the discovery of face-responsive neurons in non-human primates. In macaques, certain populations of cells in the inferior temporal cortex were reported to be responsive only to faces (Desimone, Albright, Gross, & Bruce, 1984) as opposed to other types of objects. These cells were sensitive to different facial features as compared to non-sense pictures and were less responsive to faces rotated to a profile view (Perrett, Rolls, & Caan, 1982). Brain imaging work in macaques reported specific brain regions responsible for face processing as opposed to body parts or man-made objects (Pinsk, DeSimone, Moore, Gross, & Kastner, 2005).

The first evidence that there were face-specific regions in the human brain was put forward by Bodamer (1947). Bodamer (1947) reported patients with brain damage who could not perceive faces, but had no deficits in detecting other types of objects. He introduced the term 'prosopagnosia' for these patients. With the advent of brain imaging, it has been possible to localize regions in the human brain that are responsive to different types of stimuli. Multiple experiments have shown that when individuals see pictures of faces as opposed to other types of objects, areas in the temporal lobe, specifically the fusiform gyrus (FG) and superior temporal sulcus (STS) are uniquely activated (Haxby et al., 1999; Kanwisher, McDermott, & Chun, 1997). Research suggests a neural network that supports identifying and processing faces, as opposed to any other type of stimuli

(Haxby, Hoffman, & Gobbini, 2000). This speciality in the human brain reflects the importance of perceiving and processing faces for highly social primates like humans.

Eyes

The ability to perceive and process changes within the face is crucial for making use of social communication cues. Specifically, gaze movements provide important information for social cognition such as attention, theory of mind and empathy (Baron-Cohen, 1995).

Behavioural studies in non-human primates indicate that eyes are the most salient facial feature. Studies have shown that rhesus monkeys (Keating & Keating, 1982) and baboons (Kyes & Candland, 1987) spend more time viewing the eye region when viewing faces as compared to other facial features. Rhesus monkeys will follow gaze movements (Emery, Lorincz, Perrett, Oram, & Baker, 1997) and by doing so will shift their attention in the direction of the perceived gaze direction (Deaner & Platt, 2003). While it was previously reported that there is a specialization for identifying faces within ones own species, the ability to detect gaze movements and then shift attention accordingly in the direction of the eye movement appears to also occur across species. In other words, non-human primates will orient attention in the direction of *human* eye movements (Ferrari, Kohler, Fogassi, & Gallese, 2000) and humans will orient attention to eye movements of *non-human* primates (Deaner & Platt, 2003). These findings suggest that processing gaze movements is critical for all primates and is mediated by common mechanisms in humans and non-human primates.

Shepherd, Deaner, and Platt (2006) reported that social status modulated rhesus monkey's shifts of attention to gaze movements. Macaques of low-status follow the gaze movements of all other rhesus monkeys, whereas high-status macaques selectively follow the gaze movements of other high status monkeys. These findings suggest that social environment influences gaze orienting in rhesus monkeys. This will be relevant when discussing sex differences to reflexive orienting.

Developmental research in humans suggests that following gaze is an innate ability. Newborns prefer to look at a face with open eyes as compared to closed eyes (Batki, Baron-Cohen, Wheelwright, Connellan, & Ahluwalia, 2000) and are able to discriminate between direct and averted gaze (Farroni, Csibra, Simion, & Johnson, 2002). Infants at 4 months of age have greater neural activity as recorded by event-related potentials (ERP) to direct gaze versus averted gaze (Farroni et al., 2002; Farroni, Johnson, & Csibra, 2004). In accordance with these findings, Reid, Striano, Kaufman, and Johnson (2004) reported that the direction of gaze successfully cues four-month old infants to objects as measured by ERP. Additionally, without the gaze cue Reid and Striano (2005) reported infants look at two objects for equally long, as opposed to when an adult had directly gazed at one object. This finding suggests that infants are able to discriminate gaze movements and more importantly, use the shifts as relevant information cues.

In a process paralleling the discovery of face specific regions in the human brain, research with non-human primates suggests that there may be brain regions which are uniquely responsive to specific aspects of the face, such as eye movements. Certain cells in the macaque are responsive to head orientation (profile vs. full face) and gaze orientation (direct vs. averted) (Perrett et al., 1985). Specifically, in the superior temporal sulcus (STS) of the macaque brain, a population of cells are highly responsive to body and head movements (Perrett et al., 1985).

Evidence from lesion studies in humans suggests that there are eye movement detection regions. Individuals with damage to the STS are reported to have difficulty perceiving gaze movements (Campbell, Heywood, Cowey, Regard, & Landis, 1990). Some patients with amygdala damage have difficulty detecting gaze movements (Broks et al., 1998). Brain imaging studies have demonstrated that the STS is responsive to eye movements (Puce, Allison, Bentin, Gore, & McCarthy, 1998) and this has also been found for the middle temporal gyrus and superior temporal gyrus (Calder et al., 2002; Wicker, Michel, Henaff, & Decety, 1998; Wicker, Perrett, Baron-Cohen, & Decety, 2003). Of note, the amygdala and intra parietal sulcus are also responsive to gaze movements (Hoffman & Haxby, 2000; Kawashima et al., 1999). These brain regions are implicated in attention and in detecting emotional content from faces (Adolphs, Tranel, Damasio, & Damasio, 1994; Corbetta, Shulman, Miezin, & Petersen, 1995). Therefore, it is not surprising that eye movements activate these regions due to their importance in relaying social information.

A particularly relevant study to the current experiment was carried out by Kingstone, Tipper, Ristic, and Ngan (2004). The authors suggested that the previously mentioned STS response to eye movements might reflect a response to shifts in attention, rather than a response to eyes per se. In order to test this, eye movements and arrows were shown as cues of attention while individuals underwent brain imaging. Kingstone et al. (2004) reported that while both stimuli were able to reflexively orient the participants' attention, significantly greater STS activation was reported during the eye movements as compared to the arrows. These brain imaging findings were supported by the report of a patient who had a lesion in the right superior temporal gyrus. This patient was unable to use eye direction cues to reflexively shift attention, but had no difficulties with arrows (Akiyama et al., 2006).

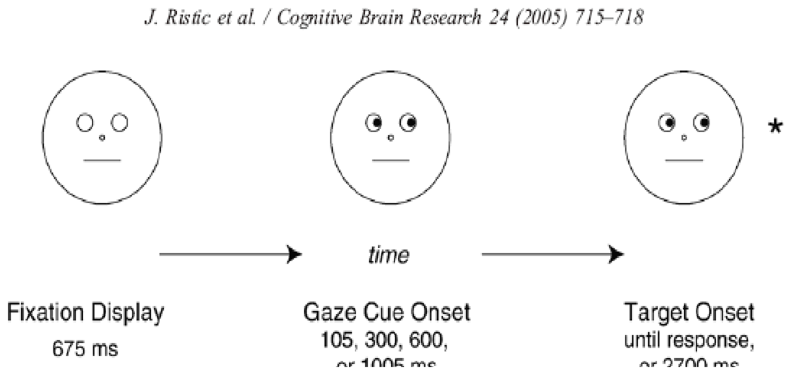
Eye gaze movements and attention experiments

This section closely reviews studies that have used gaze movements as well as other types of social and non-social stimuli (i.e. arrows) to reflexively orient attention. The current experiment expands upon this prior field of research.

Driver et al., (1999), Friesen and Kingstone (1998) and Langton and Bruce (1999) published the first studies showing that movements in gaze can trigger reflexive shifts of spatial attention. These results were replicated with variations in the stimuli and timing. The classic paradigm is that a face appears with direct gaze, followed by the pupils appearing shifted to the left or the right (see Figure 1). After a specified duration, a target appears at either the gazed-at location, or the opposite side. Participants are faster to identify the target at the gazed-at location and such a finding suggests that the gaze shift re-directed their attention.

The finding that gaze shifts reflexively orient attention has been replicated many times (see Table 1). Some studies have probed the phenomenon further by asking whether in fact eyes are special, or whether there are other factors which influence the ability for individuals to automatically shift attention to eye movements.

Figure 1 Typical paradigm to use schematic faces with shifts in eye gaze as spatial cues of attention.



Stimuli

Different studies have manipulated the stimuli in gaze cueing experiments. In this way it has been possible to test whether the eyes alone drive the attention shift, or whether the context has manipulated the gaze-shift.

Head Orientation

A group of studies examined whether head orientation influences the ability to shift attention reflexively in response to eye movements. Hietanen (1999) reported that averted eyes drive the shifts in attention, rather than just a shift in the orientation of the head. Specifically, when participants were shown pictures of profile views of heads where the eyes had a compatible gaze, there was no attention shift. But when profile views of the head were shown and the eyes were averted, then attention was shifted. This suggested that information from the head and eyes is integrated. In conjunction with these findings, Langton, Honeyman, and Tessler (2004) reported that head orientation influenced the ability to discriminate direct versus averted eye movements. Furthermore, when eyes were shown alone, without the reference of head orientation, it was harder for participants to correctly identify eye gaze direction. Lastly, Bayliss, di Pellegrino, and Tipper (2004) reported spatial cueing effects when the head was shifted 90 degrees clockwise or anticlockwise and the eyes were averted. Similar to studies with upright faces, after seeing the rotated face participants were asked to find targets on the left or right side. Surprisingly, participants were cued as if the face had been presented upright. These findings, in concordance with Bayliss and Tipper (2006), suggested that there was an object (head)-centered shift of attention. Specifically, when the head was shifted 90 degrees clockwise or anticlockwise and the eyes in the face were averted, attention was shifted in the direction as if the face was presented upright and toward the actual spatial direction of gaze. In conjunction with those previously mentioned, these studies suggest that information of eye direction is integrated from the head orientation.

Another group of studies have specifically examined whether inverting the face 180 degrees influences attention to gaze direction. Changing the face in such a way is relevant because prior face perception experiments demonstrated that inverting the face disrupts configural face processing (Yin, 1969) as well as processing gaze direction. Multiple studies have reported that inverting the face disrupts the automatic shift of attention induced by gaze movements (Kingstone, Friesen, & Gazzaniga, 2000; Langton & Bruce, 1999; Tipples, 2005).

Langton and Bruce (1999) found that inverting the face disrupted attention orienting to vertical cues (i.e. looking up or down) but not to horizontal cues (looking left or right). These findings were replicated by Tipples (2005). Langton and Bruce (1999) also reported that inverting the face did not disrupt the ability to detect direct or averted eye gaze cues (left vs. right). It was suggested that these findings indicate that head position serves as a directional cue only for vertical but not horizontal cues (Tipples, 2005). Interestingly, a study found that when the face is inverted but the eyes remain upright, gaze detection is not disrupted (Jenkins & Langton, 2003). This is in line with the idea that eyes are the most salient aspect of the face to shift attention, and therefore, can induce a reflexive shift without the context of the face.

The finding that there are differential effects when inverting the face, depending on the direction of gaze, has led researchers to ask to what extent other facial features, also influenced by head position, automatically shift attention to gaze movements. Langton et al. (2004) reported that nose angle influenced eye gaze detection but, when the face was inverted, this effect disappeared. This finding provides evidence that there is some type of configural processing related to the ability to detect gaze shifts. In a subsequent experiment Tipples (2005) reported that raising the eyebrows resulted in faster responses to targets than when the eyebrows were not raised. This result also supports the idea that local features may influence the automatic cueing of gaze detection. However, in a follow-up experiment Tipples (2005) reported that irrespective of the eyebrow, raised eyelids (i.e. which exposes more of the sclera as well as increasing the distance between eye brow and eye-lid) enhances the cueing response. Presumably this is because raised eye brows carry emotional information (a cue for surprise or fear or interest) and such emotional states have ‘intentionality’ (Brentano, 1970) in the sense that the mental state ‘refers’ or ‘points to’ something other than itself (i.e., an object or event in the person’s line of sight) (Baron-Cohen, 1995).

In summary, examining the role of head orientation in shifting attention to gaze direction has led to a discussion of the extent to which other facial features serve as direction cues, in conjunction with the eyes. The studies mentioned here suggested that eyes are the most salient cues when examining the attention shifted by gaze movements. However, other facial features and head orientation influence shifts of attention. Since the inversion effect is only found for vertical and not horizontal cues, it remains unclear to what extent the other facial features may influence this phenomenon.

Stimulus expression and identity

A few studies have examined whether the type of stimulus or facial expression has an impact upon the automatic cueing effect reported in these paradigms. Hietanen and Leppanen (2003) found that different facial expressions (happy, angry and fearful) do not influence the spatial cueing affect.

Quadflieg, Mason, and Macrae (2004) reported that different types of cues do not alter the automatic orienting of attention. Specifically, Quadflieg et al. (2004) utilized different schematic pictures of animate faces (human, monkey, chimpanzee and tiger) versus inanimate (apple, glove). The inanimate pictures had eyes placed in them. All cue stimuli that had eyes looking where the target appeared produced faster cueing effects compared to when the cue ‘looked’ in the opposite direction relative to where the target appeared. These findings suggest that identity of the cue does not alter the cueing response. In line with these findings, Ristic and Kingstone (2005) reported that cars with wheels which looked similar to eyes produce automatic shifts of attention when they were referred to as containing eyes (and these were similar to the Quadflieg et al. (2004) pictures). This result was not found however, when the car was first referred to as a car versus as a picture with eyes. These studies indicate that the identity of the stimulus is not important, so long as there are eyes within the stimuli.

Paradigm design

Additional studies have hoped to further understand whether the shift of attention is automatic to the eye movements per se, or caused by another factor. Friesen, Moore, and Kingstone (2005) tested whether it is the cue (eye movement) or just the sudden appearance of a peripheral target, which shifts the participant’s attention. Friesen et al. (2005) used the typical gaze cueing paradigm, but added a second distracter target, which appeared in the mirror location of the other target. Friesen et al. (2005) found that the magnitude of the cueing effect was the same when there was a distracter target or when there was only one peripheral target. This result suggests that it is the eye movements alone which trigger the shift in attention.

Another paradigm manipulation utilized by several studies is to vary the instructions during the task. Driver et al. (1999) and Friesen and Kingstone (1998) informed participants that the eye gaze cue would counter-predict where the target would appear. Both studies reported that despite informing participants that the eye gaze cue would be non-predictive, participants still showed a cueing effect. Driver et al. (1999) further showed that when the gaze cue was anti-predictive (targets were more likely at the location opposite the cue), a cueing effect was still observed. These findings demonstrate that the shift in attention is reflexive.

Bayliss and Tipper (2006) reported that when participants viewed faces whose eyes would always predict the target location, vs. never, or vs. half of the trials, the participants rated those that always predicted target location as more trustworthy compared to those that never predicted target location. While there were no differences in cueing effects in changing the directions (Driver et al., 1999; Friesen & Kingstone, 1998) these findings suggest that shifts in gaze influence personality trait attribution (Bayliss & Tipper, 2006).

Studies have used different time durations between the target stimuli and the cue, SOAs. The reflexive shift of attention to gaze direction can be produced after seeing the cue for only 100ms (Driver et al., 1999; Langton & Bruce, 1999). Previously mentioned in the section 'Mechanisms of Attention,' there is no Inhibition of Return (IOR) to cued target locations. Therefore, when the gaze shift cue occurs for 700ms (Driver et al., 1999) or 1000ms (Langton & Bruce, 1999), there is no latency in response to the cued targets versus the non-cued targets. One experiment (Frischen & Tipper, 2004) reported IOR to gaze cues at SOAs of 2400ms.

Table 1 Summary of experiments that utilized face, gaze and/ or arrows as cues to shift attention

Experiment	Stimuli Type	Variables	Main Finding
Friesen and Kingstone (1998)	Schematic face	L or R averted gaze vs. target location	Gaze shifts reflexively orient attn
Driver et al. (1999)	Static digitized head-only	L or R averted gaze vs. target location	Gaze shifts reflexively orient attn
Langton and Bruce (1999)	Static digitized head-only	Head orientation and gaze shifts (up,down, L and R) vs. target location	Head and gaze shifts reflexively orient attn
Hietanen (1999)	Static digitized head-only	Head orientation vs. gaze shifts (L and R) vs. target location	Averted eyes shift attention, regardless of head orientation. Profile head views without eye shift do not
Langton and Bruce (2000)	Digitized male face, neck and torso	Finger pointing gestures vs. head direction and gaze	Head-direction and hand gestures produced interference effects
Ristic, Friesen and Kingstone (2002)	Schematic face and arrows	Gaze shifts and arrow directions vs. target location	Both cues reflexively orient attention in adults and preschoolers. Split brain patient data suggests different neural systems
Tipples (2002)	Digitized arrows	Arrow direction vs. target location	Arrows reflexively orient attn
Friesen and Kingstone (2003)	Schematic faces	Gaze shifts measured with keypress and eye movements	No enhancement for overt vs. covert orienting
Friesen and Kingstone (2003)	Schematic faces	Averted gaze with abrupt onset cues	Eye gaze does not produce IOR
Hietanen and Leppanen (2003)	Schematic and real dynamic faces	Gaze shifts with diff. Expression and stimuli type	Orienting to eye shifts is independent of expression
Bayliss et al. (2004)	Digitized faces	Eye shifts and head orientation 90deg	Eyes coded in relation to head orientation
Frischen and Tipper (2004)	Photographed faces, objects	Different stimuli and SOA intervals	Gaze produces IOR at longer SOAs
Friesen, Ristic and Kingstone (2004)	Gaze cues and arrows	Gazed at locations for reflexive vs. voluntary orienting	Gaze but not arrows reflexively orients covert attn
Quadflieg et al. (2004)	Faces, animals and objects w/eyes, arrows	Identity of cue vs. target location	Orienting to gaze is insensitive to identity of gaze cue
Bayliss et al. (2005)	Digitized faces	L or R averted gaze and arrows vs. target location	Cueing affect to gaze and arrows greater in women vs. men
Friesen, Moore and Kingstone (2005)	Schematic face	L or R averted gaze vs. target location and distracter	Cueing affect the same with or without distracter
Gibson and Bryant (2005)	Arrows	Cue timing intervals	Cue duration effects attention shifts and appears to be a top-down process
Ristic and Kingstone (2005)	Schematic face and car	L or R averted gaze or wheels vs. target location	Once stimulus is seen as eyes, effect persists

Experiment	Stimuli Type	Variables	Main Finding
Tipples (2005)	Schematic and digitized faces	1. Inverted faces, eyes. 2. Eyebrows raised. 3. Sclera and iris inverted. 4. Angry expression	Orienting affected by changeable aspects of the face vs. invariant
Bayliss and Tipper (2006)	Real face picture	Faces 1.always looked at target 2.never or 3. both	Gaze cues influence personality perception
Bayliss and Tipper (2006)	Digitized faces	Eye shifts and head orientation 90 degrees	Gaze cues influence spatial and object-centered attention

Gestures

Non-verbal gestures are intrinsically linked to how we communicate with other individuals. The traditional view regarding gestures is that they are distinct from spoken language. Gestures were thought to be for the benefit of the speaker (Rime & Schiaratura, 1991) and therefore it was assumed that it was not important for listeners to process or even attend to gestures. Others have argued that gestures are crucial for the listener to be able to decode the speaker’s communicative intent i.e., the meaning (Kendon, 1980; McNeill, 1992). Langton, O'Malley, and Bruce (1996), using a version of the Stroop paradigm, showed that participants were unable to ignore gestures when coupled with spoken words. Because gestures contain so much communication information, it is not surprising young human children develop the skills to perceive and produce gestures from a very early age (Bruner, 1974).

For the purpose of this review, as it relates to the current experiment, only one specific gesture, finger pointing, is discussed. Finger pointing is a universal gesture in social communication to convey what the gesturer is referring to, or where the gesturer wants the listener to shift their attention (Scaife & Bruner, 1975).

There is a significant limitation in examining finger pointing perception in non-human primates. Extended index finger pointing is not consistently used by non-human species as a communicative gesture (Leavens & Hopkins, 1999). However, by studying how they interpret *human* finger pointing, we can hope to further understand the development of this gesture in humans.

The data is inconclusive whether the human pointing gesture has social meaning for non-human primates (for a review across non-human species, see Miklosi and Soproni (2006)). Some studies suggest that pointing gestures do cause a shift in attentional orientation to varying degrees in non-human species. Capuchin monkeys respond to dynamic pointing (Anderson, Sallaberry, & Barbier, 1995; Vick & Anderson, 2000) whereas chimpanzees are not as responsive (Tomasello, Call, & Hare, 1997). However, variables such as time spent with humans, how the pointing gesture was produced (i.e. with gaze or other body movements, static vs. dynamic) and how far away the experimenter was from the animal have made conclusions difficult to draw (for analysis and review see (Miklosi & Soproni, 2006)). In sum, the non-human primate data regarding pointing as an attentional cue is somewhat unclear.

Research with human children provides evidence that finger pointing is associated with language development. Infants as early as 12 days old imitate finger movements (Meltzoff & Moore, 1977). Finger pointing is assumed to reflect communicative intent, prior to actual language development (Masataka, 1995). Masataka (1995) reported that by

3 months old, index-finger extensions occur more frequently with speech-like vocalizations. Children at 14 months old understood that a pointing gesture would lead them to a hidden toy, therefore, understanding the gesture as communicative (Behne, Carpenter, & Tomasello, 2005). In terms of producing their own gestures, spontaneous pointing has been observed from as young as 9-14 months, and at least 3 functional forms of the gesture have been distinguished: protoimperative pointing (pointing to obtain something), protodeclarative pointing (pointing to share attention), and pointing to name an object (Baron-Cohen, 1987; Baron-Cohen & Staunton, 1994; Bretherton & Beeghly, 1982; Camaioni, Perucchini, Muratori, & Milone, 1997).

Goldin-Meadow and Wagner (2005) suggested that pointing helps the listener to understand the speaker's thoughts, and in this sense it has been regarded as a precursor in the development of a 'theory of mind' (Baron-Cohen & Swettenham, 1996). Delay in pointing has also been found to predict language delay and autism (Baron-Cohen et al., 1996).

Supporting evidence that pointing is important comes from neurological research. Single cell recordings suggest perception of body movements have been localized in the macaque brain. Perrett et al. (1985) found neurons responsive to general body movements in the STS. An fMRI study with monkeys corroborated these findings (Pinsk et al., 2005). When non-human primates were shown moving macaque body parts these activated the STS. Jellema and Perrett (2003) reported that cells in the STS had a more robust activation in response to seeing faces *after* body movements were shown, versus being shown other types of movement prior to the faces. These findings suggested that these cells respond to agentive behaviour.

There are regions in the human brain uniquely responsive to the perception of biological motion, including gestures. Areas in the inferotemporal regions, including the STS, are responsive to meaningful versus meaningless gestures (Decety et al., 1997; Grezes, Costes, & Decety, 1999). Instrumental gestures such as protoimperative pointing (i.e. look over there) activate the left inferior frontal cortex and left middle frontal cortex, both the laterality (left hemisphere) and specific areas are regions associated with language processing (Gallagher & Frith, 2004). These findings suggest that biological motion is a unique type of stimulus coded in neural regions that are specifically attuned to these stimuli.

Sex differences

In non-human primates, Thomsen (1974) reported that young female rhesus monkeys made more frequent eye contact with the experimenter. Research with humans has found that female neonates spend more time looking at a face whereas male neonates spend longer looking at a mechanical mobile (Connellan et al., 2000). This finding suggests an innate difference in processing social stimuli between the sexes. At 12 months of age, females spend more time looking at faces as opposed to moving cars, whereas males show the opposite preference (Lutchmaya & Baron-Cohen, 2002).

Many studies have found specific cognitive differences between men versus women. There is a male superiority on spatial tasks such as mental rotation (Collins & Kimura, 1997; Geary, Gilger, & Elliott-Miller, 1992; Voyer, Voyer, & Bryden, 1995) whereas women are better at episodic memory (Herlitz, Nilsson, & Backman, 1997) and some verbal tasks (Hyde & Linn, 1988). Neuroimaging data support these behavioural differences, showing that different neural regions are recruited in men and women during mental rotations tasks (Butler et al., 2006) verbal and memory tasks (Frings et al., 2006).

Of specific relevance to the current study are the differences in men and women in perceiving the social environment (e.g., faces). Women have better face recognition skills as opposed to men, and these are not explained by different levels in estradiol (Yonker, Eriksson, Nilsson, & Herlitz, 2003), intelligence (Herlitz & Yonker, 2002) or verbal processing (Herlitz, Airaksinen, & Nordstrom, 1999). Women are better at picking up subtle nuances from facial expressions (Hall, 1978). Women rate happy and angry faces as being very intense, whereas men only rate the angry faces as being intense (Biele & Grabowska, 2006). This finding suggests that angry faces are potentially more salient to men, whereas women find happy faces just as salient. Men and women show differential brain activations when seeing faces (Fischer et al., 2004). Finally, Bayliss et al. (2005) reported women had a greater reflexive response to shifts in gaze as well as to arrows. These studies all suggest that men differ from women in how they process social cues, specifically faces.

Autism Spectrum Conditions

Autism Spectrum Conditions (ASC) is the term used to describe individuals who have a diagnosis of autism, High-Functioning Autism (HFA) or Asperger Syndrome (AS). The word 'spectrum' denotes the heterogeneity of the condition and that the level of functioning varies among this population. Often the terms High-Functioning Autism and Asperger Syndrome are used interchangeably because individuals with these diagnoses present with similar symptoms. All subdivisions of the ASC are considered Pervasive Developmental Disorders (PDD), conditions which significantly impair children's social and psychological development (APA, 1994).

Autism is characterized by impairments in three categories: Social interaction, communication, and restricted, stereotyped and repetitive behaviours (preoccupation with parts of objects) (APA, 1994). Individuals with AS are considered a separate diagnostic category because they do not manifest a delay in language or cognitive development (APA, 1994). If an individual meets diagnostic criteria for Autism or has an early language delay, they can never receive a diagnosis of AS (APA, 1994).

Currently, there is some controversy about whether there should be diagnostic distinctions among individuals with AS and those with HFA. While these distinctions are clear in terms of diagnostic criteria, often individuals with HFA appear to be very similar to those with AS. Therefore, when analyzing studies that include individuals with an ASC, it is imperative to be cautious of any conclusions which are made about the entire spectrum, if only a subgroup has been tested.

Prevalence and Etiology

Autism affects approximately 5.6 out of 1000 children in the United States (Shieve, Rice, Boyle, S.N., & Blumberg, 2006). ASC affects boys more than girls (4:1 boys to girls) and when examining the AS population alone, the ratios can surge up to 10:1 (boys to girls) (Ehlers & Gillberg, 1993).

There is currently no single known cause of ASC. However, studies among siblings strongly suggest that there is a strong genetic factor (Bailey, 1995). Relatives of individuals with ASC express some of the phenotype related to the condition (Bailey, Palferman, Heavey, & Le Couteur, 1998; Baron-Cohen et al., 2006; Bishop, Maybery, Wong, Maley, & Hallmayer, 2006). While there has been a lot of press regarding specific environmental agents that may cause ASC (i.e. the MMR vaccine) there is currently no conclusive evidence to support such a claim (Richler et al., 2006).

Social Interaction Impairments

Among the three core impairments in ASC, many studies have focused on abnormal social interactions. The qualitative impairments include irregular use of gaze, a lack of seeking to share enjoyment with others and abnormal gestures during social exchanges (APA, 1994). One method to examine these impairments is to study how individuals with ASC process and interpret faces and facial features, specifically the eyes.

Faces

Langdell (1978) was among the first to report abnormal face processing in adolescents with autism. He demonstrated that the autism population had poorer whole face processing, focused more on the mouth region and were superior at identifying inverted faces compared to typically developing controls. Other studies have replicated these findings.

Abnormal whole face perception in children with autism was reported by Tantam, Monaghan, Nicholson, and Stirling (1989) who demonstrated deficits in face discrimination. Boucher and Lewis (1992) reported that face recognition was impaired in children with autism compared to typically developing controls. Boucher and Lewis (1992) found that there was a preference for buildings compared to faces in the autism population. This inclination for the inanimate object was not surprising because individuals with ASC often prefer to play with objects versus spend time with people (Baron-Cohen et al., 1986).

The superior processing of inverted faces in those with ASC (or the lack of a face inversion effect) was replicated by Hobson, Ouston, and Lee (1988). van der Geest, Kemner, Verbaten, and van Engeland (2002) found that greater time was spent on inverted faces by those with HFA compared to controls, as measured by eye tracking. As previously mentioned, inverting faces disrupts holistic face processing, and typically developing individuals have greater difficulty processing the rotated face. The finding that individuals with ASC have no disruption when seeing inverted faces suggests that they have impairments processing the face holistically (Jolliffe & Baron-Cohen, 1997; van der Geest et al., 2002).

These behavioural reports have been corroborated by brain imaging studies. Studies have examined whether face responsive regions in the brain in typically developing individuals are similarly activated in the ASC population. To date, the neuroimaging data is somewhat inconclusive. Some studies report abnormal FG and STS activation to faces in the ASC population (Hubl et al., 2003; Pierce, Muller, Ambrose, Allen, & Courchesne, 2001; Schultz et al., 2000) whereas others have not replicated this (Hadjikhani et al., 2004; Pierce, Haist, Sedaghat, & Courchesne, 2004). Interestingly, one study reported that FG activation in the ASC population correlated with the amount of time spent fixating on the eye region of the face (Dalton et al., 2005). This finding suggests that abnormal face processing by individuals with ASC may be explained by the lack of time spent looking at the eye region. Lastly, an intriguing finding that parents of children with autism had poorer face recognition abilities compared to control adults suggests that there may be a genetic factor in face processing skills (Dawson et al., 2005).

Eyes

Joseph and Tanaka (2003) demonstrated that typical individuals are adept at identifying faces from the eyes, whereas individuals with ASC performed best when relying upon the mouth. This finding fits with eye tracking studies showing that individuals with autism spend more time focusing on the mouth region compared to the eyes (Klin, Jones, Schultz, Volkmar, & Cohen, 2002) and less time on all facial features (eyes, nose and mouth) as opposed to non-feature areas of the face (Pelphrey et al., 2002). Baron-Cohen, Wheelwright, and Jolliffe (1997) demonstrated that typical individuals use the eye region of the face to decode complex emotional expressions, whereas decoding basic emotional expressions is possible with equal success using the mouth region. People with ASC exhibited deficits in complex emotion recognition, particularly when only the eyes were available.

These results suggest that the strategies to process faces are different in those with ASC compared to controls. A series of experiments have studied whether individuals with ASC differ from controls in their ability to detect shifts in gaze movements and reflexively shift attention in response to gaze movements. Senju, Yaguchi, Tojo, and Hasegawa (2003) reported with an oddball task that children with autism showed no differences in detecting the direct gaze targets versus the averted gaze targets, whereas typically developing children were superior at distinguishing direct gaze versus the averted gaze. To date, results are inconclusive as to whether shifts in gaze reflexively orient attention in individuals with ASC compared to controls.

A series of studies Chawarska, Klin, and Volkmar (2003), Kylliainen and Hietanen (2004), Senju et al. (2004) and Swettenham et al. (2003) have reported that shifts in gaze *do* reflexively shift attention in the ASC population. Kylliainen and

Hietanen (2004) reported that children with autism automatically shifted attention to static gaze cues. There were no differences between the groups in their ability to discriminate where the gaze was directed (left, right or direct). Swettenham et al. (2003) found that children with autism were similar to controls in that they automatically shifted attention to static gaze cues. In Experiment 2, Swettenham et al. (2003) used inverted faces and reported that there was still a cueing effect that occurred in both groups. This result is in line with prior studies in typically developing individuals showing a cueing effect in inverted faces with horizontal eye cues (Langton & Bruce, 1999; Tipples, 2005). However, the authors were somewhat surprised by the result and suggested that the repeated number of presentations of the stimuli might have induced the cueing effect (Swettenham et al., 2003).

Chawarska et al. (2003) reported with eye movement data that children aged 2 years with autism oriented to peripheral targets after seeing gaze direction cues. However, there were group differences for scrambled faces. The children with autism did not differentiate between scrambled versus non-scrambled stimuli, whereas the typically developing toddlers attended more readily to the non-scrambled eye movements. Lastly, Senju et al. (2004) reported that eye gaze shifts and arrows reflexively oriented attention in children with autism. All volunteers were first told that the cue would correctly show where the target was going to appear on 50% of the trials. For the second experiment, the participants were told the cue would be predictive on only 20% of the trials and therefore, it should be ignored. There were no differences among the groups for the first experiment. During this second experiment, typically developing children had less reflexive shifts of attention to the arrows as compared to the eyes. This result confirmed that eyes automatically cue a shift in the viewer's attention, even when they were consciously ignored. In contrast, the autism group was equally cued by the eyes and the arrows, indicating that they did not have an automatic preference for the social cue. This finding is similar to that of Chawarska et al. (2003), suggesting that non-social stimuli are more salient for the autism group compared to the controls.

In contrast, Johnson et al. (2005), Ristic et al. (2005), and Vlamings et al. (2005) and have shown that there are differences between the ASC population and controls when viewing shifts in gaze, specifically that they do not have a reflexive shift of attention. Ristic et al. (2005) reported that when gaze cues were predictive of target location only 20% of the time, typically developing controls shifted attention to the eyes automatically, whereas the adults with HFA did not. Senju et al. (2004) also reported population differences for non-predictive arrow cues, yet this study expanded those findings by demonstrating a difference to non-predictive gaze cues. Vlamings et al. (2005) reported that adults with HFA had no reaction time differences to the gaze cues versus the arrow cues. However, the typically developing group were significantly slower to the gaze cues versus the arrows. Secondly, Vlamings et al. (2005) reported that there was a difference in right versus left cueing for the eye task in the control group, but not for the arrows. The adults with HFA did not have a laterality effect for either eyes or arrows. These results suggest there is a difference in the control population in response to the eyes versus arrows, which was not found in the HFA group.

Johnson et al. (2005) reported that toddlers with autism did not differentiate between congruent (when cue predicted target location) and incongruent trials (when cue did not predict target location) during a spatial attention paradigm with eye movements as the cues. Eye tracking was used to measure saccades as participants oriented to targets. While the toddlers were able to perform the task, the lack of differentiation to the two different types of trials suggested that they did not have a reflexive shift of attention induced by viewing the eye movements.

Brain imaging and event-related potentials (ERP) data suggested that there are abnormal brain activations when individuals with ASC perceive gaze shifts. Senju, Tojo, Yaguchi, and Hasegawa (2005) found that children with autism had different N2 responses to direct and averted gaze compared to typically developing children. Specifically, the autism group did not have a lateralized response to gaze cues compared to controls. Second, the amplitude for the control group was larger for direct gaze compared to averted gaze, but there were no differences in the autism group. This result fits with the behavioural study that found no differences when children with autism perceived direct versus averted gaze (Senju et al., 2003). Pelphrey, Morris, and McCarthy (2005) reported that adults with autism activated the STS when perceiving shift in eye gaze, similar to controls. However, the autism group did not have differential brain activations when they viewed faces with gaze shifts which either looked at a peripheral stimulus or away from the stimulus. The controls did have distinct brain activation patterns to the two types of stimuli, suggesting that they were processing the meaning of the eye shifts and the greater context of the scene (Pelphrey et al., 2005). Finally, Haist, Adamo, Westerfield, Courchesne, and Townsend (2005) reported that there were abnormal patterns of activation in individuals with ASC during a spatial attention task (not with faces). This finding suggested that the neural foundation for spatial attention may be impaired in individuals with ASC.

While the behavioural studies remain inconclusive about whether gaze movements can reflexively shift attention in individuals with ASC, it appears that processing eye movements and the mental states that these might signify is impaired. Many studies have reported that individuals with ASC are delayed in developing Shared Attention (Baron-Cohen, 1987; Baron-Cohen, Allen, & Gillberg, 1992; Charman et al., 1998; Dawson et al., 2004; Leekam, Lopez, & Moore, 2000; Mundy, Sigman, Ungerer, & Sherman, 1987). These impairments extend to difficulty processing different mental and emotional states from the eye region (Baron-Cohen, 1995; Baron-Cohen et al., 1999; Baron-Cohen, Wheelwright, Hill, Raste, & Plumb, 2001). It may therefore be that the deficits in shared attention and reading mental states from facial expressions are linked to a deficit in automatic orientation to gaze movements, though the nature of this link is not yet well understood.

Gestures

Individuals with ASC use fewer gestures to communicate. Baron-Cohen (1987), Landry and Loveland (1988) and Stone, Ousley, Yoder, Hogan, and Hepburn (1997) reported that children with autism were less likely to use pointing to communicate with another person. Mitchell et al. (2006) reported in young children with autism, 12 months and 18 months, that there were significant delays in producing a variety of communicative gestures, including pointing. This replicates earlier work showing that if children with ASC use pointing at all, it tends to be the protoimperative function (i.e. requesting an object), but that protodeclarative pointing (i.e. sharing experiences) is markedly reduced if not absent (Baron-Cohen, 1989);(Baron-Cohen & Staunton, 1994). This finding confirms reports that pointing development may be tied to typical language development and that delays in gesture may be one of the earliest signs of ASC (Baron-Cohen et al., 1992; Baron-Cohen et al., 1996; Mitchell et al., 2006).

Individual differences on the Autism-Spectrum

Autism-Spectrum Quotient

The Autism Spectrum Quotient (AQ) is a brief, self-report questionnaire that reliably measures autistic traits (Baron-Cohen et al., 2001). The AQ predicts clinical diagnosis of an ASC (Woodbury-Smith, Robinson, Wheelwright, & Baron-Cohen, 2005). Autistic traits are not only found in individuals with a diagnosis, but are also present in the typically developing population along a continuum (Baron-Cohen et al., 2001). Men have significantly more autistic-like traits than women, as measured by the AQ (Baron-Cohen et al., 2001). And students of science and math score higher on the AQ compared to humanities students (Baron-Cohen et al., 2001).

Three experiments of social attention correlated their findings with scores on the AQ. Bayliss et al. (2005), Bayliss and Tipper (2005) and Bayliss and Tipper (2006) used a spatial cueing paradigm with gaze cues and arrows and recorded reaction times for when the cue predicted or did not predict target location. In Bayliss and Tipper (2005) the targets appeared either on a whole face, on a scrambled face, on a tool or on tool parts. Individuals who scored high on the AQ were cued more towards the scrambled cues versus the whole faces or tools regardless of the cue type (gaze or arrow). The effect was strongest for the faces. Specifically, those who scored lower on the AQ were much more strongly cued to the whole face versus those that scored high on the AQ. The authors suggested that those who had higher scores on the AQ found the scrambled objects more appealing because of their bias to process details (Baron-Cohen et al., 2001).

Bayliss et al. (2005) also used a spatial cueing paradigm where eye gaze shifts served as cues and then targets would appear on either the left or right side of the screen. Individuals who scored lower on the AQ were oriented more towards gaze shifts. It should be noted that this difference was only for one of three different cue durations and there was no difference between low or high AQ scorers when viewing arrows. However, only a subgroup of the participants completed the AQ. Therefore, there was a very small sample size. This experiment supported the notion that social attention behaviour could be correlated with scores on the AQ.

Lastly, Bayliss and Tipper (2006) used the spatial eye gaze cueing paradigm to examine personality judgements. As previously mentioned in the section ‘paradigm design' participants rated the faces which always predicted target location to be more trustworthy than the faces which never predicted target location. This personality assessment in individuals who had high scores on the AQ was less pronounced compared to the low AQ scorers. This suggested that individuals with high AQ scores did not use gaze direction to judge personality as compared to the low AQ scorers.

Empathy Quotient

Empathy is the drive to identify the emotional state of another individual and then to respond with an appropriate emotion to their emotional state (Baron-Cohen & Wheelwright, 2004). The ability to empathize with another individual is crucial for social communication. The Empathy Quotient (EQ) is a brief, self-report questionnaire which reliably measures an individual's ability and tendency to empathize. Individuals with ASC score lower on the EQ compared to the typically developed population (Baron-Cohen & Wheelwright, 2004). Prior research with EQ reported that the general population also differs along a continuum on the EQ, and men score significantly lower than women (Baron-Cohen & Wheelwright, 2004). Lawrence, Shaw, Baker, Baron-Cohen, and David (2004) reported that there was an association between the EQ and the ability to infer different mental states from eyes. This result confirmed that the EQ is a validated measure of empathy.

Systemizing Quotient

Systemizing is the drive to analyze or construct rule-governed systems. The Systemizing Quotient (SQ) is a brief, self-report questionnaire that reliably measures an individual's tendency to systemize (Baron-Cohen et al., 2003). Individuals with ASC score significantly higher than the general population on the SQ (Baron-Cohen et al., 2003). Among the general population, men score significantly higher on the SQ compared to women (Baron-Cohen et al., 2003).

The AQ, EQ and SQ are correlated (Wheelwright et al., 2006). Specifically, AQ can be predicted by the difference between scores on the EQ and SQ. Individuals who score higher on the AQ have higher SQ scores but lower EQ scores (male profile) whereas those who score lower on the AQ have lower SQ scores but higher EQ scores (female profile). Second, there is a small negative correlation between the EQ and SQ. This suggests that there is a slight trade-off between these two abilities (Wheelwright et al., 2006).

The Extreme Male Brain

Based upon the results from the AQ, EQ and SQ, as well as other psychological experiments, Baron-Cohen (2002; 2003) suggested a general principle for how individuals with ASC, and men and women in the general population function in the social and non-social environment. Specifically, Baron-Cohen (2002) suggested that men (on average) have a stronger drive to systemize, whereas women (on average) show a stronger drive to empathize. Individuals with ASC can be conceptualized as having an extreme of the typical male profile (Baron-Cohen, 2002; 2003).

Current Experiment: Aims and Hypotheses

The current experiment examines whether there are differences in shifts of attention to social vs. non-social stimuli in typically developing men vs. women and provides preliminary data on whether there are differences in individuals with ASC. There were 5 specific aims to the experiment.

1. To test whether stimuli reflexively oriented attention. It was hypothesized that the stimuli would reflexively orient attention as measured by mean reaction times (RT) to the congruent (when cues predicted target locations) versus incongruent trials (when the cue did not predict target location).

2. To measure whether there would be differences in shifts of attention to social (faces and hands) versus the non-social (arrows, cars and squares) stimuli. The hypotheses were that there would be overall faster RT to the social stimuli. Furthermore, it was hypothesized that faces would induce faster shifts of attention based upon the saliency of faces and eyes as compared to hands.

3. To test whether there were differences in men versus women in their ability to shift attention to the social versus non-social stimuli. The hypotheses were that women would be faster to shift attention to the social stimuli (Bayliss et al., 2005).

4. To test whether three measures of cognitive style (Autism Quotient, Empathy Quotient, and Systematizing Quotient) correlate with orienting of attention to social versus non-social stimuli. It was hypothesized that individuals who scored higher on the AQ and SQ would be faster in orienting to the non-social stimuli, whereas individuals who scored higher on the EQ would orient faster to the social stimuli (Baron-Cohen et al., 2003; Baron-Cohen & Wheelwright, 2004; Baron-Cohen et al., 2001).

5. To test whether individuals with ASC would differ from typically developing controls in their shift of attention to the two broad types of stimuli. The hypotheses were that the ASC population would be slower to orient to the social stimuli and would be faster at responding to the non-social stimuli, specifically the cars.

While multiple experiments have utilized faces or eye movements to produce shifts of spatial attention, no prior studies in typically developing individuals or those with ASC have directly examined the difference between faces vs. hands vs. cars. Second, only one prior study reported a sex difference in orienting attention. Lastly, only two studies have used the AQ as an independent measure of cognitive style as it relates to reflexive shifts of attention to social stimuli. This experiment contributes more data and adds additional information by using the EQ and SQ, which measure two different dimensions of social communication.

Method

Participants

Cambridge University Students

A total of 67 Cambridge University students participated in the experiment. Seven were excluded from analysis because they failed to complete the AQ, EQ and SQ. The final group of participants consisted of 30 male students (27 right-handed, 3 left-handed; mean age 21.500 years; SD: 2.789) and 30 female Cambridge University students (28 right-handed, 2 left-handed; mean age 21.449; SD: 2.944). Data from these 60 participants is complete and so is fully analysed in this thesis, as a test of the first 4 aims.

Autism Spectrum Condition Participants

20 people with a diagnosis of High-Functioning Autism or Asperger Syndrome are being recruited to participate in the experiment. Participants have been recruited via the Autism Research Centre. All have a diagnosis of ASC by a qualified professional based on DSM-IV critieria (APA, 1994) and by definition had no history of general developmental delay. At the time of submission, 7 of these 20 have been fully tested, and their results are reported as work in progress. Their data are relevant to the fifth aim, but will be completed beyond the time scale of the submission of this thesis.

Age Matched, General Population Controls

In order to provide an age and education-matched control sample for the ASC participants, *non*-Cambridge University students must be recruited and tested. (At the time of submission, only two individuals have participated and therefore, will not be reported here. This data collection is on-going). This group is essential for testing the 5th aim of this project, but is outside the timeframe for the submission of this thesis.

All participants took part in the experiment in exchange for £5. Prior to participating, all individuals signed an informed consent form (see Appendix 1) and were told they could terminate participation at any point during the experiment. All participants had normal or corrected vision and were naïve to the purpose of the experiment.

Stimuli and Apparatus

There were six types of stimuli divided into social (male and female faces and hands) versus non-social (cars, arrows and squares). The male and female face, hand and car were all dynamic videos. The videos were recorded indoors with a digital camera. All video stimuli were recorded in front of a white sheet which served as a background. The videos were imported and edited in iMovie.

The face stimuli were of the head and shoulders and measured 8cm X 5.5cm on the screen (see Figure 2). The man and woman volunteered to be videotaped. The car was a yellow toy car and measured 5cm X 5cm on the screen (see Figure 3). The hand was a female hand and only the wrist and below was visible (see Figure 2). The hand measured 5cm X 4.5 cm on the screen.

The non-dynamic stimuli (crosshair, arrows and squares) were constructed in PowerPoint. The arrows measured 5.5cm X 0.5cm and the squares 2cm X 2cm.

All stimuli were viewed on a Dell Latitude 1300. The stimuli were presented and the data was recorded in DMDX (Forster & Forster, 2003).

The AQ, EQ and SQ

Prior to participating, individuals were asked to complete the AQ, EQ and SQ and answer personal data questions (age, occupation, highest level of education, handedness and other known DSM-IV diagnoses) online at www.cambridgepsychology.com. If they had not registered on the website and completed the questionnaires prior to testing, they were sent follow up requests to do so.

The AQ is a 50-item, self-report questionnaire which assesses social skills, communication skills, imagination abilities, attention switching and attention to details (Baron-Cohen et al., 2001; Woodbury-Smith et al., 2005). There are 10 statements in each of the 5 categories and participants had to choose whether they ‘strongly agree’, ‘slightly agree’, ‘slightly disagree’, or ‘strongly disagree’ with each statement. 1 point was given if they choose the ‘autistic’ type response and otherwise they received a 0. The higher the score on the AQ, the more autistic-like traits the individual possesses.

The EQ is a 60-item, self-report questionnaire which assesses empathy (Baron-Cohen & Wheelwright, 2004). There are 40 statements and 20 filler statements in order to distract the participant from the subject of the questionnaire. Like the AQ, participants had to choose whether they ‘strongly agree’, ‘slightly agree’, ‘slightly disagree’, or ‘strongly disagree’ with each statement. 1 point was given if the participant had the mildly empathetic behaviour or 2 points if they gave a response for the strong empathic behaviour. The higher the score on the EQ, the more empathy the individual possesses.

The SQ-Revised (SQ-R) was used in this experiment as an updated version of the SQ (Wheelwright et al., 2006). It is a 75-item, self-report questionnaire which assesses systemizing tendencies (Baron-Cohen et al., 2003). The statements had agreement or disagreement statements similar in format to that used in the AQ and EQ (see above). The SQ-R was scored such that 1 point was given if the participant chose the mildly systematizing behaviour and 2 points if they gave the response for the strong systematizing behaviour. The higher the score on the SQ-R the more systemizing tendencies the individual possesses.

Procedure

All participants completed the experiment in a quiet testing room in the Downing Site at Cambridge University. Including practice trials, the experiment took approximately one hour to complete. Individuals were seated comfortably in a well-lit room and were approximately 57 cm from the computer screen.

Each trial started with a black cross hair on a white background which appeared for 670 ms and was then followed by a static image for 900ms of the stimuli in a neutral state. For the faces, car and hands the neutral state was the stimulus pointing directly at the viewer. For the arrow trials a straight black line appeared without an arrow head. And for the square trials, two black squares appeared, neither one was bolded (see Figure 3). Following the neutral state, the stimuli would change to become a cue. The faces, hands and car would shift 40 degrees to the left or 40 degrees to the right for a total duration of 300ms. For the arrow trials, an arrowhead would appear for 300ms on either the left or right side (see Figure 3). And during the square trials, one of the two squares would become bolded for 300ms (see Figure 3).

After the cue had disappeared, a white screen would appear with either the letter 'T' or the letter 'F' presented on either the left or right side of the screen. If the letter was a 'T', then the participant was asked to press the left shift key on the keyboard. If it was an 'F', then they pressed the right shift key. Participants were told to watch the videos or pictures and then respond as quickly and as accurately as possible to the targets.

The cues predicted the target location for 50% of the trials and were in a random order for each stimuli type. There were a total of 120 trials for the hand and car conditions, 60 trials for the female face, 60 trials for the male face and 60 trials for the arrow and square conditions. Within each stimulus type, there was an equal number of 'T's and 'F's which appeared in a random order and were also equally presented on the left and right side of the screen. Each stimuli type made up a single block and each participant saw all six blocks. The order in which the blocks appeared was randomized for each participant, except for cars. Cars were the first stimuli presented to all participants in order to ensure that they were viewed as cars per se, and not as a face-like object (Ristic & Kingstone, 2005). Each participant completed a practise trial before beginning the experiment.

Figure 2 Examples of the social stimuli and time course. The top row shows an incongruent trial for the hand stimuli, middle row shoes a congruent trial for the female face and the bottom row shoes a congruent trial for the male face. The hand and face images are still-frames taken from the videos.

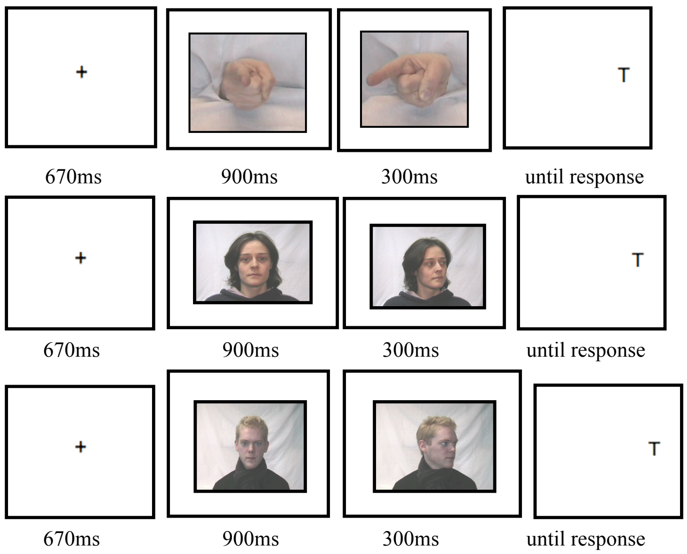
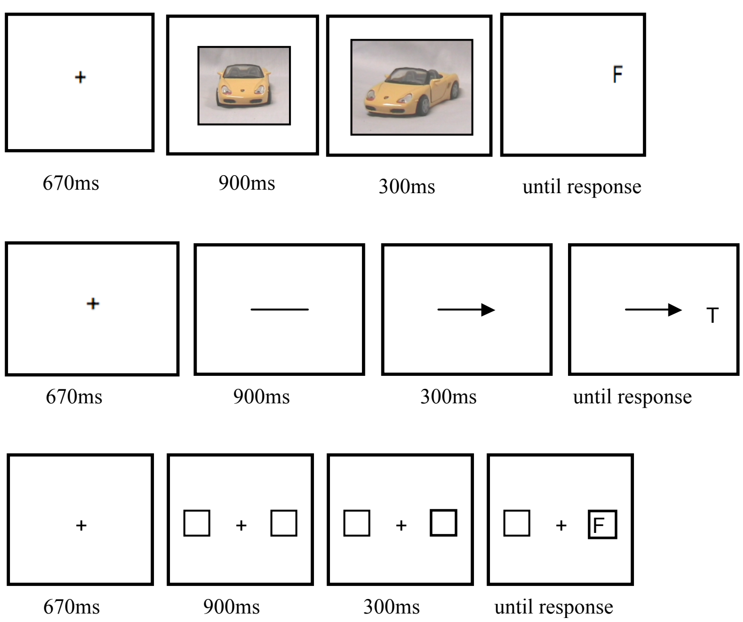


Figure 3 Examples of the non-social stimuli and time course. The top row shows an incongruent trial for the car stimuli, middle row shows a congruent trial for the arrows and the bottom row shoes a congruent trial for the squares. The car images are still-frames from the video.



Design

The dependent measure was the participant reaction time (RT) for the stimuli. The within-subject factor Stimuli Type was whether the stimulus was a social (face or hand) or non-social cue (cars, arrows or squares). The other within-subject factor was Cue Type. There were two Cue Types: congruent was when the cue predicted target location, whereas incongruent was when the cue was in the opposite direction as where the target appeared.

There were two phases of data analysis for the student data. Phase 1 was a 2 X 2 repeated measures analysis of variance with Stimuli Type (social vs. non-social) and Cue Type (congruent vs. incongruent) as within-subject factors. Sex of the participant was a between subject factor and the scores on the AQ, EQ and SQ were covariates. Phase 2 of analysis comprised of three parts in order to further understand how scores on the AQ, EQ and SQ influence reaction times to the different stimuli. Data was divided into groups depending on how individuals scored on the AQ, the EQ; and the SQ.

First, high and low AQ scorers were identified as the top 33.3% or bottom 33.3% of scorers and separated into two groups and those in the middle were excluded from analysis. A 2 X 2 repeated measures analysis was performed with sex of participant and AQ group (high or low) as between subject factors. The EQ and SQ were covariates.

Second, high and low EQ scorers were identified as the top 33.3% or bottom 33.3% of scorers and separated into two groups and those in the middle were excluded from analysis. A 2 X 2 repeated measures analysis of variance was performed with sex of participant and EQ group (high or low) as between subject factors and the AQ and SQ scores were covariates.

Lastly, high and low SQ scorers were identified as the top 33.3% or bottom 33.3% of scorers and separated into two groups and those in the middle were excluded from analysis. A 2 X 2 repeated measures analysis of variance was performed with sex of participant and EQ group (high or low) as between subject factors and AQ and EQ scores as covariates.

Due to the small sample of ASC participants, no statistical testing is yet appropriate for their data. This will be completed after the timeframe of the thesis, but some description of the preliminary ASC data is reported.

Preliminary task validation

After five Cambridge University student participants had completed the experiment, the mean RT data for correct trials was analyzed for each stimuli type. This was to check whether there was a difference in the Cue Types (congruent vs. incongruent trials). Since multiple prior studies reported a strong main effect of Cue Type (see 'Eye Gaze Movements and Attention Experiments'), it was imperative that this difference in mean RT was found even in N = 5. Preliminary analysis of each person and overall averages found that congruent trials for all 6 stimuli were on average faster than mean RT for incongruent trials. No other preliminary analyses were completed on this small subgroup.

Results

Student Data

Mean RTs were calculated for each participant for the six stimuli conditions (congruent X incongruent). Errors for each stimuli type were calculated and removed from RT analysis (average 3.4%). Responses slower than 1,000ms or faster than 250ms (1.67%) or 2 standard deviations above or below the mean (4.5%) were removed from RT analysis. The social stimuli were averaged by cue type (hands/female face/male face X congruent vs. incongruent) and the non-social stimuli were averaged by cue type (arrows/cars/squares X congruent vs. incongruent).

A pairwise comparison found no difference in error rates for the social (3.49%) versus non-social (3.24%) stimuli $t\ (59) = -\ 1.052$, $p < 0.297$.

There was a main effect of Cue Type $F(1, 55) = 7.222$, $p < 0.010$, with faster RT on congruent trials (see Table 2). There was also a main effect of Stimuli Type $F(1, 55) = 6.556$, $p < 0.013$, with faster RT to the social stimuli (see Table 3). The interaction between the two independent variables was not significant $F(1,55) = 2.260$, $p < 0.138$.

There was no significant difference between men and women for Cue Type $F(1, 55) = 1.257$, $p < 0.267$ nor was there an effect of sex for Stimuli Type $F(1, 55) = 2.396$, $p < 0.127$. The observed power for the effect of sex and Cue Type was 0.197, partial eta-squared was 0.022. The observed power for the effect of sex and Stimuli Type was 0.331, partial eta-squared was 0.042.

Table 2
Main Effects: Reaction times in ms and standard error of the mean (SEM) for all student participants for congruent vs. incongruent trials

Cue Type	Mean	SEM
congruent	460.17	5.501
incongruent	480.946	5.151

Table 3

Main Effects: Reaction times in ms and standard error of the mean (SEM) for all student participants for social vs. non-social trials

Stimuli	Mean	SEM
social	452.8074	5.6313
non-social	488.3066	5.4371

Table 4 Reaction time in ms and standard deviation (STD) for all student participants for all stimuli types

Stimuli	Congruence	Mean	STD
arrows	congruent	480.698	58.52
arrows	incongruent	480.029	58.489
cars	congruent	481.737	58.43
cars	incongruent	489.011	54.931
hands	congruent	448.538	47.039
hands	incongruent	470.368	44.612
femface	congruent	439.088	51.099
femface	incongruent	456.173	49.849
maleface	congruent	443.195	50.577
maleface	incongruent	459.484	46.667
squares	congruent	470.185	58.424
squares	incongruent	532.768	57.662

Figure 4: Cueing validity effect

Graph illustrates mean RT (ms) for congruent vs. incongruent trails in each stimuli type

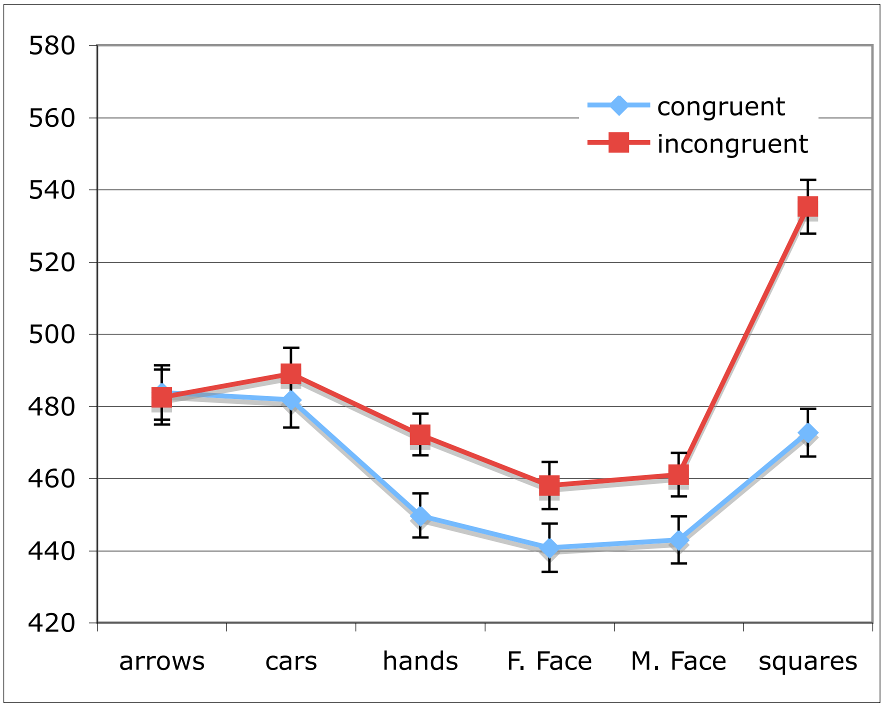
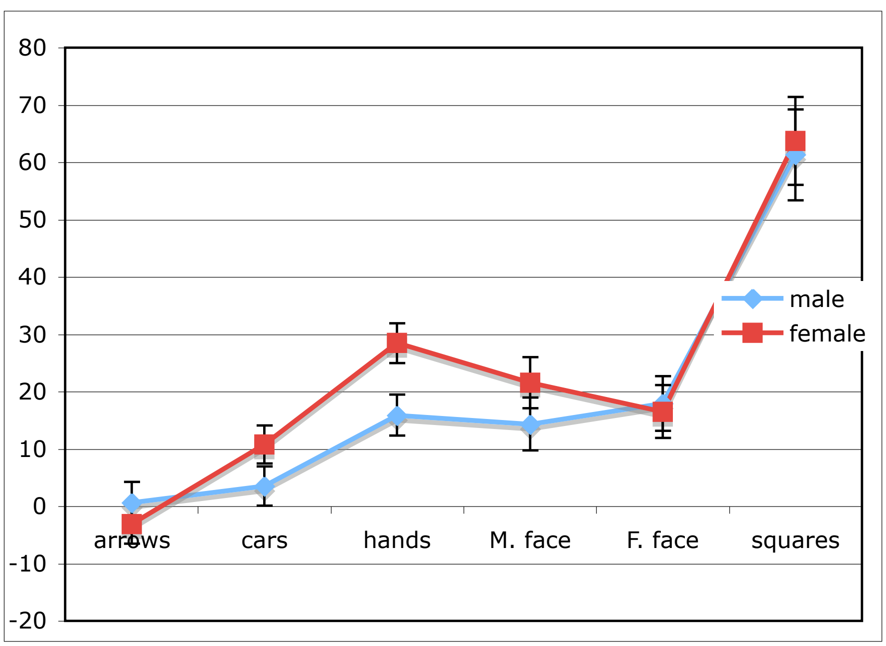


Figure 5: Sex Differences

Graph illustrates the cueing validity effect (incongruent – congruent (ms)) for each stimulus in men vs. women



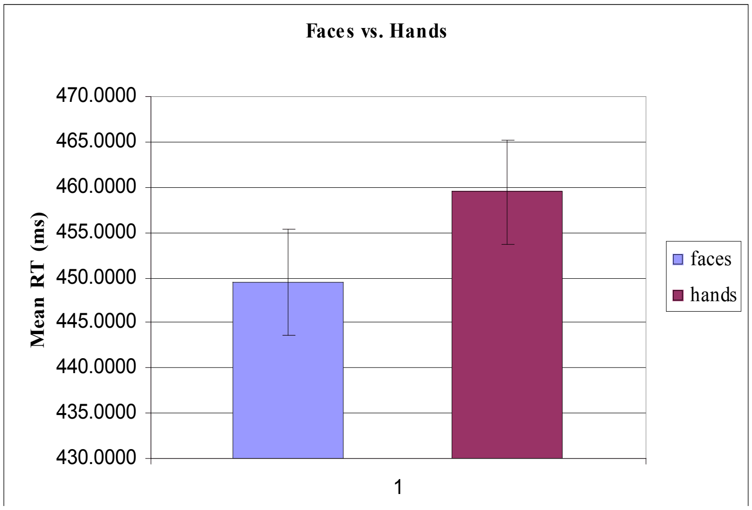
Another repeated measures ANOVA was conducted *without* the square stimuli since these pictures were qualitatively different than the other stimuli. In the analysis, social stimuli remained the same as with prior analysis (hands/female face/male face X congruent vs. incongruent) whereas the non-social stimuli included only the arrows/cars X congruent vs. incongruent. Similar to previously reported results, there was a main effect of Cue Type ($F(1, 56) = 57.990$, $p < 0.0001$) with faster responses on congruent trials. There was a main effect of Stimuli Type ($F(1, 56) = 46.260$, $p < 0.0001$) with faster responses to social stimuli.

Post-hoc t-tests

A paired t-test between faces vs. hands was conducted to determine whether there was a difference among the social stimuli. Mean RT to faces was significantly faster than for hands ($t(59) = -3.434$, $p < 0.001$). A second paired t-test between hands vs. arrows was conducted because hands have not been used as a cue stimulus prior to this experiment. Mean RT to hands was significantly faster compared to arrows ($t(59) = 2.545$, $p < 0.014$). The Bonferroni Adjusted p value was 0.025, so both pairwise comparisons were significant.

Figure 6

Graph illustrates mean RT for faces vs. hands



AQ, EQ, SQ

The AQ, EQ and SQ scores for the students were normally distributed. Mean AQ was 16.00 (SD = 6.46) (male M = 17.70, SD = 6.087; female M = 15.50, SD = 6.735). Mean EQ was 43.95 (SD = 12.079) (male M = 41.00, SD = 11.89; female M = 46.90, SD = 11.728). Lastly, mean SQ was 60.87 (SD = 21.620) (male M = 62.33, SD = 20.34; female M = 59.40, SD = 23.09). A one-way ANOVA showed no significant difference between men and women on the AQ, $F(58) = 1.762$, $p < 0.190$, the EQ, $F(58) = 3.745$, $p < 0.058$ and the SQ, $F(58)$, $p < 0.604$. The effect size for sex was small with the AQ ($r = 0.169$, $d = 0.343$), EQ ($r = -0.242$, $d = -0.499$) and SQ ($r = 0.067$, $d = 0.135$) which could explain the lack of sex differences.

Figure 7 Mean and Standard Deviations (STD) for the AQ, EQ, SQ scores in Students

		Mean	STD
AQ	Male	17.7000	6.08645
	Female	15.5000	6.73514
EQ	Male	41.0000	11.88740
	Female	46.9000	11.72780
SQ	Male	62.3333	20.33569
	Female	59.4000	23.08694

Subgroups of AQ

Phase 2 of analysis separated the data into groups of high and low AQ scorers. High AQ scorers (men = 11, women = 9) were identified as those who had a score of 18 or above (the top 33.3%) (M = 23.20, SD = 4.675) and low AQ scorers (men = 8, women = 12) were those who had a score of 14 or below (the bottom 33.3%) (M = 10.200, SD = 2.894).

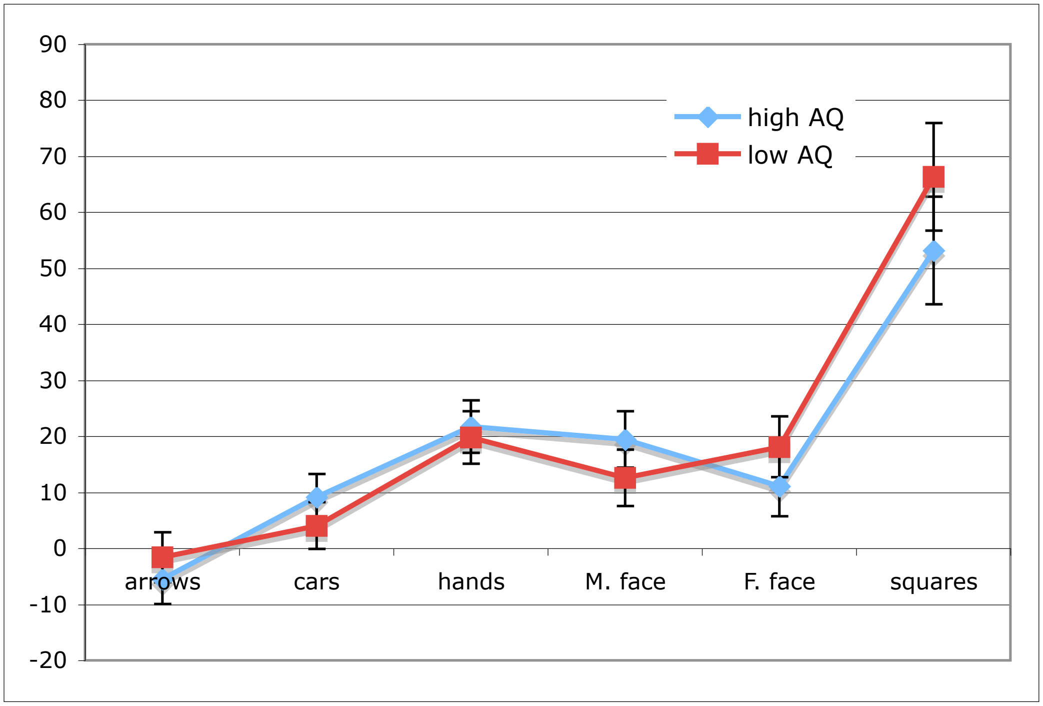
A repeated measures ANOVA was performed with AQ group as a between-subjects factor. Cue Type and Stimulus Type were within-subject factors, sex was a between-subjects factor and EQ and SQ were covariates. The main effect of Cue Type remained significant, $F(1, 34) = 13.024$, $p < 0.001$. Unlike the prior analysis, there was no main effect of Stimulus Type, $F(1, 34) = 0.342$, $p < 0.562$. This suggests that the differences in responses to the social vs. non-social stimuli are explained by AQ.

There was also a significant effect between Cue Type and SQ, $F(1, 34) = 7.450$, $p < 0.010$. In order to further understand this effect, a correlation analysis was performed in each AQ group separately. In the High AQ scorers SQ was negatively correlated with RT on the incongruent squares ($r = -0.485$, $p < 0.03$). In the Low AQ scorers, SQ was positively correlated with RT on congruent arrows ($r = 0.714$, $p < 0.001$) and incongruent arrows ($r = 0.667$, $p < 0.001$).

There was a new effect between Stimuli Type and sex, $F(1, 34) = 5.568$, $p < 0.024$. Independent sample t-tests in the high AQ scorers demonstrated no significant differences between men and women for the social vs. non-social stimuli, but there was a significant difference between men and women on the arrows ($t = 2.395$, $p < 0.028$), with women responding significantly faster than men (men $M= 520.96$ vs. women $M = 461.668$). In the low AQ scorers there were no significant differences between men and women, nor were there significant differences for any specific stimulus. This explains the interaction between Stimuli Type, Sex and AQ Group $F(1, 34) = 4.100$, $p < 0.051$.

Figure 8

Graph illustrates cueing validity effect (incongruent – congruent (ms)) for each stimulus in high AQ scorers vs. low AQ scorers



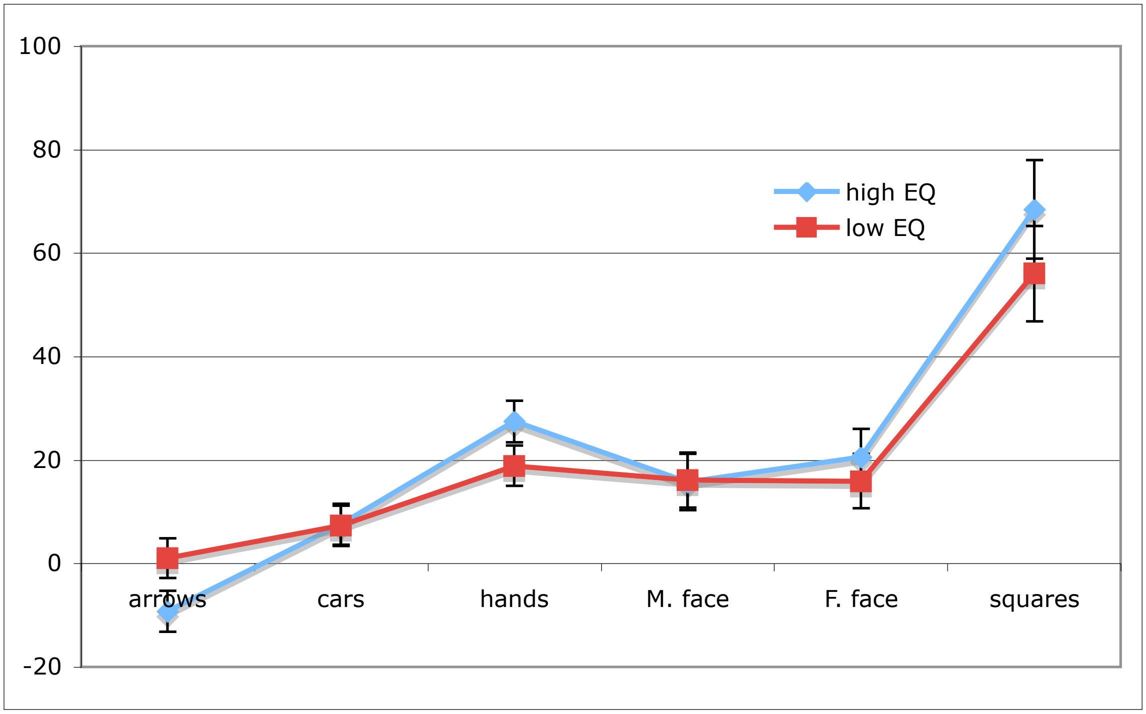
Subgroups of EQ

High EQ scorers (n = 20; men = 7, women = 13) were identified as those who had a score of 50 or above (top 33.3%) (M = 57.550, SD = 4.639) and low EQ scorers (n = 20; men = 14, women = 6) were those who had a score of 38 or below (bottom 33.3%) (M = 30.400, SD = 5.906). A 2 X 2 repeated measures ANOVA was performed on the data with Cue Type and Stimuli Type as within-subject factors, sex and EQ group were between-subjects factors and the AQ and SQ scores were covariates. The main effect of

Cue Type was significant ($F(1, 34) = 14.448$, $p < 0.001$). There was also a main effect of Stimulus Type ($F(1, 34) = 10.825$, $p < 0.002$). No other effects were significant.

Figure 9

Graph illustrates cue validity effect (incongruent – congruent (ms)) for each stimulus type in high EQ scorers vs. low EQ scorers



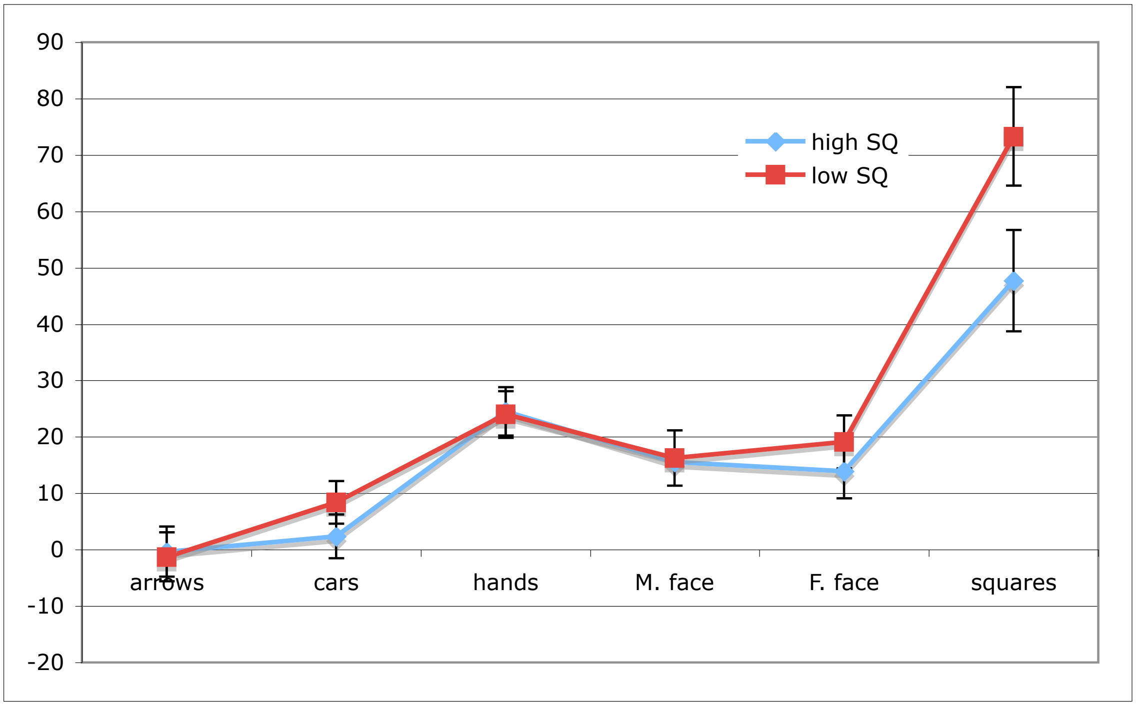
Subgroups of SQ

High SQ scorers (n = 20; men = 11, women = 9) were identified as those who had a score of 66 or above (top 33.3%) (M = 84.950, SD = 14.028) and low SQ scorers (n = 20; men = 8, women = 12) were those who had a score of 49 or below (bottom 33.3%) (M = 38.350, SD = 7.125). We conducted a 2 X 2 repeated measures ANOVA with Cue Type and Stimulus Type as within-subject factors, sex and SQ group were between-subjects factors and AQ and EQ scores were covariates. The main effect of Cue Type was no longer significant ($F(1, 34) = 0.550$, $p < 0.463$). Nor was there a main effect of Stimulus Type ($F(1, 34) = 3.462$, $p < 0.071$).

Among high versus low SQ scorers, there was a significant effect between Stimulus type and sex of participant ($F(1, 34) = 5.764$, $p < 0.022$). Independent sample t-tests in the high SQ scorers showed no significant differences among men vs. women for social $t(18) = 0.318$, $p < 0.754$ or non-social stimuli $t(18) = 1.137$, $p < 0.270$ and low SQ scorers for social $t(18) = - 0.936$, $p < 0.362$ and non-social stimuli $t(18) = 0.113$, $p < 0.911$.

Figure 10

Graph illustrates cueing validity effect (incongruent – congruent (ms)) for each stimulus type in high SQ scorers vs. low SQ scorers



ASC Participant Data

At the time of submission, the ASC sample was small (n = 7) and therefore, the data presented here is preliminary and meant to provide a foundation for future work that will attempt to complete the experiment with this population. The mean RT data was treated in the same manner as with the student data. Mean RT were calculated for each participant for the six stimuli conditions (congruent X incongruent). Errors (1.64%) and responses slower than 1,000ms or faster than 250ms (1.85%) or 2 standard deviations above or below the mean (4.82%) were removed from reaction time analysis.

A paired-sample t-test revealed that there was a significant difference between Cue Types (congruent vs. incongruent) $t(6) = -3.035$, $p < 0.023$. But there was no significant difference between Stimuli Type (social vs. non-social) $t(6) = -0.723$, $p < 0.497$.

Table 4 Mean reaction times in ms and standard error of the mean (SEM) for Cue Type in n = 7 ASC participants

	Mean	**SEM**
congruent	511.935	31.046
incongruent	538.122	29.086

Table 5 Mean reaction time in ms and standard error of the mean (SEM) for Stimuli Type in n = 7 ASC participants

	Mean	**SEM**
social	519.014	34.162
non-social	531.044	27.274

Table 6

Mean reaction time in ms and standard error of the mean (SEM) for all stimuli types in n = 7 ASC participants

	Mean	**SEM**
arrows	527.8066	29.51643
cars	480.6666	23.45109
hands	525.0316	34.41243
faces	516.0050	34.52225
squares	584.6602	32.12145

Discussion

This experiment demonstrated there was a faster shift of attention to social (hands and faces) versus non-social (cars, arrows and squares) cues in a student population. Within the social stimuli, there was faster orienting to faces versus hands. There was no sex difference. Preliminary data in ASC individuals demonstrated a cueing effect (faster to respond to congruent vs. incongruent trials) but no difference in response to the social versus non-social stimuli.

Aim 1

The results with the student population replicated prior gaze cueing paradigms e.g. (Driver et al., 1999; Friesen & Kingstone, 1998; Langton & Bruce, 1999) in that individuals were faster to respond when the cue predicted target location versus when it did not (see Figure 4). This result suggests that the cue stimuli produced an automatic shift of attention.

Aim 2

Consistent with the hypotheses, the student population had a greater cueing validity effect to the social versus non-social stimuli. As shown in Figure 4, there was a greater cueing effect for the hands and faces versus the arrows and cars. There was a large cueing effect for the non-social square stimuli. However, these stimuli were qualitatively different than the other non-social stimuli. When excluded from the analyses, there was still a greater cueing validity effect for the social versus non- social stimuli. Examining the mean RT data, participants were faster to faces versus hands and were also faster to orient to hands versus arrows. These findings provide new evidence for how aspects of the environment differ in their ability to orient attention.

The finding that there are differences in shifting attention to faces versus hands versus arrows is consistent with neurological data that there are face (Hoffman & Haxby, 2000), gaze movement (Puce et al., 1998) and gesture (Decety et al., 1997) specific regions in the brain for processing these stimuli. The result that the biological agents shift attention more than arrows is in congruence with prior research which demonstrated that eye gaze movements, but not arrows, activate the STS (Akiyama et al., 2006; Kingstone et al., 2004).

The findings that faces were stronger in shifting attention versus the hands supports the Baron-Cohen (1994) Eye Direction Detector (EDD) module. As noted in the Introduction, the EDD suggests that shifts in gaze are more important for orienting attention as opposed to other biological agents. The findings reported here support the idea that faces and eye movements contain critical cues for shifting our attention e.g. (Driver et al., 1999; Friesen & Kingstone, 1998; Langton & Bruce, 1999), but expand upon the literature by indicating that they do so more than other biological signals.

In this experiment, both the head and gaze shifted whereas many prior experiments just used a shift in gaze e.g. (Driver et al., 1999; Friesen & Kingstone, 1998). The findings that the combination of the gaze and head shift reflexively oriented attention are similar to those reported by Langton and Bruce (1999) but unlike those reported by Hietanen (1999). There were some major differences between this experiment and Hietanen (1999). First, Hietanen (1999) presented the face cue for 50ms, whereas this experiment did so for 300ms. Second, it was a static cue and the face stimuli used here were dynamic videos. Lastly, Hietanen (1999) presented the cue already shifted whereas this experiment first presented the face looking at the participant in a frontal view and then it would shift to the left or right. These paradigm differences could account for the varying results.

Aim 3

Contrary to the hypotheses, there was no reported sex difference (see Figure 5). The results are unlike those reported by Bayliss et al. (2005) who reported a sex difference to gaze and arrow cues. However, one major difference between this experiment and Bayliss et al. (2005) was the SOA. The sex difference reported by Bayliss et al. (2005) to gaze cues was found only at an SOA of 700ms, whereas this experiment only used SOAs of 300ms. Therefore, this experiment reports similar results to Bayliss et al. (2005) in that there was no sex difference to gaze cues at 300ms.

Bayliss et al. (2005) reported females were faster than males to respond to arrows at SOAs of 300ms. While not significant, this experiment found a 25 ms difference between men and women to arrows at SOAs of 300ms (men: 492ms vs. women: 467ms). Bayliss et al. (2005) found a significant difference at 19ms. This suggests that with more statistical power (larger sample size) this study would have found a significant sex difference to arrows.

This experiment used only 300ms SOAs because the most robust gaze cueing responses were reported at 300ms and 700ms (Driver et al., 1999). 700ms was not used as the primary SOA because of the possibility of inducing inhibition of return (IOR) in response to the cues. While gaze shifts (Friesen & Kingstone, 2003) have not produced an inhibition of return (IOR) response at these time intervals, the possibility of it occurring with the other stimuli was possible. It should be noted that IOR occurs around 300ms (Posner & Cohen, 1984) and therefore, it is possible that by choosing 300ms this experiment has not fully controlled for this variable.

Aim 4

The theory of conducting Phase 2 of analysis (separating the data into high and low AQ, EQ and SQ scorers) was to eliminate the middle scorers from the data and concentrate on the more extreme scorers. It is these two ends of the spectrum that provide a more informative analysis of how AQ, EQ and SQ score might associate with shifts in attention. Before a discussion of the Phase 2 results, it should be noted that Phase 1 of analysis (all AQ, EQ and SQ scores were included as covariates) did not find a significant effect. This lack of an effect probably reflects the small sample size (inadequate statistical power) as there were also no significant sex differences, which were previously reported on the three questionnaires (Baron-Cohen et al., 2003; Baron-Cohen & Wheelwright, 2004; Baron-Cohen et al., 2001).

Consistent with the hypotheses, there was an association between scores on the AQ and orienting of attention to the social vs. non-social stimuli (see figure 8). During Phase 2, when the group of high AQ scorers was compared to low AQ scorers, the previous difference between the social versus non-social stimuli disappeared. This finding suggested that the AQ score was accounting for the difference between the two stimuli. These results are consistent with Bayliss et al. (2005) and Bayliss and Tipper (2005) who reported that scores on the AQ associated with differences in orienting spatial attention. The findings are in conjunction with prior work which shows that individuals who score higher on the AQ have poorer social and communication skills (Baron-Cohen et al., 2001).

When high AQ scorers were compared to low AQ scorers there was an effect between SQ score and Cue Type. Specifically, among the high AQ scorers, greater scores on the SQ meant shorter reaction times to incongruent trials for squares. Individuals who score higher on the AQ also tend to score higher on the SQ (Wheelwright et al., 2006). And individuals who score higher on the SQ have superior attention to detail, or detailed local processing (Baron-Cohen et al., 2003). Therefore, this increased ability to respond to incongruent trials could reflect a drive to process details and perhaps ignore the cue. However, as to why only the squares were significant is unclear. Among the low AQ scorers, higher scores on the SQ correlated with longer reaction times to arrows, both congruent and incongruent trials. In other words, low AQ scorers, with a low SQ score were fast at responding to arrows. This is a more female profile (Baron-Cohen, 2002) and therefore, consistent with Bayliss et al. (2005) who reported females were faster to respond to arrows. These findings provide further detailed information about the individual differences in orienting attention to the specific stimuli.

Contrary to the hypotheses, there was no association between scores on the EQ to the social vs. non-social stimuli (see Figure 9). This is somewhat surprising because the EQ is a direct measure of empathy, which is closely related to interacting with the social world (Baron-Cohen & Wheelwright, 2004). This puzzling finding warrants further investigation.

In congruence with the hypotheses, SQ score had a very marginal association with social vs. non-social stimuli. In the same manner as with the AQ score, when dividing high vs. low SQ scores, there was no longer a significant difference between social versus non-social stimuli. Yet, this finding must be treated with caution because the effect was marginal as social versus non-social stimuli differed at a significance level of $p < 0.07$. Therefore, this result suggests that the SQ score may explain differences among the social versus non-social stimuli.

This experiment also demonstrated that when comparing low and high SQ scorers, there was no longer a significant difference between congruent versus incongruent trials (see figure 10). Individuals who are good systemizers pay attention to details, perhaps at a cost to global processing (Baron-Cohen, 2002; Baron-Cohen et al., 2003). The findings here suggest that the individual differences to the automatic, reflexive shift of attention could be explained by the ability to systemize.

Aim 5

At the time of submission, the ASC sample was very small (n = 7) and the age-, educated- matched control population was too little to consider for preliminary analysis. The ASC data did provide some initial significant findings, but must be treated with extreme caution due to the small sample size.

There was a difference in the ASC population to congruent vs. incongruent trials. Individuals were faster to respond when the cue predicted target location versus when it did not. This is in congruence with prior work in the ASC population which reported a cueing effect (Senju et al., 2004; Swettenham et al., 2003) to gaze and arrow cues. However, it is counter to other studies which reported no cueing effect in individuals (Ristic et al., 2005) and toddlers (Johnson et al., 2005) with autism.

There was no significant difference between social versus non-social stimuli. The sample size is too small to make definitive projections of whether this finding will remain. It is interesting to note that the ASC individuals were fastest in orienting attention to the cars (480ms) with the next fastest for faces (516ms) and then hands (525ms). These initial results are intriguing and provide an interesting foundation for future work.

Limitations and Future Work

The choice of using only one SOA limits the scope of this experiment and the ability to compare it to previous findings. Therefore, it is important that future work use these stimuli at different SOA intervals in order to address whether the Bayliss et al. (2005) sex difference to gaze shifts at a SOA of 700ms could be replicated.

Second, the motion in the dynamic videos was not controlled for in this experiment. Therefore, it is possible that the motion by these stimuli caused the shifts in attention, versus the actual stimulus per se. Hietanen and Leppanen (2003) reported no difference in response to static gaze shifts versus dynamic pupil movement. Recent reports with ERPs show that both static and dynamic gaze cues speed up early visual processing (Schuller & Rossion, 2001, 2004). However, future work should use social (hands and faces) versus non-social (cars) in schematic form and attempt to replicate the findings reported here.

Another limitation to this experiment was that IQ was not measured. It would be important to ensure that the variability in orienting attention was not due to variation in IQ scores.

Prior cueing studies have examined whether there is laterality difference when orienting spatial attention. Vlamings et al. (2005) reported that typically developing individuals have a greater effect from right side cueing in response to gaze shifts and arrows versus left side cueing. This was also found with ERPs to gaze shifts (Watanabe, Miki, & Katigi, 2002). Vlamings et al. (2005) did not find a laterality effect in individuals with autism. Because examining laterality was beyond the aims and scope of this experiment, this analysis was not performed at the time of submission. However, future work should assess whether there are differences in the student population to right versus left side cues. And once the ASC population is complete, analysis should include whether there are differences in the ASC population versus typically developing individuals.

This experiment was designed so that results could have been influence by the Simon Effect (Simon & Craft, 1970). Targets were presented on either the left or right side of the screen and participants pressed either the left or right shift key on the keyboard depending on which target letter they saw. Therefore, if the target appeared on the same side of the screen as the correct key response, according to the Simon Effect, individuals would be faster to respond to this key. However, all trials were equally distributed so that there was an equal number of key and targets on both sides. Future work would limit the possibility of this interference and have keyboard presses that are not lateralized.

Lastly, as was previously addressed, future work will complete the ASC sample of n = 20 and n = 20 educated and age matched controls.

Conclusions

This experiment provides evidence in a student population that social stimuli have greater influence in shifting attention versus non-social stimuli. Specifically, the results provide novel evidence that faces orient attention faster than hands. While there was no sex difference, there appeared to be individual differences in shifting attention. In particular, differences in orienting to the social versus non-social stimuli were contingent upon how individuals scored on the AQ. This implies that variations among individuals in orienting attention can be explained the presence of certain traits which characterize ASC.

The ASC sample at the time of submission was too small to fully characterize, but preliminary results are suggestive that there might be differences in their orienting of attention to social versus non-social stimuli as compared to typically developing individuals. These results will help to further elucidate the social and communication impairments which characterize ASC.

Appendix 1

Ethics Approval

Dear Professor Baron-Cohen

Sex and Gender Identity

The Cambridge Psychology Research Ethics Committee has given ethical approval to your research project: Sex and Gender Identity, as set out in your application dated 24 January 2006.
The Committee attaches certain standard conditions to all ethical approvals. These are:

(a) that if the staff conducting the research should change, any new staff should read the application submitted to the Committee for ethical approval and this letter (and any subsequent letter concerning this application for ethical approval);
(b) that if the procedures used in the research project should change or the project itself should be changed, you should consider whether it is necessary to submit a further application for any modified or additional procedures to be approved;
(c) that if the employment or departmental affiliation of the staff should change, you should notify us of that fact.

In addition, one Committee member made the following comments:
1. "The Consent Form needs to indicate exactly what is being asked of the subjects, how long it will take, and what they will be given in return."
2. "Participants should be told about both phases of the study at the outset, not asked to participate in one study and then asked to participate in another."

You may wish to amend your forms.
Members of the Committee also ask that you inform them should you encounter any unexpected ethical issues.
If you will let me know that you are able to accept these conditions, I will record that you have been given ethical approval.
Yours sincerely

K S Douglas
Cc: Ms R Jones

Appendix 2

Recruitment Letter

UNIVERSITY OF CAMBRIDGE

	Rebecca Jones Research Coordinator Tel: (0)1223 746157 Fax: (0)1223 746033 rj272@cam.ac.uk	Social Attention Project Douglas House 18b Trumpington Road Cambridge CB2 2AH http://www.cambridgepsychology.com	

DATE, 2006

Dear Patient ID XXX,

Thank you for your interest in taking part in new projects at the Autism Research Centre. We are currently looking for volunteers with autism spectrum conditions (ASC) for a new project that examines attention to faces and objects. The research aims to investigate how individuals with ASC differ from typically developing individuals in response to looking at faces and objects. You will be asked to look at pictures on a computer screen, and make rapid judgements for them. It will take approximately one hour and you will be paid for all travel expenses as well as five pounds for your time.

I would be most appreciative if you could email me (rj272@cam.ac.uk) if you are interested in participating.

I very much look forward to speaking with you soon.

With thanks for considering this request and for helping with social attention research.

Yours sincerely,

Rebecca Jones
Project Co-ordinator

Appendix 3

Consent Form

	Rebecca Jones Research Coordinator Tel: (0)1223 746157 Fax: (0)1223 746033	Social Attention Project Douglas House 18b Trumpington Road Cambridge CB2 2AH http://www.cambridgepsychology.com/gender/	

Purpose of Project:

The aim of the study is to further understand how individuals differ in attention. We are interested in studying attention because it is an important aspect of how individuals interact with others. You will be asked to look at pictures on a computer screen and make rapid judgements about them. You will be paid £5 when you have completed the study. This project has received ethical approval from the Psychology Research Ethics Committee of the University of Cambridge.

Consent Form

By signing this consent form, I understand the aims of the study and that all data will be kept confidential. My name will not be associated with the data, but rather there will be a numerical code to identify my answers. I understand that results, which are published will never identify specific individuals involved.

I am aware that I may withdraw at any stage during the experiment with no penalties.

Signed____

Date_______________________

Appendix 4

Sample DMDX script

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N 60 <s 60> <t 4000><rcot><d 200><cr><nfb> f 150 <id "keyboard"><dwc 0><dbc
255255255> <vm 1024,768,768,16,0>
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0 <ln -4>"Your job is to wait until you see either", <ln -2>"the
letter 'T' or the letter 'F'.",<ln 0>"Press the LEFT SHIFT
key for T”,<ln 2>”or the RIGHT SHIFT key for F.", <ln
4>"Respond as quickly as possible.",<ln 5>"Press space
to continue";
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-1 <ms% 710><bmp>"CrossHair"/<dv -1,-1,0.75,0.75>  "jac_left_100”<ms% 1355>/*   <ln 0> "T
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-2 <ms% 710><bmp>"CrossHair"/<dv -1,-1,0.75,0.75>  "jac_left_100”<ms% 1355>/*   <ln 0> "T
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-3 <ms% 710><bmp>"CrossHair"/<dv -1,-1,0.75,0.75>  "jac_left_100”<ms% 1355>/*   <ln 0> "T
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+8 <ms% 710><bmp>"CrossHair"/<dv -1,-1,0.75,0.75>  "jac_left_100”<ms% 1355>/*   <ln 0> "F
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