Individual Differences in Social Cognitive Processes between Neurotypical College Students High and Low in Autistic Traits

Catherine Irene Mitchell

Woodbridge, VA

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Catherine Irene Mitchell

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Committee Chair
Associate Professor Cheryl Dickter, Psychology
College of William & Mary

Associate Professor Joshua Burk, Psychology
College of William & Mary

Associate Professor Jennifer Stevens, Psychology
College of William & Mary

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ABSTRACT

The autism spectrum may extend into the general population, as previous work has suggested that there is a normal distribution of subclinical autistic traits among neurotypical individuals. Individuals with high levels of autistic traits display interpersonal challenges that are qualitatively similar to those exhibited by individuals diagnosed with autism spectrum disorders (ASD). In ASD, social challenges may be mediated by differences in social cognition. The current study investigated to what extent social cognitive differences exist between individuals with high and low levels of subclinical autistic traits. Participants were 171 undergraduate students who scored high or low on the Autism Spectrum Quotient (AQ). Differences were found between High AQ and Low AQ participants along several social cognitive and behavioral dimensions. High AQ participants reported higher levels of social anxiety and fewer daily conversations than Low AQ participants. Accuracy on a Theory of Mind task was lower in High AQ than Low AQ participants, but only when stimulus eye gaze was averted. Patterns of preferential attention to faces also varied between High AQ and Low AQ participants, contingent on configural and temporal factors. Low AQ participants exhibited a stronger attentional preference for upright faces versus cars and inverted faces at 100ms. When a competing car stimulus was presented, High AQ participants preferentially attended to faces more strongly than did Low AQ participants at 200ms and 500ms. Inverted face distractor stimuli elicited a stronger attention bias to upright faces by Low AQ than High AQ participants at 500ms. Emotion complexity did not differentially affect preferential attention to faces between the two groups. These results build on previous literature by characterizing specific patterns of social cognitive processing differences associated with subclinical autistic traits.

KEYWORDS: autism spectrum disorder, social cognition, face processing

TABLE OF CONTENTS

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Autism Spectrum Disorder (ASD) is a pervasive developmental disorder characterized in the DSM-V by difficulties with social communication and social interaction, restricted interests, and repetitive behavior (American Psychological Association, 2013). As a spectrum disorder, this diagnosis encompasses a wide range of symptomology and levels of function. The conceptualization of autism as a spectrum disorder also suggests the existence of a subclinical range of variability in autistic traits. For example, family members of ASD individuals often express similar but less intense variations of autistic traits, referred to as the Broad Autism Phenotype (BAP) (Bolton et al., 1994). Evidence suggests that these subclinical autistic traits may also be continuously distributed and heritable in the general population (Constantino & Todd, 2003; Hoekstra, Bartels, Verweij, & Boomsma, 2007; Hurst, Mitchell, Kimbrel, Kwapil, & Nelson-Gray, 2007; Stewart & Austin, 2009), and they are associated with a variety of psychosocial and interpersonal difficulties (Bolton et al., 1994; Hurst et al., 2007; Jobe & White, 2007; Piven, Palmer, Jacobi, Childress, & Arndt, 1997). Recent studies highlight the importance of better characterizing the BAP, in order to both better understand mechanisms underlying ASD and to assess challenges faced by individuals with subclinical autistic traits (Wainer, Ingersoll, & Hopwood, 2011).

To assist in the characterization of the BAP in the general population, Baron-Cohen, Wheelwright, Skinner, Martin, & Clubley (2001) developed the Autism Spectrum Quotient (AQ) as a self-report measure to quantify an individual's level of autistic traits. Many studies have used the AQ to examine individual differences between individuals high in autistic traits (High AQ) and low in autistic traits (Low AQ) (Lockwood, Bird, Bridge, & Viding, 2013; Nummenmaa, Engell, von dem Hagen, Henson, & Calder, 2012; Russell-Smith, Bayliss, & Maybery, 2013; Wakabayashi, Baron-Cohen, & Wheelwright, 2006). Multiple studies have found that the AQ successfully differentiates parents of ASD children and non-ASD children, supporting its validity as a potential measure of BAP (Bishop et al., 2004; Wheelwright, Auyeung, Allison, & Baron-Cohen, 2010). Personality research using the AQ indicates that High AQ individuals tend to score high on neuroticism and low on extraversion (Austin, 2005; Wakabayashi et al., 2006), with some High AQ samples also scoring low on agreeableness (Austin, 2005) and conscientiousness (Wakabayashi et al., 2006). When the AQ is included in factor analyses of personality measures, autistic traits emerge independent of the Big Five personality traits and may represent a distinct personality dimension (Wakabayashi et al., 2006). A construct validation study of the BAP by Wainer and colleagues (2011) identified pragmatic language difficulties, aloofness, and rigidity as three primary dimensions of the BAP. The BAP is also associated with psychopathology and interpersonal functioning. Individuals high in subclinical autistic traits report higher levels of social anxiety (Bolton et al., 1994; Wainer et al., 2011), as well as reduced interest in social interactions (Wainer et al., 2011), a low number of quality friendships (Jobe & White, 2007; Piven et al., 1997), and a higher frequency of experiencing bullying (Kunihira et al., 2006).

In ASD, these social challenges may be the result of impairments in social cognition, many components of which seem to have developed differently in this population (see Pelphrey, Adolphs, & Morris, 2004 for a review). Social cognition includes a variety of cognitive processes that mediate individuals' responses to social information, such as orienting attention to social stimuli, processing faces, identifying emotions, and interpreting the intentions of others (Theory of Mind) (Brothers, 1990) . Specific patterns of impairment in social cognition have been identified that distinguish between ASD and other psychopathologies that affect social functioning, such as schizophrenia (Couture et al., 2010; Russell-Smith et al., 2013), psychopathy (Richell et al., 2003), and anorexia nervosa (Adenzato, Todisco, & Ardito, 2012). While BAP is well characterized in terms of personality components (Austin, 2005; Kunihira et al., 2006; Russell-Smith et al., 2013; Wakabayashi et al., 2006), and social behavior (Jobe & White, 2007; Piven et al., 1997; Trevisan & Birmingham, 2015), the specific social cognitive profile of BAP is still unclear. Some studies have identified an association between subclinical autistic traits and impairments in Theory of Mind (Baron-Cohen, Wheelwright, Hill, Raste, & Plumb, 2001; Miu, Pană, & Avram, 2012; Oliver, Neufeld, Dziobek, & Mitchell, 2016) attention to faces (Bayliss & Tipper, 2005; Miu et al., 2012; Nummenmaa et al., 2012, 2012), and configural face processing (Bayliss & Tipper, 2005; Sasson, Nowlin, & Pinkham, 2013). Other studies have found the BAP to be associated with personality or social behavior differences but not with impairments in Theory of Mind (Kunihira et al., 2006; Russell-Smith et al., 2013, p.; Sasson et al., 2013), or attention to faces (Miu et al., 2012).

When social cognitive differences are identified in BAP, these differences are typically subtle in nature, such as slower latency to identify emotions on a Theory of Mind task but no impairment in accuracy (Miu et al., 2012), or moderation of social gaze cueing effects by configural features of peripheral targets (Bayliss & Tipper, 2005). Physiological evidence suggests that individuals with BAP may utilize unique social cognitive strategies that are distinct from those used by individuals with a clinical ASD diagnosis and neurotypical individuals without BAP (Dalton, Nacewicz, Alexander, & Davidson, 2007; Kaiser et al., 2010). Further research into specific individual differences in performance across a variety of social cognitive tasks is necessary in order to clarify the pattern of social functioning and challenges unique to BAP. Identification of such a pattern has implications for better understanding the social challenges faced by BAP individuals, and for further investigating the etiology of clinical and subclinical autistic traits. The following sections will review several social cognitive and behavioral processes implicated in social interaction that may differ between High AQ and Low AQ individuals.

Quantity and Quality of Social Interaction

At a behavioral level, individuals engage in different numbers of conversations each day. The quantity and quality of an individual's social interactions is both affected by underlying social cognitive processes and has the potential to affect these processes (De Jaegher, Di Paolo, & Gallagher, 2010; Klin, Jones, Schultz, & Volkmar, 2003) . Early in life, face-to-face conversations play an important role in the development of social cognition. Garfield and colleagues (2001) argue that the development of Theory of Mind is contingent upon both language acquisition and social interaction, which intersect during conversations. Typically developing children are predisposed to desire to engage in social conversations with their peers, and these interactions enhance their social cognitive abilities, which encourages them to engage in further social interactions (Klin, et al., 2003). Children with ASD do not appear to exhibit this same preference to attend to and engage with social stimuli (Jones & Klin, 2013). Klin and colleagues describe this disruption in the feedback loop between social interactions and social cognition as a critical mechanism in the development of ASD:

> The possibility that, in autism, the relative salience of social stimuli might be diminished … could be the basis for a cascade of developmental events in which a child with this condition fails to enact a relevant social world, thus failing to accrue the social experiences suggested … to be the basis for social cognitive development. (2003)

Attention to Social Stimuli

Social orienting.

The relative salience of social stimuli mentioned by Klin and colleagues (2003) refers to the degree to which individuals are inclined to orient their attention to social stimuli, such as faces. This orientation of attention is one of the earliest social cognitive processes recruited during a social interaction, whereby an individual directs cognitive resources to a social stimulus in order to facilitate further social cognitive processing. Although this orienting of attention can occur through other mechanisms than the visual system (e.g. Auvray, Lenay, & Stewart, 2009), visual orienting of attention to faces is the primary focus of the current study. The allotment of preferential attention to human faces is an evolutionarily adaptive and early-developing cognitive mechanism. Infants preferentially attend to faces compared to non-face stimuli, starting as early as hours after birth (Johnson, Dziurawiec, Ellis, & Morton, 1991). This initial infant orientation to faces is the first step in an increasingly complex series of bidirectional interactions with social stimuli that shapes the development of cortical structures that facilitate sophisticated social interaction (Jones, Carr, & Klin, 2008; Klin et al., 2003; Meltzoff & Moore, 1997).

Typically developing children continue to preferentially attend to faces and refine their face processing abilities throughout their lifespan. But between two to six months of age, a subset of infants exhibit a mean decline in the amount of visual fixation on faces broadly, and eyes specifically; these infants are more likely to later receive a diagnosis of ASD (Jones & Klin, 2013). By twelve months of age, infants who are later diagnosed with ASD fixate significantly less on faces than typically developing infants (Osterling, Dawson, & Munson, 2002) and exhibit poor eye contact and abnormal visual tracking of stimuli in social situations (Zwaigenbaum et al., 2005). By 24 months, children with ASD fixate on the eye region of faces less than 50% as frequently as typically developing children (Klin et al., 2003), and focus significantly less than their typically developing peers on the eyes of approaching adults, with the degree of fixation predictive of level of social disability (Jones et al., 2008). Individuals with ASD continue to exhibit differences in attentional orientation to social stimuli throughout development. When watching conversation scenes from movies, adults with ASD fixate significantly less than neurotypical individuals on faces and eyes (Klin et al., 2003). This diminished attention to social stimuli further disrupts the feedback system between social cognition and social behavior, accentuating differences in social interaction associated with ASD.

Dot-probe paradigms.

Preferential attention can be examined using a dot-probe paradigm, which allows for the comparison of attention between two stimuli during different time points of processing. In a dot-probe task, participants are shown pairs of images for a set display duration (the Stimulus Onset Asynchrony [SOA]), and then the images are replaced by a dot that appears behind one of the two images. Participants are tasked with indicating the location of the dot. The speed with which participants respond to the location of the dot when it is behind different stimuli can be analyzed to determine a measure of preferential attention. Dot-probe studies have been used extensively to examine implicit racial biases (e.g. Dickter, Gagnon, Gyurovski, & Brewington, 2015), and to examine preferential attention to threatening stimuli in anxiety disorders (e.g. Bradley, Mogg, & Millar, 2000). Adjusting the SOA in dot-probe studies allows for investigations of the time course of attentional processing of stimuli. For example, most individuals preferentially attend to the more negative of a pair of emotional stimuli presented for 100ms, but at 500ms this negativity bias is observed only in individuals high in anxiety or depression, suggesting that vigilance to threat in these populations is due to difficulty disengaging attention from threatening stimuli (Cooper & Langton, 2006; Mingtian, Xiongzhao, Jinyao, Shuqiao, & Atchley, 2011).

Dot-probe studies can also be used to examine attentional orienting to social and non-social stimuli. A dot-probe study by Bindemann, Burton, Langton, Schweinberger, & Doherty, (2007) found that neurotypical individuals preferentially attend to faces compared to non-face objects at SOAs of 100ms, 500ms, and 1000ms. A dot-probe study by Moore, Heavey, & Reidy (2012) found that at SOAs less than 200ms neither neurotypical nor ASD individuals exhibited a bias to faces compared to cars and houses, but at 200ms a face bias emerged for the neurotypical group. This is similar to the results of an eye-tracking study by Fletcher-Watson, Leekam, Benson, Frank, & Findlay (2009), which found that over the course of 3000ms, ASD and neurotypical individuals exhibited the same overall attentional bias to social stimuli compared to non-social stimuli, but examinations of only the first visual fixations revealed less preferential attention to social stimuli in the ASD group. Together, the results of the study by Moore and colleagues (2012) and Fletcher-Watson and colleagues (2009) suggest that attention bias to faces by ASD and neurotypical individuals varies at different time points in processing, with preferential attention to faces emerging earlier in neurotypical individuals.

It is notable that the study by Bindemann and colleagues (2007) found a face bias for neurotypical individuals as early as 100ms whereas the study by Moore and colleagues (2012) did not find a face bias for low autistic trait individuals prior to 200ms. This could be explained by differences in the type of non-face distractor stimuli that were used in those two studies. Bindemann and colleagues (2007) used non-face face object stimuli, such as water faucets and other household objects, which were perceptually quite different both from faces and from the other non-face object stimuli in the study. Moore and colleagues (2012) used car and house stimuli, selected especially for their configural resemblance to faces. Although perceptual similarity to faces affords greater experimental control, it might also obscure face bias effects early in processing. Humans frequently perceive faces in face-like objects like cars and houses, a phenomenon known as face pareidolia (Chalup, Hong, & Ostwald, 2010; Liu et al., 2014; Windhager et al., 2012). Face pareidolia has been shown to engage the same neural processing patterns generally considered to be selective for biological faces (Rossion & Caharel, 2011). House and car stimuli presented for less than 200ms might be more difficult to categorize as non-face objects compared to the configurally distinct household objects used in the Bindemann (2007) study. However, the utilization of stimuli too dissimilar to faces might overestimate the attentional biases to faces. Thierry, Martin, Downing, & Pegna (2007) demonstrated that some observed processing differences between face and non-face stimuli could result from the greater interstimulus perceptual variance (i.e. variance in stimulus size, orientation, shape) within non-face stimulus sets compared to face stimulus sets, rather than from characteristics of faces themselves.

While evidence highlights the importance of controlling the configural and perceptual variance in non-face stimuli, including a configurally disrupted distractor stimulus could be beneficial as well. Inverted faces maintain low-level perceptual similarity to upright faces but introduce a configural disruption that alters typical face processing mechanisms (Farah, Tanaka, & Drain, 1995). Neurotypical individuals are less accurate at recognizing inverted faces (Eimer, 2000; Yovel & Kanwisher, 2005) and recruit different brain regions when processing inverted faces compared to upright faces (Aguirre, Singh, & D'Esposito, 1999). Neurotypical individuals are theorized to primarily employ a holistic processing strategy for faces that relies on a schematic representation of the configuration of an upright face. Inversion of face images would therefore hinder typical face processing mechanisms because the resulting images conflict with this configural face encoding mechanism (Farah et al., 1995; Freire, Lee, & Symons, 2000; Rakover, 2013). Interestingly, there is some evidence that individuals with ASD do not process faces holistically, nor do they exhibit impaired processing of inverted compared to upright faces (Behrmann et al., 2006; Webb et al., 2012).

The inclusion of both perceptually controlled non-face objects and configurally disrupted inverted faces as distractor stimuli in studies of preferential attention to faces allows for the examination of different mechanisms that may underlie attentional biases to faces. Upright images of cars maintain configural similarity to a face, but lack the low-level perceptual features that distinguish biological faces as social stimuli. Inverted faces maintain low-level perceptual features unique to faces, but disrupt configural schemes associated with face processing (Farah et al., 1995). The former allows for an investigation of the role of biological and social face cues on attentional face bias, and the latter probes the effect of configural face processing mechanisms on preferential attention to faces.

In addition to examining preferential attention in studies using face stimuli with neutral expressions, faces displaying emotion could enhance or impair preferential attention to faces. In neurotypical individuals, the presence of emotional content seems to increase attentional processing speed (Ashwin, Wheelwright, & Baron-Cohen, 2006; Dolan, 2002). This enhancement effect is not apparent in ASD individuals (Ashwin, Wheelwright, et al., 2006). Emotionally expressive faces may therefore elicit stronger or weaker attentional bias depending on individual differences in autistic traits. The effect of emotional valence on attentional bias to faces versus non-faces was examined in a dot-probe study by Ribeiro & Fearon (2010) with participants who scored high and low on a measure of Theory of Mind, a social cognitive process that is often impaired in ASD (Baron-Cohen, 2000). Participants in the low Theory of Mind group exhibited greater attentional bias to negatively valenced emotional faces than household objects at 1000ms, but not to positively valenced emotional faces (Ribeiro & Fearon, 2010). This is evidence that characteristics of emotional expressions may interact with individual differences in social cognition to predict attentional orienting to faces. ASD individuals seem to differentially process certain types of emotion expressions as well. Simple emotions such as happiness and anger appear to be processed more efficiently by ASD individuals than complex emotions such as surprise and fear (Baron-Cohen, Spitz, & Cross, 1993; Davies, Bishop, Manstead, & Tantam, 1994; Kasari, Sigman, & Yirmiya, 1993; Loveland et al., 1997). Individual levels of autistic traits might therefore predict differential attentional orienting to faces contingent upon emotion complexity.

Theory of Mind

A later stage in processing during a social interaction, after orienting to the relevant social stimulus, is the ability to decode complex emotional and intentional cues presented by interaction partners. This social cognitive skill is known as Theory of Mind (Premack & Woodruff, 1978) and it is commonly identified as the cognitive component of empathy. While affective empathy (feeling another person's emotions) seems to be intact in ASD, Theory of Mind (identifying and understanding another person's emotions) appears to be impaired (Smith, 2009). A deficit in Theory of Mind is posited by some to be a key component of ASD (Baron-Cohen, 1997), and is associated with difficulties navigating social situations (Ashwin, Chapman, Colle, & Baron-Cohen, 2006). Theory of Mind may also be impaired in High AQ individuals, who exhibit reduced cognitive perspective-taking on tasks involving attributing social motivations to geometric shapes (Lockwood et al., 2013), and reduced implicit learning of social cues during a gaze-cuing paradigm with antisocial and prosocial faces (Hudson, Nijboer, & Jellema, 2012).

The Reading the Mind in the Eyes Test (Eyes Task) developed by Baron-Cohen, Wheelwright, Hill, et al. (2001) is a commonly used Theory of Mind task. This task assesses individuals' ability to read complex mental states from only the eye region of a face. Eyes seem to convey more emotional and intentional information than other regions of the face. Neurotypical individuals attend primarily to the eye region of faces when completing emotion identification tasks, whereas ASD individuals focus more on the mouth region (K. A. Pelphrey et al., 2002; Spezio, Adolphs, Hurley, & Piven, 2007). Masking the eye region of a face negatively impacts facial recognition accuracy by neurotypical individuals more than masking any other facial feature (McKelvie, 1976), and deficits in emotion recognition during typical aging are associated with less attention to eye than mouth regions of the face (Wong, Cronin-Golomb, & Neargarder, 2005). Accuracy in identifying mental states from the eye stimuli in the Eyes Task is considered a measure of Theory of Mind. Consistent with reports of Theory of Mind impairments in ASD (Baron-Cohen, 2000; Garfield et al., 2001; Senju, Southgate, White, & Frith, 2009), ASD individuals generally perform less accurately on the Eyes Task than neurotypical individuals (Baron-Cohen, Wheelwright, Hill, et al., 2001; Kaland, Callesen, Møller-Nielsen, Mortensen, & Smith, 2008).

Some studies have found evidence that Theory of Mind, as measured by the Eyes Task, is also affected in BAP, with relatives of ASD individuals identifying emotions less accurately than control participants on this task (Baron-Cohen & Hammer, 1997; Losh & Piven, 2007). General population studies using the AQ have yielded more mixed results. The original study of the Eyes Task found that performance was negatively associated with AQ (Baron-Cohen, Wheelwright, Hill, et al., 2001), but further studies have found no differences in performance on the Eyes Task between High AQ and Low AQ participants (Kunihira et al., 2006; Russell-Smith et al., 2013). Since social functioning of High AQ individuals is not impaired on a clinical level, it is possible that the global processing skills assessed by the Eyes Task are not affected by subclinical levels of autistic traits.

Another possibility is that further analysis of performance on the Eyes Task could reveal more subtle differences, such as sensitivity to the eye gaze direction of stimuli. Eyes Task stimuli display a mix of direct and averted gaze (Baron-Cohen, Wheelwright, Hill et al., 2001), but to our knowledge this has not yet been investigated as a potential factor affecting performance on the Eyes Task. Baron-Cohen, Wheelwright, Hill and colleagues (2001) acknowledged variations in eye gaze when they revised the Eyes Task, but only in the context of ensuring that gaze direction alone could not be relied upon to select correct responses. Recent studies utilizing different paradigms have uncovered differences in the processing of eye gaze by High AQ individuals, including diminished gaze cueing effects (Bayliss, Pellegrino, & Tipper, 2005), and atypical patterns of brain activation to averted compared to direct eye gaze in areas of the brain associated with Theory of Mind (Nummenmaa et al., 2012).

Social Anxiety

Social interactions may be accompanied by some level of social anxiety, which can also affect social cognitive processes. Social anxiety has been shown to increase (Moser, Huppert, Duval, & Simons, 2008) and decrease (Chen, Ehlers, Clark, & Mansell, 2002; Mansell, Clark, Ehlers, & Chen, 1999) attention bias to emotional cues, depending on context (see Machado-de-Sousa et al., 2010). Evidence suggests that individuals with high levels of social anxiety might also be impaired in distinguishing face from non-face objects (Davis et al., 2011). Social anxiety is often comorbid with ASD, with estimates ranging from 49% (Kuusikko et al., 2008) to 57% (Bellini, Peters, Benner, & Hopf, 2007) co-occurrence in young adults with ASD. High AQ individuals also generally display elevated levels of social anxiety symptomology (Kunihira et al., 2006; Russell-Smith et al., 2013; White, Bray, & Ollendick, 2012). Although the social components of ASD and the symptoms of social anxiety are similar in many ways, factor analyses confirm that they are separable constructs, albeit highly correlated (Freeth, Bullock, & Milne, 2013; White et al., 2012). Additionally, unique electrophysiological activation has been identified corresponding to each condition during social cognitive tasks (Richey et al., 2012), and social anxiety contributes unique variance to the success of certain social interventions for ASD (Antshel et al., 2011).

The Current Study

The current study aimed to characterize individual differences between neurotypical college students with high and low levels of autistic traits, as measured by the AQ. A range of factors involved in different levels of social cognition and social functioning were assessed, including social anxiety, quantity of daily social interaction, preferential attention to face stimuli, and Theory of Mind.

Self-reports of social anxiety symptomology were collected in the current study in order to a) assess levels of social anxiety in High AQ and Low AQ students, and b) control for the effects of social anxiety on social cognitive tasks in order to isolate the effects of autistic traits. We predicted higher levels of social anxiety in High AQ compared to Low AQ students. Participants in the current study were also asked to report the number of daily conversations in which they participated. We defined conversations as face-to-face verbal interactions with another person lasting longer than five minutes. The specification of five minutes was chosen in order to filter out insubstantive small talk, which was found not to correlate with well-being (Mehl, Vazire, Holleran, & Clark, 2010). Face-to-face interactions were assessed because these engage face processing systems that are measured in other tasks in the current study, and which may not be activated during telephone or online conversations. Due to the bidirectional feedback relationship between social interactions and the social cognitive component of social functioning, we predicted that High AQ college students, who exhibit lower social skills, would report fewer daily conversations than Low AQ college students.

Two dot-probe tasks were included in the current study in order to examine preferential attention to face stimuli. The Face/Non-Face Dot-Probe task examined attention to faces compared to non-face objects (cars) and atypical face images (inverted faces). The Basic/Complex Emotion Dot-Probe task examined attention to faces displaying different emotions (basic or complex) compared to inverted neutral faces. Both dot-probe tasks utilized a range of SOAs (100ms, 200ms, 500ms, 1000s), in order to examine differences in the time course of processing between Low AQ and High AQ individuals.

The absence of preferential orienting to social stimuli early in processing is a hallmark of ASD (e.g. Klin et al., 2003), but there is some evidence that preferential attention to faces compared to non-face objects is equivalent between neurotypical and ASD individuals later in processing (Fletcher-Watson et al., 2009). The Face/Non-Face Dot-Probe task was designed to examine whether this pattern of delayed preferential attention to faces would also be associated with subclinical autistic traits. Cars and inverted faces were used as distractor stimuli to investigate different mechanisms that might underlie differences in preferential attention to faces: social salience and configural processing. We anticipated that Low AQ individuals would preferentially attend to faces significantly more than Low AQ individuals at short SOAs (initial orienting), regardless of whether the distractor was a car or an inverted face. At longer SOAs (sustained attention), we expected High AQ participants to display the same level of preferential attention to faces as Low AQ participants later in processing (longer SOAs), but that this shift would emerge at different time points depending on the distractor stimulus. Preferentially attending to biological faces compared to cars indicates sensitivity to the social salience associated with biological face features, rather than simply face configurations (Klin et al., 2003). Preferential attention to upright versus inverted faces appears to be driven by the utilization of a specialized configural face processing strategy (Frieire et al., 2000). Individuals with clinical ASD attribute less social salience to faces and do not seem to process faces using the same configural strategy as neurotypical individuals (Behrmann et al., 2006). We predicted that High AQ participants would be more sensitive to social salience of stimuli than configural features, as reduced salience of social stimuli seems to be associated with more pronounced social deficits (Klin et al., 2003), and there is some evidence that the face processing strategies used by BAP individuals differ from individuals with low levels of autistic traits (Dawson et al., 2005).Therefore, we hypothesized that High AQ participants would preferentially attend to faces compared to cars sooner than when upright faces were paired with inverted faces.

The Basic/Complex Emotion Dot-Probe task assessed the effect of emotions of differing complexity on attention to faces. In light of evidence that ASD is associated with challenges in processing complex emotions such as fear and surprise (Baron-Cohen et al., 1993; Davies et al., 1994; Kasari et al., 1993; Loveland et al., 1997), we expected that High AQ participants would not process complex emotions as efficiently as basic emotions, such as happiness and anger. We predicted that this would manifest in terms of a temporal delay in preferential attention to complex faces on the dot-probe task, with High AQ participants preferentially attending less to complex emotion faces compared to inverted faces than Low AQ participants at short SOAs and no difference at long SOAs. High AQ and Low AQ participants were hypothesized to exhibit similar attentional biases to basic emotion faces compared to inverted faces at all SOAs.

Given previous conflicting findings about Theory of Mind performance in High AQ individuals, we did not establish firm hypotheses for the Eyes Task. Theory of Mind is a more advanced social cognitive process than attentional orienting to social stimuli. If no overall difference in Theory of Mind is found between High AQ and Low AQ participants, this would suggest that subclinical autistic traits are not associated with impairments in higher order social cognitive processes that are affected in clinical ASD. However, it is also possible subtle social cues such as eye gaze direction might affect performance on the Eyes Task. This task contains a mix of trials with direct and averted eye gaze, which have been shown to elicit different neural responses in individuals with high and low levels of autistic traits (Nummenmaa et al., 2012). Theory of Mind differences sensitive to eye gaze direction might be masked in the Eyes Task when performance on direct and averted gaze trials is examined as a unitary construct, and gaze direction was therefore examined in the current study as an additional factor on the Eyes Task. Social anxiety may also affect processing of eye gaze, and therefore additional exploratory analyses were performed to investigate whether autistic traits and social anxiety symptomology each contribute unique variance to Eyes Task performance on direct and averted gaze trials (Schmitz, Scheel, Rigon, Gross, & Blechert, 2012).

Method

Participants

Participants were recruited over three academic semesters from a pool of 1387 undergraduate students who completed a mass testing survey for course credit. The mass testing survey included the Autism Spectrum Quotient (AQ), a self-report measure of autistic behaviors, described below. AQ scores were used to recruit one group of participants with high levels of autistic-like traits and another group of participants with low levels of autistic-like traits. AQ score cut-offs for these two groups were determined by calculating the frequency distribution cutpoints for the top third (AQ > 20) and bottom third (AQ < 14) of AQ scores from a sample of 727 undergraduate students who completed the mass testing survey in previous semesters. These cut-off scores were used to recruit participants for the current study, who were invited to participate for course credit. Of the eligible participants, this study was completed by 171 students (69 male; M_{age} = 19.08). The High AQ recruitment group consisted of 114 participants (44 male; M_{age} = 19.01), and the Low AQ recruitment group consisted of 57 participants (24 male; M_{age} = 19.21). Participants took the AQ a second time during the testing session; pre-recruitment and post-recruitment AQ scores showed high test-retest reliability (r = .91). This research was approved by the Protection of Human Subjects Committee at the College of William and Mary.

Materials

Computer Tasks

Reading the Mind in the Eyes Test (Eyes Task). The "Reading the Mind in the Eyes Test" (Eyes Task) was developed by Baron-Cohen, Wheelwright, Hill, Raste, and Plumb (2001) as a measure of an individual's skill at identifying complex emotions and intentions using only information conveyed through human eyes. Performance on the Eyes Task is often considered a measure of Theory of Mind (Ribeiro & Fearon, 2010). The Eyes Task consists of one practice trial and one block of 36 experimental trials. Each trial displays a central greyscale image of an actor displaying a unique facial expression (18 male actors, 18 female actors), cropped to only display eyes, and surrounded by four emotion words matched on valence. Participants are tasked with indicating which of the four emotion words best corresponds to the image. Direction of eye gaze also varied between stimuli, with 16 stimuli exhibiting averted eye contact and 20 stimuli exhibiting direct eye contact. The emotions corresponding to the images with direct eye gaze in the experimental trials were: playful, regretful, skeptical, accusing, doubtful, decisive, tentative, upset, friendly, fantasizing, defiant, pensive, interested, hostile, desire, flirtatious, confident, serious, concerned, and insisting. Averted eye gaze experimental trials represented the following mental states: cautious, interested, reflective, distrustful, nervous, suspicious, worried, fantasizing, uneasy, despondent, and preoccupied. The practice trial displayed a direct eye gaze and a panicked expression. Correct emotion labels for each image were determined through consensus response from eight independent raters (Baron-Cohen, Wheelwright, Hill, et al., 2001).

The current study delivered the Eyes Task on a computer. On each trial, participants indicated their choice of the most appropriate emotion word for the image by pressing a computer key corresponding to the location of the selected word ("s" for top left, "x" for bottom left, "k" for top right, and "m" for bottom right). See Appendix A for example trials. In order to minimize confounds due to individual variance in vocabularies, if participants did not know the meaning of one of the four word options, they were instructed to press the spacebar, and that trial was discarded from analysis. Key reminders were displayed in the corresponding corner of the screen during each trial, and a reminder to press the spacebar if a word was unknown was displayed along the bottom of the screen. Scores on the Eyes Task range from 0 to 36, with one point awarded for each correct answer. The original study by Baron-Cohen and colleagues (2001) found that individuals with ASD scored an average of 21.6 points (60% accurate) on the Eyes Task, whereas a community sample without ASD scored an average of 26.2 points (73.78% accurate). The current study computed accuracy on the Eyes Task by dividing the number of trials with correct responses by the number of trials with valid keyboard input, to account for trials in which participants indicated they did not know the meaning of one of the four emotion word options. Internal consistency for the Eyes Task is often not reported, and Cronbach's alpha values in studies that do report internal consistency for the Eyes Task range from $\alpha = .58$ to $\alpha = .70$ (Vellante et al., 2013). In the current sample, internal consistency on the Eyes Task was on the lower end of the range of previously reported reliabilities, $\alpha = .56$.

Face/Non-Face Dot-Probe.

Stimuli. The stimuli for this task consisted of 28 upright neutral face images, 28 inverted neutral face images, and 28 upright car images. The 28 images of neutral faces, used for both the upright and inverted final stimuli, were taken from the JACNEUF (Matsumoto & Ekman, 1995) face database. The JACNEUF database contains images of front-facing neutral faces from 28 Caucasian actors and 28 Japanese actors. Only the Caucasian faces were used in the current study. JACNEUF is a complementary database to JACFEE, which contains emotional expressions scored using the Facial Action Coding System (FACS), a system of quantifying expressions by observing facial muscle movements. The images in the JACNEUF database have been assessed by trained FACS coders and determined to lack noticeable muscle movement associated with facial expressions.

The 28 car images were taken from a stimulus set developed by (Thierry et al., 2007) and (Dering, Martin, Moro, Pegna, & Thierry, 2011) consisted of 100 front-facing photographs of cars of various makes, years, and models. The images in the car stimulus set were specifically designed to minimize interstimulus perceptual variance (ISPV), the degree of configural differences between stimuli. ISPV is well-controlled in most face databases, since faces tend to be the same size, shape, and presented in the same orientation, but car stimuli used in face-processing studies often do not account for ISPV. Thierry and colleagues (2007) showed that an EEG amplitude typically considered to be specific to faces did not distinguish between faces and cars when the both stimulus sets had low ISPV. The car image database developed by Thierry et al. (2007) controls ISPV by presenting all car images centered, fully front-facing, and scaled to the same size. For the current study, a pilot survey containing the 100 original low ISPV car images was distributed to 31 independent raters to determine how face-like each car image appeared. Each car image was presented to raters in random order. Most raters did not complete the entire survey, but the random order of presentation ensured that all car images were rated several times. Each car image was rated by at least 4 times, and the average number of ratings for an image was 6.87. The questions asked about each image were:

1. OVERALL: How much does this image of a car resemble a face? (Not at all like a face; very slightly like a face, slightly like a face, much like a face, very much like a face)
2. EYES: Does this image of a car have a distinct eye region? (Yes; No)
3. MOUTH: Does this image of a car have a distinct mouth region? (Yes; No)

4. EMOTION: What emotion does this car's "face" seem to express? (Happy; Sad; Angry; Surprised; Disgusted; Fearful; Neutral; Other: ________)
5. How masculine/feminine does this car look? (Very masculine; slightly masculine; neither masculine nor feminine; slightly feminine; very feminine)

Questions were displayed on the same page as the image of the car that was currently to be rated, and always appeared in the same order for each image. The 28 cars rated in the pilot survey as most face-like according to the "OVERALL" question were selected for use in the dot-probe experimental task. All 28 cars rated as most face-like were also consistently rated as having a distinct eye region and a distinct mouth region. Not enough data were collected to analyze the emotion and gender ratings for each car.

Face and car images were edited in the GNU Image Manipulation Program (GIMP) in order to further decrease ISPV for both stimulus groups. Using GIMP, face images were cropped into an oval shape, with ears, hair, and other non-face features cropped out. Hair that obstructed the forehead region was digitally removed by replacing hair with skin texture copied from other portions of the face. The oval-cropped faces were all resized to equivalent dimensions, and then converted to grayscale, in order to control for differences in image brightness and color that could affect perception. A new inverted face stimulus was then created from each face stimulus by flipping the images across the horizontal axis. Car images were cropped into the same oval shape and size as the faces, and also converted into grayscale. After all image manipulation was completed, a MatLab script was used to equate the luminance of every face, inverted face, and car image. The final stimuli consisted of 28 upright neutral face images, 28 inverted neutral face images, and 28 car images, all grayscale and cropped into ovals of equivalent size.

Paradigm. The Face/Non-Face Dot-Probe task used in this study utilized the dot-probe paradigm developed by MacLeod, Mathews, and Tata (1986). The dot-probe paradigm is used to examine relative attention between two simultaneously presented stimuli. Participants are tasked to attend to the fixation cross that appears at the beginning of each trial and then to identify the side of the screen on which a dot appears. Between the presentation of the fixation cross and the appearance of the dot, two stimuli are briefly displayed on either side of the screen (the duration of display is known as the Stimulus Onset Asynchrony [SOA]). If a participant's attention is drawn to one of the two stimuli, the participant should respond more quickly to the location of the dot when it is behind the attended stimulus than the non-attended stimulus. By subtracting reaction times on trials when the dot followed different types of stimuli, participant attentional biases among the examined stimuli can be determined.

For the Face/Non-Face Dot Probe task in the current study, the goal was to examine attentional biases toward face and non-face objects along different time points in attentional processing. Each trial consisted of three phases: a fixation cross displayed for either 300ms, 350ms, 400ms, 450ms, or 500ms; two stimuli displayed for SOAs of either 100ms, 200ms, 500ms, or 1000ms; and a dot displayed until the system registered a participant response. The duration of the fixation cross was variable in order to deter the participant from anticipating the rhythm of the task, and the fixation cross was located in the middle of the screen both horizontally and vertically, in order to re-center participants' attention at the start of each trial. The variation in duration of stimuli was an experimental manipulation to examine the effect of processing time on attention bias. SOAs of 100ms and 200ms were chosen in order to assess initial attentional orienting. Previous studies have identified these SOAs as the earliest time point when preferential attention to faces versus non-face objects emerges in dot-probe studies (Bindemann et al., 2007; Moore et al., 2012). Eye-tracking studies indicate that SOAs of

400ms or longer in dot-probe studies allow sufficient time for overt shifts of visual fixation to occur (Petrova, Wentura, & Bermeitinger, 2013). The current study included SOAs of 500ms and 1000ms to investigate attention biases in later processing, which may occur at some level of conscious awareness.

During the middle phase of each trial, two stimuli were displayed simultaneously, centered vertically on the screen. One stimulus appeared on the left side of the screen, midway between the center and the edge of the screen along the horizontal axis, and the other stimulus appeared on the right side of the screen, midway between the center and the edge of the screen along the horizontal axis. The final phase of each trial consisted of a small dot that appeared, centered, behind the location of one of the two stimuli from the previous phase. The dot remained on the screen until participants submitted a keyboard response. The instructions for participants were to focus on the fixation cross at the beginning of each trial, and then to indicate the location of the dot by pressing “x” on the keyboard if the dot was on the left and “m” on the keyboard if the dot was on the right. See Appendix B for a task schematic.

The Face/Non-Face Dot Probe task consisted of 72 experimental trials containing an upright face and an inverted face, 72 experimental trials containing an upright car and an inverted face, and 144 filler trials (8 face / face trials, 40 car / car trials, 32 inverted face / inverted face trials, and 64 car / face trials). Each trial type consisted of an equal number of trials where the stimuli remained on the screen for 100ms, 200s, 500ms, and 1000ms, and the dot was equally likely to appear on the left as the right side of the screen for all trials. Trials were presented to participants in a randomized order, and participants were offered an opportunity to take a short break after the first 102 trials and after the second 102 trials. During breaks, participants were instructed to rest until they were ready to resume the task.

Basic/Complex Emotion Dot-Probe.

Stimuli. This task was similar to the Face/Non-Face Dot-Probe task, but it investigated attention bias between neutral and emotional faces rather than faces and cars. Original stimuli for this task were taken primarily from the NimStim database (Tottenham et al., 2009). The NimStim database is a database containing 672 images of front-facing faces displaying a variety of facial expressions from 25 Caucasian actors and 18 actors of other racial groups, matched for attractiveness. Expressions on the NimStim database have been validated through consensus of independent, untrained raters regarding what emotion is depicted by each expression. For the Basic/Complex Emotion task, the NimStim database was the source for images of 28 neutral faces, 22 angry faces, 22 fearful faces, 22 happy faces, and 22 surprised faces (half male actors and half female actors in each category). These emotions were chosen to allow for an examination of the effect of emotional complexity on attention bias to faces, while counterbalancing valence. Anger (negative valence) and happiness (positive valence) are considered to be basic emotions, whereas fear (negative valence) and surprise (positive valence) are considered to be complex emotions (Baron-Cohen, Spitz, & Cross, 1993). Since neutral faces would be viewed more frequently than each emotional face, an additional 18 neutral faces (9 male, 9 female) were included from the JACNEUF database (Matsumoto & Ekman, 1995) in order to introduce more variety. Face images were cropped into equally sized ovals in GIMP, converted to grayscale, and edited to remove hair in the facial area, using the same procedure described for the Face/Non-Face stimuli. A set of inverted face stimuli was created by inverting a copy of each neutral face. The final set of stimuli consisted of 46 neutral faces, 46 inverted neutral faces, 22 angry faces, 22 fearful faces, 22 happy faces, and 22 surprised face. Luminance was equated between stimuli using a MatLab script.

Paradigm. The overall structure of each trial in the Basic/Complex Emotion Dot-Probe was the same as for the Face/Non-Face Dot-Probe, with differences in the number of trials and the types of stimuli presented. (See Appendix C for example stimulus pairs.) The Basic/Complex Emotion Dot Probe task consisted of 256 experimental trials containing an upright emotional face and an inverted neutral face (64 anger / inverted face, 64 fear / inverted face, 64 happy / inverted face, 64 surprise / inverted face), and 152 filler trials (8 anger / anger, 8 fear / fear, 8 happy / happy, 8 surprise / surprise, 8 anger / neutral, 8 fear / neutral, 8 happy / neutral, 8 surprise / neutral, 8 neutral / neutral, and 32 neutral / inverted face). There were a total of 408 trials. Each trial consisted of an equal number of trials where the stimuli remained on the screen for 100ms, 200s, 500ms, and 1000ms, and the dot was equally likely to appear on the left as the right side of the screen for all trials. Trials were presented to participants in a randomized order, and participants were presented with the opportunity to take 3 short breaks, one after each set of 102 trials. During breaks, participants were instructed to rest until they were ready to resume the task.

Questionnaires

The Autism Quotient Scale (AQ). The AQ is a self-report measure developed by Baron-Cohen and colleagues (2001) to measure an individual's level of autistic behaviors, based on the idea that autism exists along a spectrum of symptom intensity. It contains 50 questions answered on a Likert scale from 1 (Strongly Agree) to 4 (Strongly Disagree), and contains five subscales: social skills (e.g. "I prefer to do things with others rather than on my own."), communication (e.g. "I frequently find that I don't know how to keep a conversation going." [Reverse-coded]), imagination (e.g. "If I try to imagine something, I find it very easy to create a picture in my mind."), attention to detail (e.g. "I usually notice small sounds when others do not." [Reverse-coded]), and attention-switching (e.g. "I find it easy to do more than one thing at once."). After reverse-coding, answers are then dichotomized as either 0 (Agree) or 1 (Disagree). Total scores on the AQ can range from 0 to 50, with lower scores indicating fewer autistic behaviors and higher scores indicating more autistic behaviors. A score of 26 or above is considered to be an indicator of Asperger's syndrome (Woodbury-Smith, Robinson, Wheelwright, & Baron-Cohen, 2005), and a score of 32 or higher is considered to be an indicator of autism (Baron-Cohen, Wheelwright, Skinner, et al., 2001). The AQ has been shown to have good internal consistency in a student sample ($\alpha = .81$) and a community sample ($\alpha = .71$), and to have strong test-retest reliability ($\alpha = .70$) (Hoekstra, Bartels, Cath, & Boomsma, 2008). The internal consistency for the AQ was strong in the current sample ($\alpha = .87$)

The Abbreviated Social Phobia and Anxiety Inventory (SPAI-23). Social anxiety disorders such as social phobia are highly co-morbid with ASD (Mukaddes & Fateh, 2010), and the conditions share similar symptomology, such as discomfort in social situations. The SPAI is a 23-item measure of social phobia and anxiety (Roberson-Nay, et al., 2007). The SPAI consists of two subscales, social phobia (max score: 64; e.g. "I feel anxious when having to interact for longer than a few minutes with other people.") and agoraphobia (max score: 68; e.g. "Being in large open spaces makes me feel anxious."). A score of 12 or higher on the agoraphobia scale indicates that panic disorder is likely. Social phobia is assessed by subtracting the agoraphobia subscale score from the social phobia subscale score. If this difference score is greater than or equal to 30, social phobia is possibly indicated. The current study interpreted higher SPAI difference scores as indicating higher levels of social anxiety. Internal consistency of the SPAI is high among college students (SP: $\alpha = .95$; AG: $\alpha = .88$), and test-retest reliability is strong (SP: $\alpha = .78$; AG: $\alpha = .72$) (Schry, Roberson-Nay, & White, 2012). Internal consistency in the current sample was consistent with previous literature for both the social phobia subscale ($\alpha = .94$) and the agoraphobia subscale ($\alpha = .86$).

Daily Conversation Measure. Prior research has found a link between autistic characteristics and the quantity and quality of social relationships among neurotypical college students (Jobe & White, 2007). In order to examine potential differences in social interaction engagement between High AQ and Low AQ participants, a short measure asking about daily conversations was included in the current study. This measure consisted of several questions about the number of face-to-face conversations participants have in a typical day. In order to encourage more accurate estimates, participants were asked specifically for the number of people with whom they had face-to-face conversations during the previous day, rather than asking them to estimate about a hypothetical average day. Conversations were defined as two-way face-to-face interactions that lasted for five minutes or longer. Participants were also asked about the ages and occupations of their conversational partners, and whether the number of conversations they reported was above or below average for them. All questions were forced-choice with predefined answer options. See Appendix D for the full conversation measure given to participants.

Procedure

Eligible participants received an email with instructions on how to register to participate in the current study for course credit. Participants were told that the study concerned "social categorization" to discourage them from guessing the purpose of the study and consciously adjusting their attention to or away from different stimuli. Participants came to the lab to complete the study in groups ranging from one to four individuals. Sessions were administered by experimenters who were blind to the AQ score and AQ recruitment group of the participants. Upon arrival in the lab, each participant sat at an individual computer station that was screened off from other participants. Participants were given informed consent, asked to sit up straight, remain still, and not talk to other participants for the duration of the study. Straight posture was requested throughout the study in order to ensure that participants were viewing stimuli from a consistent viewing angle, and to prevent a reaction time bias toward either side of the screen due to participants physically leaning in that direction.

Each participant then completed the three computerized tasks, which were counterbalanced across two dimensions. The order of the Eyes Task and the dot-probe tasks was randomized between two blocks, and the order of the Face/Non-Face and Basic/Complex Emotion dot-probe tasks was counterbalanced within the dot-probe block. Participants were given a self-timed break between each block, in addition to the self-timed breaks within the dot probe tasks. Before the dot-probe block began, a practice dot-probe block was presented, which consisted of six trials randomly sampled from all possible Face/Non-Face and Basic/Complex task trials. Upon completion of the computerized tasks, participants completed a survey containing demographic questions, the AQ, the SPAI-23, and the daily conversation measure. Participants were then debriefed and given course credit.

Results

Autism Quotient (AQ) Scores

Of the 171 participants who completed the study, post-recruitment AQ scores reclassified 21 participants into a different AQ group than the AQ group indicated by their pre-recruitment AQ scores. Fifteen participants were reclassified from the High AQ Group (AQ > 19) to the Middle AQ Group (13 < AQ < 20), and six participants were reclassified from the Low AQ group (AQ < 14) to the Middle AQ Group. No participants were reclassified from the High AQ Group to the Low AQ Group or vice versa. Participant AQ scores changed by an average of

-0.27 points (*SD* = 3.51) from pre-recruitment to post-recruitment. A one factor repeated measures ANOVA comparing the absolute value of AQ change between the participants who moved from Low AQ to Middle AQ, participants who moved from High AQ to Middle

AQ, and participants who did not change in AQ group classification from pre- to post-recruitment revealed a significant difference in the magnitude of AQ changes between the three groups, $F(2,162) = 14.08$, $p < .01$. Post-hoc tests using Tukey HSD revealed that AQ score change was significantly less for participants who did not change classification status ($M = .09$, $SD = 3.36$) than for participants who moved either from Low AQ to Middle AQ ($M = 3.40$, $SD = 0.99$) or High AQ to Middle AQ ($M = 3.93$, $SD = 0.57$). Due to the greater fluctuation observed in AQ scores for participants whose classification status changed compared to participants whose classification status did not change, those 21 participants who moved into the Middle AQ group upon analyses of post-recruitment AQ scores were excluded from further analyses.

Five additional participants (High AQ: N = 1; Low AQ: N = 4) were excluded from further analysis due to failure to follow instructions or missing substantial portions of data. The final sample size consisted of 145 participants (58 male; $M_{age} = 19.05$), whose AQ scores were consistently high (AQ > 19) or consistently low (AQ < 14) at both pre- and post-recruitment. There were 94 participants in the High AQ group (37 male; $M_{age} = 19.02$) and 49 participants in the Low AQ group (21 male; $M_{age} = 19.10$). An independent samples t-test confirmed that AQ scores were significantly different higher in the High AQ group ($M = 26.05$, $SD = 4.89$) than the Low AQ group ($M = 9.44$, $SD = 2.57$), $t(143) = -22.43$, $p < .01$.

Gender Differences

Analyses were run with gender as an additional between subjects factor for each measure included in the current study, but no significant gender differences were found for any of the measures.

Additional Self-Report Measures

Social anxiety (SPAI difference scores).

SPAI difference scores were significantly positively correlated with AQ scores, $r(145) = .60$, $p < .01$, and an independent samples t-test on SPAI scores between the Low AQ and High AQ groups indicated a significant difference in SPAI difference scores, $t(143) = -9.12$, $p < .01$. Participants in the High AQ group reported significantly more social anxiety ($M = 26.95$, $SD = 8.03$) than participants in the Low AQ group ($M = 13.95$, $SD = 8.41$). To account for this confound, and due evidence that social anxiety affects attention to faces in dot-probe studies (Bradley et al., 2000; Fox, 2004; Mansell et al., 1999) and performance on emotion identification tasks (Machado-de-Sousa et al., 2010), SPAI difference scores were used as a covariate in data analysis for the two dot-probe tasks and the Reading the Mind in the Eyes task.

Daily conversation measure.

A measure of participants' daily number of conversations was taken by asking participants to report how many conversations they had participated in during the previous day, along the following scale: "none", "1 person", "2 people", "3 – 5 people", "6 – 9 people", "10 – 15 people", and "more than 15 people". Participants were also asked to indicate whether this number was lower than average, average, or higher than average on a 5-point Likert scale. An independent samples t-test indicated that the typicality of the reported number of conversations did not differ between the Low AQ ($M = 2.70$, $SD = 0.58$) and High AQ ($M = 2.84$, $SD = 0.55$) groups, $t(143) = -1.45$, $p > .05$, with reports from each group representing a fairly typical day. Due to a low sample size for the response options of "none," "1 person," and "more than 15 people," response options were condensed into four categories: "0 – 2 people," "3 – 5 people," "6 – 9 people," and "10 or more people." High AQ participants generally reported engaging in fewer daily conversations (*Mode* = "3 – 5 people") than Low AQ participants (*Mode* =

"more than 10 people"). A Somers' *d* analysis of ordinal association confirmed a significant negative association between AQ group and number of self-reported daily conversations, *d* = -.41, $t_{approximate}$ = -4.32, *p* < .01, such that in a combinatorial examination of High AQ / Low AQ participant pairs, the proportion of pairs in which High AQ participants reported more daily conversations than Low AQ participants was 41% lower than pairs in which Low AQ participants reported more daily conversations. See Figure 1 for a graph of response distributions for the two groups.

Eyes Task

Accuracy on the Eyes Task was calculated for each participant as the percent of trials in which the correct emotion descriptor was selected, excluding trials where the participant entered an invalid keyboard response or pressed 'spacebar' to indicate that one of the four emotion descriptor options was an unknown word. A one-way (AQ group) ANCOVA was conducted on accuracy on the Eyes Task with SPAI difference score as a covariate. When controlling for the effect of SPAI, a main effect of AQ group on accuracy emerged, $F(1,142) = 4.99$, $p = .03$, such that Low AQ participants more accurately identified emotions ($M = 77.30$, $SD = 11.60$) than High AQ participants ($M = 72.47$, $SD = 10.82$). To investigate the covariate effect of SPAI, a multiple regression analysis was performed on Eyes Task accuracy scores, with SPAI difference scores and AQ scores as continuous predictors, $R^2 = .05$, $p = .03$. SPAI difference score was a significant positive predictor of Eyes Task accuracy, $\beta = .21$, $p = .05$, whereas AQ score was a significant negative predictor of Eyes Task accuracy, $\beta = -.27$, $p = .01$. In the current sample, higher social anxiety predicted higher accuracy in mental state identification, but autistic traits carried the opposite effect, predicting lower accuracy.

Prior research indicates that individuals with High AQ may process faces with direct and averted eye gaze differently than Low AQ individuals (Nummenmaa et al., 2012). Since a mix of direct and averted eye gaze was included in stimuli for the Eyes

Task, it was hypothesized that gaze direction might moderate differences in task performance due to autistic traits. In order to investigate this in the current sample, accuracy scores for each participant were subset into one accuracy score for trials with direct gaze and another accuracy score for trials with averted gaze. A two-way (AQ group x Gaze Direction) mixed factorial ANCOVA was conducted, including SPAI difference score as a covariate, on accuracy scores for the two gaze conditions. An interaction emerged between AQ Group and Gaze Direction, $F(1,142) = 3.77$, $p = .05$, such that High AQ and Low AQ participants did not differ in accuracy on direct gaze trials ($M_{HighAQ} = 74.44$, $SD_{HighAQ} = 12.09$; $M_{LowAQ} = 76.48$, $SD_{LowAQ} = 13.01$), but High AQ participants less accurately identified mental states in averted gaze trials ($M_{HighAQ} = 69.97$, $SD_{HighAQ} = 15.01$; $M_{LowAQ} = 78.35$, $SD_{LowAQ} = 16.12$) (see Figure 2). A multiple regression with SPAI difference and AQ scores as continuous predictors of direct gaze accuracy did not result in a significant model, $R^2 = .01$, $p > .05$, but a multiple regression with the same predictors on averted gaze accuracy revealed significant prediction by SPAI difference score, $\beta = .26$, $p = .01$, and AQ group, $\beta = -.29$, $p = .01$, $R^2 = .06$, $p = .01$. Higher SPAI difference scores predicted higher accuracy on averted gaze Eyes Task trials, but higher AQ scores predicted lower accuracy. The effect of AQ on Theory of Mind abilities measured by the Eyes Task task appears to be driven by difficulty identifying mental states in faces with averted eye gaze, but this difficulty may be counteracted by an effect of social anxiety increasing mental state identification accuracy.

Face/Non-Face Dot-Probe

Two participants, one in the High AQ group and one in the Low AQ group, were excluded from Face/Non-Face Dot-Probe analyses due to mean reaction times more than 3 standard deviations from the mean of their respective AQ Groups. The resulting sample size for Emotion Dot Probe analyses was $N = 143$ (High AQ: $N = 94$, 36 male,

M_{age} = 19.00, M_{AQ} = 26.03, SD_{AQ} = 4.91; Low AQ: *N* = 49, 20 male, M_{age} = 19.08, M_{AQ} = 9.41, SD_{AQ} = 2.58). Average accuracy, defined as the percent of trials on which participants correctly indicated the location of the probe, on the Face/Non-Face Dot-Probe task was 97.23% (*SD* = 6.71) for the High AQ Group and 98.52% (*SD* = 1.86) for the Low AQ Group. The difference in accuracy between the groups was not significant, $t(141) = 1.32$, $p > .05$. Trials in which participants did not correctly identify the location of the probe were excluded from further analyses. Summary reaction time variables were calculated for each of the 16 trial experimental trial types, which were factorial combinations of the following variables: Probe Location (Target, Distractor), Distractor Type (Inverted Face, Car), and SOA (100ms, 200ms, 500ms, 1000ms). Eight face bias scores were then calculated, one for each Distractor Type / SOA combination, by subtracting participants' average reaction time on trials where the probe was behind the Distractor (Car or Inverted Face) from participants' average reaction time on trials where the probe was behind the Target (Upright Face) at each SOA. The resulting face bias scores represent attentional bias toward (positive face bias scores) or away from (negative face bias scores) upright faces, with a face bias score of zero indicating no different in attentional bias.

A 2 (Distractor Type) x 4 (SOA) x 2 (AQ Group) mixed factorial repeated measures ANCOVA with SPAI difference scores as a covariate was used to examine differences in face bias scores. There was a significant three-way interaction between Distractor Type, SOA, and AQ Group, $F(3, 420) = 4.61$, $p < .01$. This interaction was probed by conducting separate mixed factorial 4 (SOA) x 2 (AQ Group) ANCOVAs on face bias scores for each Distractor. Significant SOA x AQ Group interactions were found for Car Distractor trials, $F(3, 420) = 6.59$, $p < .01$, and for Inverted Face Distractor trials, $F(3, 420) = 3.89$, $p = .01$. These interactions were further probed by conducting simple main effect analyses using estimated marginal means controlling for SPAI levels.

Simple main effect analyses revealed significant differences in face bias scores between High AQ and Low AQ groups for Car Distractor trials at 100ms, $t(420) = 2.52$, $p = .01$, 200ms, $t(420) = 2.70$, $p = .01$, and 500ms, $t(420) = 5.24$, $p < .01$ (see Figure 3). High AQ and Low AQ participants did not differ in their attentional bias toward or away from upright faces compared to cars at 1000ms, $t(420) = 0.47$, $p > .05$. At 100ms, Low AQ participants exhibited significantly higher attentional bias ($M = 28.62$, $SD = 114.24$) than High AQ participants ($M = -7.93$, $SD = 106.46$) toward upright faces compared to cars. At 200ms and 500ms, this pattern reversed from the pattern at 100ms, with High AQ participants exhibiting significantly higher attentional bias (200ms: $M = 24.04$, $SD = 90.26$; 500ms: $M = 33.34$, $SD = 126.72$) than Low AQ participants (200ms: $M = -15.03$, $SD = 96.88$; 500ms: $M = -42.35$, $SD = 135.94$) toward upright faces compared to cars. For Inverted Face Distractor trials, face bias scores were significantly different between High AQ and Low AQ groups at 100ms, $t(420) = 4.12$, $p < .01$, and 500ms, $t(420) = 2.53$, $p = .01$ (see Figure 4). High AQ and Low AQ participants did not differ in their attentional bias toward or away from upright faces compared to inverted faces at 200ms, $t(420) = 0.52$, $p > .05$, and the two groups differed with marginal significance at 1000ms, $t(420) = 1.82$, $p = .06$. At 100ms and 500ms, Low AQ participants exhibited significantly stronger attentional bias (100ms: $M = 20.97$, $SD = 125.16$; 500ms: $M = 24.17$, $SD = 106.26$) than High AQ participants (100ms: $M = -38.66$, $SD = 116.64$; 500ms: $M = -12.39$, $SD = 98.99$) toward upright faces compared to inverted faces. The difference in attention bias scores was marginally significant at 1000ms, with a trend toward High AQ participants displaying a significantly higher attentional bias ($M = 9.89$, $SD = 57.49$) than Low AQ participants (Low AQ: $M = -16.50$, $SD = 61.67$) toward upright faces compared to inverted faces. At 200ms, no difference in attentional bias between upright and inverted faces was observed between Low AQ ($M = 6.42$, $SD = 96.60$) and High AQ ($M = -1.12$, $SD = 90.07$) groups.

Basic/Complex Emotion Dot-Probe

Three participants, all in the High AQ group, were excluded from Basic/Complex Emotion Dot-Probe analyses due to mean reaction times more than 3 standard deviations from the mean of their respective AQ Groups. The resulting sample size for Basic/Complex Emotion Dot-Probe analyses was N = 142 (High AQ: N = 92, 21 male, M_{age} 19.10, M_{AQ} = 9.44, SD_{AQ} = 2.57; Low AQ: N = 50, 35 male, M_{age} = 19.03, M_{AQ} = 26.13, SD_{AQ} = 4.93). Average accuracy in identifying probe location was 98.04% (SD = 3.36) for the Basic/Complex Emotion Dot-Probe task, and did not significantly differ between AQ Groups, $t(140) = -1.44$, $p > .05$, with 97.49% accuracy (SD = 4.72) for the Low AQ group and 98.33% accuracy (SD = 2.29) for the High AQ group. Only correct trials were used in further analyses. Each experimental trial consisted of an upright emotion face (Target) and an inverted neutral face (Distractor). Sixteen average reaction time scores were calculated, one for each combination of Probe Location (Target, Distractor), SOA (100ms, 200ms, 500ms, 1000ms) and Emotion Complexity (Basic, Complex). Basic emotion trials consisted of trials with Happy and Angry target faces, and Complex emotion trials consisted of trials with Fearful and Surprised target faces. Eight face bias scores were then calculated by subtracting the average reaction time on trials when the probe was located behind the Target stimulus from the average reaction time on trials when the probe was located behind the Distractor, for each Emotion Complexity/SOA combination.

A 2 (Complexity) x 4 (SOA) x 2 (AQ Group) mixed factorial repeated measures ANCOVA with SPAI difference score as a covariate was conducted for face bias scores. No interactions were significant, and the only main effect was for SOA, $F(3,417) = 4.40$, $p = .01$, which was driven by a significant decrease in face bias scores between 500ms (M = 5.97, SD = 33.72) and 1000ms (M = -3.55, SD = 40.16), $t(142) = 2.52$, $p = .01$. This result was not of theoretical interest to the current study, which hypothesized an effect of

AQ Group. See Figure 5 for a graph of the mean face bias scores for Low AQ and High AQ participants for each Complexity / SOA combination.

Order Effects

The order of block presentation was counterbalanced between participants. Approximately half of the participants completed the Eyes Task before the two dot-probe tasks, and the remaining participants completed the two dot-probe tasks before the Eyes Task. Within the dot-probe block, approximately half of the participants completed the Face/Non-Face Dot Probe before the Basic/Complex Emotion Dot-Probe, and the remaining participants completed the Basic/Complex Emotion Dot-Probe before the Face/Non-Face Dot-Probe. To check for order effects, additional analyses were run for each task that included order as a covariate.

For the Eyes Task, including order of completion of the Eyes Task and the dot-probe tasks as a covariate in accuracy analyses did not result in any main effects or interactions involving the order variable. For the Face/Non-Face Dot-Probe task, including order of completion of the Face/Non-Face and Basic/Complex Emotion dot-probe tasks as a covariate did not affect analyses of face bias scores.

For the Basic/Complex Emotion Dot-Probe task, an order effect on face bias scores did emerge. A 2 (Complexity) x 2 (AQ Group) x 2 (Dot-Probe Order) ANCOVA with SPAI difference scores as a covariate resulted in a AQ Group x Dot-Probe Order interaction, $F(1,137) = 4.92$, $p = .03$ (see Figure 6). Post hoc comparisons indicated that overall face bias scores on the Basic/Complex Emotion Dot-Probe task were higher for Low AQ participants who completed the Basic/Complex Emotion Dot-Probe before the Face/Non-Face Dot-Probe ($M = 9.36$, $SD = 35.16$) compared to Low AQ participants who completed the Face/Non-Face Dot Probe before the Basic/Complex Emotion Dot-Probe ($M = -2.47$, $SD = 31.51$), $t(49) = 2.33$, $p = .02$. Overall face bias scores on the Basic/Complex Emotion Dot-Probe for High AQ participants did not differ between

Face/Non-Face first (*M* = 1.19, *SD* = 23.82) and Basic/Complex Emotion first order conditions (*M* = -0.98, *SD* = 23.30), $t(49) = 0.58$, $p > .05$. The main effect of SOA from previous analyses without Order was retained, and no further main effects or interactions emerged.

Discussion

The current study aimed to characterize differences in social cognition and social behavior between neurotypical college students with high and low levels of self-reported autistic traits, as measured by the AQ. The High AQ group in the current study is theorized to represent individuals who fit the characteristics of the BAP. Differences were found between High AQ and Low AQ participants with regard to their temporal and configural processing of faces, sensitivity to eye gaze direction on a Theory of Mind task, social anxiety, and quantity of daily conversation. Complexity of facial emotion did not affect attentional bias to emotional faces in either group. The results of the current study build on the existing literature characterizing social cognitive and social behavioral patterns associated individuals expressing high levels of subclinical autistic traits (Brunyé et al., 2012; Hudson et al., 2012; Kunihira et al., 2006; Sasson et al., 2013; Suda & Takei, 2011).

Social Cognition

The primary findings in the current study relate to the relationship between subclinical autistic traits and social cognitive processing. College students who self-reported high levels of autistic traits responded differently than their peers with low levels of autistic traits on a Theory of Mind task, and on one of two tasks measuring attention bias to faces. Differences in social cognitive performance between the two groups were subtle, emerging only under certain conditions. Theory of Mind performance did not differ between groups when interpreting mental states from expressions with direct eye gaze, but this component of Theory of Mind was impaired in the High AQ group in response to averted eye gaze. A potential compensatory effect of social anxiety was also observed on the Theory of Mind task, with social anxiety predicting higher accuracy in interpreting averted eye gaze expressions. Preferential attention to upright faces compared to non-face objects and inverted faces was initially weaker in High AQ participants, but High AQ participants exhibited stronger attentional preference to social than non-social stimuli latter in processing. This pattern of subtle differences in social cognition is in line with previous findings that suggest that the social cognitive profile of individuals fitting the BAP is distinct from individuals with low levels of autistic traits (Hudson et al., 2012; Masashi Suda, 2011; Miu et al., 2012), but with impairments that are less pronounced than those characteristic of clinical ASD (Dawson et al., 2002; Kaiser et al., 2010; Piven et al., 1997). The conditions that elicited different social cognitive performance between High AQ and Low AQ groups in the current study are reviewed in the following sections.

Theory of Mind and Eye Gaze

Prior studies of autistic traits and Theory of Mind as measured by the Eyes Task have yielded mixed results (Baron-Cohen, Wheelwright, Hill, et al., 2001; Kunihira et al., 2006). The results of the current study suggest Theory of Mind differences can be found between High AQ and Low AQ individuals under certain conditions. Initial analyses indicated that overall performance on the Eyes Task was lower for the High AQ group than the Low AQ group. However, further analyses indicated that this effect was sensitive to gaze direction, a specific stimulus feature that conveys an additional level of social information. Accuracy of mental state identification did not differ between the two groups when the eyes in the stimulus image displayed a direct gaze. When the gaze of the stimulus eyes was averted, High AQ participants identified mental states with significantly less accuracy than did Low AQ participants. This is consistent with a previous study that found that individuals with high levels of autistic traits display less brain activation in regions related to Theory of Mind when viewing faces with averted eyes than do individuals with low levels of autistic traits (Nummenmaa et al., 2012). These results suggest that Theory of Mind is primarily intact in BAP, but it may be modulated by social cues such as gaze direction.

Additionally, accuracy on averted gaze trials was uniquely predicted by both autistic traits and social anxiety, in opposite directions. Autistic traits predicted lower accuracy in mental state identification, while social anxiety predicted higher accuracy. Several researchers have suggested that BAP individuals may employ compensatory strategies that moderate the relationship between their autistic predispositions and their performance on social tasks (Adolphs, Spezio, Parlier, & Piven, 2008; Kaiser et al., 2010). The current study found that social anxiety in High AQ individuals enhanced emotion identification on averted gaze trials, in opposition to the effect of autistic traits. This suggests that social anxiety could serve a compensatory role in this population. Schmitz and colleagues (2012) found that individuals with high trait social anxiety display enhanced neural processing of eyes with averted gaze compared to low trait social anxiety individuals. Socially anxious individuals are particularly attentive to expressions that indicate negative social evaluation (Moser et al., 2008; Winton, Clark, & Edelmann, 1995), and averted eye gaze is often associated with these types of expressions (Itier & Batty, 2009; Schmitz et al., 2012; Strick, Holland, & van Knippenberg, 2008). Many of the stimuli in the Eyes Task with averted gaze represent mental states with a negative social evaluative component, such as “nervous,” “suspicious,” “distrustful,” and “uneasy.” Although averted gaze is often associated with negative valence, socially anxious individuals also differentially process neutral faces with direct and averted eye gaze (Schmitz et al., 2012), indicating that this effect is not driven by valence per se.

Social anxiety levels are often elevated in BAP (Freeth et al., 2013) and, consistent with the literature, the High AQ group in the current study reported higher levels of social anxiety than the Low AQ group. Social anxiety predicted greater accuracy in interpreting mental state from averted eyes in the current study, while autistic traits predicted lower accuracy. Previous studies that have found no difference in Eyes Task performance due to autistic traits but these studies have not controlled for social anxiety or examined eye gaze effects (Kunihira et al., 2006; Russell-Smith et al., 2013). The results of the current study suggest that Theory of Mind differences due to subclinical autistic traits may not be observable at a global level, but are contingent on stimulus characteristics such as eye gaze direction. These differences may be masked by trait social anxiety, which has been associated with enhanced processing of expressions involving averted eye gaze.

Preferential Attention to Faces

Faces versus non-faces: Temporal and configural effects.

High AQ and Low AQ participants exhibited distinct temporal patterns of preferential attention to faces, which were also contingent upon the configural properties of distractor stimuli. Low AQ participants traits exhibited a significantly greater preference for face images early in processing, at 100ms, compared to High AQ participants. This 100ms effect was found regardless of whether the distractor image was a car or an inverted face. Patterns of attention to faces by High AQ and Low AQ participants diverged at later time points in processing for the different distractor stimuli. When faces were presented alongside car images, the initial 100ms group difference flipped at 200ms and 500ms, with High AQ participants preferentially attending to faces more than Low AQ participants did. When faces were presented alongside inverted faces, High AQ participants never exhibited a greater face bias than Low AQ participants, with no group differences at 200ms, and a greater face bias for Low AQ participants at 500ms. By 1000ms, no difference in attentional bias was observed between the two groups for either distractor stimulus.

The results at 100ms indicate a stronger initial orientation to faces in Low AQ participants than High AQ participants. This is consistent with evidence that neurotypical individuals preferentially orient to social stimuli from an early age (Frank, Vul, & Johnson, 2009; Goren, Sarty, & Wu, 1975; Pascalis, de Schonen, Morton, Deruelle, & Fabre-Grenet, 1995), and early in attentional processing (Bindemann, Burton, Hooge, Jenkins, & De Haan, 2005; Dering et al., 2011). ASD individuals do not seem to display the same preferential initial orientation to social stimuli (Fletcher-Watson et al., 2009; Kaiser et al., 2010; Moore et al., 2012). Low AQ individuals and High AQ individuals in the current study displayed an analogous differential response in initial orienting at 100ms. However, responses as early as 200ms did not reflect this difference in initial orienting. High AQ participants attended significantly more to faces than cars at 200ms than did Low AQ participants, and the two groups did not differ in preferential attention between upright and inverted faces at this time point. Previous studies have found that ASD individuals still do not preferentially orient to social stimuli at 200ms (Moore et al., 2012). Slower initial orienting to faces may be analogous between ASD and High AQ individuals at 100ms, but by 200ms High AQ participants attended to faces at the same rate as or more strongly than Low AQ participants, depending on configural features of the distractor stimuli.

Participants in the current study with high levels of autistic traits preferentially attended to faces than cars at 200ms and 500ms more than did participants with low levels of autistic traits. At 200ms, this increase in preferential attention to faces by High AQ individuals may reflect a delay in the mechanism responsible for initial orienting to social stimuli in Low AQ individuals. The elevated face bias score at 500ms for High AQ individuals may represent sustained attention to faces (Bindemann et al., 2005), slower face processing, or difficulty disengaging attention from faces (Koster, Crombez, Verschuere, & De Houwer, 2004). Further modifications to the dot-probe design, or the utilization of eye-tracking technology would be necessary in order to determine the cause of this attention bias in later processing. It is unclear why attention bias to faces decreased in Low AQ individuals at 200ms and 500ms, as previous studies have found a neurotypical face bias at both of these time points (Bindemann et al., 2005; Moore et al., 2012). Dot-probe studies often find a sustained attention bias to threatening images (Fox, Russo, Bowles, & Dutton, 2001; Colin MacLeod & Mathews, 1988), so it is possible that Low AQ individuals displayed lower attention biases to faces later in processing because faces are not threatening stimuli to this population. Another possibility is that the similarity of the car stimuli in the current study to faces resulted in face-like processing of these stimuli after an initial bias to biological face stimuli. By 1000ms, High AQ and Low AQ individuals converged in their attention bias to faces compared to cars, but means for both groups indicate that neither stimulus was preferred at this time point. Prior studies support this finding that when more time is allotted for processing, attention to social stimuli is similar between individuals with both high and low levels of subclinical autistic traits (Fletcher-Watson et al., 2009).

When upright faces were presented alongside inverted faces, a different temporal pattern of processing emerged. Attention bias for upright faces did not differ between High AQ and Low AQ participants at 200ms or 1000ms, and attention bias for upright faces was lower in high autistic trait participants at 100ms and 500ms. Visual inspection of the data suggests that Low AQ participants seemingly alternated attention between upright and inverted faces, with greater attention given to upright faces early and midway through processing. High AQ participants seemed to overall attend less to upright faces than low autistic trait participants did, but these differences did not manifest as often as when faces were paired with cars. Whereas cars are configurarly similar to faces but lack the low-level features that imbue faces with biological and social meaning, inverted faces maintain these low-level features but represent a disruption of the prototypical configuration of a face (Freire et al., 2000). Evidence suggests that BAP individuals exhibit different neural processing patterns in response to faces and objects than individuals with low levels of autistic traits (Dawson et al., 2005), perhaps indicating differences in configural face processing such as those observed in ASD (Webb et al., 2012). This could be reflected in the different patterns of attention bias to faces found in the current study for car and inverted face distractor stimuli. The emergence at several time points of higher attentional preference for faces in High AQ individuals compared to Low AQ individuals when the alternative stimulus was a car but not an inverted face could indicate that low-level biological features of faces are more salient to High AQ individuals than the typicality of face configurations.

Basic and complex emotions.

Results from the emotion dot probe task did not support the hypothesis that attention biases to faces would be further modulated by emotional expressions of varying complexity. No difference in attention bias to upright emotional faces compared to inverted neutral faces was found between High AQ and Low AQ participants, regardless of whether the face displayed a simple or a complex emotion and regardless of SOA. While this could indicate that basic and complex emotional expressions elicit equal attentional salience to High AQ and Low AQ individuals, there are other factors that must be considered.

Four different emotions were included in this task: anger, happiness, fear, and surprise. (Baron-Cohen et al., 1993) reported lower accuracy by ASD participants in the recognition of surprise, which they attributed to the belief-based nature of this emotion compared to the basic, internally-generated emotions of happiness and anger. Fear was also included as a complex emotion in the current study based on a study by Howard et al. (2000), in which ASD participants exhibited a selective impairment in fear recognition. Evidence also suggests that clinical and subclinical autistic traits predict abnormal attentional responses to and affective judgments of fearful faces (Adolphs, Sears, & Piven, 2001; Hudson et al., 2012). The results of the current study do not provide evidence that attentional preference to upright compared to inverted faces is affected by complexity of facial emotion. However, it is possible that the categorization of fear and surprise into a separate cognitive category than happiness and sadness was not a valid grouping in this study.

Additionally, an order effect was found that confounded the detection of meaningful effects in the Basic/Complex Emotion Dot-Probe task; no order effects had been hypothesized. Low AQ participants who completed the Basic/Complex Emotion Dot-Probe before the Face/Non-Face Dot-Probe exhibited greater preferential attention overall to upright emotional faces compared to inverted neutral faces than Low AQ participants who completed the dot-probe tasks in the alternative order. The two dot-probe tasks both included inverted neutral faces and upright faces, but the upright faces were neutral for the Face/Non-Face task and emotional in the Basic/Complex Emotion Dot-Probe task. The face/non-face task also included car images, which were not present in the Basic/Complex Emotion Dot-Probe task. Participants who completed the Face/Non-Face Dot-Probe task first would have seen many inverted face stimuli by the time they began the Basic/Complex Emotion Dot-Probe task, which could have altered their response to this stimulus in the Basic/Complex Emotion Dot-Probe task. The exposure of participants to car stimuli prior to the Basic/Complex Emotion Dot-Probe task could also modified the attentional processes evoked by face stimuli alone. Interestingly, High AQ individuals did not show this order effect, indicating that face processing mechanisms in these individuals may be robust to the effects of previous stimulus exposure.

Social Behavior

In addition to differences in social cognition, we predicted that social behavior would differ between Low AQ and High AQ participants, as measured by a self-report measure of daily conversation. As predicted, High AQ participants reported engaging in fewer daily face-to-face conversations lasting longer than five minutes than Low AQ participants. Social cognition has previously been identified as a mediating factor between subclinical autistic traits and social skills in BAP (Sasson et al., 2013). Although this relationship was not explicitly analyzed in the current study, it is possible that High AQ participants engage in fewer daily social conversations as a result of underlying social cognitive differences such as those observed in the current study. There is likely a feedback component to this relationship as well. Developmentally, conversations are vital to the development of social cognitive processes such as Theory of Mind, and they may also be implicated in the maintenance of social cognition throughout the lifespan (Garfield et al., 2001; Hughes & Leekam, 2004; Psaltis & Duveen, 2006). Engaging in face-to-face conversations could enhance sensitivity to social stimuli such as faces, improving accuracy on interpretation of facial expressions and encouraging faster attentional orienting to faces. Individuals who engage in fewer daily conversations encounter fewer opportunities to utilize and refine their social cognition, which could compound existing social cognitive challenges. The higher social anxiety among the High AQ participants might also deter them from engaging in conversations, independent of the effect of autistic traits. Because of the ordinal nature of the data on the conversation measure, more sophisticated analyses could not be conducted to attempt to answer these questions. However, the finding that High AQ participants may generally engage in fewer face-to-face conversations is evidence that social challenges in this group extend beyond cognitive processes.

Limitations and Future Directions

The current study suffers from several limitations. The study was limited by an uneven gender distribution, which prevented investigations of gender effects that have been previously been reported in the literature with regard to BAP (Baron-Cohen, Wheelwright, Skinner, et al., 2001; Brunyé et al., 2012; Reed, Lowe, & Everett, 2011). Additionally, a greater number of high autistic trait than low autistic trait participants completed the study, which makes the results of this study vulnerable to Type I error if the smaller sample of low autistic trait participants were not well representative of low autistic trait individuals in general. More data is currently being collected in order to address these issues.

The tasks and measures in the current study could also have been improved. Recent research suggests that the AQ is not the most reliable measure of BAP, and a measure such as the Broad Autism Phenotype Questionnaire (BAPQ) may have provided a more accurate identification of BAP individuals (Ingersoll, Hopwood, Wainer, & Brent Donnellan, 2011). However, the group differences consistent with previous studies of BAP did emerge in the current study based on groupings using the AQ, and the AQ is a frequently used measure in the study of subclinical autistic traits. The conversation measure used in the current study could be improved by allowing free response instead of forced choice, so that the resulting continuous data could be used as covariates in analyses. Ordinal data did not easily afford hypothesis testing of quantity of social interaction as a factor associated with social cognition. The inclusion of two dot-probe tasks with distinct stimuli within one testing session may not have been ideal. Although the order of tasks was counterbalanced, order effects were found that affected the results of the Basic/Complex Emotion Dot-Probe task. Additionally, the testing session was long, lasting approximately 30 to 45 minutes, and including almost one thousand experimental trials. Fatigue might have affected the quality of data collected from the social cognitive tasks in this study.

Stimuli in the dot-probe tasks of the current study may have also contributed error variance. Care was taken to control perceptual variance between stimuli, including cropping stimuli to the same size and shape, and editing out features such as hair and ears. While interstimulus perceptual variance has been identified as an important factor to control in face processing studies (Thierry et al., 2007), the tradeoff is a reduction in ecological validity. When face images are similar to real faces but differ in certain ways, it can elicit negative arousal and avoidance behavior known as the uncanny valley effect (Looser & Wheatley, 2010; MacDorman, 2006; Moosa & Ud-Dean, 2010). If the images in the current study were too heavily modified in an attempt to enhance experimental control, the uncanny valley effect may have altered participants' attentional biases to face stimuli. It would also have been beneficial to ask participants about their familiarity with cars, which could have affected their response to these stimuli. When car experts view images of cars, areas of the brain typically associated with face processing may be activated (Gauthier, Skudlarski, Gore, & Anderson, 2000). Car images might also activate face areas of the brain if they resemble a face closely enough (Hadjikhani, Kveraga, Naik, & Ahlfors, 2009; Liu et al., 2014), and there is some evidence that the face-like grill area of cars may be perceived to convey social information such as gender and emotion (Windhager et al., 2012). Although pilot data were collected about the gender and valence impressions of the car stimuli, not enough pilot data were available in order to control these factors. Resultantly, a neutral face may have been paired with a car image giving the impression of an emotionally valenced facial expression. Valence judgments of cars in the current study could have resulted in the creation of an additional, unmonitored, variable affecting participants' attention biases on this task.

Conclusion

The current study invites many further directions of research. The eye gaze effect in the Eyes Task has not previously been reported, and it would be interesting to replicate this effect and to examine how it interacts with previously identified factors affecting Eyes Task performance, such as gender (Kirkland, Peterson, Baker, Miller, & Pulos, 2013). The current study also identifies social anxiety traits as serving a potentially compensatory role during Theory of Mind processing, although much further research into this question would be necessary before drawing firm conclusions. Patterns of preferential attention to faces differed between BAP individuals and low autistic trait individuals depending on temporal and contextual factors. Social behavior also differed between individuals with high and low levels of autistic traits, with BAP individuals reporting fewer daily conversations. The nuanced results in the current study on the Eyes Task and the Face/Non-Face Dot-Probe task support the idea that BAP individuals in the general population display unique social cognitive processing strategies, which may mediate the relationship between autistic traits and social behavior. Further examination of these social cognitive patterns may provide insight into the mechanisms underlying ASD, and potential compensatory strategies utilized by BAP individuals that moderate their predisposition for autistic behavior.

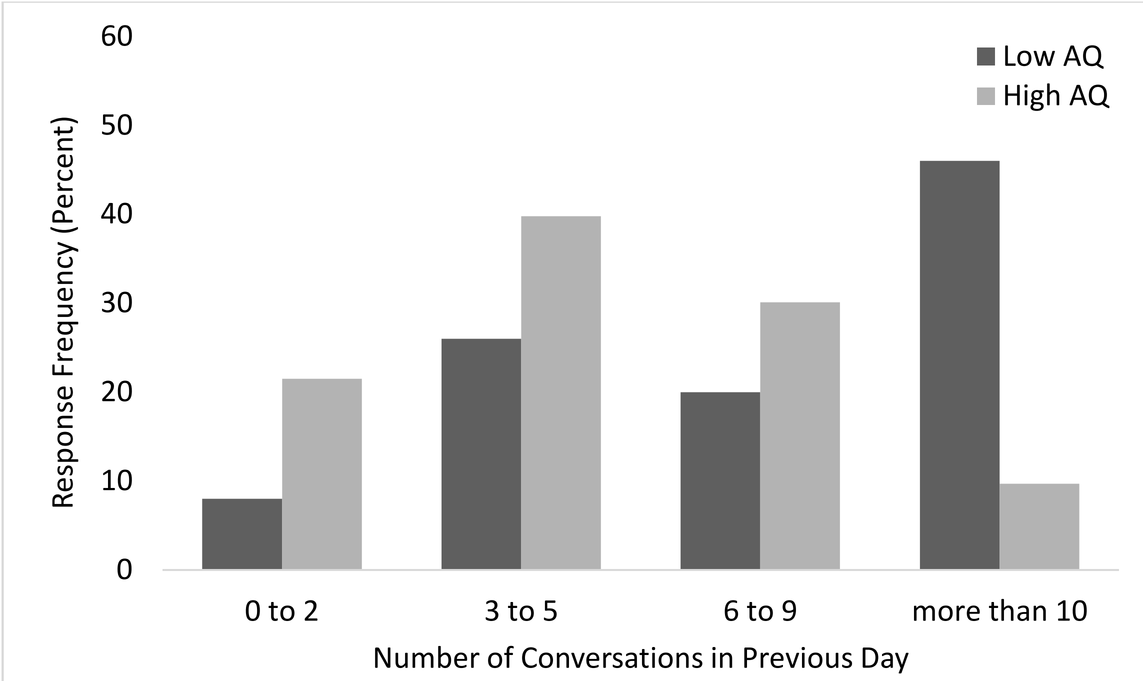

Figure 1. A comparison of the frequency distributions of Low AQ and High AQ participants' self-reported number of conversations from the previous day.

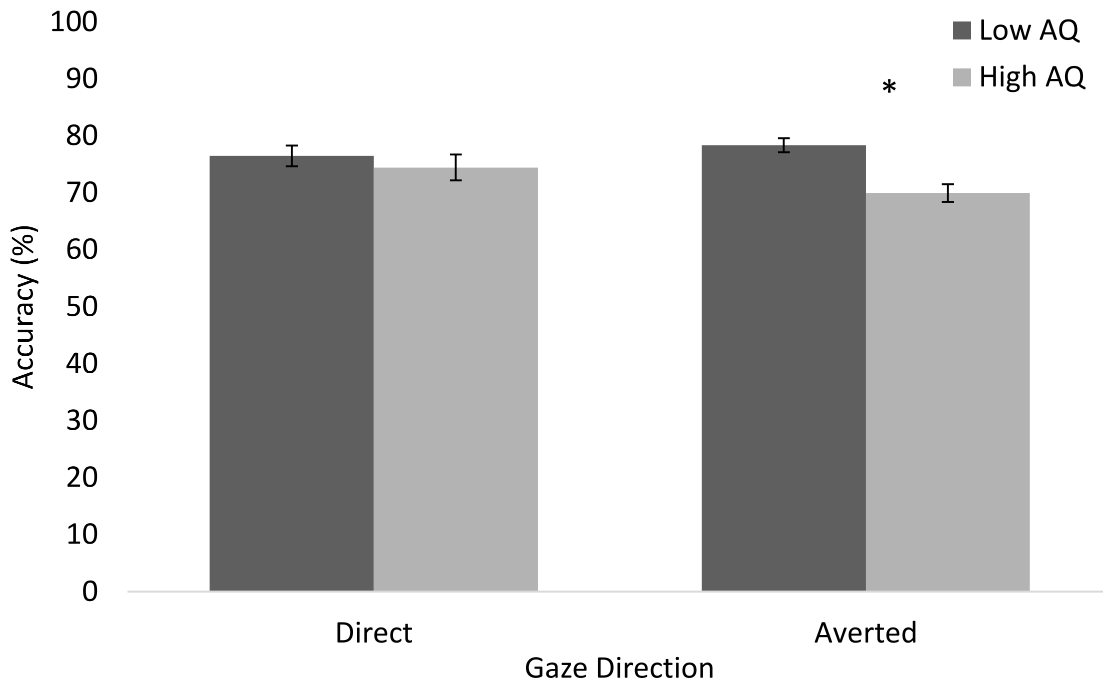

Figure 2. Emotion identification accuracy for Low AQ and High AQ participants on trials with direct gaze and averted gaze in the Reading the Mind in the Eyes task.

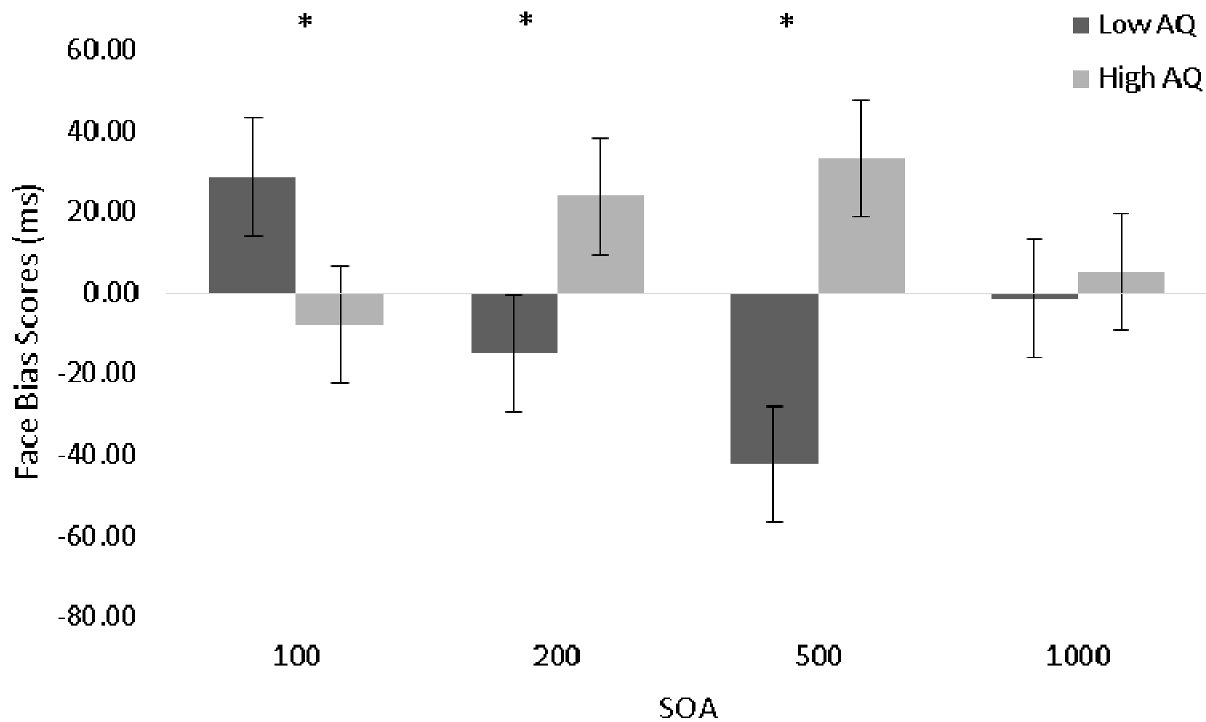

Figure 3. Face bias scores for High and Low AQ participants on Car Distractor trials at each SOA. Face bias scores are calculated as the average reaction time on Target-cued trials subtracted from average reaction time on Car-cued trials. Positive face bias scores indicate an attentional bias toward upright faces images, and negative face bias scores indicate an attentional bias toward car images.

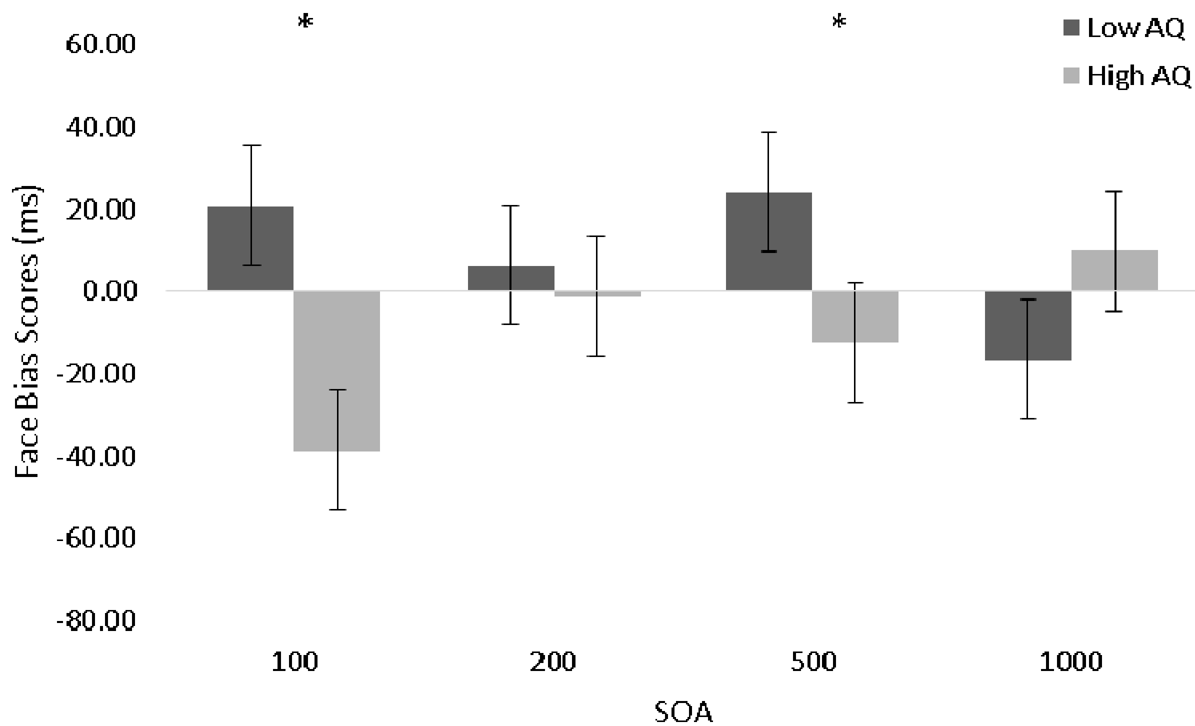

Figure 4. Face bias scores for High and Low AQ participants on Inverted Face Distractor trials at each SOA. Face bias scores are calculated as the average reaction time on Target-cued trials subtracted from average reaction time on Inverted-Face-cued trials. Positive face bias scores indicate an attentional bias toward upright faces images, and negative face bias scores indicate an attentional bias toward inverted face images.

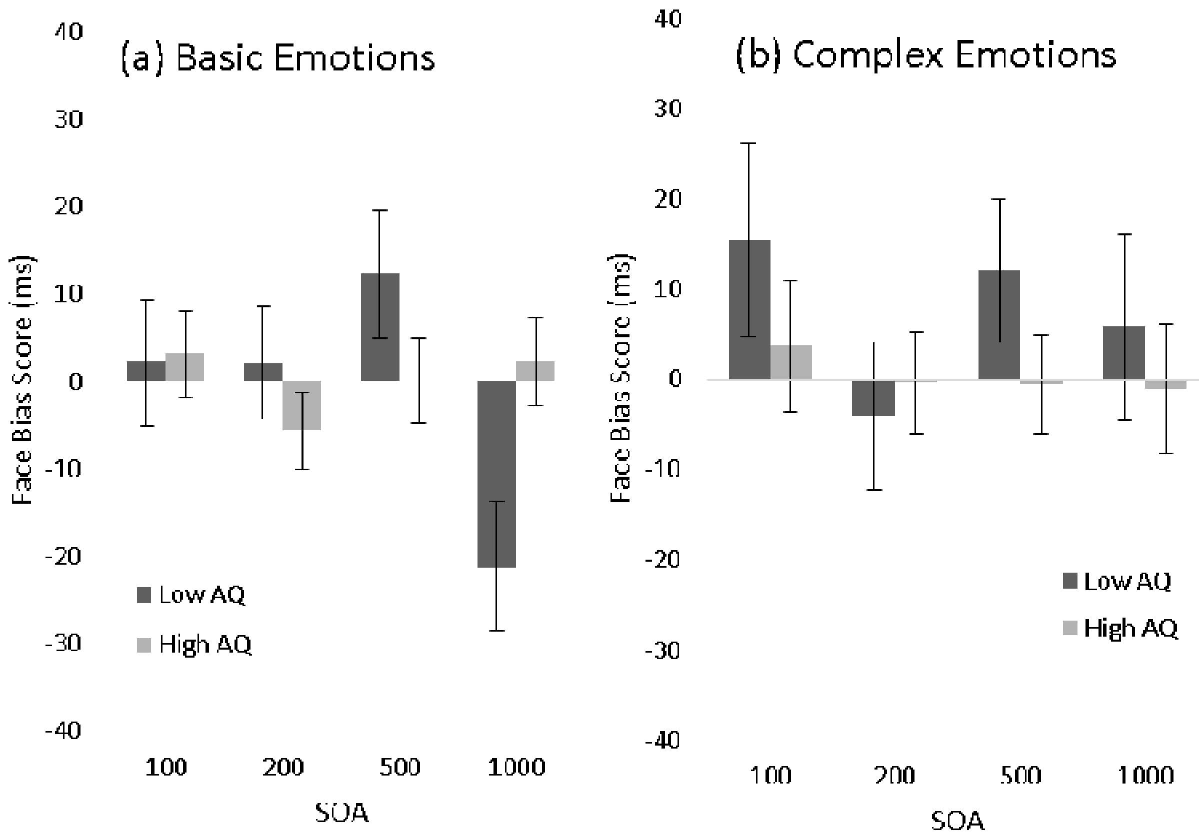

Figure 5. Face bias scores for Low AQ and High AQ participants on the Emotion Dot Probe task at each SOA for (a) trials with Basic emotion target stimuli and (b) trials with Complex emotion target stimuli. Face bias scores represent the mean reaction time on Target-cued trials (probe behind an upright emotion face) subtracted from the mean reaction time on Distractor-cued trials (probe behind an inverted neutral face). Positive face bias scores indicate an attentional bias toward upright emotional faces compared to inverted neutral faces, and negative face bias scores indicate an attentional bias toward inverted neutral faces compared to upright emotional faces.

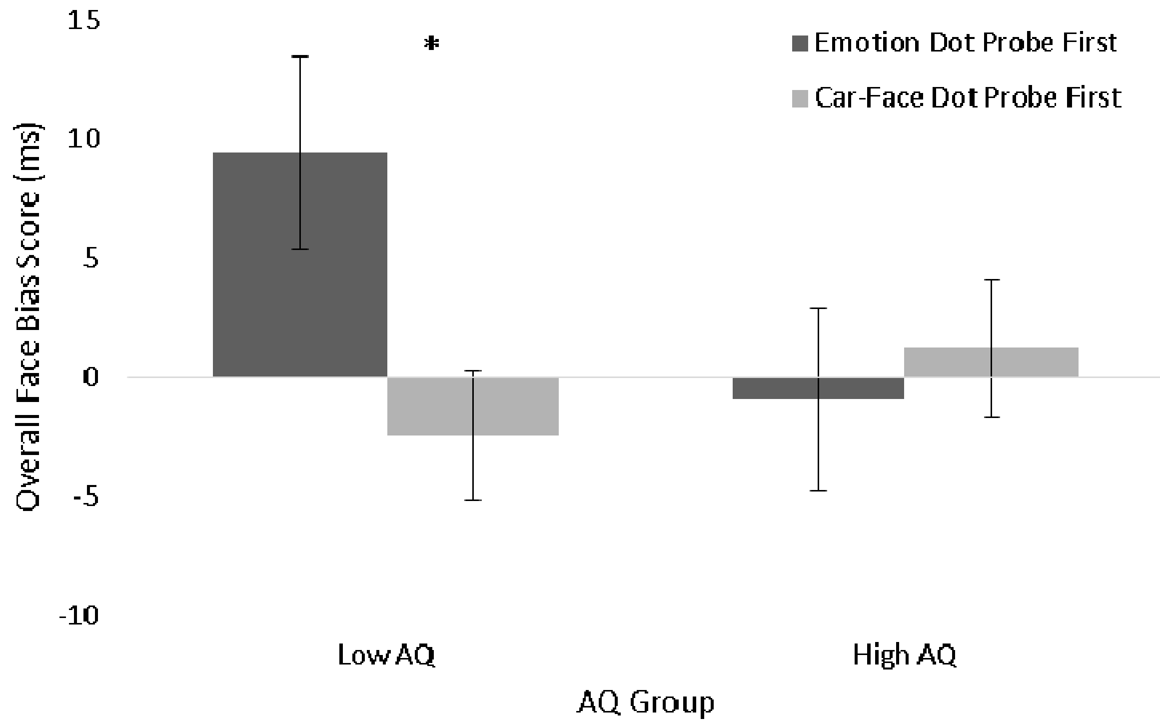

Figure 6. Face bias scores on the Emotion dot probe task across all Emotion Complexity / SOA conditions for High AQ and Low AQ participants as a function of the order in which the two dot probe tasks were completed.

Appendix A

Example Eyes Task Stimuli

(Baron-Cohen, Wheelwright, Hill, et al., 2001)

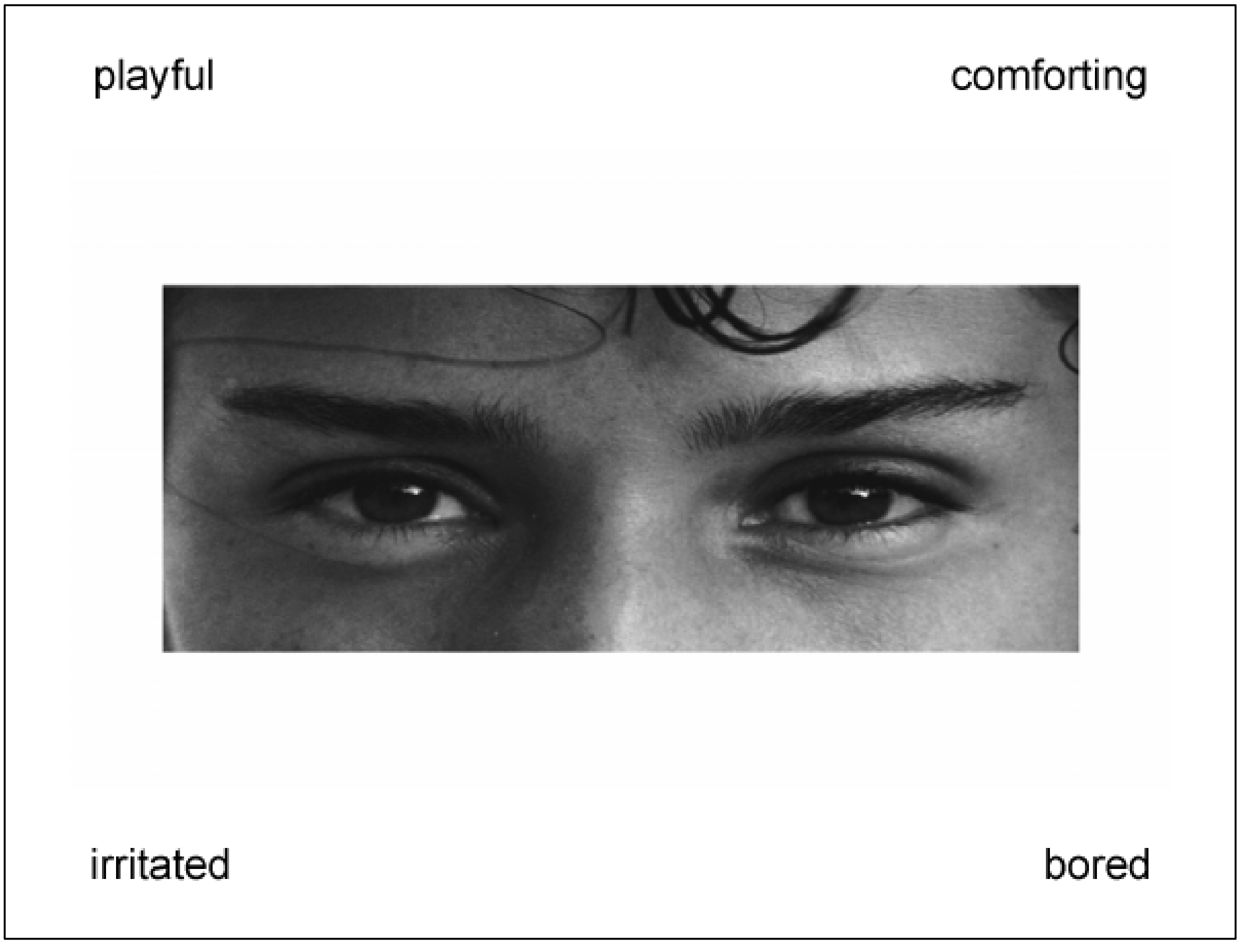

Figure A1: Example eyes task trial with direct eye gaze. Participants must indicate which of the four presented emotion words best represents the displayed expression. The correct answer on this trial is “playful.”

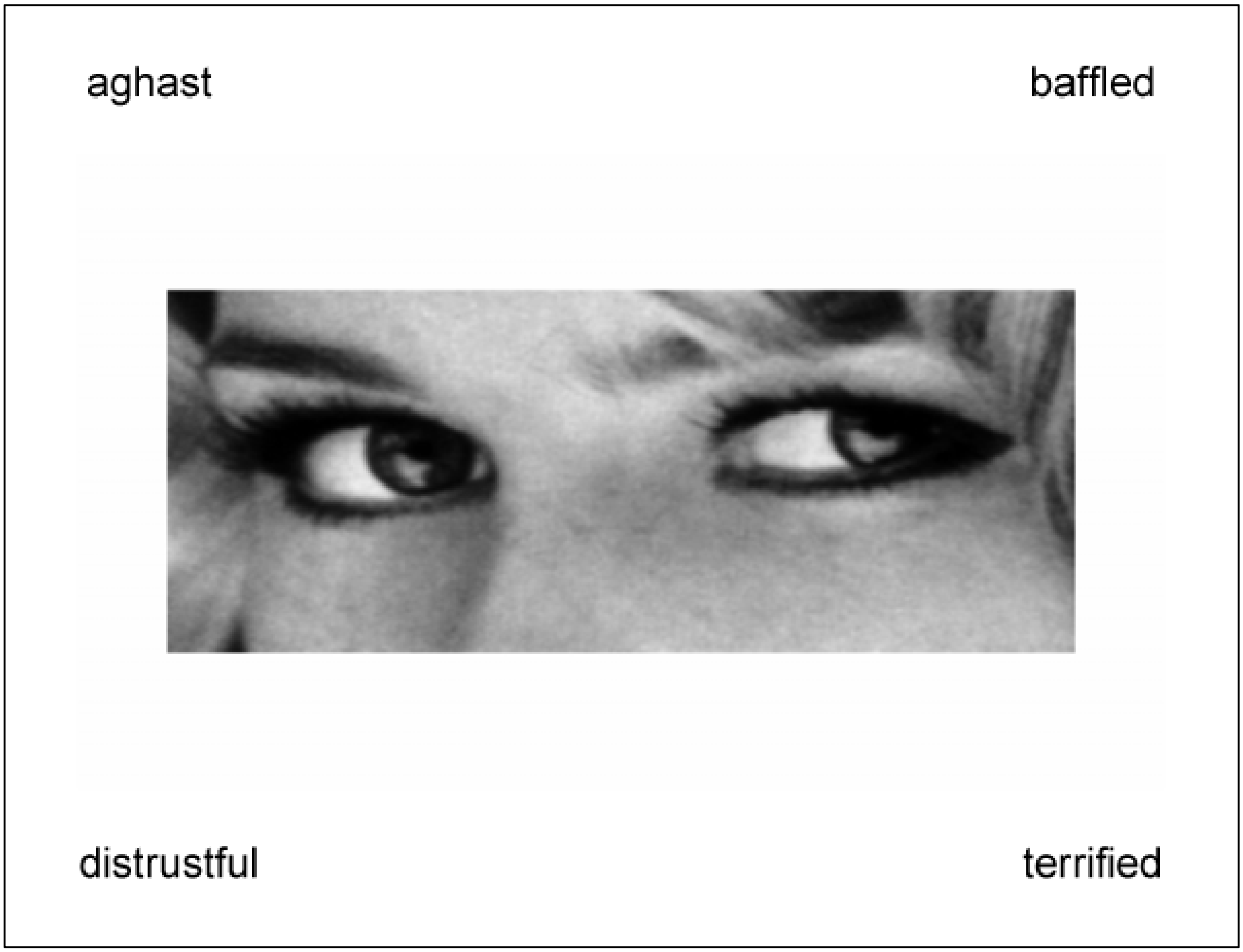

Figure A2: Example eyes task trial with averted eye gaze. Participants must indicate which of the four presented emotion words best represents the displayed expression. The correct answer on this trial is “distrustful.”

Appendix B

Face/Non-Face Dot-Probe Task Schematic

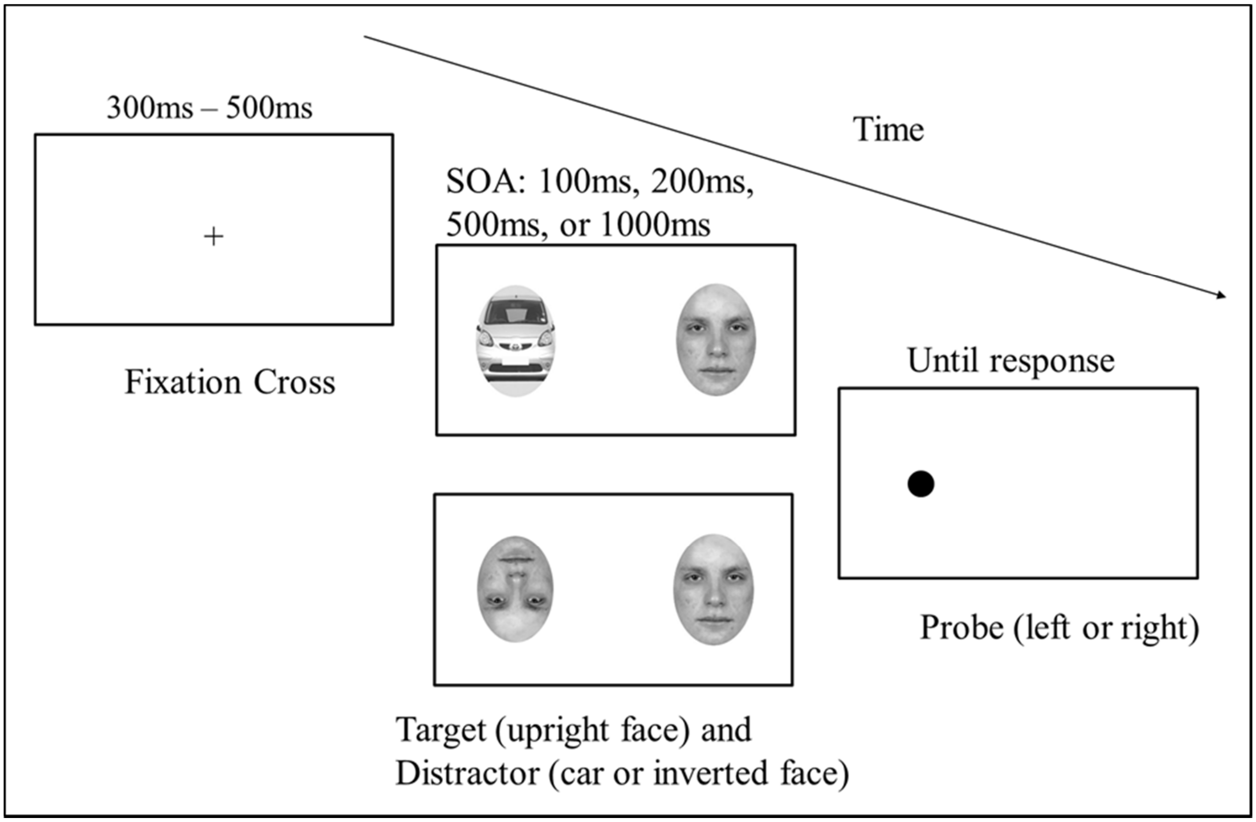

Figure B1: Each trial in the face/non-face dot probe task begins with a fixation cross in the center of the screen for a variable duration ranging from 300ms – 500ms. Next, a target (upright face) and distractor (car or inverted face) image pair is presented, one on each side of the screen. Images are presented for 100ms, 200ms, 500ms, or 1000ms. The image pair then disappears, and a dot is displayed behind the location of one of the images. Participants are tasked with indicating on which side of the screen the dot appears, and the dot remains on the screen until a response is registered.

Appendix C

Sample Stimulus Pairs for the Basic/Complex Emotion Dot-Probe Task

		Target (Upright Emotion Face)	Distractor (Inverted Neutral Face)
Simple			
	Anger		
	Happiness		
Complex			
	Fear		
	Surprise		

Appendix D

Daily Conversation Measure

Think back to yesterday. In the course of the whole day and evening, with about how many people did you have conversations (face-to-face talking for 5 or more minutes)? Group conversations involving multiple people count as only one person.

- O None
- O 1 person
- O 2 people
- O 3 – 5 people
- O 6 – 9 people
- O 10 – 15 people
- O More than 15 people

Check as many categories as describe the people you conversed with in the conversations that you reported in the previous question. These people were:

- ☐ Same age group people
- ☐ Adults older than you
- ☐ Teen-agers
- ☐ Family members
- ☐ Non-family members
- ☐ College students
- ☐ Professors
- ☐ Other (please specify):

Compared to an average day, how would you classify the number of conversations you had yesterday?

- O Much less than average
- O Less than average
- O Average
- O More than average
- O Much more than average

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