

Variability in the Visual Perception of Human Motion as a Function of the Observer's Autistic Traits

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Introduction

As described throughout this book, typical observers exhibit remarkable sensitivity to the social information conveyed by the bodily movement of other people. While researchers have historically motivated their studies of the perception of human movement by asserting that successful social behavior depends on it (for review see Blake & Shiffrar, 2007), empirical evidence for this long-standing assumption has only recently been collected. Of course, typical individuals vary in their social skills. This natural variability provides an inroad into understanding the connection between social abilities and social perception. If successful social behavior relies upon the accurate perception of other people's movements, then individuals with deficits in social function might reveal atypical sensitivity to human action.

The Autism Spectrum

Autism is a pervasive developmental disorder defined by impairments in social function, communication and repetitive or stereotyped behaviors (see also Pelphrey chapter in this volume). Lack of social interest, or 'autistic aloneness', was noted as a defining feature of this disorder in the first diagnostic description (Eisenberg & Kanner, 1956). Because there is substantial heterogeneity in the diagnosis, it is referred to as autism spectrum disorder, or ASD. Currently, most researchers do not consider autism to be a dichotomous phenomenon. Rather, they posit that the autistic spectrum extends into the non-clinical population. This concept of the broad autism phenotype (Dawson et al., 2002; Piven, Palmer, Jacobi, Childress, & Arndt, 1997) has gained traction as parents (Bishop et al., 2004; Constantino & Todd, 2005) and siblings (Constantino et al.,

2006) of individuals diagnosed with ASD can also exhibit autistic traits. Moreover, several studies have now shown that individuals in the general population present sub-clinical levels of autistic traits (Baron-Cohen, Wheelwright, Skinner, Martin, & Clubley, 2001; Constantino & Todd, 2003; Posserud, Lundervold, & Gillberg, 2006) and such traits are continuously and normally distributed in the non-clinical population (e.g., Hurst, Mitchell, Kimbrel, Kwopil & Nelson-Gray, 2007).

Since autism is a social disorder at its core, assessing the magnitude of autistic traits enables empirical investigation of individual differences in social abilities in "typical" observers. Furthermore, such research can provide an inroad into the cognitive and perceptual styles associated with the autism spectrum. Over the past decade, several researchers have developed self- and parental-report measures to assess the magnitude of autistic traits in non-clinical groups of individuals with normal intelligence. Use of these measures in empirical settings serves to compliment the traditional methodology of studying autism, namely, the comparison of clinical and matched control groups (Kennedy, 2009). Indeed, the use of these surveys is beginning to clarify the relationship between autistic behaviors and tendencies with performance on a variety of psychophysical tasks (e.g. Grinter et al., 2009; Stewart, Watson, Allcock, & Yaqoob, 2009), neurophysiological measures (Di Martino et al., 2009; von dem Hagen, Yu, Ewbank, & Calder, in press), and genetics (e.g., Chakrabarti et al., 2009). These studies clearly illustrate the promise of examining individual differences in autistic traits in the study of genes, brain and behavior.

This chapter focuses on the relationship between social capabilities and visual sensitivity to other people's actions. While the causal direction of this relationship is unclear at this time, current evidence nonetheless suggests a tight coupling between action perception and social ability. Although a variety of stimuli has been used to study the perception of human movement, we focus here on point-light stimuli.

Visual Perception in ASD

How do observers with ASD see the world? Some theories of visual perception in observers with ASD emphasize a local processing bias (e.g., Frith, 1989; Happé & Frith, 2006; Mottron & Burack, 2001) consisting of a generalized tendency to rely on featural and local information at the expense of extracting the gist or seeing the big picture. Other theories suggest that compromised social perception, in specific, characterizes this pervasive developmental disorder (Klin, Jones, Schultz, & Volkmar, 2003; Pelphrey & Carter, 2008; Schultz, 2005). Certainly, a vast literature of studies that utilize static displays has documented a local or part-based visual processing strategy in ASD (e.g., Jolliffe & Baron-Cohen, 1997; Mottron, Burack, Stauder, & Robaey, 1999; Shah & Frith, 1983) that is accompanied by a relative failure to integrate image subregions holistically (Dakin & Frith, 2005). For example, individuals with ASD are able to focus on local image parts and rapidly find hidden shapes within meaningful pictures faster than typically developed participants (e.g., Shah & Frith, 1983). It is unclear whether, or under what conditions, this local processing bias in the analysis of static form extends to motion processing (for review see Kaiser & Shiffrar, 2009b). Initial reports indicated that observers with ASD exhibited elevated motion coherence thresholds (Bertone, Mottron, Jelenic and Faubert, 2003; Davis, Bockbrader, Murphy, Hetrick, & O'Donnell, 2006; Milne et al., 2002; Pellicano, Gibson, Maybery, Kevin, & Badcock, 2005; Spencer et al., 2000). In these tasks, participants detect or report the direction of coherent motion in random dot kinematograms, which are standard psychophysical stimuli made up of dots randomly scattered within some window. Most of the dots move randomly from frame to frame while varying percentages of dots move together. Observers' ability to integrate the individual dot motions together to detect the presence of coherent motion or the direction of that motion is assessed by motion coherence thresholds. Elevated motion coherence thresholds indicate a reduced ability to process global motion signals and/or a reliance on the local motion signals. Concordant with the above studies, Grinter and colleagues recently showed that autistic traits, in non-clinical adults, are associated with elevated motion coherence thresholds (Grinter et al., 2009).

However, the relationship between ASD and motion coherence thresholds is far from clear. Several studies have reported no deficits in visual perception of coherent motion in observers on the autism spectrum (de Jonge et al., 2007; Del Viva, Igliazzi, Tancredi, & Brizzolaro, 2006; Milne et al., 2006). Importantly, there appears to be no obvious methodological differences between studies that have and have not identified elevated motion coherence thresholds in observers with ASD (Kaiser & Shiffrar, 2009b). The variability of motion coherence threshold complicates our understanding of a local processing

bias as the defining feature of visual processing in observers with ASD.

Alas, heterogeneity in clinical phenotype is an inherent aspect of this spectrum disorder. Behavioral studies have documented differences in visual motion processing in individuals with ASD as a function of language delay (Takarae, Luna, Minshew, & Sweeney, 2008), motor abilities (Price, 2006; Price, Shiffrar, & Kerns, under review), stimulus complexity (Bertone et al., 2003), stimulus duration (Davis et al., 2006) and ASD diagnosis (Spencer & O'Brien, 2006; Tsermentseli, O'Brien, & Spencer, 2008). Dakin and Frith (2005) have suggested that variability in visual motion processing may be explained by an underlying dysfunction in the Superior Temporal Sulcus (STS), an area located at an intersection of the dorsal and ventral pathways (Baiser, Ungerleider, & Desimone, 1991). This region supports a variety of functions (Hein & Knight, 2008) including the perception of social information (Allison, Puce, & McCarthy, 2000). Several researchers have suggested that dysfunction in the STS underlies the characteristic impairments in social behavior in ASD (e.g., Pelphrey & Carter, 2008; Zilbovicius et al., 2006).

Notably, there is mounting evidence for a specific deficit in social perception in observers with ASD. When static face perception was compared with object perception, children with ASD exhibited a category-specific face impairment that reflected a failure to process faces holistically (Wolf, Tanaka, Klaiman, Cockburn, Herlihy, Brown et al., 2008). Since the face is an inherently social stimulus, these results suggest that a local processing bias may not fully account for the marked deficits in visual sensitivity to faces (e.g., Klin & Jones, 2006; Wolf et al., 2008). Additional evidence for disrupted social perception in ASD, rather than simply a face-processing deficit, comes from a study of the inversion effect with static stimuli. Inversion of a stimulus is thought to disrupt global or configural processing, and typical observers demonstrate better recognition of upright than inverted faces (Yin, 1969). Reed and colleagues (Reed et al., 2007) reported that typical observers exhibited an inversion effect for faces and body postures but not houses. In comparison, a group of individuals with high functioning autism showed a face inversion effect but did not show an inversion effect for static body postures (Reed et al., 2007). These results suggest that observers with high functioning autism may process the images of bodies in a local and, thus, atypical manner. If a local processing bias fully characterized visual processing in observers with ASD, then no inversion effect would be expected in any condition. Taken together, these studies demonstrate atypicalities in the visual analysis of socially relevant stimuli amongst observers with ASD that is related to, but not strictly characterized, by a local processing bias.

Observers with ASD Look at People Less

Preferential looking paradigms and eye-tracking data suggest that children and adults with ASD exhibit atypical attention to people's bodies and actions. Typically developed infants are sensitive to manipulations of the orientation of human movement and this sensitivity becomes specialized during the first year of life (e.g., Pinto, 1997). Remarkably, 2 day-old infants preferentially attend to upright versus inverted displays of biological motion, namely, point-light hen locomotion, even

though they obviously have had no experience with chickens (Simon, Regolin & Bulf, 2008). Usually, children demonstrate preferential gaze to canonical, coherent displays of human movement during the first years of life (Bertenthal, Proffitt, & Cutting, 1984; Fox & McDaniel, 1982; Frankenhuus, Barrett, & Johnson, this volume). Toddlers with ASD, on the other hand, do not exhibit a preference for upright versus inverted displays of human movement (Klin, Lin, Gorrindo, Ramsay, & Jones, 2009). Eye-tracking data do not directly indicate an observer's comprehension of what is seen but this recent study by Klin and colleagues demonstrates that, early in life, children with ASD are less sensitive than their typically developing peers to manipulations of the orientation of human movement.

Eye tracking studies have provided further evidence of variations in the distribution of visual attention across peopled scenes. Compared to typical controls, children with ASD look less at people in interactive movie scenes (Klin, Jones, Schultz, Volkmar, & Cohen, 2002; Leekam, Lopez, & Moore, 2000). Children (Riby & Hancock, 2008) and adults (Fletcher-Watson, Findlay, Leekam, & Benson, 2009) with ASD are also less likely to orient towards people in static displays. Since static images prime motion percepts (Freyd, 1983) and trigger activity in the neural mechanisms underlying motion perception (Kourtzi & Kanwisher, 2000), it makes sense that attentional processing of static and dynamic images of people are related.

In typical observers, visual sensitivity to point-light displays of human movement is defined, in part, by an observer's experience watching a depicted action in the real world. For example, observers are better able to differentiate the identities of point-light defined people whom they know in the real world than the identities of point-light strangers (Jacobs, Pinto, & Shiffrar, 2004; Loula et al., 2005). It follows that a failure to attend to other peoples' actions would eventually decrease visual sensitivity to those actions. It is unclear, however, whether atypical patterns of gaze in observers with ASD results in atypical percepts of human movement later in life or whether dysfunction in the STS and related brain areas causes atypical gaze and impaired human motion perception.

ASD and The Perception of Human Motion

A rapidly evolving literature has sought to determine whether individuals with ASD exhibit deficits in their visual analysis of other peoples' actions. Such studies commonly use point-light stimuli created by attaching markers or point-lights to a person's body and head and then recording that person's movements so that only the point-lights are visible (Johansson, 1973). The resultant displays are thought to isolate motion processes as they are only recognized as human when the dots are in motion. From these displays, naïve typical observers readily detect a wealth of social information including a point-light actor's actions (Dittrich, 1993; Poizner, Bellugi & Lutes-Driscoll, 1981), emotional state (Atkinson, Dittrich, Gemmel, & Young, 2004; Clarke, Bradshaw, Field, Hampson, & Rose, 2005; Chouchourelou, Matsuka, Harber, & Shiffrar, 2006; Dittrich, Troscianko, Lea, & Morgan, 1996; Pollick, Paterson, Bruderlin, & Sanford, 2001), gender (Kozlowski & Cutting, 1977; Pollick, Kay, Heim, & Stringer, 2005), identity (Jokisch, Daum, & Troje, 2006; Loula, Prasad, Harber, & Shiffrar, 2005), intentions (Runeson, & Frykholm, 1983; Sebanz & Shiffrar, 2009), vulnerability (Gunns,

Johnston, & Hudson, 2002) and potential reproductive fitness (Brown et al., 2005). Researchers have begun to examine the perception of human movement in point-light displays in various developmental disorders, to better understand the relationship between social perception and social function.

Several neurodevelopmental disorders, which are characterized by impaired social behavior, including Obsessive Compulsive Disorder (Kim et al., 2008), Down syndrome (Virji-Babul, Kerns, Zhou, Kapur, & Shiffrar, 2006) and Schizophrenia (Kim, Doop, Blake, & Park, 2005), have been associated with atypicalities in visual sensitivity to coherent human motion in point-light displays. For instance, children with Down syndrome can perceive and interpret point-light displays of human action but they do not discriminate human from object movement as well as typically developing controls (Virji-Babul et al., 2006). Children with Down syndrome are also impaired in their ability to identify a point-light person's emotional states and to distinguish between atypical and typical gaits portrayed by point-light walkers (Virji-Babul et al., 2006). But, impairments in the perception of human movement are not a diagnostic feature of all developmental disorders. For instance, individuals with William's syndrome exhibit spared biological motion perception despite visuospatial processing deficits (Jordan, Reiss, Hoffman, & Landau, 2002). Notably, William's syndrome is associated with hypersociability, or overfriendliness, (Meyer-Lindenberg, Mervis, & Berman, 2006). Thus, as indicated below, intact perception of human movement and preserved social abilities contrasts with the opposite pattern in ASD. It is possible that in the case of social disorders, impairments in visual sensitivity to human action might compromise the ability to detect and interpret social information (Kim et al., 2008).

Researchers are currently examining the developmental trajectories, underlying mechanisms and direction of influence in the association between social perception and social abilities (see Pelphrey & Shultz, this volume). In the sections below, we review what is currently known about the visual perception of human movement by observers with ASD. While observers with ASD can perform categorization and detection tasks, distinct patterns of performance along with neurophysiological data illustrate this socially impaired population's atypical sensitivity to the ways in which people move their bodies.

1. Categorizing Human Movement

A growing body of research has shown that observers with ASD can categorize actions and emotions in point-light displays. However, their patterns of performance differ from those of typical control observers. Studies in which participants *verbally* describe or label what they see in point-light movies suggest a specific deficit in recognizing emotion in human movement. Children and adults with ASD perform as well as controls in describing the actions (e.g., walking running, jumping) performed by point-light actors (Hubert et al., 2007; Moore, Hobson, & Lee, 1997; Parron et al., 2008). However, they are not as fast (Moore et al., 1997) or accurate (Hubert et al., 2007; Parron et al., 2008) as control observers in describing the emotional states (e.g., angry, happy, fearful) of point-light actors. Some researchers have interpreted this pattern of results as suggesting that ASD is associated with impaired emotion but typical action recognition in

point-light displays of human motion. However, the above studies all used a free-response labeling task, leaving open the possibility that cross-group differences in expectancy, attention, motivation and language abilities may have influenced the results (Blake, Turner, Smoski, Pozdol, & Stone, 2003; Atkinson, 2009).

A recent study by Atkinson (2009) indicates that individuals with ASD exhibit atypical action recognition as well as atypical emotion recognition. Instead of a verbal free-report measure, in which observers simply describe what action or emotion they see, Atkinson asked observers to choose a label from a list to describe each stimulus. Under these conditions, adult observers with ASD demonstrated an emotion recognition deficit. However, a group of adults with ASD group was less accurate than controls at labeling emotions *and* actions in both full-light and point-light displays. Thus, observers with ASD experience deficits in their visual perception of human motion that are not specific to point-light displays but rather generalize to realistic, full-bodied depictions of moving people. Furthermore, the finding that ASD and typical control groups differed in their classification of emotions and actions suggests that forced-choice labeling may be a more sensitive measure than verbal labeling, especially for observers on the autism spectrum.

Taken together, these categorization studies demonstrate that the visual perception of human movement is atypical in ASD and that experimental response type influences whether these atypicalities in action and emotion recognition are apparent. The evidence for an emotion-processing deficit in ASD has been repeatedly demonstrated (also see Losh et al., 2009) but the specificity of this impairment is not fully understood. For instance, while Atkinson (2009) reported impaired recognition of anger and happiness, other researchers (Losh et al., 2009; Losh, personal communication) found particularly compromised recognition of positive emotions. Future research is needed to clarify the exact nature of emotion processing from human movements by observers with ASD.

2. Neural Atypicalities

Mounting neurophysiological evidence is consistent with atypical processing of human movement in observers with ASD. For example, the results of brain imaging studies suggest that the visual analysis of point-light displays of human motion depends upon different neural mechanisms in observers with and without autism. Activity in the posterior region of the STS (STSp) is necessary for the visual perception of moving point-light people by non-autistic individuals (Grossman, Battelli, & Pascual-Leone, 2005; Saygin, 2007). In observers with ASD, this area is compromised by marked decreases in gray matter concentration, rest hypoperfusion and atypical engagement during social tasks (Boddaert et al., 2004; Pelphrey, Morris, McCarthy, & LaBar, 2007; Waiter et al., 2004). As described in Kevin Pelphrey and Sarah Shultz's chapter in this volume, the STS appears to be tuned for the perception of human movement in typical observers (Carter & Pelphrey, 2006; Pyles, Garcia, Hoffman, & Grossman, 2007) but not in observers with ASD (Pelphrey & Carter, 2008). The exact nature of the interplay between genes, brain and behavior is yet to be determined (Pelphrey & Shultz, this volume) but some researchers have suggested that STS anomalies during early brain development may "constitute the first step" in

the trajectory of neural dysfunction underlying ASD (Zilbovicius et al., 2006).

When observers with and without ASD passively view point-light displays of human walking while in a scanner, their patterns of neural activity differ. For example, Herrington and colleagues (Herrington, Baron-Cohen et al., 2007) asked individuals with Asperger Syndrome (AS) and matched controls to view a point-light walker that was either coherently organized or scrambled. Scrambled point-light walkers are typically constructed by randomly relocating the starting positions of all of the walker's points within some predefined area (Thornton, this volume). Coherent and scrambled point-light walkers usually contain points that are identical in number, size, luminance, and velocity and differ only in the presence of the global hierarchical structure of the human body. In the study by Herrington et al. (2007), participants performed a two-alternative focused choice task outside of the scanner and reported, on each trial, the direction of point-light walkers gait. While both the AS and control groups performed this task at ceiling, fMRI measures indicated significantly less activity in the superior temporal region, including both MT+/V5 and the STS, in participants with AS than in controls. Areas MT+ and STS are highly interconnected in monkeys (e.g., Weller, Wall, & Kass, 2004) and neurotypical humans (e.g., Bradley, 2001), which might explain the coupled decrease in activity in these areas. Freitag and colleagues (Freitag et al., 2008) have reported converging evidence for processing differences in STS. In this study, observers with ASD and matched controls performed a discrimination task with coherent and scrambled point-light walkers while outside the scanner. Both groups of observers were at ceiling in their ability to differentiate scrambled from coherent point-light walkers. However, when these same observers passively viewed these same stimuli while being scanned, fMRI data indicated differences in STS activity between the two groups of observers (Freitag et al., 2008).

3. Detecting Human Movement

In accord with the neurophysiological evidence summarized above, behavioral studies have also documented differences in visual sensitivity to point-light displays of human movement between observers with ASD and controls. In the first such study, Blake and colleagues (2003) asked participants to perform a human motion detect task in which they viewed coherent and scrambled point-light displays and then reported when they saw coherent human motion. Participants also performed a global form detection task to insure that performance in the human motion task reflected more than the ability to integrate visual information over space. In this control task, observers pointed to the location of a static circle created by an alignment of oriented line segments. While observers with ASD performed as well as controls in their detection of coherent static circles, observers with ASD were relatively compromised in their ability to detect the presence of coherent human motion. These researchers concluded that the visual analysis of human movement, in specific, is impaired in ASD. Other researchers have also reported impaired sensitivity to point-light displays of human motion by observers with ASD (Price, 2006; Price, Kerns & Shiffrar, under review). Yet, it is unclear from these studies whether this deficit is specific to the perception of human motion

or instead reflects a deficit in processing coherent motion in general. Indeed, as discussed above, it remains an issue of contention whether observers with ASD experience deficits in their visual sensitivity to coherent motion in random dot kinematograms.

To determine whether the detection of human motion, *per se*, differs in observers with ASD, we conducted a series of studies that compared visual sensitivity to human and object movements. In a preliminary study (Kaiser, Delmolino, Tanaka, & Shiffrar, under review), we asked adolescent and adult participants with high functioning Autism or Asperger's Syndrome and child and adult control observers to detect coherent human or tractor motion in point-light displays. In one block of trials, participants saw coherent and scrambled point-light movies of human motion one at a time and reported after each movie whether or not the dots were stuck to a person. In another block of trials, participants viewed coherent and scrambled movies of tractor motion and reported whether each movie contained dots that were stuck to a tractor (Figure 1). The use of an object motion condition provides a means of controlling against the possibility that decrements in the visual perception of coherent human motion simply reflect decrements in the perception of all coherent motion.

As in the study by Blake and his colleagues (2003), the observers with ASD in our study were able to detect coherent human motion in point-light displays at above chance levels. Not surprisingly, they were also able to detect coherent object movement (in this case, that of a tractor). However, divergent patterns of performance across the ASD and control groups suggested an interesting perceptual difference. Consistent with previous studies (e.g., Pinto & Shiffrar, 2009), typical observers demonstrated greater visual sensitivity to human movement than to equally complex non-human (tractor) movement. However, the ASD group exhibited equivalent levels of perceptual sensitivity to human movement and tractor movement (Figure 2-A). This pattern of results suggests that while typically developed visual systems may be tuned for the detection and analysis of human movement, the visual systems of people with ASD may not be. In processing human and object movement similarly, it is as if the visual systems of people with ASD "objectifies" human movement. In any case, it is easy to imagine that a lack of specialized processing of other people's movements may underlie some of the social deficits associated with the ASD.

4. Masked Point-Light Displays

All of the studies reviewed above used point-light stimuli that were not masked. In other words, when the "target" stimulus, whether coherent human or tractor motion, was present, all of the points in the stimulus were attached to a person or tractor. There were no other points. In analyzing such unmasked displays, typical observers use both local (point-by-point) and global (spatiotemporally extended) processes to perceive coherent motion (Thornton, Pinto, & Shiffrar, 1998). Since observers with ASD default to local processes, at least when analyzing static displays (e.g., Shah & Frith, 1983, 1993; Jolliffe & Baron-Cohen, 1997; Frith, 1989), they may have relied on local motion analyses to detect the presence of human movement. One local motion solution to this task, for instance, might be the determination of whether a point near the bottom of

the screen moves like a foot. Masking disrupts local analyses and, in typical observers, substantially increases reliance on global analyses (e.g., Cutting, Moore, & Morrison, 1988). While point-light masking is frequently applied to test global analyses of human movement by typical observers, we were the first to use it with observers with ASD (Kaiser et al., under review). To the extent that observers rely on local analyses, masking should disrupt their performance on coherent motion detection tasks. Moreover, because masking limits local processing, it encourages both observers with ASD and typical observers to employ comparable means of detecting coherent human and object motion in point-light displays. Thus, increasing task difficulty and limiting reliance on local cues might allow a more appropriate, or meaningful, comparison of group performance.

In a blocked design task, we asked observers with and without ASD to perform a detection task with human and object motion in masked point-light displays (Figure 2; Kaiser et al., 2009b). In the block of trials depicting human motion, observers viewed each movie and reported whether some of the dots were stuck to a person. In the tractor motion block, observers reported whether or not some of the dots were stuck to a tractor. Once again, the ASD group demonstrated equivalent sensitivity to human motion and tractor movement while typical child and adult controls were more sensitive to the presence of coherent human motion (Figure 2-B). This pattern of performance mimics that in the unmasked conditions even though both groups were forced to use global processes to perform the task. Importantly, the ASD group performed above chance in both conditions, indicating that they are capable of using global processes to perform the task. These results further support the hypothesis that typical observers experience enhanced visual sensitivity to human movement while observers with ASD lack that selective enhancement. Finally, above chance performance in the tractor motion condition indicates that these results reflect more than a general deficit in sensitivity to coherent visual motion.

5. Autistic Traits and Detection of Human Motion

While the above review describes growing evidence for atypical visual processing of human motion by observers with ASD, the issue of how to match control and experimental groups calls such evidence into question. Even under conditions in which observers with ASD and controls have been rigorously matched, it is never entirely clear what group differences in performance actually reflect. For instance, chronological and mental age correlate with performance on detection (Blake et al., 2003) and categorization (Atkinson, 2009) tasks. Such findings raise the possibility that variability in factors peripheral to the diagnosis of autism, *per se*, contribute to group differences found in experimental tasks. Importantly, there is a significant relationship between severity of autism, as measured by the Autism Diagnostic Observation Schedule (ADOS), and the ability to detect point-light human movement (Blake et al., 2003). Furthermore, neurophysiological evidence suggests a connection between social perception and social abilities. For instance, in observers with ASD, patterns of BOLD signal change during face perception correlate with the observer's severity of social dysfunction as measured by the ADOS (Hadjikhani, Joseph, Snyder, & Tager-Flusberg, 2006). In sum, there is good reason to believe that the differences between ASD and control groups

discussed above reflect a true association between the autism spectrum and sensitivity to human movement and between social capabilities and visual sensitivity to the actions of people.

If ASD, *per se*, is associated with decrements in processing human action, then individuals with autistic traits might also show decrements in visual sensitivity to human movement. The examination of psychophysical performance as a function of autistic traits in non-clinical populations allows researchers to avoid many of the problems inherent to matching clinical and non-clinical groups and, thus, can help to solidify the conclusions of studies investigating clinical populations. Secondly, this methodology provides a novel window into individual differences within the so-called typical population. For years, researchers studying visual percepts of point-light actions have argued that the ability to accurately analyze such laboratory-specific displays reflects processes that are critical for successful function in the social world. If visual sensitivity to other people's actions is indeed linked to an observer's social abilities, then we should find a direct relationship between the two in typical observers.

To investigate this prediction, we asked typical university students in an Introduction to Psychology course to perform the same human motion and tractor motion detection tasks described above. Afterwards, these participants also completed a self-report measure of autistic traits known as the Autism-Spectrum Quotient (AQ). This brief questionnaire quantifies the magnitude of autistic traits in adults with normal intelligence (Baron-Cohen, Wheelwright, Skinner, Martin, & Clubley, 2001). Higher scores on the AQ denote more autistic traits. Our results indicated a significant negative correlation between AQ scores and sensitivity to human motion (Figure 3). As the presence of autistic traits increased, observer's performance on the human motion detection task decreased. Importantly, performance on the tractor motion detection task did not correlate with observer's AQ scores (Kaiser, Fermano, & Shiffrar, 2008; Kaiser et al., under review). Just as the ASD group described above did not exhibit a heightened sensitivity to human versus tractor motion, individuals with the most autistic traits demonstrated equivalent levels of visual sensitive to human motion and object motion. These data support the hypothesis that visual sensitivity to human motion is indeed related to social behavior in the typical population.

6. Human Motion or Biological Motion?

To further examine the specificity of the relationship between social behavior and sensitivity to human action, we conducted additional studies with point-light displays of animal motion. Of course, the term "biological motion" refers to the movements of humans and animals although it is usually used to denote the former (e.g., Blake et al., 2003). We asked whether autistic traits in typical observers are associated with compromised sensitivity to biological motion in general, or human motion in particular. Typical observers exhibit specialized processing of human compared to animal motion in point-light displays from a young age (Pinto, 1997), although global processes are engaged in the perception of both human and horse motion by adult observers (Pinto & Shiffrar, 2009). Dogs, like people, have four jointed limbs organized about a central axis. If observers with significant autistic traits are very generally

impaired in their visual sensitivity to pendular motion organized around a central axis, then autistic traits should correlate equally with observers' visual sensitivity to human and dog motions. Conversely, if autistic traits are associated with compromised abilities to analyze socially relevant information, *per se*, then observers with more autistic traits, or ASD, should demonstrate greater deficits in their visual sensitivity to human movement than to dog movement.

The study that tested this prediction was an extended replication of our previous point-light studies and involved asking observers to make the same coherence judgments of point-light dog motion, human motion, and tractor motion. The observers consisted of naïve, typical university students who completed the three coherence detection tasks, in random order, and then the AQ (Fermano, Kaiser, & Shiffrar, 2009). As before, half of the movies depicted coherent target motion (dog, human, or tractor, depending upon the experimental block) and the other half of the movies depicted scrambled versions of the coherent movies. These stimuli were presented in point-light masks. Overall, participants were best at detecting the presence of coherent human motion, next best at detecting coherent dog motion, and least accurate at detecting coherent tractor motion. Replicating our earlier result (Fermano et al., 2009), there was a significant negative correlation between autistic traits and sensitivity to human movement in masked displays (Figure 4). That is, as the magnitude of autistic traits increased, visual sensitivity to human motion decreased. There was a smaller, but not statistically significant, negative correlation between AQ scores and sensitivity to dog motion. Finally, as before, autistic traits did not vary with performance in the object condition. This pattern of results further supports the hypothesis that social abilities, as measured by the magnitude of autistic traits, are associated with visual sensitivity to human movement. The small negative correlation of AQ scores and detection of dog motion, suggests that autistic traits are at most only marginally related to perception of biological motion in general. The strong relationship between human movement and AQ scores provides evidence for a tight coupling between autistic traits and the visual analysis of human action, *per se*. Importantly, none of these studies can be used to address the direction of influence in this relationship. Additional studies are needed to examine the development of sensitivity to human movement as a function of observers' social abilities.

7. Autistic Traits & Emotional Walkers

Successful social functioning requires more than the detection of another person. It also requires the extraction of socially relevant information from other people's actions (Shiffrar, Kaiser, & Chouhorelou, 2010). The emotional content of human actions is a particularly salient cue that has been studied with point-light stimuli (e.g., Atkinson et al., 2004; Clarke et al., 2005; Dittrich et al., 1996; Pollick et al., 2001). Previous work has shown that adult observers are especially sensitive to the presence of potentially threatening human actions (Chouhorelou et al., 2006). In that study, observers performed a standard person detection task with masked point-light walkers. However, across trials, the walkers displayed different basic emotions (anger, fear, happiness, neutrality or sadness). Observers were fastest and most accurate at detecting the

presence of the angry walkers even though the walkers' emotional states were never explicitly judged nor were they mentioned in the instructions. These results suggest that a person's affective state is automatically, rapidly and proficiently monitored during the analysis of that person's actions. Enhanced perceptual sensitivity to potentially threatening stimuli has been documented in a variety of empirical settings (e.g., Hansen & Hansen, 1988; Öhman, Lundqvist, & Esteves, 2001; Öhman, Flykt, & Esteves, 2001) and likely reflects a perceptual skill of evolutionary importance (Adolphs, 2008; Whalen, 1998).

Assuming that the accurate and efficient perception of other people's emotional states is important for successful social behavior, we wondered whether the magnitude of an observer's autistic traits might be related to the enhanced detection of angry human movement. To that end, we conducted an emotional point-light walker detection study with typical adult observers (Kaiser & Shiffrar, 2009a). As in Chouhourelou et al. (2006), observers simply reported whether a walker was present or absent in each of a series of masked point-light movies. The stimuli were constructed from motion capture data. In a preliminary study, observers judged the emotional state of each walker. Point-light walker movies were eliminated whenever a walker's emotional state was not readily recognized by at least 83% of these participants. In the experimental trials, each of the point-light walkers appeared within a point-light mask. Each mask was uniquely constructed by duplicating a point-light walker and then positionally scrambling the starting locations of those duplicate points. Thus, an angry walker appeared in a mask constructed from that particular angry walker. Similarly, a sad walker appeared in a mask constructed from that same sad walker. Because this was done for each point-light walker movie, the mask and the walker had the same motion energy on every trial. This methodological technique is important because different emotional states are associated with different types of movement. For example, anger is expressed by high velocities with significant jerk while sadness is expressed by slow, smooth movements (e.g., Pollick et al., 2001). If, for example, a coherent angry walker were presented in a mask constructed by scrambling a sad walker, then the walker could be detected simply from the differences in the movements of the individual points. We eliminated that possibility by always presenting each walker, whether coherent or scrambled, within a mask constructed from that very same walker. Again, half the movies depicted a coherent walker and the other half depicted a scrambled walker. As before, on each trial, the point-light walker expressed one of five emotional states (happy, sad, angry, neutral, or fearful) and this manipulation was never mentioned to the participants. After completing this 2AFC walker detection task, participants completed the Autism-Spectrum Quotient as a measure of their autistic traits.

Participants in this task exhibited marked variability in detection performance and the magnitude of their autistic traits. Whereas Chouhourelou et al. (2006) reported that, overall, typical observers exhibited heightened sensitivity to the presence of angry point-light walkers, we found considerable individual differences in the presence of this dynamic anger superiority effect. Correlation analyses revealed a significant correlation between AQ scores and detection of angry walkers such that

observers with more autistic traits were less sensitive to the presence of these potentially threatening human movements (Figure 5). After correcting for multiple correlation analyses, AQ score did not correlate with detection performance with walkers expressing any of the other four emotional states (Kaiser & Shiffrar, 2009a). While this study does not address the direction of influence in this effect, these results indicate that typical observers' social capabilities, as assessed by the AQ, are associated with their visual sensitivity to potentially threatening human movements.

Observers with ASD consistently demonstrate decrements in their visual sensitivity to the emotional content of human actions in studies that use either free-response (Hubert et al., 2007; Moore et al., 1997; Parron et al., 2008) or forced-choice (Atkinson, 2009; Losh et al., 2009) techniques. The above results suggest that, amongst typical observers, autistic traits are associated with decreased sensitivity to the emotional states expressed by point-light walkers. These behavioral results fit well with neurophysiological evidence of atypical processing of static images of human bodies conveying emotion (Hadjikhani et al., 2009). Nonetheless, neurophysiological studies of the perception of point-light displays of emotional human movement by observers with ASD are needed to clarify the mechanisms underlying emotion processing in this population. Neuroimaging studies with typical adults have shown that passively viewing caricatured silhouettes, point-light displays, and whole-body postures depicting emotional states engages regions in the STS and the amygdala (Bonda, Petrides, Ostry, & Evans 1996; Hadjikhani & de Gelder, 2003; de Gelder, Snyder, Greve, Gerard, & Hadjikhani, 2004). In line with these findings, atypical neural response to moving emotional faces has also been reported in observers with ASD (Pelphrey et al., 2007). Hence, these two social brain areas, with documented abnormalities in ASD, likely contribute to, or underlie, atypical emotion perception in this population (e.g., Baron-Cohen et al., 2000; Schultz, 2005).

Conclusions

Sensitivity to the information conveyed by others' actions is thought to support successful function in the social world (Shiffrar et al., 2010). While this assumption has historically motivated empirical investigations of the visual perception of human action (Blake & Shiffrar, 2007), the few studies that have directly tested this assumption are relatively new and have been reviewed above. The results of these studies converge in supporting the existence of a direct relationship between an observer's real world social capabilities and that observer's visual sensitivity to human movement, *per se*.

While mounting empirical evidence supports a tight coupling of social abilities and visual sensitivity to human action, the direction of this relationship remains unclear. Do observers with significant autistic traits experience compromised social lives because they have difficulty perceiving and interpreting other people's actions? Or do they experience deficits in their visual sensitivity to human movement because they lead less social lives, and as a result, gain relatively little experience watching other people act? Or both? Because ASD is a developmental disorder, researchers are increasingly focusing on describing the trajectory of atypical perceptual development and its relationship to social deficits (e.g., Schultz, 2005). Indeed, studies of infants

and children with and without ASD have begun to clarify our understanding of the development of this relationship (e.g., Simion et al., 2008; Yoon & Johnson, 2009; Pelphrey & Carter, 2008; Klin et al., 2009). As non-invasive neurophysiological methods become available for use with younger participants, researchers will uncover more of the mechanisms underlying compromised social behavior in ASD (e.g., Saxe & Pelphrey, 2009) and thereby strengthen our understanding of the connection between social perception and social behavior.

Individuals with ASD, or more autistic traits, exhibit compromised social function in accordance with a decreased sensitivity to the wealth of affective information conveyed by the people moving around them in the social world. Researchers are enthusiastically attempting to define the nature of the broad autism phenotype, or the extension of autistic traits into the typical population (e.g., Best, Moffat, Power, Owens, Johnstone, 2008). Such studies compliment those with clinical groups, which aim to uncover the exact nature and underlying mechanisms of atypical social function in ASD. Together, such research has great potential to improve diagnosis and treatment of the essence of this developmental disorder. Certainly, clarifying how observers with ASD perceive and interpret the people around them will provide a comprehensive description of the building blocks of 'autistic aloneness'. While future studies will deepen our understanding of social perception and social behavior, the important connection between the two is no longer just an assumption.

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Figure Captions

Figure 1: Schematic illustrations of point-light stimuli. In the actual displays, the outlines are not shown. (A) Point-light person. (B) Point-light tractor. (C) Masked point-light person.

Figure 2: (A) Performance (perceptual sensitivity) of experimental groups on detection task with unmasked displays. (B) Performance of each experimental group on the detection task with masked displays. Error bars indicate standard error.

Figure 3: Perceptual sensitivity to human and object motion by Autism-Spectrum Quotient score. * indicates $p < .05$.

Figure 4: Perceptual sensitivity to human, animal and object motion by Autism-Spectrum Quotient score. * indicates $p < .05$.

Figure 5: Perceptual sensitivity to emotional human motion by Autism-Spectrum Quotient score. * indicates $p < .01$.

Figures

Figure 1.

(A)



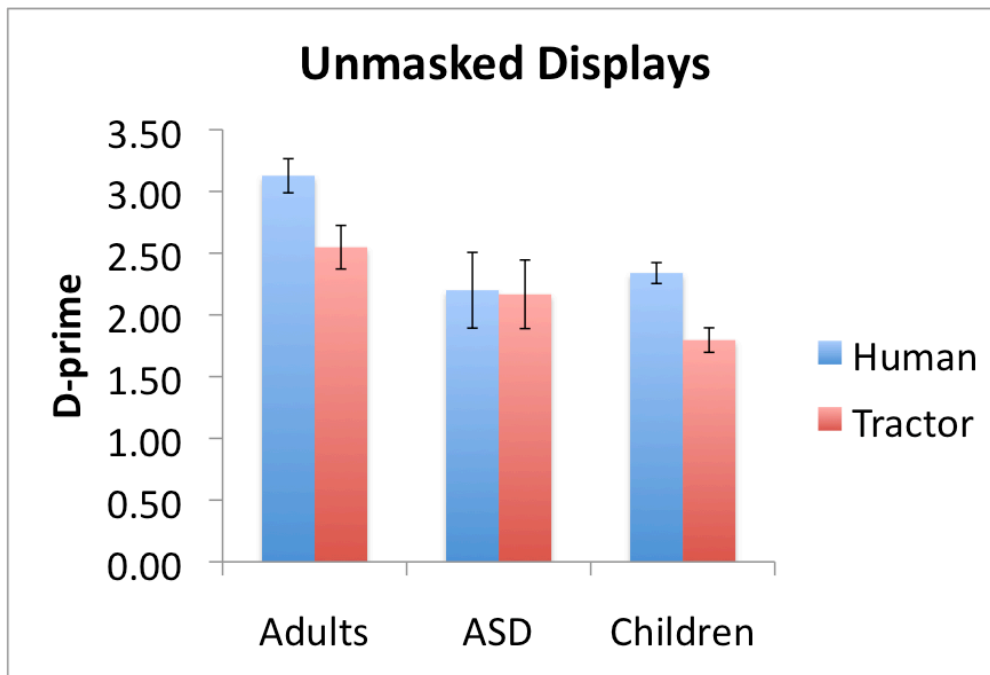
(B)



(C)



Figure 2.
(A)



(B)

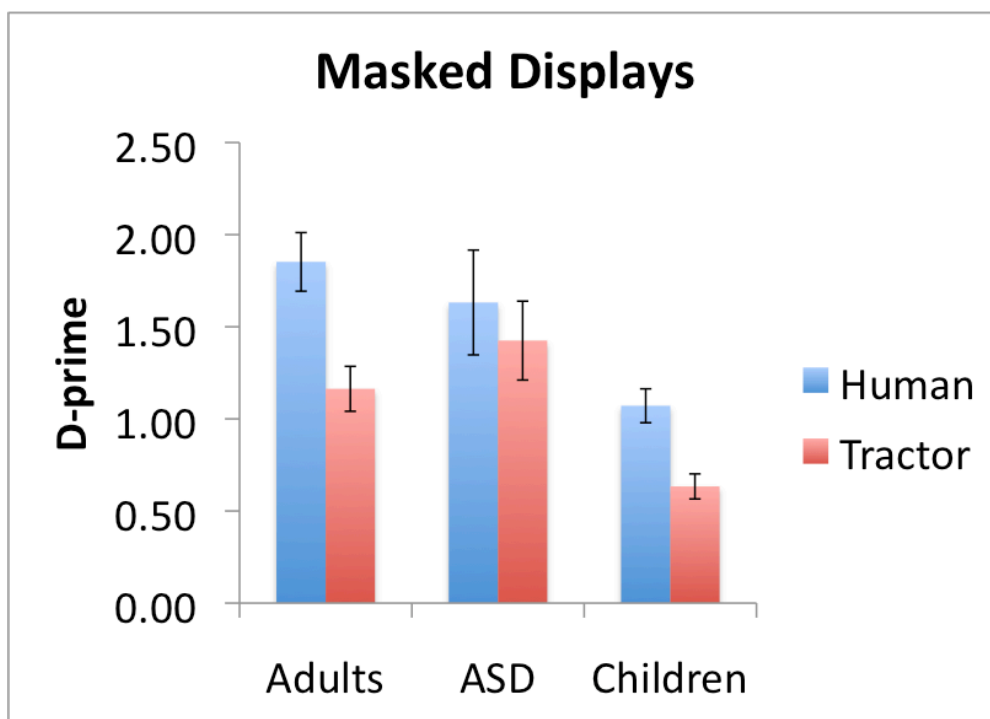


Figure 3.

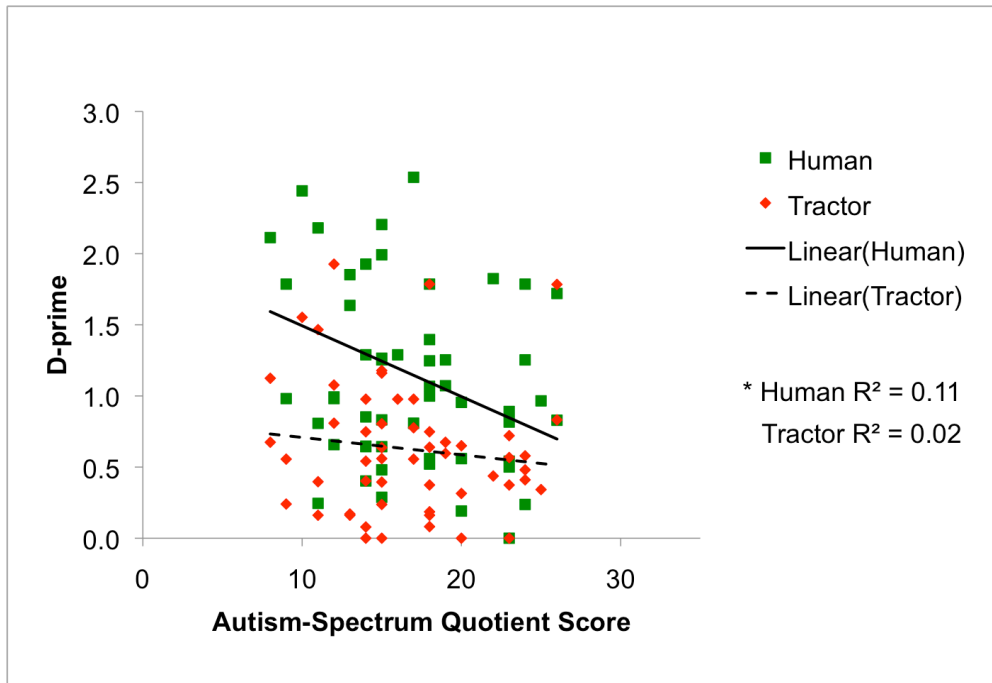


Figure 4.

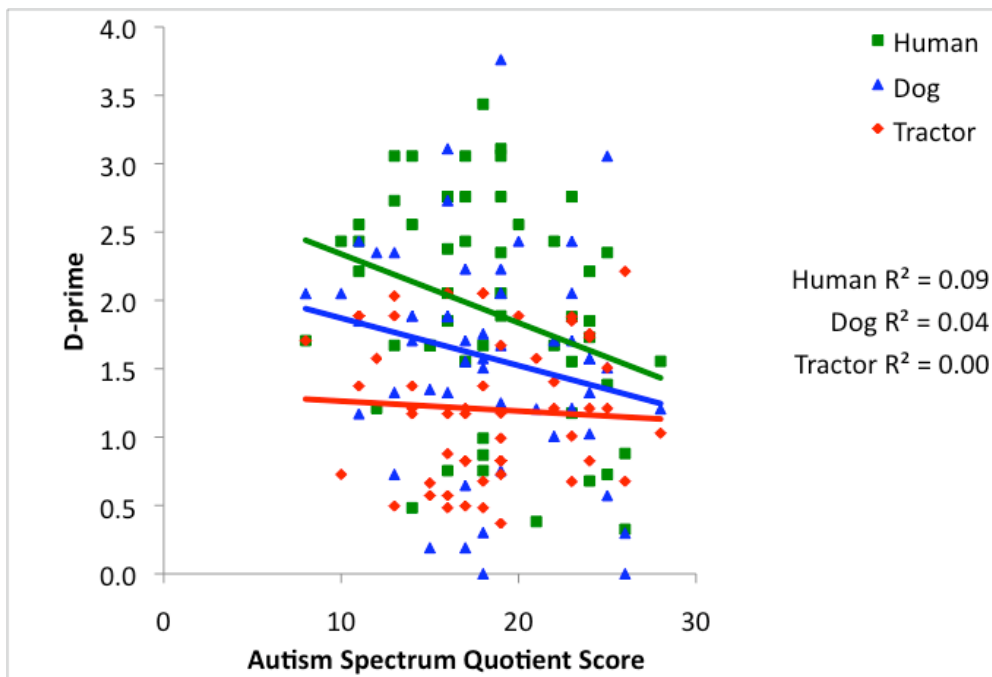


Figure 5.

