VISUOSPATIAL ATTENTION AND AUTISM SPECTRUM TRAIT EXPRESSION

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The Supervisory Committee certifies that this ***disquisition*** complies with North Dakota State University's regulations and meets the accepted standards for the degree of

MASTER OF SCIENCE

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ABSTRACT

Pseudoneglect (PN: Bowers & Heilman, 1980) references neurotypical leftward attentional bias reflective of right hemisphere (RH) specialization for spatial attention. Phasic visual cues can alter PN magnitude (McCourt et al., 2005). Tonic leftward bisection error for Uncued (UC) lines and its modulation with left (LC) and right (RC) cues were confirmed. Reported Autism Spectrum Disorder (ASD) neurobehavioral concomitants include greater lateralized RH function (Floris et al., 2015), narrowed visuospatial attentional spotlight (Robertson et al., 2013), reduced leftward bias in the grayscales task (English et al., 2015), and facial processing deficits. Neurotypical individuals' judgments for chimeric faces and cued line bisection tasks were recorded, and analyzed as a function of their Autism Spectrum-Quotient (ASQ) scores. We find two distinct visual attention processing differences associated with high autistic trait expression. ASQ score, handedness, gender, and age were predictive of PN modulation UC to RC and degree of leftward bias for chimeric faces.

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LIST OF ABBREVIATIONS

ASD..Autism Spectrum Disorder

AQ..(Adult) Autism Spectrum Quotient (alternative)

ASQ..(Adult) Autism Spectrum Quotient

CDC ....Centers for Disease Control

ED ....Executive Dysfunction

EF...Executive Function Deficit

WCC ....Weak Central Coherence

FFA ....Fusiform Face Area

IQ ....Intelligence Quotient

LC ....Left Cue

LVF ....Left Visual Field

OFC..Orbitofrontal Cortex

PFC ....Prefrontal Cortex

PN ....Pseudoneglect

RC ....Right Cue

RH ....Right Hemisphere

SE...Systemizing and Empathizing

ToM..Theory of Mind

STS...Superior Temporal Sulcus

WCC ....Weak Central Coherence

UC ....Uncued

PURPOSE AND BACKGROUND

The purpose of this study was to clarify some of the conflicting results in previous studies regarding visual processing deficits in persons with Autism Spectrum Disorder (ASD). The Centers for Disease Control and Prevention (CDC, 2014) estimated the prevalence for ASD to be 1 in 68 children in the United States. Not only are those diagnosed with ASD a relatively small percentage of the population, but diagnosis with ASD is often complicated by comorbidity with other developmental disorders. Severe cases of ASD present with behavioral deficits and comorbid cases often result in increased number and severity of behavioral deficits. The small representation in the population paired with behavioral deficits make it challenging to recruit and test diagnosed individuals, and the small number of diagnosed individuals that can be identified are not always able to perform tasks in the laboratory. Because ASD traits are exhibited on a spectrum, neurotypical (neurologically normal) individuals express such traits to varying degrees. I take a dimensional approach to the study of ASD by testing neurotypical individuals screened for the number of autistic traits they present. Based on neurotypical samples, inferences can be made about clinical populations (Focquaert & Vanneste, 2015). The primary question of interest was whether individuals high on the autism spectrum would exhibit significantly different patterns of visuospatial attention (such as the degree of tonic spatial bias, or the susceptibility to phasic exogenous capture) than individuals exhibiting fewer numbers of autistic traits. Preslar et al. (2014) noted that links between ASD and left handedness have been proposed. The incidence of ASD in males is five times the incidence in females (CDC, 2014). Information about handedness, gender, and age were also collected to address these questions in the current sample.

Many studies reporting differences between ASD participants and controls have suffered from a lack of sufficient statistical power due to relatively small samples. Given the relatively large sample size for the experiments conducted in this study, enough statistical power was achieved to state with a greater degree of conviction whether those with high autistic trait expression do (or do not) differ in their allocation of visuospatial attention from neurotypical individuals.

Autism Spectrum Disorder

Autism Spectrum Disorder (ASD) is considered a developmental disorder. *The Diagnostic and Statistical Manual of Mental Disorders* (5th ed.; *DSM–5*; American Psychiatric Association, 2013) lists the requirements by which ASD is diagnosed and the predominant theme in description and diagnosis of ASD is disruption of social function, as exhibited mainly by communication and interaction difficulties. Intelligence deficits or overall developmental delay commonly accompany ASD, but are not unique to ASD. Symptoms are present at early developmental stages, but may not always be evident or clear outside social contexts or can be masked by compensatory strategies (American Psychiatric Association, 2013). ASD has high comorbidity with other deficits and disorders and great variety in the combinations of expressed symptoms. It is difficult sometimes to understand that individuals with such disparate symptomatic expression could have the same disorder.

ASD Theories

Most theories about ASD focus on the behavioral symptoms related to social dysfunction without much regard for other underlying cognitive or physiological factors. Theories that have attempted to address potential underlying cognitive factors have not been successful at identifying factors that are present at all levels of trait expression. If all individuals on the autism spectrum share a diagnosis, it is problematic if they do not also have in common a theoretical explanation for their symptoms. One aspect of the diagnostic criteria in the *DSM-5* that is often trivialized compared to social deficits is “Hyper- or hypo-reactivity to sensory input or unusual interests in sensory aspects of the environment” (American Psychiatric Association, 2013). This criterion is most relevant to the present study and to developing better theories of ASD. Some theories adequately describe and predict the behavior of most individuals with autism, but fail when it comes to those with Asperger syndrome (no longer a diagnostic category) and those diagnosed with more general High-Functioning Autism (HFA). Understanding perceptual processing unique to all on the autism spectrum is a key component to building new theories that can truly describe and predict behavior across the entire spectrum and not just within the context of social impairment.

The foremost early cognitive theories for ASD that have persisted in evolved forms include Theory of Mind (ToM), Extreme Male Brain (later Systemising and Empathising, which will be adapted from its British publication spelling to American written English from this point forward: Systemizing and Empathizing), Weak Central Coherence (WCC), and Executive Dysfunction (ED).

Theory of Mind (ToM)

The Theory of Mind (ToM) explanation for ASD was initially proposed by Baron-Cohen, Leslie, and Frith (1985) and borrowed its nomenclature from Premack and Woodruff (1978) and much of its theoretical structure from Leslie (1984). ToM, as proposed by Premack and Woodruff (1978), was defined as the assignment of mental states to self and others, and was conceptualized to question whether such ability existed in chimpanzees. Leslie (1987) later extended his contribution to the initial publication by delving further into the ability of children to pretend as a necessary development along the path to what he termed “metarepresentation”, or the ability to internalize and project mental states. Metarepresentation and ToM are similar concepts, but Leslie’s research on pretense with children was key for Baron-Cohen’s further development of the concept of ToM. Baron-Cohen et al. (1985) synthesized the ideas from Leslie’s (1984) work in child development and ToM and attempted to explain ASD in a framework where adoption or internalization of others’ mental states was lacking due to cognitive impairment. Perhaps the greatest success of the Baron-Cohen et al. (1985) study was that it illustrated how attributes belonging to comorbid disorders could be separated from symptoms that were unique to ASD. Down’s syndrome and neurologically normal participants were used as controls in the study. This was an important methodological decision because low mental age and IQ were confounded with symptoms of ASD. Using a paradigm developed by Wimmer and Perner (1983), Baron-Cohen et al. (1985) demonstrated that IQ could be separated from ASD as a major underlying developmental characteristic because the Down’s syndrome and neurologically normal children performed similarly well on a mental representation task while children with autism performed poorly on the same task. The key feature of the ‘false belief task’ (Wimmer and Perner, 1983) that supported Baron-Cohen’s ToM explanation for ASD was that the task at which the ASD children had performed poorly required them to adopt a mental state representative of a doll character in the task scenario. A sequence of events portrayed by dolls was presented. One of the dolls placed a marble in a location and exited the scenario. After the doll’s exit, the marble was moved to a new location. Participants were asked to indicate where the doll that had exited the scenario would look for the marble. The majority of children with autism children pointed to where the marble actually was rather than to where the doll with limited information should have thought it was. The child development research of

Leslie combined with ASD participants' difficulty understanding the mental states of others came together in ToM to provide a plausible cognitive deficit that could explain social dysfunction typical of those with ASD. The fact that 4 of the 20 children with autism in the study had passed the false belief task brought criticism about ToM being able explain all cases of ASD. Other tasks were devised that were supposed to be a more direct and pure measurements of participants' ability to internalize and project mental states. The Strange Stories Task (Happé, 1994) presented participants with scenes where characters said something they did not genuinely mean. Even if participants with autism guessed that what was said was not true, they struggled to explain why it was said. Failure to understand the motivation behind the nonliteral language was considered support for the ToM explanation for ASD and the task held for high functioning ASD participants. "Reading the Mind in the Eyes Task" (Baron-Cohen et al., 2001a) asked participants to make inferences about the mental state of someone from a picture of just their eye and the immediately surrounding area. ASD participants performed less accurately at identifying emotional states from the pictures. The conclusion was that the task was a specific test of ToM and that the ability was deficient in those with ASD (Baron-Cohen et al., 1997, 2001a, 2001c). An important obstacle for Baron-Cohen's ToM explanation of ASD came when Happé (1995) found a strong link between verbal mental age and performance on false belief tasks. This forced Baron-Cohen to modify his original idea that ASD participants lacked ToM and to instead promote the idea that the lack of ToM was a developmental delay in ASD rather than a frank deficit. Each time participants with ASD would pass a task thought to purely measure ToM, the task would be modified and proclaimed a better measure of ToM. Tailoring tasks more specifically to measuring ToM and considering lack of ToM a developmental delay rather than a deficit eventually left the theory with little power to explain anything but a narrow range of social deficits.

Empathizing-Systemizing (ES) Theory

With the range of ASD behavior that could be explained by ToM having grown narrow, Baron-Cohen (2002) promoted the Extreme Male Brain explanation for ASD (originally conceived in an early form by Hans Asperger in 1944), and it later evolved further in combination with ToM into the Empathizing-Systemizing theory (Baron-Cohen, 2009). According to Extreme Male Brain theory, the brains of males are organized such that they are better at systemizing while the brains of females are organized to be more adept at empathizing, and those with ASD have an extreme version of the systemizing male brain (Baron-Cohen, 2002). This contrast between the genders in cognitive style or strategy was an extension of well documented sex differences predominantly for spatial and language processing, where males tend to excel at spatial processing and females tend to excel at language processing (Baron-Cohen, 2002). With ES theory, systemizing was characterized as a logical and mathematical strategy that could be used to make predictions about ones environment. The environment and the objects in it could be treated like a system and variables. Individuals exhibiting high levels of systemizing would show a high desire to identify patterns or rules and organize their environment based on these observations (Baron-Cohen, 2009). Empathizing was defined similarly to ToM and reflected an ability to interpret and predict the thoughts, emotions, and behaviors of another person (Baron-Cohen, 2009). Baron-Cohen (2009) was careful to note that some females rate higher on systemizing than empathizing and that some males score higher on empathizing than systemizing, but that in general more males had greater systemizing abilities and more females had more pronounced empathizing abilities. Superior average performance by one gender over the other in several cognitive domains has been established in the literature for some time (see Levy & Heller, 1992 for a summary). Documentation of lateralization differences between males and females has also been present in scientific literature for some time (for a review see McGlone, 1980), typically with greater lateralization in males. Gender differences in cognitive domain superiority and lateralization paired with the cognitive strategies outlined by Baron-Cohen (2009) provide a plausible basis for the multicomponent revised ToM/Extreme Male Brain/ES theory (2009). One difficulty that arises has its origin in exactly the fact that ES is a multicomponent theory. There is no offer of an underlying element that would bind these components. The ToM, low empathizing, and high systemizing aspects of the combined theory can explain some symptoms social dysfunction, but again I am returned to the question of whether the explanation holds for individuals at all points on the spectrum. Extreme systemizing and Extreme Male Brain components together can potentially explain superior performance by persons with ASD on tasks suited to a logical, mechanical cognitive strategy and perhaps may even explain insistence on sameness. There is still high and low reactivity to sensory stimuli that cannot be explained. Beyond explaining sensory sensitivity, it is a challenge to identify a developmental stage or series of developmental stages and corresponding anatomy that could place combined ES theory at the origin of ASD.

Weak Central Coherence (WCC) Theory

Frith (1989) proposed weak central coherence (WCC) as an explanation for ASD. Navon (1977) provided compelling evidence that processing of global features of visual scenes temporally precedes the processing of local details of visual scenes. An overused but effective example is seeing the forest before the individual trees. According to Navon (1977), global to local processing of visual scenes (in neurotypical individuals) occurs in a hierarchical way starting with the most general global attributes of a scene and proceeding to more specific local details. Within this framework, the longer someone views a scene, the greater the amount of local detail that can be extracted. Frith (1989) initially proposed that ASD was characterized by a bias toward local versus global processing, and that impairment in global processing may be a contributing factor. Later Happé and Frith (2006) would refine WCC to include only a bias toward local processing and excluded any conclusion about impairment in global processing. Persons with ASD were theorized to focus on the smallest possible unit or detail and to have difficulty processing the sum of units as a whole to derive meaning. Support for the idea that ASD involved a bias toward local features accrued with use of experiments that employed embedded figure tasks (Happé & Frith, 2006). Persons with ASD were better at identifying objects within objects, but less adept at identifying larger more global objects into which the smaller objects were embedded (Shah & Frith, 1993). A bias toward local processing that is the foundation of WCC might account for both the strengths (islets of ability) and deficits displayed by persons with ASD. Symptoms other than social dysfunction could also be explained by the local processing bias described by WCC. The strengths of WCC as a theory were that it could be applied to multiple levels of perceptual processing from early stages through executive function and that it was not just a deficit or developmental delay in function like the original ToM explanation for ASD, but rather a "cognitive style" that had both benefits and disadvantages (Frith, 1989). The ToM explanation would necessitate a developmental error, delay, or some sort of damage to account for ASD, but according to Frith & Happé (1994), WCC was more subject to environmental factors. The limitations of WCC perhaps outweigh its predictive power. It does not make specific predictions about underlying physiology or perceptual processing unique across the autism spectrum outside local versus global processing. Even the differences between those with ASD and other groups in global versus local processing has met with criticism because such differences are task specific (Ozonoff & McEvoy 1994; Mottron et al., 1999). One possibility that could unify Baron-Cohen's (2006) systemizing hypothesis and the local perceptual processing bias described by Frith is that both are tied to hemispheric lateralization. If systemizing and local feature processing are both more lateralized to the same hemisphere and those with higher autistic trait expression differ from neurotypicals in the degree of this lateralization, then the two seemingly disparate theories may be describing two behavioral effects that arise from the same underlying physiological antecedent. This marriage is unlikely to be successful because once again there are conflicting results in the literature, this time regarding lateralization of local versus global processing. There is more support for LH lateralization for local processing and RH lateralization for global processing (Christie et al., 2012) which is opposite the evidence necessary to marry the theories successfully.

Executive Function (EF) Deficit or Executive Dysfunction (ED) Theories

Executive Function Deficit (EF) or Executive Dysfunction (ED) theories cast the widest net when attempting to explain ASD. The generality of Executive Dysfunction (ED) is both its greatest strength and greatest weakness. It can account for a great number of behavioral patterns, but can only explain them in a broad and generic way. ED has also varied in description from one researcher to another. Executive Function coordinates or manages cognitive processes usually related to problem solving over time. Most definitions of Executive Function include planning and execution, sustained attention, inhibition, and working memory. The theory that executive function might be impaired in those with ASD originated from the observation that individuals with brain damage, particularly to prefrontal cortex (PFC), expressed symptoms also common among persons with autism (Rajendran & Mitchell, 2007; Ozonoff et al., 1991a).

Executive function deficits are not unique to ASD. Distinction had to be made between ED deficits specific to ASD versus those found with schizophrenia, Attention Deficit Hyperactivity Disorder (ADHD), and other disorders. Some researchers (Ozonoff, 1997) pointed to a subset of executive function specific to ASD such as “cognitive flexibility” but others found no significant difference between ASD participants and controls on other executive function tasks (Rajendran & Mitchell, 2007). Despite having the potential to explain symptoms of ASD other than social dysfunction, executive dysfunction does not seem to apply to all individuals with ASD and is not specific about underlying anatomical or physiological causes for deficits or advantages that do seem to occur in those with ASD (e.g. inhibition is universally problematic or selective attention is universally heightened). The predictions made by ED theory are too general and not present across the entirety of the spectrum.

Even the most supported cognitive theories cannot account for individuals at all points across the autism spectrum and often describe behavior that is not always unique to those with ASD. Many of the findings that have been reported have also been contradicted or had their scope narrowed by subsequent studies. Reports that those diagnosed with ASD have abnormal visual mechanics or sensitivity are inconsistent and not always supported by methodology when it is closely examined (Simmons et al., 2009). A likely candidate in the early visual processing stages that can account for superior and inferior performance on visual tasks by those with ASD is attention (Robertson et al., 2013). Whether or not those with more autistic traits perform differently on visuospatial attention tasks will provide some indication of whether the basis for visual behavioral symptoms of ASD begin at lower levels of information processing or have their origin at higher levels of processing.

Neural Noise Theory

A more recent theory that potentially explains ASD behavior and that has a more concrete physiological basis is neural noise theory. This theory has potential to explain behavior from its origin in physiology through various levels of cognition. The basis for neural noise theory is stochastic resonance (Benzi et al., 1981). Stochastic resonance describes a boost in signal by adding noise. Somewhat counterintuitively, by decreasing the signal-to-noise ratio, the signal strength is increased. Stochastic resonance was initially invoked to explain fluctuations in Earth's climate throughout its evolution. The diverse application of the concept to other disciplines was soon adopted and it found particular usefulness in neuroscience to describe networks of neurons. Stochastic resonance was of value in forming ASD theory because it afforded an explanation for both superior and inferior performance by persons with autism on behavioral measures. If persons with autism carry at any given time more neural network noise, then they could at times exhibit superior performance on some tasks due to a boost in neural signal from a decrease in signal-to-noise ratio (stochastic resonance), whereas on other tasks inferior performance might be observed because the additional neural network noise in ratio to the incoming signal was not optimum for stochastic resonance. In these instances, the additional noise inherent to those on the ASD spectrum would do exactly what one would intuitively think it would do, decrease neural signal strength and thereby limit sensory processing capability. As early as the 1960s researchers were making a link between personality traits (behavioral expressions) and level of physiological arousal (Eysenck, 1967). Eysenck proposed that introversion was related to high levels of central nervous system arousal (1967). Internal overstimulation could explain the tendency of more introverted individuals to avoid situations involving large amounts or high intensities of sensory input. More recently it has been suggested that introversion is embedded within the autism spectrum (Grimes, 2010). A direct precursor to the adaptation of stochastic resonance to ASD was the promotion by Rubenstein and Merzenich (2003) that an increased ratio of excitation to inhibition in persons with autism could underlie sensory processing differences. Epilepsy is an extreme form of heightened neural activity that results in a sort of electrical storm in the brain. It is widely documented that the prevalence of epilepsy is higher among persons with autism than in the general population, but the degree to which the higher prevalence is reported varies from roughly 5% to 46% as opposed to less than 1% in the general population in the U.S. (Spence & Schneider, 2009). Even in children with autism that have not been diagnosed with and have no history of epilepsy, epileptiform EEG rates are increased (Hughes & Mylen, 2005). Considering the relationship ASD shares with introversion, inherent inhibition and excitation, and epilepsy, it is easy to understand the application of neural noise and stochastic resonance to ASD theory.

In a lengthy and thorough review of ASD visual processing, Simmons et al. (2009) highlight increased neural noise as potential explanation for a number of findings. Children with ASD exhibited enhanced performance for first-order contrast detection tasks with noise, but decreased performance for second-order contrast detection with noise (Bertone et al., 2005; Simmons et al., 2009). Motion coherence performance by those with ASD could be explained by local motion noise (Dakin & Frith, 2005: Simmons et al., 2009). Noisy internal face representations could help explain facial processing difficulties in ASD and local stochastic enhancement paired with global noise interference could aid understanding superior visual search performance in ASD (Simmons et al., 2009). Underlying physiological explanations include a higher number of neural connections in sensory cortex or an absence of difference in connectivity but with additional rate of misfiring neurons (Simmons et al., 2009). Davis and

Plaisted-Grant (2015) also make an argument for neural noise as an explanation for behavior in ASD, but argue that it is a decreased level of internal noise that is responsible for observed behaviors. Both accounts describe noise as variability, but the low noise account refers to "small-scale neural networks" (Simmons & Milne, 2015: Davis & Plaisted-Grant, 2015). Simmons and Milne (2015) advocate that the low and high noise explanations may not be contradictory, but instead complement one another. The key to untangling the two accounts lies in determining whether small-scale neural networks, more global activation, or some combination of the two is responsible for observable behavior (Simmons & Milne, 2015). Whether one of these theoretical explanations or a combination of low and high noise accounts proves most supported by empirical findings, the potential influence on ASD research following these lines of inquiry is clear. The research described here is more concerned with establishing clear results at the basic perceptual level with visual attention given the variability in reports regarding such processing in those with ASD. However, one prediction that should provide at least tentative support for further investigating neural noise in ASD is that as at higher scores on the AQ survey, there should be an increase in variability on the line bisection task. Whether due to low or high levels of internal noise, if the internal neural noise level is different in individuals with more autistic traits, then greater variability in perception would be expected.

Related Research and Current Direction

There have been a number of reports about processing of single modality stimuli in those with ASD, some of which have shown differences from neurologically normal individuals (e.g. O'Riordan, 2004; O'Riordan & Plaisted, 2001). Rinehart (2002) found only executive function differences, but not visual perception differences among those with ASD. More relevant to the current line of inquiry are reports of lateralization expressed by those with higher numbers of autistic traits. Most neurologically normal individuals show a left visual field (LVF) bias in a variety of visuospatial tasks indicating a right hemisphere lateralization for processing of such tasks. There has not been much consensus about whether lateralization differences are present in ASD. Ashwin et al. (2005) reported a lessened left visual field bias in persons with autism compared to neurotypicals when viewing chimeric faces, but also reported a leftward bias in those with ASD in a non-facial processing task that was not mimicked by neurologically normal participants. English et al. (2015) used a greyscale task and found a lessened leftward bias in participants with more autistic traits. Floris et al. (2015) reported brain symmetry differences between ASD participants and controls, with ASD participants showing greater right hemisphere and lessened left hemisphere lateralization. Preslar et al. (2014) reported a decreased strength of lateralization among those with ASD. Robertson et al. (2013) found that spatial attention in those with ASD decreased markedly with increased temporal distance from cues suggesting a "sharper spatial gradient of attention" and that the steepness of this gradient was related to severity of ASD symptoms (p. 6776). Ronconi et al. (2013) found in children with ASD a prolonged narrowing of attention and slow widening of attention.

Asymmetries of Visuospatial Attention

Visuospatial attention can be assessed in a variety of ways. One of the most straightforward and easiest to implement is line bisection. There are two principal variations of the line bisection task: method of adjustment (manual) line bisection and forced-choice line bisection (also known as the "Landmark" task). Line bisection usually results (in neurotypical individuals) in a phenomenon termed pseudoneglect (Bowers & Heilman, 1980). Pseudoneglect (PN) refers to a tonic leftward attentional bias in neurotypical individuals, revealed by leftward misbisection of horizontal lines. PN is theorized to reflect the specialization of the RH for the deployment of spatial attention (Heilman & Van Den Abell, 1980; Foxe, McCourt & Javitt, 2003). A number of factors can affect assessment of visuospatial attention as measured by line bisection. The decision to use forced-choice rather than manual line bisection is associated with a greater effect size and reduces motor system noise in measurement of PN (Jewell & McCourt, 2000; Benwell et al., 2013). Individual characteristics that have demonstrated effects on PN include age, gender, and handedness (Jewell & McCourt, 2000). As age increases, bisection error moves rightward eventually crossing the veridical midpoint of the line (crossover effect). Males make larger leftward bisection error than do females. Dextrals show greater leftward bisection error than do sinistrals (Jewell & McCourt, 2000). Line length and the amount of time spent engaged in a task have been shown to affect PN, with decrease in line length and increased time on task both showing reduction if not reversal of leftward attentional bias (Benwell et al., 2013). Viewing distance from the stimulus has shown reduction in PN (Nicholls et al., 2016). Visuospatial attention spans both internally driven, voluntary (endogenous) and externally driven, reflexive (exogenous) attention. Thomas et al. (2014) demonstrated that exogenous distractors in the upper visual field could also bias attention to the left. Cues have been shown provide a robust indication of how PN can be affected by exogenous factors (McCourt et al., 2005). When cues are added to a line bisection task, the error in line midpoint estimation can be increased or decreased dependent upon whether the cue is presented to the right or left of the line. Cues to the left of the line midpoint tend to exaggerate the bias whereas cues to the right tend to lessen or sometimes reverse the bias (McCourt et al., 2005).

Another well established and easy to implement task that measures visuospatial attention is the chimeric faces task. Since used with commissurotomy patients (Levy, Trevarthen, & Sperry, 1972), chimeric faces have been used to assess laterality of facial processing. The chimeric faces, as used in this study, are composite faces of the same individual. Two photos of an individual are taken, one with the individual smiling, and the other with them not smiling. The faces are divided vertically and then combined so that one half of the face is smiling while the other half is not. Most neurologically normal individuals report about 65 % of the time that a face is happier when the smile is on the left side of the screen. The higher incidence of reported happiness with the smile on the left is also considered a leftward attentional bias. Cued tachistoscopic line bisection and chimeric faces both provide reliable measures of general attentional deployment, but beyond this shared general relationship with attentional deployment, chimeric faces and line bisection do differ, particularly with regard to their social information content. Line bisection contains no socially relevant information and chimeric faces contain arguably the most socially relevant of all information, faces. Similarity or differences in performance on these two tasks as a function of autistic trait expression clarifies some conflicting reports about perception in those with high autistic trait expression and whether the perceptual differences are purely of a social nature.

METHOD

Participants

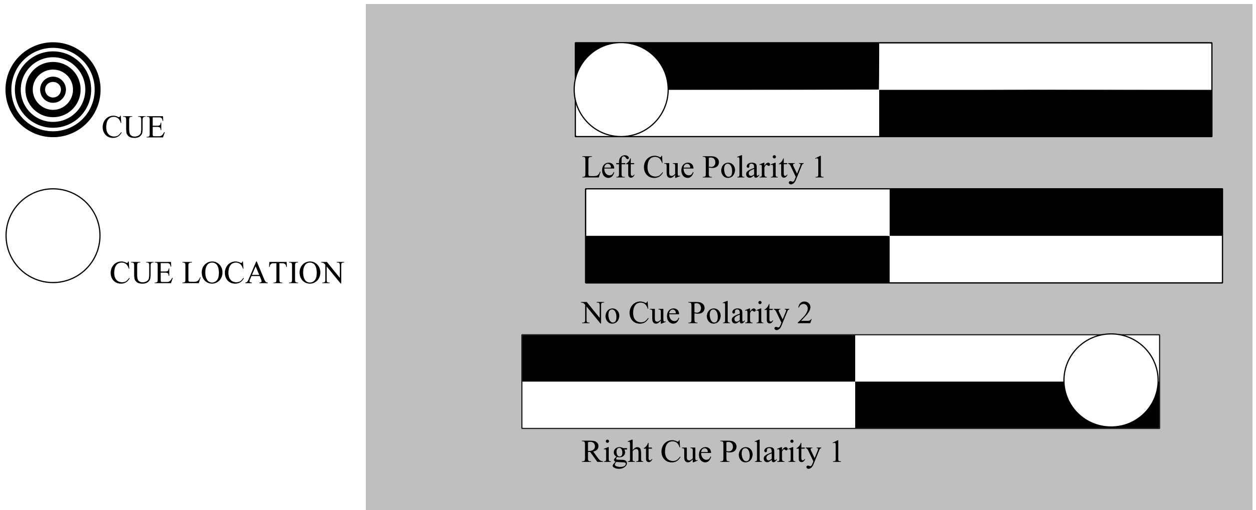
Participants were recruited through a university-wide email notification system at North Dakota State University. All faculty, staff, and students were invited to participate. Of the more than 1500 individuals that completed an online survey during the first phase of the study, 236 completed laboratory tasks during the second phase of the study. Completion of the first phase of the study afforded eligibility for the second phase of the study, but no other compensation was offered. Monetary compensation was given for completion of the second phase of the study. Participants were predominantly white, right hand dominant, and ranged from 18 to 59 years of age. Exclusions (34) reduced the number of participants that remained for analysis to 202 (122 female).

Line Bisection Task

Stimuli and Apparatus

Screen resolution was 1024 x 768 pixels (38.67º x 29.49º) with a refresh rate of 100 Hz and a mean luminance of 49 cd/m^2. Viewing distance was 57 cm. Stimuli were horizontally oriented lines of 100% contrast that were centered with respect to both the midsagittal plane of each subject and the computer screen. Line width and height were 700 pixels and 80 pixels, respectively (27 x 3 cm = 27° x 3.0 °). Lines were pre-transected with transectors occupying 15 locations, ranging from ± 0.6° of visual angle with respect to veridical line midpoint. Cue diameter was 80 pixels (3 cm = 3.0 °). Cues were positioned such that their centers were ± 310 pixels (11.69 °) from center of lines. This ensured that the left and right edges of the cues coincided with the left and right edges of the lines. Cue duration was 60 ms and line duration was 150 ms. Cue onset to line onset asynchrony was 120 ms. There were three cue conditions:

left cue, right cue, and no cue. The number of trials per condition per block was 1 with two polarities (position of black and white portions of the line). The number of blocks was five and the total number of trials was 450. Participants varied in time taken to complete the task, but ranged between 20 and 40 minutes. Figure 1 provides example stimuli and presentation parameters.



Pixels	Degrees	Horizontal Location of Vertical Transector
-16	-0.6	
-13	-0.49	
-10	-0.38	
-8	-0.3	
-6	-0.23	
-4	-0.15	
-2	-0.08	
0	0	
2	0.08	
4	0.15	
6	0.23	
8	0.3	
10	0.378	
13	0.491	
16	0.604	

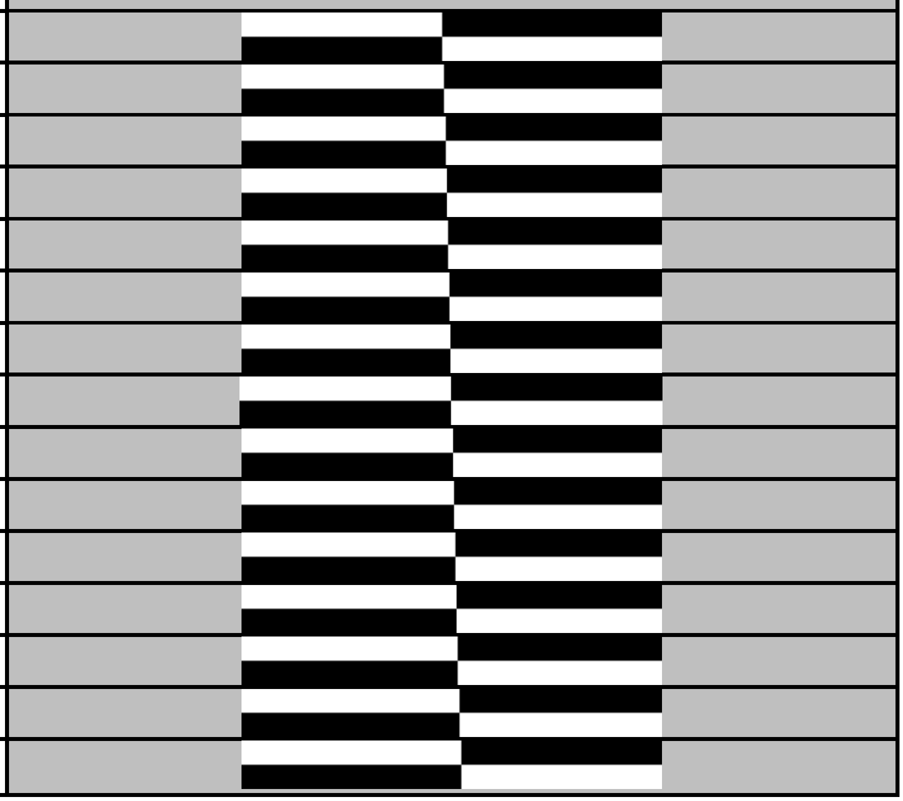


Figure 1. Example stimuli and presentation parameters for line bisection.

Chimeric Faces Task

Screen resolution was 1024 x 768 pixels (38.67º x 29.49º) with a refresh rate of 100 Hz and mean luminance of 48.85 cd/m^2. Viewing distance was 57 cm. The visual field containing the smiling half of the composite face was randomized, with 40 total faces presented 10 times each in one block consisting of 400 total trials. Participants varied in time taken to complete the task, but ranged from 15 to 30 minutes. Figure 2 provides an example stimulus.

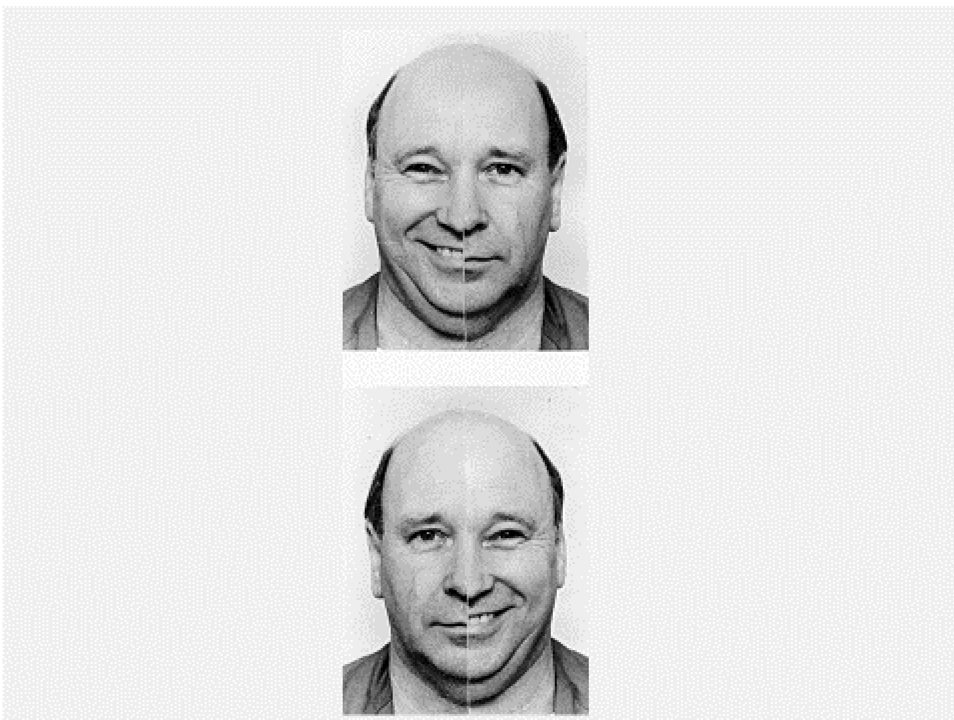


Figure 2. Example chimeric faces stimulus.

Procedure

The initial recruitment invitation provided a link to a website where informed consent could be viewed and an online version of the Adult Autism-Spectrum Quotient (interchangeably AQ or ASQ, Baron-Cohen et al., 2001b) could be completed. Individuals that completed the online survey were contacted via email and invited to participate in the next phase of the study.

Those interested in completing the second phase of the study were scheduled for a laboratory testing session.

Participants were, upon arrival to the laboratory, asked to be seated in a room adjacent to the experiment and complete informed consent and handedness inventory forms. Two measures of handedness, the Edinburgh Handedness Inventory (Oldfield, 1971) and the Flinders Handedness survey (Nicholls et al., 2013) were presented. Participants were reminded after completion of the forms that participation in the study was voluntary and that they could leave at any time during testing and be compensated for time spent in the laboratory. Participants were then moved to the testing room and given a seat in front of the experimental monitor and asked to adjust the height of their chair so they could fit comfortably into a chin rest. The chin rest assured alignment of participants' midsagittal planes with the veridical midpoint of the presentation monitor. It was explained to each participant that they would perform two tasks, a line bisection task and a chimeric faces task. Participants received $15.00 per hour for participation in laboratory testing sessions which took approximately one hour to complete. Copies of all appropriate forms have been included in the Appendix.

Line Bisection Task

For the line bisection task, the pre-transected lines were described verbally and pictures of example stimuli were shown for clarity. Emphasis was placed on the brief duration of the stimuli and the importance of maintaining focus at the center of the presentation monitor. Notice was given that transectors varied in distance from the true center of the lines and that incorrect responses to the most obvious transector locations would be followed with an auditory tone. The presence of multiple auditory signals served as an indication to the experimenter that participant performance was poor, likely due to inability or lack of effort. Participants were asked to determine whether the transector was left or right of what they perceived to be the center of each line. A left mouse response would indicate a transector location left of perceived line midpoint while a right mouse response would indicate a transector location right of perceived line midpoint. Participants were instructed that even if they judged the transector to be at the veridical midpoint of a line, the only two response options were left and right mouse presses and one of those two options must be selected for each line presented. All participants made responses with their right hand. It was explained that the line bisection experiment consisted of 5 blocks of trials, and that breaks could be taken between blocks.

Chimeric Faces Task

A verbal description of the chimeric faces task (Levy et al., 1972) was provided to participants and they were instructed to decide which of two vertically presented composite faces they judged to be happier. Judgments of greater upper face positive valence were indicated by pressing the up arrow, while judgments of greater lower face positive valence were indicated by pressing the down arrow. All participants made responses with the right hand. The chimeric faces were presented in one large block and each set of faces stayed on screen until a response was made. This presentation allowed participants to take breaks whenever they chose to do so.

Analysis

Line Bisection Task

Data Screening

For all participants, in all three cue conditions, percent leftward responses (%L) were plotted as a function of transector location (Figure 3). These psychometric data were fitted by method of least-squares to a modified logistic function:

$$\%L = \frac{(1-a)}{2} + \frac{a}{1 + e^{-(x-x_0)/b}}$$

where x is transector location, a is an intensity parameter, b is a slope parameter, and x_0 is the transector location corresponding to the point of subjective equality (PSE). PSE refers to transector position which participants see as being at the center of the line. While PSE (parameter x_0) indexes the accuracy (bias) of line bisection, the slope of the psychometric function (parameter b) indexes the precision of perceptual judgments. A total of 236 participants completed the line bisection task. However, 33 participants were eliminated from the analysis due to psychometric fits that were poor (see Figure 4), likely indicative of lack of conscientious effort or inability to perform the task. One additional participant was eliminated because their age was outside the range specified in the recruitment (18 to 40).

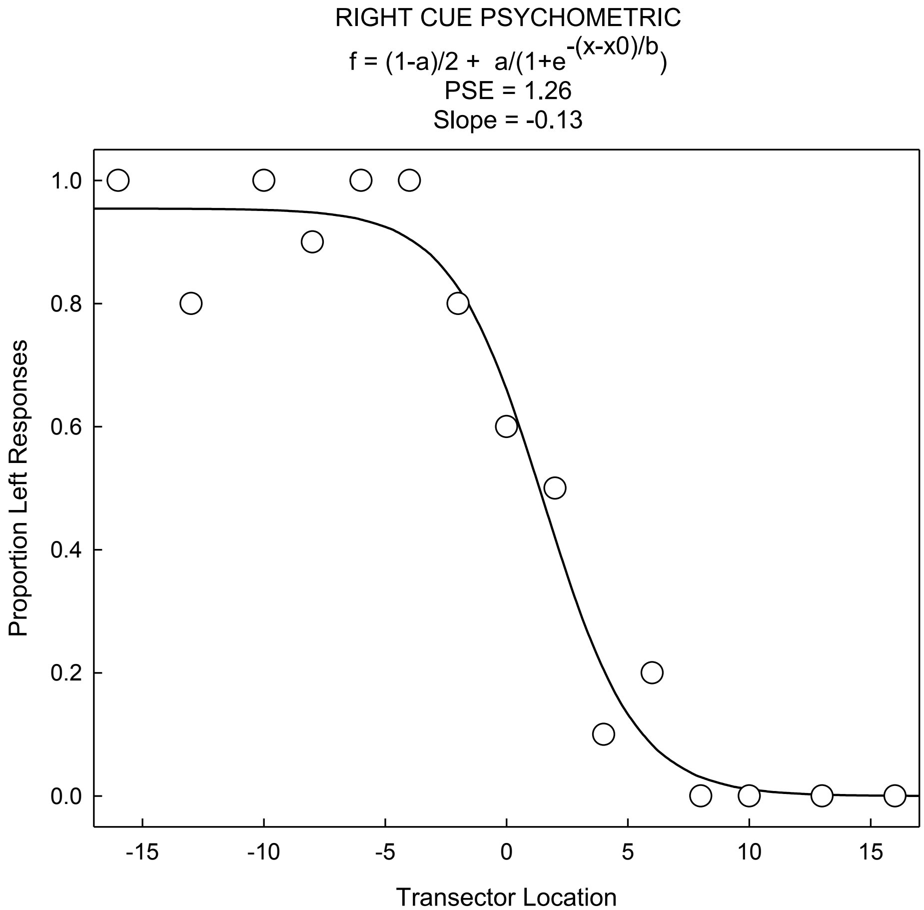


Figure 3. Plotted logistic function for the right cue condition with computed PSE and slope.

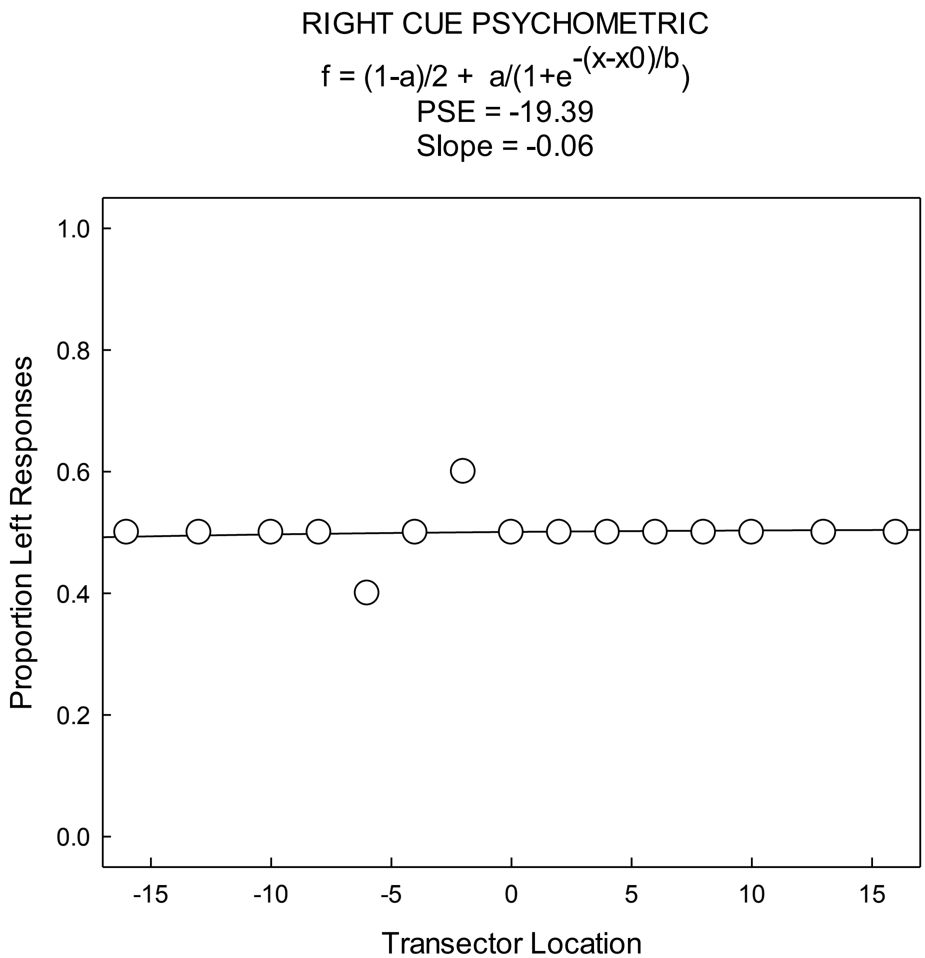


Figure 4. Example of a poor psychometric fit for the logistic function that would have led to exclusion from data analysis.

Statistical Methods

A one sample *t*-test was used to establish whether, in the UC condition, a leftward error in line bisection was present across all participants when collapsing across ASQ score was captured. A repeated measures ANOVA with cue condition as the grouping factor was then used to determine if cuing successfully modulated the tonic leftward bisection error found in the UC condition. Post hoc t-tests using the Bonferroni correction were used to elucidate between which cue conditions significant group differences for the repeated measures ANOVA existed. Of the two measures of handedness, the Edinburgh survey was chosen for analysis because it allowed for more variability. A regression model including ASQ score, Edinburgh handedness score, gender, and age as predictors was then employed to predict PSE and slope for UC, UC-LC, and UC-RC.

Chimeric Faces Task

Data Screening

Of the 236 participants that completed the lab session, 33 were eliminated before analysis based primarily on their performance in the line bisection task. If data from these participants was not adequate for analysis for the line bisection, the same lack of ability or lack of effort was likely also characteristic of their performance in the chimeric faces task.

Statistical Methods

A regression model including ASQ score, Edinburgh handedness score, gender, and age as predictors was employed to predict participants' proportion of left responses to the chimeric faces stimuli. Additional regression models using each of the ASQ subscores (Social Skills, Communication, Attention Switching, Attention to Detail, and Imagination) with Edinburgh handedness score, gender, and age was used to predict proportion of left responses to the chimeric faces stimuli.

RESULTS

Line Bisection Task

Confirmatory Parametric Statistics

The first thing to confirm was a tonic leftward bisection error (negative PSE for UC condition) when collapsing across ASQ score for the entire sample. A single sample t-test, when collapsing across ASQ score for the entire sample for the UC condition, indicated a leftward PSE that differed significantly from zero, $t(202) = -11.52$, $p < .001$, 95% CI [-.21,-.15]. A repeated measures ANOVA using the Greenhouse-Geisser correction, with cue type as the factor determining group membership, confirmed a cuing effect collapsed across all participants without consideration to ASQ score, $F(1.56, 308.13) = 194.75$, $p < .001$, and $\eta^2 = .49$. Post hoc *t*-tests using the Bonferrroni correction indicated PSE differed significantly at the $p < .001$ level among all three cue conditions: UC vs. RC, t(201) = -12.32, p<.001, 95% CI[-.16, -.12]; UC vs. LC, t(201) = -10.84; p<.001, 95 % CI[-.18, -.12]; LC vs. RC t(201) = -15.89; p<.001, 95% CI[-.33,-.25]. The tonic leftward bias found with the uncued line ($M = -.18$, $SD = .23$) was exaggerated with a left cue ($M = -.34$, $SD = .26$) and diminished with a right cue ($M = -.05$, $SD = .26$).

Multiple Regression Approach

The right and left cue PSEs and slopes alone allow little interpretation, but the amount of change from the uncued line PSE and slope to the right and left cue PSE and slope allows discussion of to what degree participants' tonic bias and precision can be modulated by cuing. AQ score, handedness, gender, and age were all used in a linear regression model to predict separately line bisection PSE, slope, modulation of PSE, and modulation of slope. The PSE and slope for the uncued condition served as the tonic assessment from which any modulation occurred. For both PSE and slope two modulations were possible, from no cue to left cue, and from no cue to right cue. The modulation was quantified by subtracting the right and left cue PSE and slope from the uncued PSE and slope. The modulation from no cue to right cue PSE was UC PSE – RC PSE. The modulation from no cue to left cue PSE was UC PSE – LC PSE. The modulation from no cue to right cue slope was UC slope – RC slope. The modulation from no cue to left cue slope was UC slope – LC slope. All assumptions for multiple regression analysis were met. Results of the predictive regression models can be found in Table 1 (PSE) and Table 2 (slope) with significant findings highlighted for viewing ease.

Table 1

AQ score, handedness, gender, and age predicting PSE and PSE modulation

			UC PSE			
Predictor	B	SE B	β	*t*	*p*	CI
AQ Score	.000	.002	-.117	1.071	.285	[-.000, .000]
Handedness	-.000	.000	-.036	-1.660	.099	[-.000, .000]
Gender	.000	.033	-.129	.507	.613	[-.001, .002]
Age	-.000	.004	-.127	-1.817	.071	[.000, .000]

$F(4, 197) = 2.350$, $p = .056$, and $R^2 = .046$

Table 1. *AQ score, handedness, gender, and age predicting PSE and PSE modulation (continued)*

RC PSE						
Predictor	B	SE B	β	*t*	*p*	CI
AQ Score	-.001	.002	-.030	-.423	.673	[-.005, .003]
Handedness	.000	.000	-.007	-.098	.922	[-.001, .001]
Gender	-.003	.037	-.006	-.090	.929	[-.077, .077]
Age	-.012	.004	-.193	-2.740	.007	[-.021, -.003]

$F(4, 197) = 2.023$, $p = .093$, and $R^2 = .039$

LC PSE						
Predictor	B	SE B	β	*t*	*p*	CI
AQ Score	-.004	.002	-.142	-1.989	.048	[-.008, .000]
Handedness	.000	.000	-.013	.179	.859	[-.001, .001]
Gender	-.054	.039	-.101	-1.406	.161	[-.130, .022]
Age	-.001	.005	-.010	-.141	.888	[-.010, .008]

$F(4, 197) = 1.376$, $p = .244$, and $R^2 = .027$

Table 1. *AQ score, handedness, gender, and age predicting PSE and PSE modulation (continued)*

UC - RC PSE						
Predictor	B	SE B	β	*t*	*p*	CI
AQ Score	-.002	.001	-.118	-1.681	.094	[-.005, .001]
Handedness	.000	.000	.062	.883	.378	[.000, .001]
Gender	-.056	.023	-.173	-2.446	.015	[-.101, -.011]
Age	.005	.003	.131	1.879	.062	[.000, .011]

Table 1. *AQ score, handedness, gender, and age predicting PSE and PSE modulation (continued)*

$F(4, 197) = 2.819$, $p = .026$, and $R^2 = .054$

UC - LC PSE						
Predictor	B	SE B	β	*t*	*p*	CI
AQ Score	.001	.002	.055	.763	.446	[-.002, .004]
Handedness	.000	.000	.024	.331	.741	[-.000, .001]
Gender	-.005	.029	-.013	-.178	.859	[-.063, .053]
Age	-.006	.004	-.130	-1.830	.069	[-.013, .001]

$F(4, 197) = .945$, $p = .439$, and $R^2 = .019$

Table 2

AQ score, handedness, gender, and age predicting slope and slope modulation

UC Slope						
Predictor	B	SE B	β	*t*	*p*	CI
AQ Score	.000	.000	.039	.540	.590	[.000, .000]
Handedness	-.000	.000	-.085	-1.174	.242	[.000, .000]
Gender	.000	.001	.054	.744	.458	[-.001, .002]
Age	-.000	.000	-.018	-.251	.802	[.000, .000]
$F(4, 197) = .485$, $p = .747$, and $R^2 = .010$						

RC slope						
Predictor	B	SE B	β	*t*	*p*	CI
AQ Score	.000	.000	-.056	-.798	.426	[.000, .000]
Handedness	.000	.000	.200	-2.831	.005	[.000, .000]
Gender	-.005	.003	-.126	-1.781	.076	[-.010, .001]
Age	.000	.000	.056	.794	.428	[.000, .001]
$F(4, 197) = 2.673$, $p = .033$, and $R^2 = .051$						

Table 2. *AQ score, handedness, gender, and age predicting slope and slope modulation (continued)*

LC slope						
Predictor	B	SE B	β	*t*	*p*	CI
AQ Score	-.000	.000	-.039	-.545	.586	[.000, .000]
Handedness	-.000	.000	-.075	-1.048	.296	[.000, .000]
Gender	.000	.000	-.050	-.688	.492	[-.001, .000]
Age	.000	.000	.003	.039	.969	[.000, .000]
$F(4, 197) = .525$, $p = .717$, and $R^2 = .011$						

UC - RC slope						
Predictor	B	SE B	β	*t*	*p*	CI
AQ Score	.000	.000	.063	.899	.370	[.000, .000]
Handedness	-.000	.000	-.212	-3.014	.003	[.000, .000]
Gender	.005	.003	.134	1.897	.059	[.000, .011]
Age	.000	.000	-.058	-.827	.409	[-.000, .000]
$F(4, 197) = 3.037$, $p = .019$, and $R^2 = .058$						

Table 2. *AQ score, handedness, gender, and age predicting slope and slope modulation (continued)*

UC - LC slope						
Predictor	B	SE B	β	*t*	*p*	CI
AQ Score	.000	.000	.052	.722	.471	[.000, .000]
Handedness	-.000	.000	-.037	-.514	.608	[.000, .000]
Gender	.001	.001	.070	.966	.335	[-.001, .002]
Age	-.000	.000	-.017	-.235	.815	[.000, .000]

$F(4, 197) = .368$, $p = .831$, and $R^2 = .007$

Summary

The single sample *t*-test confirmed that our sample of neurotypical individuals showed the expected left attentional bias that has been reported many times previously. The repeated measures ANOVA confirmed susceptibility of PN to transient cues (McCourt et al., 2005). The modulation with cuing was as expected, exaggerated with left cues and diminished with right cues.

Beyond what was expected when collapsing across ASQ score for the entire sample, there were some effects for both PSE and slope that were predicted by ASQ score, handedness, gender, and age. Despite the overall model not being predictive of RC PSE at the $p < .05$ level, an argument could be made for borderline significance at the $p < .10$ level. Considering this borderline significance, the coefficient for age was a significant predictor of RC PSE. As age increases, the RC PSE becomes more negative (Figure 5). This would seem to suggest that with increased age participants were less susceptible to the right cue. With the elimination of the eldest participant, the age range was 18 – 39. With this in mind, a scatter plot for participants between the ages of 18 and 28 versus RC PSE was visually inspected to determine if the same trend held for a narrower age range of participants. The steepness of the slope with the 18 – 28 group was less steep, but the same trend held (Figure 6). Again with LC PSE the overall model failed to be predictive (p = .244), but there was a significant coefficient, this time for ASQ score. Inspection of the confidence interval for the ASQ coefficient in the model predicting LC PSE revealed that the confidence interval did not contain zero, but bordered it within three decimal places, indicating little predictive power for the coefficient. The overall model was successfully predictive of UC - RC PSE. Because multidimensional graphs are not plausible in this or really any format, ASQ was used as the only predictor for illustrative purposes (Figure 7). The difference between UC and RC PSE becomes more negative the higher ASQ score becomes, indicating more of a right cue effect. This supposition is supported by the lack of significant prediction in the UC condition. Participants did not differ across ASQ score in their tonic leftward bias, but did differ in the amount this bias was shifted by the right cue. Looking at the individual coefficients for the regression predicting UC - RC PSE, gender was the only significant one. Female participants had more negative differences when subtracting their UC PSE from their RC PSE, indicating more effect from the right cue (Figure 8).

The full regression model including ASQ score, handedness, gender, and age was predictive of both RC slope and UC - RC slope, and the coefficient that was significant in both cases was handedness. With the coefficients three decimal places below zero in both cases, there is no practical significance in either case. Inspection of the confidence intervals for the individual coefficients revealed that the confidence intervals for handedness in both instances border zero by three decimal places, also indicating the effect is not likely of practical significance. It is also noteworthy that the R^2 indicate the percent of variance accounted for in the response variables that can be explained by the predictors is minimal.

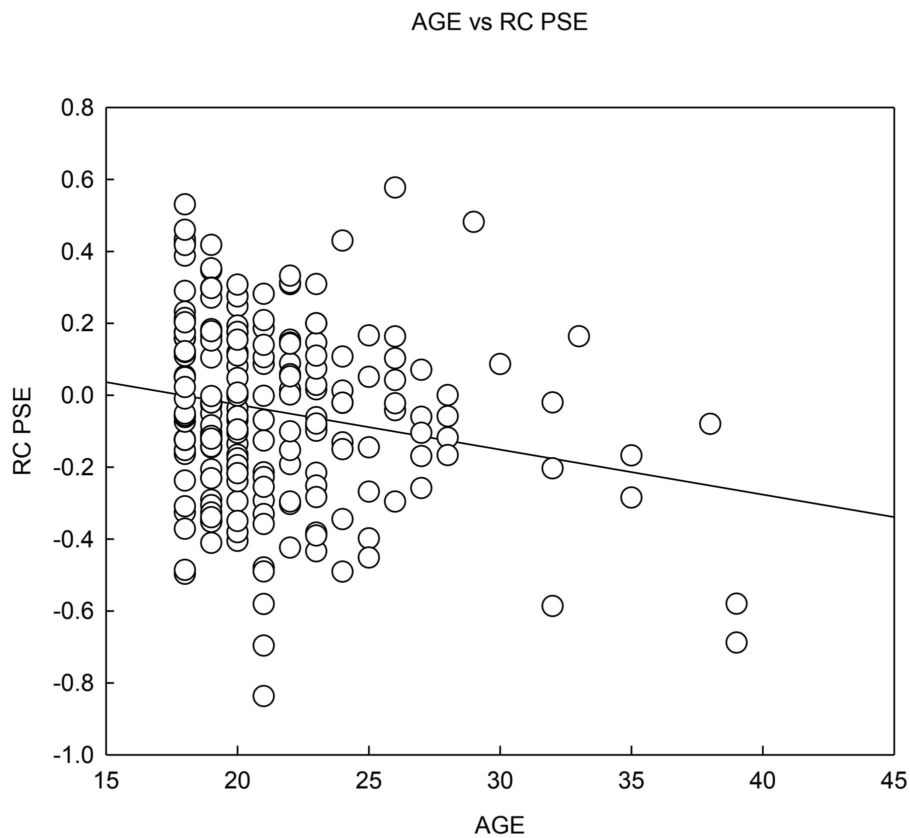


Figure 5. Ages 18 to 39 vs RC PSE.

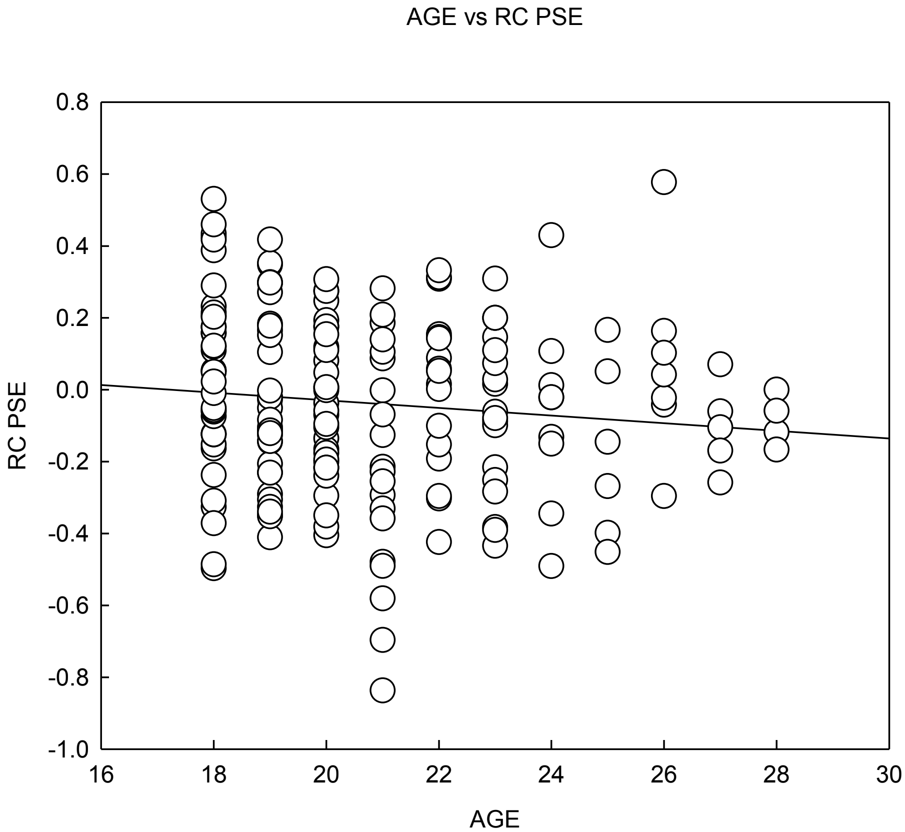


Figure 6. Ages 18 to 28 vs RC PSE.

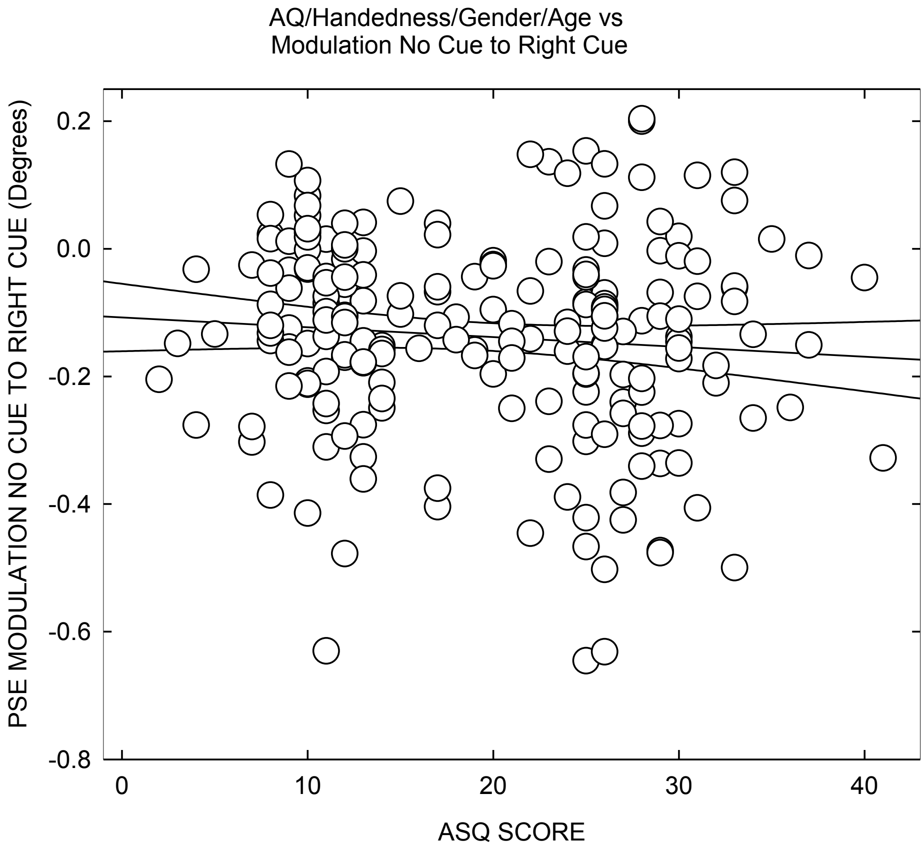


Figure 7. ASQ score vs PSE modulation UC to RC.

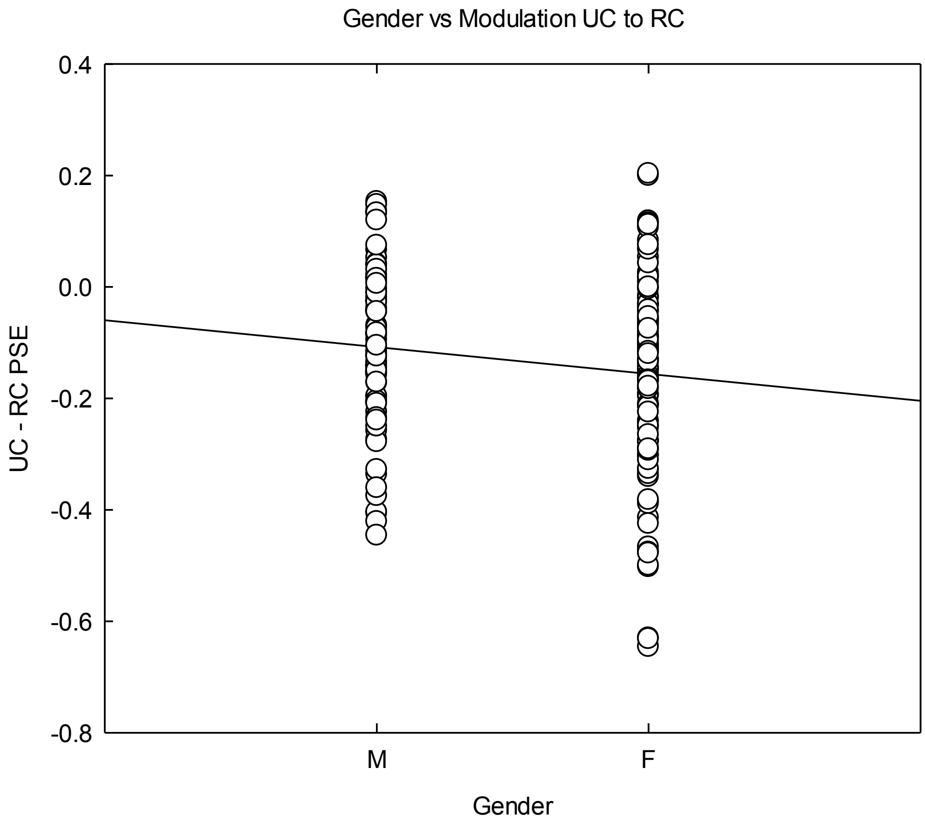


Figure 8. Gender vs modulation UC to RC.

Chimeric Faces

Multiple Regression Approach

AQ score, Edinburgh handedness, gender, and age were all used in a linear regression model to predict participants' proportion of left responses to the chimeric faces. Each of the AQ survey subscales (Social Skills, Communication, Attention Switching, Attention to Detail, and Imagination) were also used in combination with handedness, gender, and age to predict participants' proportion of left responses to the chimeric faces. All assumptions for multiple regression analysis were met. Results for all models are shown in Table 3.

Table 3

AQ score and each of its subscales with handedness, gender, and age predicting proportion of left responses to the chimeric faces

Total AQ Score						
Predictor	B	SE B	β	*t*	*p*	CI
AQ Score	.006	.002	.175	2.485	.014	[.001, .011]
Handedness	.000	.000	.068	.970	.333	[.000, .001]
Gender	.061	.045	.096	1.346	.180	[-.028, .150]
Age	.005	.005	.063	.894	.372	[-.006, .016]
$F(4, 197) = 2.550$, $p = .041$, and $R^2 = .049$						

Social Skills						
Predictor	B	SE B	β	*t*	*p*	CI
AQ Subscore	.018	.007	.180	2.569	.011	[.004, .033]
Handedness	.000	.000	.074	1.045	.297	[.000, .001]
Gender	.050	.045	.078	1.102	.272	[-.039, .138]
Age	.004	.005	.056	.800	.425	[-.006, .015]
$F(4, 197) = 2.659$, $p = .034$, and $R^2 = .051$						

Table 3. *AQ score and each of its subscales with handedness, gender, and age predicting proportion of left responses to the chimeric faces (continued)*

Communication						
Predictor	B	SE B	β	*t*	*p*	CI
AQ Subscore	.017	.009	.136	1.916	.057	[-.001, .035]
Handedness	.000	.000	.069	.966	.335	[.000, .001]
Gender	.061	.046	.095	1.325	.187	[-.030, .151]
Age	.005	.005	.065	.800	.358	[-.006, .016]

$F(4, 197) = 1.911$, $p = .110$, and $R^2 = .018$

Attention Switching						
Predictor	B	SE B	β	*t*	*p*	CI
AQ Subscore	.022	.009	.167	2.388	.018	[.004, .040]
Handedness	.000	.000	.071	1.001	.318	[.000, .001]
Gender	.054	.045	.085	1.203	.230	[-.035, .143]
Age	.005	.005	.068	.974	.331	[-.005, .016]

$F(4, 197) = 2.430$, $p = .049$, and $R^2 = .047$

Table 3. *AQ score and each of its subscales with handedness, gender, and age predicting proportion of left responses to the chimeric faces (continued)*

Attention to Detail						
Predictor	B	SE B	β	*t*	*p*	CI
AQ Score	-.002	.010	-.017	-.238	.812	[-.023, .018]
Handedness	.000	.000	.071	.986	.325	[.000, .001]
Gender	.047	.046	.074	-1.033	.303	[-.043, .138]
Age	.006	.005	.083	1.173	.242	[-.004, .017]
$F(4, 197) = .990$, $p = .414$, and $R^2 = .020$						

Imagination						
Predictor	B	SE B	β	*t*	*p*	CI
AQ Score	.029	.012	.170	2.412	.017	[.005, .053]
Handedness	.000	.000	.059	.840	.402	[-.001, .001]
Gender	.066	.046	.103	1.433	.151	[-.024, .156]
Age	.006	.005	.076	1.088	.278	[-.005, .017]
$F(4, 197) = 2.459$, $p = .047$, and $R^2 = .048$						

Summary

The full regression model used with the line bisection PSE and slope parameters was also employed with the chimeric faces analysis and was predictive of the proportion of left responses made by participants. Each of the ASQ subscales (Social Skills, Communication, Attention Switching, Attention to Detail, and Imagination) were also used separately in regression models with handedness, age, and gender to predict participants' proportion of left responses and all but two (Communication and Attention to Detail) were successful in doing so. The most important thing to note from each of these models is that ASQ score was the single statistically significant coefficient in each of them and none of the confidence intervals bordered zero by small margins like was seen with the PSE and slope measures from the line bisection task. In each of the significant prediction models (total ASQ, Social Skills, Attention Switching, and Imagination), as ASQ score increased so did the proportion of left responses by participants indicating a greater LVF bias for positive valence facial expressions.

DISCUSSION

Cued tachistoscopic line bisection and chimeric faces both provide reliable measures of general attentional deployment. The current findings indicate that beyond this shared general relationship with attentional deployment, the detailed processing mechanisms for line bisection and chimeric faces are distinct and the mechanisms unique to processing chimeric faces vary as a function of autistic trait expression more consistently and to a greater degree than do pseudoneglect and its modulation as measured with line bisection.

After examining the regression models for the line bisection data and viewing basic scatter plots of ASQ score vs PSE and slope measures, there was no greater variability with increased ASQ scores. There does not appear to be any support for greater or lesser resting neural noise levels among those with higher autistic trait expression. The one measure that would have best captured any varying degree of neural noise would have been the slope for the psychometrics in the line bisection task. The slope depicts the precision with which participants made judgments, with steeper slopes indicating more precision. Greater precision would coincide with less inherent system noise. There was no greater or lesser variability in psychometric slopes as ASQ score increased. These experiments were not expressly designed to test these theories and it is possible that the salience of the stimuli and the cognitive load required to perform the task are not suited to capture information that would more directly support or contradict neural noise theories for ASD. It is also possible that one of this study's limitations could be responsible for the lack of evidence. By recruiting and testing neurotypical individuals, we may have not been accurately assessing individuals with diagnosed ASD. However, two individuals in the study volunteered information about childhood diagnoses and their scores on the ASQ, though in the low thirties and above the mean, were not at the upper end of the range of scores (Maximum

= 41) and neither individual showed a greater amount of variability than individuals with lower scores. Another potential limitation of this study was that greater than half of the participants (122/202) were female. Autism has a much higher incidence in males than females. Critics might suggest the significance of the regression model for UC - RC PSE was driven essentially by gender. This is a possibility, but generally female brains are thought to be less lateralized than male brains, not more lateralized in the LH. If the female participants in this sample were indeed more LH lateralized, a lessened UC condition PSE (or even a positive PSE) or a lessened shift from UC to LC PSE should have been observed.

Results from this study at best tentatively support the some aspects of the predominant cognitive theories of ASD that have persisted over the years. ToM and its later evolution with Extreme Male Brain theory into a combined SE theory would have been tentatively supported had we found a clear increase in RH lateralization for the line bisection task with increase in ASQ score, but that was not the case. Only the shift in PN magnitude from the UC to the RC condition was found, and this effect was opposite the direction that would support greater RH lateralization for the task. Tentative support for WCC can be found with the lack of effect for the UC PSE – LC PSE, but the increased effect for the UC PSE – RC PSE seems to contradict WCC predictions. An argument could be made that the chimeric faces results support in some way an ED theory of ASD, but those same results could be used in support of lower level processing theories that have little, if anything, to do with higher order cognitive processes. Any support that could be found for ED theory of ASD from the chimeric faces results would be indirect and lacking specificity like the theory itself.

Unfortunately, after reviewing the findings for the line bisection and chimeric faces tasks, the results corroborate few of the findings reported by other researchers listed earlier. Line bisection results did not mimic the lessened bias in the greyscales task found by English et al. (2015). We found an increased RC effect with increase in ASQ score not the decreased lateralization reported by Preslar et al. (2014). The only finding that tentatively supports a narrower focus of attention (Ronconi et al., 2013) is the lacking UC to LC PSE result. The UC to RC PSE shift contradicts a narrowing of the visuospatial attentional spotlight, but could indicate a bias in deployment of the attentional spotlight to the RVF. More testing is necessary to delineate. We did not directly address the steepness of attentional gradient suggested by Robertson et al. (2013) and advocate others incrementally increase the horizontal length of the line stimuli and hence the angle at which the cues would be viewed as a future pursuit. Unlike the lessened LVF bias that Ashwin et al. (2005) reported for participants with Asperger syndrome, this study shows an increased LVF bias for positive valence as ASQ score increased.

CONCLUDING THOUGHTS

The temptation with these results is to oversimplify their meaning by attributing observed behavioral patterns to differences in general lateralization for low level visual processes in those with a higher degree of autistic trait expression. Although this conclusion may hold true on some level, more testing is necessary to better characterize and contextualize current findings. The UC to RC change in PSE indicates an increased RC effect for those with higher ASQ scores. This could be a clue to general higher LH activation, but the lack of a significant results for UC and UC to LC PSE likely instead means that the underlying cause is more complicated. It is recommended that future research investigate the possibility that this study failed to capture effects for UC and UC to LC PSE due to our choice of line length or viewing distance (the latter is less likely). What regions and systems are at play and how do these differ for attention as measured by line bisection versus chimeric faces? How much of a difference does the lessened modulation in PN by cues in the RVF make in an individual's perceptual experience? Facial processing has been the subject of much research and the "social brain" can be understood generally as described by Brothers et al. (1990) and includes, among other structures, the orbitofrontal cortex (OFC), superior temporal sulcus (STS), and the fusiform face area (FFA). If the current results can be reduced to lateralization, it is likely lateralization more heavily involving one or more of these "social brain" areas in conjunction with a more general heightened parietal activation indicative of lateralization differences. The general increase in parietal activation attributed to greater RH lateralization cannot explain the line bisection results of this study. The only significant result from the line bisection task would seem to indicate the opposite, a greater LH lateralization as autistic trait expression increases. Something like the social brain network or part(s) of it are needed to explain the increased bias for chimeric faces found here. The greater strength of the effect for the chimeric faces found here supports this assessment, but again, more information is necessary before further conclusions can be drawn. The effects for the chimeric faces were more consistent, but even those effects were small. The amount of variability in %L responses to the chimeric faces explained by the predictors in the regression models does not indicate a large difference across autistic trait expression levels at lower levels of visual processing even for socially relevant information. Moving forward, my recommendation is to look at specific structures, regions, and systems that have concrete physiological bases and codification and can be described by simple behavioral measures like the ones used in this study. Electrophysiological and imaging techniques are encouraged when such structures, regions, and systems are 1) detectable at surface levels and not entirely internal and 2) the error inherent in the measurement technique does not outweigh the conclusions that can be met. The end goal is to eliminate as many of the over 100 genes that have thus far been implicated in ASD. Linking behavioral performance to structures, regions, and systems and then investigating gene contribution to development and function of those structures, regions, and systems is a straightforward path to this goal.

A final thought is to re-evaluate the notion that ASD is indeed a spectrum disorder and that all of the symptoms listed in the diagnostic criteria are unique to ASD and not separable from ASD like mental age and IQ. It is possible that a single underlying cause for social deficits and perceptual irregularities present in persons with ASD will be identified. It is also possible that new findings will eliminate some symptoms from the diagnostic criteria or subdivide the autism spectrum into a family of related but differentiable developmental disorders. This study provides a preliminary step toward addressing these issues by demonstrating that visuospatial attention for socially relevant and irrelevant information is divisible at relatively low level of visual processing and that those with higher autistic trait expression differ more strongly from those with lower autistic trait expression in visuospatial attention for socially relevant information. However, the amount that those with greater autistic trait expression differ from those with lesser autistic trait expression in visuospatial attention for socially relevant information at low levels of visual processing is small and may not be relevant practically with regard to day to day function.

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APPENDIX A. ADULT AUTISM SPECTRUM QUOTIENT SURVEY

The Adult Autism Spectrum Quotient (AQ)
Ages 16+

SPECIMEN, FOR RESEARCH USE ONLY.

How.to.fill.out.the.questionnaire

Below are a list of statements. Please read each statement very carefully and rate how strongly you agree or disagree with it by circling your answer.

DO NOT LEAVE ANY STATEMENT OUT.

Examples

E1. I am willing to take risks.	definitely agree	slightly agree	slightly disagree	definitely disagree
E2. I like playing board games.	definitely agree	slightly agree	slightly disagree	definitely disagree
E3. I find learning to play musical instruments easy.	definitely agree	slightly agree	slightly disagree	definitely disagree
E4. I am fascinated by other cultures.	definitely agree	slightly agree	slightly disagree	definitely disagree

1. I prefer to do things with others rather than on my own.	definitely agree	slightly agree	slightly disagree	definitely disagree
2. I prefer to do things the same way over and over again.	definitely agree	slightly agree	slightly disagree	definitely disagree
3. If I try to imagine something, I find it very easy to create a picture in my mind.	definitely agree	slightly agree	slightly disagree	definitely disagree
4. I frequently get so strongly absorbed in one thing that I lose sight of other things.	definitely agree	slightly agree	slightly disagree	definitely disagree
5. I often notice small sounds when others do not.	definitely agree	slightly agree	slightly disagree	definitely disagree
6. I usually notice car number plates or similar strings of information.	definitely agree	slightly agree	slightly disagree	definitely disagree
7. Other people frequently tell me that what I've said is impolite, even though I think it is polite.	definitely agree	slightly agree	slightly disagree	definitely disagree
8. When I'm reading a story, I can easily imagine what the characters might look like.	definitely agree	slightly agree	slightly disagree	definitely disagree

9. I am fascinated by dates.	definitely agree	slightly agree	slightly disagree	definitely disagree
10. In a social group, I can easily keep track of several different people's conversations.	definitely agree	slightly agree	slightly disagree	definitely disagree
11. I find social situations easy.	definitely agree	slightly agree	slightly disagree	definitely disagree
12. I tend to notice details that others do not.	definitely agree	slightly agree	slightly disagree	definitely disagree
13. I would rather go to a library than a party.	definitely agree	slightly agree	slightly disagree	definitely disagree
14. I find making up stories easy.	definitely agree	slightly agree	slightly disagree	definitely disagree
15. I find myself drawn more strongly to people than to things.	definitely agree	slightly agree	slightly disagree	definitely disagree
16. I tend to have very strong interests which I get upset about if I can't pursue.	definitely agree	slightly agree	slightly disagree	definitely disagree
17. I enjoy social chit-chat.	definitely agree	slightly agree	slightly disagree	definitely disagree

18. When I talk, it isn't always easy for others to get a word in edgeways.	definitely agree	slightly agree	slightly disagree	definitely disagree
19. I am fascinated by numbers.	definitely agree	slightly agree	slightly disagree	definitely disagree
20. When I'm reading a story, I find it difficult to work out the characters' intentions.	definitely agree	slightly agree	slightly disagree	definitely disagree
21. I don't particularly enjoy reading fiction.	definitely agree	slightly agree	slightly disagree	definitely disagree
22. I find it hard to make new friends.	definitely agree	slightly agree	slightly disagree	definitely disagree
23. I notice patterns in things all the time.	definitely agree	slightly agree	slightly disagree	definitely disagree
24. I would rather go to the theatre than a museum.	definitely agree	slightly agree	slightly disagree	definitely disagree
25. It does not upset me if my daily routine is disturbed.	definitely agree	slightly agree	slightly disagree	definitely disagree
26. I frequently find that I don't know how to keep a conversation going.	definitely agree	slightly agree	slightly disagree	definitely disagree

27. I find it easy to "read between the lines" when someone is talking to me.	definitely agree	slightly agree	slightly disagree	definitely disagree
28. I usually concentrate more on the whole picture, rather than the small details.	definitely agree	slightly agree	slightly disagree	definitely disagree
29. I am not very good at remembering phone numbers.	definitely agree	slightly agree	slightly disagree	definitely disagree
30. I don't usually notice small changes in a situation, or a person's appearance.	definitely agree	slightly agree	slightly disagree	definitely disagree
31. I know how to tell if someone listening to me is getting bored.	definitely agree	slightly agree	slightly disagree	definitely disagree
32. I find it easy to do more than one thing at once.	definitely agree	slightly agree	slightly disagree	definitely disagree
33. When I talk on the phone, I'm not sure when it's my turn to speak.	definitely agree	slightly agree	slightly disagree	definitely disagree
34. I enjoy doing things spontaneously.	definitely agree	slightly agree	slightly disagree	definitely disagree
35. I am often the last to understand the point of a joke.	definitely agree	slightly agree	slightly disagree	definitely disagree

36. I find it easy to work out what someone is thinking or feeling just by looking at their face.	definitely agree	slightly agree	slightly disagree	definitely disagree
37. If there is an interruption, I can switch back to what I was doing very quickly.	definitely agree	slightly agree	slightly disagree	definitely disagree
38. I am good at social chit-chat.	definitely agree	slightly agree	slightly disagree	definitely disagree
39. People often tell me that I keep going on and on about the same thing.	definitely agree	slightly agree	slightly disagree	definitely disagree
40. When I was young, I used to enjoy playing games involving pretending with other children.	definitely agree	slightly agree	slightly disagree	definitely disagree
41. I like to collect information about categories of things (e.g. types of car, types of bird, types of train, types of plant, etc.).	definitely agree	slightly agree	slightly disagree	definitely disagree
42. I find it difficult to imagine what it would be like to be someone else.	definitely agree	slightly agree	slightly disagree	definitely disagree
43. I like to plan any activities I participate in carefully.	definitely agree	slightly agree	slightly disagree	definitely disagree

44. I enjoy social occasions.	definitely agree	slightly agree	slightly disagree	definitely disagree
45. I find it difficult to work out people's intentions.	definitely agree	slightly agree	slightly disagree	definitely disagree
46. New situations make me anxious.	definitely agree	slightly agree	slightly disagree	definitely disagree
47. I enjoy meeting new people.	definitely agree	slightly agree	slightly disagree	definitely disagree
48. I am a good diplomat.	definitely agree	slightly agree	slightly disagree	definitely disagree
49. I am not very good at remembering people's date of birth.	definitely agree	slightly agree	slightly disagree	definitely disagree
50. I find it very easy to play games with children that involve pretending.	definitely agree	slightly agree	slightly disagree	definitely disagree

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APPENDIX B. EDINBURGH HANDEDNESS SURVEY

Initials:________________________ Sex:__________________Age:______

Please indicate your preferences in the use of your hands/feet/eyes in the following activities by filling in the appropriate bubble.

(a) Exclusively Left
(b) Mostly Left
(c) No Preference
(d) Mostly Right
(e) Exclusively Right

Hands

1. Writing _____________

2. Drawing _____________

3. Throwing a ball _____________

4. Using a scissors _____________

5. Using a toothbrush _____________

6. Holding a knife (without fork) _____________

7. Using a spoon _____________

8. Holding a broom (upper hand) _____________

9. Striking a match (hand holding match) _____________

10. Opening a box (hand opening lid) _____________

Feet
11. Kicking a Football ________________

Eyes
12. Looking in a peephole ________________

From “The assessment and analysis of handedness: The Edinburgh inventory,” by R. C. Oldfield, 1971, *Neuropsychologia, 9*(1), 97-113. Copyright [1971] by Elsevier. Reprinted with permission.

APPENDIX C. FLINDERS HANDEDNESS SURVEY

Flinders Handedness Survey (FLANDERS)

Last name:……………………………………..First name:……………………………………….

Date of birth:…………………………………Sex (m/f)………………………………………….

The ten questions below ask which hand you prefer to use in a number of different situations. Please tick one box for each question, indicating whether you prefer to use the left-hand, either-hand, or the right-hand for that task. Only tick the 'either' box if one hand is truly no better than the other. Please answer all questions, and even if you have had little experience in a particular task, try imagining doing that task and select a response.

		Left	Either	Right
1	With which hand do you write?			
2	In which hand do you prefer to use a spoon when eating?			
3	In which hand do you prefer to hold a toothbrush when cleaning your teeth?			
4	In which hand do you hold a match when you strike it?			
5	In which hand do you prefer to hold the rubber when erasing a pencil mark?			
6	In which hand do you hold the needle when you are sewing?			
7	When buttering bread, which hand holds the knife?			
8	In which hand do you hold a hammer?			
9	In which hand do you hold the peeler when peeling an apple?			
10	Which hand do you use to draw?			

Handedness Score (please don't fill this out)	

From "The Flinders Handedness survey (FLANDERS): a brief measure of skilled hand preference," by M. E. R. Nicholls, N. A. Thomas, T. Loetscher, and G. M. Grimshaw, 2013. *Cortex 49*, 2914-2926. Copyright [2013] by Elsevier. Reprinted with permission.

APPENDIX D. PARTICIPANT PAYMENT FORM

North Dakota State University

Department of Psychology
Center for Visual Neuroscience

Research Participant Payment Form

Name____________________________ Date_____________

Amount paid $_________

Mailing address:

____

(Street)

____

(City) (State) (Zip)

By signing below, I acknowledge that I have received the noted amount for my participation in a research study conducted by the Center for Visual Neuroscience.

____

Signature

NDSUNorth Dakota State University

Department of Psychology

Minard Hall 332Q

Fargo, ND 58108-6050

701-231-6822

APPENDIX E. INFORMED CONSENT

Title of Research Study: Asymmetries in Visuospatial Attention and Autism Spectrum Behaviors.

This study is being conducted by: Dr. Mark McCourt, 132A24 Minard Hall, Department of Psychology, and Dr. Lynnette Leone, 134E16 Minard Hall.

Why am I being asked to take part in this research study? You have been invited to participate in this study because you participated in Phase 1 of this experiment in which you completed the Adult Autism Spectrum Quotient (AQ) online.

What is the reason for doing the study? When estimating the midpoint of a horizontal line, normal observers misjudge it to be leftward of its true center, reflecting a bias to attend to left visual space. While neurological disorders such as autism have been variously associated with enhancements and deficits in visuospatial processing, few studies have examined the relationship between behaviors and preferences associated with autism and performance on line-bisection tasks. The Adult Autism Spectrum Quotient (AQ) is a recognized research tool which identifies behaviors and preferences typically associated with the autism spectrum. *It is not a clinical diagnostic tool*. The present study aims to use a common bisection task to examine biases in visuospatial attention associated with variations in scores on the AQ.

What will I be asked to do? You will complete computerized tests such as the line bisection task in the lab. Following your consent to take part in the experiment, you will complete questionnaires that determine your hand preference, after which the researcher will briefly summarize the tasks, and provide you opportunities to ask questions.
To complete the computer tasks, you was seated at a comfortable distance from a visual display and will observe stimuli presented on the computer screen. Your task is to make judgments regarding the physical characteristics of the stimuli, by pressing a button.

Where is the study going to take place, and how long will it take? This study is taking place in our laboratory room in Minard Hall, on the NDSU campus. Including consent provision and explanation of procedures, experiments of this kind generally take approximately 30-60 minutes to complete.

What are the risks and discomforts? There is no deception whatsoever used in this experiment. There are no known risks involved in these tasks. While it is not possible to identify all potential risks in research procedures, the researcher(s) have taken reasonable safeguards to minimize any known risks to the participant. If new findings develop during the course of this research, which may change your willingness to participate, we will tell you about these findings.

What are the benefits to me? This study is designed to answer basic questions regarding attention to viewed images and how visual information is perceived. However, you may not get any direct benefit from being in this research study.

What are the benefits to other people? Basic research experiments like this have no immediate and direct benefit from the results on participants, however, it is hoped that through them we gain some insight and understanding regarding some normal human behaviors and neurological conditions and perhaps develop techniques to prevent or repair effects of these conditions.

Do I have to take part in the study? Your participation in this research is your choice. If you decide to participate in the study, you may change your mind and stop participating at any time without penalty or loss of benefits to which you are already entitled.

What are the alternatives to being in this research study? You have the alternative of not consenting to participate in this research study. If you do not wish to participate you may discontinue at any time.

Who will see the information that I give? All information that is obtained from your participation during this study and that can be identified with you will remain strictly confidential, and will not be disclosed without your written permission. We will keep private all research records that identify you. Your information was combined with information from other people taking part in the study. When we write about the study, we will write about the combined information that we have gathered. You will not be identified in these written materials. We may publish the results of the study; however, we will keep your name and other identifying information private. Data and records created by this project are the property of the University and the investigator. You may have access to information collected on or about you, but not to information collected on or about others participating in the project. After the ending of the project the data was archived.

Can my taking part in the study end early? Your participation is voluntary and you may quit at any time. Your decision whether or not to participate will not affect your present or future relationship with North Dakota State University, the Department of Psychology, or the experimenters. If you decide to participate, you are free to withdraw your consent and to discontinue participation at any time.

Will I receive any compensation for taking part in this study? You will receive $15 for your participation in this study.

What if I have questions?

Before you decide whether to accept this invitation to take part in the research study, please ask any questions that might come to mind now. Later, if you have any questions about the study, you can contact the researcher, Dr. Mark McCourt, mark.mccourt@ndsu.edu.

What are my rights as a research participant?

You have rights as a participant in research. If you have questions about your rights, or complaints about this research, you may talk to the researcher or contact the NDSU Human Research Protection Program by:

- Telephone: 701.231.8908 or toll-free 1.855.800.6717
- Email: ndsu.irb@ndsu.edu
- Mail: NDSU HRPP Office, NDSU Dept. 4000, PO Box 6050, Fargo, ND 58108-6050.

The role of the Human Research Protection Program is to see that your rights are protected in this research; more information about your rights can be found at: www.ndsu.edu/irb .

Documentation of Informed Consent:

You are freely making a decision whether to be in this research study. Signing this form means that

1. you have read and understood this consent form
2. you have had your questions answered, and
3. you have decided to be in the study.

You was given a copy of this consent form to keep.

____ ____________

Your signature Date

____

Your printed name

____ ____________

Signature of researcher explaining study Date

____

Printed name of researcher explaining study