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Social Perception and Social Abilities:
Relationships between Action Perception and Autistic Traits

By Martha Danielle Kaiser

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written under the direction of

Professor Maggie Shiffrar

and approved by:

Dr. BJ Casey

Dr. Mauricio Delgado

Dr. Kent Harber

Dr. Gretchen Van de Walle

Dr. Maggie Shiffrar

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ABSTRACT OF THE DISSERTATION

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by Martha Danielle Kaiser

Dissertation Director: Professor Maggie Shiffrar

Vision scientists have historically motivated their studies of the perception of human movement by asserting that successful social behavior depends upon it. But does it? Five psychophysical studies were performed to address this question. To the extent that social capabilities are related to visual sensitivity to human motion, observers with deficits in social function should show selective decrements in their visual sensitivity to human movement. Autism Spectrum Disorder (ASD) is characterized by impairments in social function and autistic traits extend into the general population. Thus, the magnitude of observers' autistic traits can serve as a measure of their social skills. The experiments reported here utilized a point-light target detection task in which observers reported whether a display contained coherent human, animal, or object movement. Overall, typical observers were consistently most sensitive to the presence of coherent human

movement. In Experiments 1 – 3, both typically developing children and typically developed adults exhibited this pattern of performance. In contrast, observers with ASD and typical observers with increased autistic traits demonstrated equivalent sensitivity to human and object motion. Experiment 4 examined the specificity of this effect by testing relative sensitivity to animal motion. The results of this study indicated that typical adult observers were better able to detect the presence of coherent human motion relative to animal or object motion. Furthermore, autistic traits only correlated with detection of human motion. Experiment 5 tested whether a previously documented perceptual effect; namely, enhanced sensitivity to angry human motion, was related to social abilities. The results of this study indicated that enhanced detection of potentially threatening, angry, human movement decreased as the magnitude of an observer's autistic traits increased. Overall, the results of these studies support a tight coupling of laboratory studies of visual sensitivity to the presence of coherent human movement and social behavior outside of the laboratory. Furthermore, these studies illustrate the promise of measuring autistic traits along a continuum of typical and atypical observers to study social behavior and its relation to performance on psychophysical tasks.

Dedication

To my father, the captain of his soul.

To my mother, an optimist.

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Table of Contents

Abstract of the Dissertation	ii
Dedication	iv
Acknowledgments	v
Table of Contents	vi
List of Figures	x
List of Tables	xi
List of Appendices	xii
Chapter 1: Introduction	1
1.1 Social Vision	1
1.2 Autism: A Social Disorder	4
1.3 Visual Perception in ASD	6
1.3.1 Local Processing	6
1.3.2 Motion Perception	8
1.3.3 Social Perception	9
1.4 Biological Motion Perception in ASD	11
1.5 Overview of Experiments	14
Chapter 2: Comparing the Perception of Human and Object Motion	17
2.1 Experiment 1: Typical Adult Observers and Observers with ASD	17
2.1.1 Hypotheses and Design	17
2.1.2 Methods	19

2.1.3 Results	23
2.1.4 Discussion	24
2.2 Experiment 2: Autistic Traits in Typical Adults	27
2.2.1 Hypotheses and Design	27
2.2.2 Methods	29
2.2.3 Results	30
2.2.4 Discussion	32
2.3 Experiment 3: Typically Developing Children	34
2.3.1 Hypotheses and Design	34
2.3.2 Methods	38
2.3.3 Results	39
2.3.4 Discussion	40
Chapter 3: Biological Motion or Human Motion?	43
3.1 Experiment 4: Typical Adults and Observers with ASD	43
3.1.1 Hypotheses and Design	43
3.1.2 Methods	47
3.1.3 Results	49
3.1.4 Discussion	52
Chapter 4: The Detection of Emotional Human Action	55
4.1 Experiment 5: Autistic Traits in Typical Adults	55
4.1.1 Hypotheses and Design	55

4.1.2 Methods	62
4.1.3 Results	65
4.1.4 Discussion	66
Chapter 5: General Discussion	70
5.1 Visual Experience	72
5.1.1 Observers with ASD: Looking at People Less	73
5.1.2 Predisposition for Biological Motion	75
5.2 Motoric Contributions	76
5.3 Social-Emotional Constraints	80
5.4 Beyond Moving Bodies: ASD and the STS	82
5.5 Considering Other Populations	85
5.6 Implications & Future Directions	88
5.7 Caveats	89
5.7.1 Observers with ASD	89
5.7.2 Non-human Motion Controls	90
5.7.3 Age of Participants	92
5.7.4 Measuring Autistic Traits	93
5.8 Summary and Conclusions	95
References	99
Figures	124
Tables	135

Appendices	137
Vita	150

List of Figures

Figure 1. Sample stimuli for Experiments 1 – 3.	124
Figure 2. Experiment 1: Results.	125
Figure 3a. Experiment 2: Results (overall).	126
Figure 3b. Experiment 2: Results (AQ correlations).	126
Figure 4. Experiment 3: Results (overall).	127
Figure 5. Experiment 3: Results (age correlations).	128
Figure 6. Sample stimuli for Experiment 4.	129
Figure 7a. Experiment 4: Results (Typical Group 1, overall).	130
Figure 7b. Experiment 4: Results (Typical Group 1, AQ correlations).	130
Figure 7c. Experiment 4: Results (Typical Group 2, visual experience)	131
Figure 8. Experiment 4: Results (observers with ASD, overall).	132
Figure 9a. Experiment 5: Results (upright overall).	133
Figure 9b. Experiment 5: Results (inverted overall).	133
Figure 10a. Experiment 5: Results (upright, AQ correlations).	134
Figure 10b. Experiment 5: Results (inverted, AQ correlations).	134

List of Tables

Table 1. Experiment 2: Results (AQ correlations, full and subscales).	135
Table 2. Experiment 3: Results (Age correlations).	135
Table 3. Experiment 4: Results (ASD group, AQ and performance).	135
Table 4. Experiment 5: Results (AQ correlations).	136

List of Appendices

Appendix 1. The Autism-Spectrum Quotient (Adult).	137
Appendix 2. The Autism-Spectrum Quotient (Child).	141
Appendix 3. The Autism-Spectrum Quotient (Adolescent).	146
Appendix 4. Familiarity Questionnaire.	149

Chapter 1: Introduction

“What the animal affords the observer is not only behavior but also social interaction.”

– J.J. Gibson (1979)

1.1 Social Vision

Human movement is special. People exhibit a wealth of subtle affective cues in their body movements. And, as inherently social beings, typical observers demonstrate remarkable visual sensitivity to those movements (Blake & Shiffrar, 2007). Yet, traditional models of perception assume that the visual system uniformly analyses all stimuli, regardless of category (Marr, 1982). Indeed, influential theories of visual motion perception have historically argued that all types of visual motion are processed in the same way (e.g., Shepard, 1984). Thus, vision scientists have objectified the human body for decades. That is, investigators have adopted the same theoretical and experimental approaches to study the visual analysis of the human body and non-human objects in both dynamic and static displays (Shiffrar, Kaiser & Chouhourelou, 2009). Recently, these uniform approaches to object and person perception have been challenged, as scientists are beginning to espouse a social view of vision that emphasizes the important connection between social perception and social behavior (e.g., Blake & Shiffrar, 2007; Dijksterhuis & Bargh, 2001). Broadly speaking, in this view, action understanding is a critical component of social cognition, or the capacity to perceive, interpret, and respond to social stimuli (Adolphs, 1999). Under this class of theories, visual analyses of the human body are understood as privileged, relative to analyses of non-human objects, due to the social relevance of other people (e.g., Kaiser & Shiffrar, in press).

Gibsonian, or ecological, theories of vision can be understood as precursors to modern social vision theories. According to ecological views, perception is functionally defined by affordances. That is, observers perceive the world based on what they can do with what they see; in other words, by their motor activities and capabilities (E. Gibson, 1969; J.J. Gibson, 1979). Empirical validation for such “embodied” theories of perception comes from studies of distance and slant perception, for example, that indicate that observers perceive distances as farther and slopes as steeper when their motoric abilities are restricted (Proffitt, 2006). In other words, physical environments afford different locomotor opportunities as a function of the observer’s motor ability and observers’ visual systems appear to be sensitive to such affordances. Visual stimuli can also convey social affordances (Richardson et al., 2007). By definition, these affordances reflect the observer’s own social capabilities, that is what he or she can ‘do’ with the person they see before them. Other people provide a plethora of possible social interactions including conversation, mating, cooperation, and conflict (e.g., Gibson, 1979). Arguably, the perception of other people and their actions involves the detection of more social affordances than the perception of wind blown leaves, rolling rocks, and crashing waves. If the actions of other people do indeed provide a relative abundance of potential affordances or interactions, then observers might be expected to exhibit particularly robust sensitivity to human movement. While researchers have historically motivated their studies of the perception of human movement by asserting that successful social behavior depends on it (e.g., Allison, Puce, & McCarthy, 2000; Atkinson, 2009; Atkinson, Dittrich, Gemmel, & Young, 2004; Barclay, Cutting, & Kozlowski, 1978; Bertenthal & Longo, 2007; Blake & Shiffrar, 2007; Blakemore & Decety, 2001; Bonda,

Petrides, Ostry, & Evans, 1996; Brown et al., 2005; Brownlow et al., 1997; Chouchourelou, Matsuka, Harber, & Shiffrar, 2006; Clarke, Bradshaw, Field, Hampson, & Rose, 2005; Cutting & Kozlowski, 1977; Dittrich, Troscianko, Lea, & Morgan, 1996; Freire et al., 2006; Graf et al., 2007; Gunns, Johnston, & Hudson, 2002; Heberlein, Adolphs, Tranel, & Damasio, 2004; Hubert et al., 2007; Jacobs, Pinto, & Shiffrar, 2004; Jokisch, Daum, & Troje, 2006; Loula et al., 2004; Montepare & Zebrowitz-McArthur, 1988; Moore, Hobson & Lee, 1997; Pinto, 2006; Pollick, Paterson, Bruderlin, & Sanford, 2001; Puce & Perrett, 2003; Richardson, Marsh, & Reuben, 2007; Runeson & Frykholm, 1983; Sebanz & Shiffrar, 2008; Thornton & Vuong, 2004; Ulloa & Pineda, 2007; Verfaillie, 2000; Westhoff & Troje, 2007) this assumption has not been previously tested.

If visual sensitivity reflects or is tuned for the detection of social affordances, then an observer's visual analysis of other people's actions should vary as a function of that observer's social skills. For example, observers with compromised social capabilities should demonstrate reduced levels of visual sensitivity to human action. Individuals with autism are particularly impaired in their social functioning (American Psychiatric Association, 2006). Therefore, empirical examination of the perception of human action in this population might help to characterize the proposed interconnection between social abilities and social perception. Moreover, even in non-clinical populations, individual differences in social abilities should predict observer's perceptual sensitivity to human movement. These predictions are tested in the studies described below.

Social neuroscientists have made significant advances in defining the neural underpinnings of social cognition and, more specifically, of the perception and social analysis of other people's actions (see, for example Pelphrey & Carter, 2008). The neural

structures involved in these processes are referred to as the social brain (Brothers, 1997). This network includes face-processing areas (e.g., Puce, Allison, Asgari, Gore, & McCarthy, 1996) and limbic, or emotional, neural areas such as the amygdala (e.g., Morris et al., 1996). These social brain areas are highly interconnected (e.g., Amaral, 2003) with the purported neural locus of visual representations of human actions known as the superior temporal sulcus (STS). The posterior region of the superior temporal sulcus (STSp) is a multi-modal area that plays a critical role in the perception of human movement (e.g., Grossman et al., 2000; Saygin, 2007). This region and its atypicalities in observers with ASD are discussed below.

1.2 Autism: A Social Disorder

Autism is a pervasive developmental disorder that is characterized by a triad of symptoms including qualitative impairments in social interaction, delayed or impaired communication abilities, and stereotyped patterns of behavior or restricted interests (American Psychiatric Association, 2006). The diagnostic criteria for ASD are currently under revision and will likely change to an assessment of the severity of ‘core elements’ including impaired social communication and repetitive behaviors or fixated interests (Wallis, 2009). Autism Spectrum Disorders are now recognized in one out of 150 children and there has been an increase in diagnoses over the past three decades (Rapin & Tuchman, 2008). Notably, this increase seems to be due to changes in diagnostic criteria and an increased awareness in autism but not the MMR vaccine or ethyl mercury exposure (e.g., Atladottir et al., 2007; Fombonne et al., 2006; Taylor, 2006); The cause of autism remains unclear but there is a strong genetic component that renders any post-

natal origin unlikely (Taylor, 2006). Because there is substantial heterogeneity in the diagnosis (Happé, Ronald & Plomin, 2006), it is referred to as autism spectrum disorder, or ASD. This heterogeneity poses a challenge to researchers trying to determine the cause of this complex disorder (Volkmar, Lord, Bailey, Schultz & Klin, 2004). Despite the heterogeneity in the diagnosis, social impairments run throughout the autism spectrum. As noted by Jones and Klin (2009), focusing on the mechanisms generating such homogeneity in social impairments might provide a means of better understanding ASD (Pelphrey & Shultz, in press).

Lack of social interest, or ‘autistic aloneness’, was noted as a defining feature of this disorder in the first diagnostic description (Eisenberg & Kanner, 1956). Social impairments are multifaceted and commonly affect social recognition, social communication and social imagination (Wing, 2000). Such behavioral impairments along the autism spectrum have led some researchers to focus on a deficit in mind reading in ASD; that is, an impairment in understanding others’ intentions and internal states (e.g., Baron-Cohen, Leslie & Frith, 1995). In order to interact with others properly, an observer must accurately perceive and interpret the actions of other people. This essential step must take place before interaction and higher-level social processes can occur (Pelphrey & Shultz, in press). Therefore, in the studies below, we examine the possible connection between visual perception and social impairments in ASD. We will begin with an overview of visual perception in ASD and then discuss emerging evidence for a specific deficit in social perception.

1.3 Visual Perception in ASD

1.3.1 Local Processing

In the psychological sciences, autism researchers have largely focused on the identification of and treatments for social and cognitive deficits because, at its core, ASD is a social disorder. Visual perception provides an important source of information for social and cognitive processes. Indeed, understanding how people with autism perceive their environments may be a necessary step towards understanding the social and cognitive deficits associated with autism. Consistent with this, substantial recent research has examined the relationships between autism and visual perception (e.g., see reviews by Behrmann, Thomas, & Humphreys, 2006; Dakin & Frith, 2005; Happé & Frith, 2006; Schultz, 2005). Early theories focused on a local processing bias in ASD, but more recently, researchers have emphasized a perception deficit(s) that is specific to social information. We will review the two approaches here briefly.

Individuals with ASD demonstrate supranormal local processing abilities. This seems to come at the expense of global and configural processing. A good example of the local advantage in autism comes from performance on the Embedded Figures task. Individuals with ASD are able to focus on local image parts and rapidly find hidden shapes within meaningful pictures (Jolliffe & Baron-Cohen, 1997; Shah & Frith, 1983). Because typically developed participants consider pictures in their entirety, they require more time to complete the same task. Other examples of a local processing advantage in autism are superior performance on the Block Design task (Shah & Frith, 1993), reproduction of impossible figures (Mottron, Burack, Stauder, & Robaey, 1999), visual search (O’Riordan, 2004; O’Riordan, Plaisted, Driver, & Baron-Cohen, 2001; Plaisted,

O’Riordan, & Baron-Cohen, 1998a), the ability to learn highly confusable patterns (Plaisted, O’Riordan, & Baron-Cohen, 1998b), and performance on tasks with Navon figures that are incongruent across local and global levels of analysis (Wang, Mottron, Peng, Berthiaume, & Dawson, 2007). While observers with ASD can perform global, configural processing, their default is to process information at the local level (Behrmann et al., 2006).

The Weak Central Coherence (WCC) theory of autism, originally put forward by Uta Frith (1989), describes a processing bias for featural and local information accompanied by a relative failure to extract the gist or see the big picture in every day life. In a recent update of WCC, Happé and Frith (2006) focused on a local processing advantage in ASD rather than a global processing deficit. This version of the WCC theory is similar to the theory of Enhanced Perceptual Functioning (Mottron & Burack, 2001) which argues that the local advantage does not necessarily imply a complete inability to process information configurally. Indeed, the typical global-to-local processing order has been found with high functioning adolescents (Mottron et al., 1999) and high and low functioning children with ASD (Dereulle, Rondan, Gepner, & Fagot, 2006; Ozonoff, Strayer, McMahon, & Filloux, 1994). Despite empirical findings of normal global processing abilities, individuals with ASD reliably demonstrate an automatic reliance on the local information in static visual stimuli. Do the local processing tendencies of observers with ASD extend to their perception of motion? If so, then they should exhibit deficits in visual sensitivity to globally coherent motion.

1.3.2 Motion Perception

In the past decade, several studies have suggested that the local processing tendencies found with static form perception also extend to motion perception. Most of these studies were conducted with random dot kinematograms in which varying percentages of dots travel coherently in a single direction as if attached to a flat, rigidly moving surface. The remaining dots move about randomly. Typically, the lifetime of each dot is limited, so that task performance requires the global integration of motion information across multiple dots. Several studies found elevated motion coherence thresholds for observers with ASD relative to chronological age matched and mental age matched control observers (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). Yet, other studies using the same type of stimuli and tasks found no deficits in visual sensitivity to coherent motion in observers on the autism spectrum (de Jonge et al., 2007; Del Viva, Igliozi, Tancredi, & Brizzolara, 2006; Milne et al., 2006; Price, Shiffrar, & Kerns, under review; Vandenbroucke, Scholte, van Engeland, Lamme, & Kemner, 2007). A careful comparison of these and other studies produced no obvious differences in stimuli or tasks that might account for diverging results (Kaiser & Shiffrar, 2009). In any case, the results of these motion coherence tasks do not support the hypothesis that observers with ASD automatically default to local motion analyses, at least during the visual perception of random dot kinematograms.

Alas, heterogeneity is an inherent aspect of this spectrum disorder. Studies have documented differences in motion processing tasks in individuals with ASD as a function

of language delay (Takarae, Luna, Minshew, & Sweeney, 2008), motor abilities (Price, 2006; Price et al., 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 motion processing may be explained by an underlying dysfunction in the STS, 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 movement and social information (Allison et al., 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). We will discuss the STS and social perception in greater detail below.

1.3.3 Social Perception

Researchers have sought to understand whether local processing tendencies define the classic deficit in face processing associated with ASD. For example, people with autism show selective deficits in their perception and recognition of face identity (e.g., Tanaka, Lincoln, & Hegg, 2003), in part as a result of a reliance on local form processing (Behrmann et al., 2006; Gauthier, Klaiman, & Schultz, 2009; Joseph & Tanaka, 2002). Individuals with ASD also tend to focus on the mouth instead of the whole face or the eyes. A retrospective study of first year birthday party home videos found that individuals later diagnosed with ASD demonstrated less eye contact than their typically developing counterparts (Osterling & Dawson, 1994). Under experimental conditions, young

observers with ASD, unlike matched controls, fail to make normal use of the information from the eyes and instead rely on the mouth region (e.g., Klin, Jones, Schultz, Volkmar, & Cohen, 2002; Spezio, Adolphs, Hurley, & Piven, 2007). When face perception is compared with object perception, children with ASD exhibit a category-specific face impairment that reflects both a failure to process faces holistically plus an inability to successfully utilize information from the eye region (Wolf et al., 2008). Since the face is an inherently social stimulus, the evidence from these and other studies suggests that ASD may be associated a specific perceptual deficit in the analysis of socially relevant information and a local processing bias is necessary but not sufficient to account for the marked deficits in visual sensitivity to faces (e.g., Klin & Jones, 2006).

With growing evidence for disrupted social perception in ASD, scientists have suggested that early developmental abnormalities in social brain areas might trigger a cascade of perceptual deficits that result in the impairment of social function (e.g., Schultz, 2005). The STS, a social brain area, is critical for the perception of social information, especially eye gaze and biological motion (e.g., Allison et al., 2000). Activity in 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; Zilbovicius et al., 2006). 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). It has been argued that STS anomalies during early brain development may “constitute the first step”

in the trajectory of neural dysfunction underlying ASD (Pelphrey & Carter, 2008; Zilbovicius et al., 2006).

1.4 Biological Motion Perception in ASD

The ways in which people move their bodies convey substantial social information that typical observers readily detect (for review see Blake & Shiffrar, 2007). Studies of the visual perception of bodily movement commonly use point-light stimuli created by attaching markers or point-lights to a person's body 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 observers can detect a point-light actor's actions (Dittrich, 1993; Poizner, Bellugi & Lutes-Driscoll, 1981), emotional states (Atkinson et al., 2004; Clarke et al., 2005; Chouchourelou et al., 2006; Dittrich et al., 1996; Pollick et al., 2001), gender (Kozlowski & Cutting, 1977; Pollick et al., 2005), identity (Jokisch et al., 2006; Loula, Prasad, Harber, & Shiffrar, 2005), intentions (Runeson, & Frykholm, 1983; Sebanz & Shiffrar, 2009), vulnerability (Gunns et al., 2002) and potential reproductive fitness (Brown et al., 2005).

Past studies of visual sensitivity to point-light displays of human movement by observers with ASD have drawn conflicting conclusions. In the first such study, Moore, Hobson, and Lee (1997) found that young observers with ASD and controls did not differ in the amount of time they needed to describe the actions performed by point-light people. These researchers concluded that young observers with ASD exhibit normal visual sensitivity to human movement per se. The groups differed, though, in their ability

to label the emotional content of point-light actions. Comparable tasks with observers with high functioning autism (HFA) and Asperger's Syndrome (AS) found similar results (Hubert et al., 2007; Parron et al., 2008). While these studies clearly converge in suggesting that observers with ASD can identify human motion in point light displays, the conclusion of equivalent levels of visual sensitivity across autistic and non-autistic observers is questionable. First, the verbal free report measure used in all three studies is influenced by expectancy, attention, and motivation in ways that are difficult to assess (Blake, Turner, Smoski, Pozdol, & Stone, 2003). Second, language impairments classically associated with ASD (American Psychiatric Association, 2006) further complicate the interpretation of verbal reports. Third, a recent study with forced-choice labeling of action and emotion found impairments in both of these tasks by an ASD group (Atkinson 2009), suggesting that the processing deficit is not specific to emotions but applies to human motion perception in general.

Indeed, as mentioned above, neurophysiological evidence suggests that the visual analysis of point-light displays of human motion depends upon different neural mechanisms in autistic and control observers. For example, Herrington and colleagues (Herrington 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. 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 (2AFC) direction discrimination task and reported on each trial whether the display depicted leftward or rightward facing walking motion. While both the AS and control group 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 between autistic and non-autistic individuals during the perception of point-light walkers.

Converging evidence for sensitivity differences comes from a now classic study by Blake and colleagues (2003) who asked children with ASD and controls to verbally report whether or not they saw a person in coherent and scrambled point-light displays of human motion. To insure that performance tapped more than the ability to integrate visual information over space, observers also performed a contour integration task by pointing to the location of a static circle created by an alignment of oriented line segments. Observers with ASD were impaired in their detection of coherent human motion but not coherent static form. These researchers concluded that the visual analysis of human movement, in particular, is impaired in ASD. Yet, it is unclear whether this deficit is specific to human motion perception or generalizes to all coherent motion perception. Furthermore, the use of verbal responses in the motion task, but not the contour task, is problematic.

A recent study with children and young adults with AS compared visual sensitivity to static form, coherent motion in random dot kinematograms, and point-light walkers and found selective impairments in observers with AS in the perception of human motion (Price et al., under review). Interestingly, Dean-Woodcock measures of motor system function correlated with visual sensitivity to coherent motion in random dot displays and point-light displays of human motion (Price, 2006; Price et al., under review). But these studies cannot be used to differentiate between sensitivity to human motion, in particular, and sensitivity to complex structure from motion in general.

A recent series of preferential looking studies indicates that while typical toddlers preferentially attend to canonical point-light displays of human movement, toddlers with ASD do not (Klin, Jones, Schultz, & Volkmar, 2003; Klin & Jones, 2008; Klin, Lin, Gorrindo, Ramsay, & Jones, 2009). Failure to attend to human motion could eventually decrease visual sensitivity to it. It is unclear, though, whether atypical gaze contributes to abnormal perception of human movement later in life or if dysfunction in the STS and related brain areas results in impaired human motion perception and atypical gaze.

1.5 Overview of Experiments

The conducted studies aim to investigate the visual perception of human movement in individuals with ASD and in typical individuals varying in the magnitude of their autistic tendencies. Because ASD is strongly associated with deficits in social behavior, it is important to understand how individuals with ASD perceive socially relevant information. Substantial evidence indicates that this population has perceptual impairments in the processing of faces and facial expressions, however it is unclear

whether there are similar deficits in the perception of gesture and body movement. Thus, the goal of this series of psychophysical studies is to understand visual sensitivity to human movement as a function of observers' autistic traits.

These studies utilize a detection task with point-light displays of various types of real world motion. The first two experiments compare the detection of human and object motion to assess whether individuals with ASD show deficits in their perception of human movement, *per se*. In Experiment 1, a group of typical adults and an ASD group performed a coherent motion detection task with masked and unmasked point-light displays of human and tractor motion that were coherent or spatially scrambled. Experiment 2 examined the relationship between autistic traits in typical adults and performance on the detection task from Experiment 1 using only masked displays. A group of typical children participated in Experiment 3, a modified version of Experiment 1 that included unmasked and masked displays of human and object movement. The goal of that study was twofold. First, the results provide a window into the typical developmental trajectory of perceptual sensitivity to human and object movement. Second, the performance of typical children provided an alternative control group with which to compare performance of the ASD group.

Experiment 4 compared visual sensitivity to human and non-human animal motion. Because the movements of tractors and people differ along several parameters, including the pendularity of motion trajectories and the degrees of freedom, studies of the visual perception of point-light dogs are needed to determine whether the results of Experiments 1, 2, and 3 are specific to the perception of complex pendular motion or the perception of human motion, *per se*. Experiment 5 examined the perception of point-light

displays of emotional human movement to test whether the magnitude of individual observer's autistic traits corresponds to their visual sensitivity to human movement with emotional content.

Chapter 2:

Comparing the Perception of Human and Object Motion

2.1 Experiment 1: Typical Adult Observers and Observers with ASD

2.1.1. Hypotheses and Design

In typical observers, the visual analysis of point-light displays of human and object movements differ (Bertenthal & Pinto, 1994; Blake & Shiffrar, 2007; Hiris, Krebeck, Edmonds, & Stout, 2005; Shiffrar & Pinto, 2002). Differences in visual sensitivity to human and object movement have also been reported in studies of apparent motion (Heptulla-Chatterjee, Freyd, & Shiffrar, 1996; Shiffrar & Freyd, 1990, Shiffrar & Freyd, 1993). This perceptual distinction is accompanied by findings of distinct neural areas that support the perception of possible human movement and object movement in typical observers (e.g., Bonda et al., 1996; Stevens, Fonlupt, Shiffrar, & Decety, 2000; Virji-Babul, Cheung, Weeks, Kerns, & Shiffrar, 2007). Considering the social importance of other people's actions, differentiated analyses of human and object motions may not be so surprising (Puce & Perrett, 2003; Shiffrar et al., 2009).

To determine whether individuals with ASD are impaired in the visual analysis of human movement, per se, we asked participants to perform two motion coherence tasks: one with point-light displays of human motion and another with point-light displays of object motion. By comparing visual sensitivity to coherent motion across these two tasks, we could determine whether visual sensitivity to human motion is compromised in ASD because (1) the visual perception of all complex, coherent motion is compromised or because (2) ASD is associated with a specific deficit in the perception of human

movement. To the extent that the visual analysis of human motion, per se, is compromised in observers with ASD, they should differ from typical observers in their visual sensitivity to human motion.

The majority of previous studies of the visual analysis of human movement by observers with ASD have used unmasked displays. While this condition is useful, unmasked stimuli can be processed locally. That is, participants can detect the presence of a person by focusing on a single element such as a foot dot. Indeed, the local motion signals from a few dots carry significant information about a person's movements (Pollick et al., 2001; Thurman & Grossman, 2008). Therefore, the current study employed a masking procedure to limit reliance on local cues during a detection task. Typical observers can easily detect coherent human motion in masked displays (Bertenthal & Pinto, 1994). Point-light masks are usually created by duplicating the original points of the target stimulus (person or object) and then spatially scrambling the starting location of each point. The individual elements of the resultant mask, then, have the same velocities, size and luminance as the points that make up the walker or object. Therefore, target detection requires the integration, or global processing, of several moving points.

Most studies of ASD include children because it is a developmental disorder. However, Experiment 1 involves adult and young adult participants because the perception of biological motion by typical observers is most frequently studied in these populations (Blake & Shiffrar 2007; but see Blake et al. 2003; Freire, Lewis, Maurer, & Blake, 2006; Pavlova, Krageloh-Mann, Sokolov, & Birnbaumer, 2001). Since autism is not incompatible with normal or above normal intelligence (Schultz, 2005), many studies

of this population focus on the higher functioning end of the spectrum. Asperger Syndrome is considered a type of high functioning autism. Its diagnosis entails deficits in social interaction and stereotyped or rigid behaviors in the absence of language impairments (Wing, 2000). Experiment 1 included several participants with AS. The relatively subtle language deficits associated with AS ensured that these participants would understand task instructions. The age-range of the AS participants was largely a convenient sample with the goal of matching to the typical adult group on mean chronological age. Additional studies are needed to match the ASD and control groups on more stringent measures such as intelligence subtest in addition to chronological age. Finally, while all participants in the ASD group had been previously diagnosed with AS or HFA, we were unable to administer the Autism Diagnostic Observation Schedule (ADOS) to confirm participants' diagnoses.

2.1.2 Methods

Participants

An autism group was recruited from a program for people with autism (mean age = 19.7 years, SD = 10.4) and contained six male observers with a clinical diagnosis of AS or ASD. These individuals received a monetary gift for their participation. A typical group contained thirty-two Rutgers undergraduates (26 female) who received credit toward a course requirement (mean age = 21.3 years, SD = 3.5). An independent samples t-test indicated these two groups did not significantly differ in their mean ages, $t(5) = .326$, $p = .757$. All participants were naive to the hypothesis under investigation, had

normal or corrected to normal visual acuity, and provided written informed consent. The Rutgers University Institutional Review Board approved this study.

Apparatus

The typical participants completed the experiment in the visual cognition laboratory at Rutgers University. Stimuli appeared on a 14-inch Dell TM monitor (60Hz, 1024 x 768 pixel resolution) positioned 52cm from the observer and controlled by a Dell TM Pentium computer. The ASD group completed the experiment in their school or home. For these participants, the stimuli appeared on a 15.4-inch iBuy Power Notebook laptop (60Hz, 1280 x 800 pixel) controlled by an AMD Turion 64x2 Mobile Technology TL-52 processor. For both groups of participants, the experiment was programmed in E prime (Psychology Software Tools, Inc). Movies were processed with Motion Builder 5.0 (Kaydara™). A ReActor motion capture system (Ascension Technology) measured human and tractor motions within a 3.6 by 4.8 meter area. This equipment was used in all of the subsequent experiments reported here.

Stimuli

Spatiotemporal measurements were made of sensors attached to a moving person or tractor inside the ReActor system (Figure 1). Nine sensors were attached to the actor (head, wrists (2), elbow, shoulder, feet (2), knee, waist). The actor repeatedly performed three actions: (1) walking a linear 3 m path (2) bending down to pick something up and (3) walking 1.5m and then bending down to pick something up. Then, 9 sensors were attached to the wheels (4), pivot joint (1) and front bucket (4) of a “John Deere Loader” (Peg Perego) toy tractor (124.5 x 63.5 cm). The tractor performed actions similar to the

actor: (1) rolling along a 3 m linear path (2) rotating the bucket downward to pick something up and (3) rolling 1.5m and then rotating the bucket to pick something up.

Motion capture data were converted into 8 point-light human movies and 8 point-light tractor movies (five second duration each). Motion direction (leftward or rightward) was counterbalanced within each block of trials. The point-light walker (maximum extents: 6.6 x 3.3 degrees of visual angle (DVA) and tractor (max: 4.4 x 7.7 DVA) had lateral displacement distances ranging from 8.8 to 16.1 DVA and speeds ranging from 1.76 to 3.22 DVA/sec. The points defining each stimulus were white, 0.33 DVA in diameter, and appeared against a homogeneous black background. One scrambled point-light movie was constructed from each coherent human and tractor movie by scrambling the starting locations of the points (Figure 1-E).

Across conditions, each stimulus appeared unmasked and masked. The unmasked stimuli had 9 points as described above (Figure 1-C & D). The masked stimuli contained an additional 9 masking points using the same procedure for mask formation as previous studies of point-light displays (Chouhourelou et al., 2006). Each stimulus had a unique mask that was created by duplicating the stimulus and then positionally scrambling the starting locations of those duplicate points. Each mask point was placed within a one- to five-point radius from the original walker point being masked. Each stimulus was then hidden within the scrambled mask that had been constructed from it (Figure 1-F). The close proximity of walker and mask points rendered walker detection difficult. The points defining each mask and stimulus had identical velocities, sizes, and luminance and only the configuration, or global organization, of the points defining the target distinguished it

from the points defining the mask. Thus, under these conditions, coherent motion detection involves global analyses (Bertenthal & Pinto, 1994).

Design and Procedure

In a blocked, within subjects design, each participant saw coherent and scrambled point-light person motion and tractor motion in masked and unmasked conditions. Trials were blocked by stimulus type (human or tractor) and condition (masked or unmasked). All participants completed the unmasked condition first. Each block contained 32 movies (8 coherent and 8 scrambled movies each shown twice). Block order was counterbalanced across participants within each condition. In each masking condition, participants completed two blocks of human trials and two blocks of tractor trials.

Responses were made by pressing a button labeled “yes” or another labeled “no”. In the human motion blocks, participants reported whether all (unmasked condition) or some (masked condition) of the dots were “stuck” to a person. In the tractor blocks, participants reported whether all (unmasked condition) or some (masked condition) of the dots were “stuck” to a tractor. Correct responses were “yes” to coherent motion and “no” to scrambled motion. No feedback was provided. Reaction time data were not analyzed because motor difficulties are associated with ASD (e.g., Manjiviona & Prior, 1995).

All participants completed the task in a quiet, dimly lit room. Each ASD participant completed the task with an experimenter seated next to him. If a participant with ASD could not complete the responses by himself, the experimenter helped the participant to record each response and then initiated the next trial once the participant was ready. Encouragement was provided periodically during the task although it was not contingent on the accuracy of responses.

2.1.3 Results

Visual sensitivity to the human and tractor motion was assessed with d-prime measures calculated by subtracting the normalized rate of false alarms from the normalized rate of hits for each participant with each stimulus type in each condition (Macmillan & Creelman, 1991). This measure was also used in all of the studies reported here. Detection performance by both groups was above chance in all unmasked (all p 's < .001) and masked (all p 's < .002) conditions (Figure 2).

Due to limited matching of participant groups, direct statistical comparison across groups is inappropriate. Within group, paired samples t-tests showed that the ASD group demonstrated equivalent visual sensitivity to human and tractor movement in the unmasked, $t(5) = 1.123$, $p = .312$, and masked, $t(5) = .135$, $p = .898$, conditions. However, the typical group demonstrated significantly greater sensitivity to coherent human motion than to coherent tractor motion in the unmasked, $t(31) = 3.547$, $p < .001$ and masked, $t(31) = 4.725$, $p < .001$, conditions.

Repeated measures ANOVAs were conducted for both subject groups separately, with Masking and Stimulus as within subject factors. For the ASD group, there was no significant main effect of Masking, $F(1,5) = 2.123$, $p = .205$, or Stimulus, $F(1,5) = 1.339$, $p = .2995$, nor a significant interaction, $F(1,5) = .536$, $p = .497$. For the typical group, there was a significant effect of Masking, $F(1,31) = 58.989$, $p < .0001$, and Stimulus, $F(1,31) = 26.561$, $p < .0001$, but no significant interaction, $F(1,31) = .343$, $p = .563$.

2.1.4 Discussion

This study examined whether observers with ASD experience specific deficits to their visual sensitivity to coherent human movement. There are three main findings. First, typical adult observers exhibit greater sensitivity to human motion than to tractor motion, consistent with the hypothesis that the visual system is usually tuned for the detection and analysis of socially relevant information (e.g., Brothers, 1997; Shiffrar et al., 2009). Secondly, the results of this study suggest that observers with autism are not particularly sensitive to the presence of coherent human motion as they demonstrate equivalent sensitivity to human and object movement. The tractor control permits further conclusions regarding the nature of the processing deficits found in earlier work (e.g., Blake et al., 2003; Moore et al., 1997). Since past studies did not compare human movement to another complex motion movement, performance may have reflected general motion processing deficits. Because the object and human displays in the current experiment differed only in the type of motion they contained, performance differences here likely reflected distinct processing differences between human motion and other types of complex, but non-human motion.

In contrast to predictions of impaired global processing abilities, the results of this study indicate that observers with ASD are able to process point-light displays even when reliance on local cues is limited by the addition of masking elements. The above-chance performance by the ASD group in the masked condition argues against a strong interpretation of the WCC (e.g., Frith, 1989). Indeed, there was no main effect of masking on performance by the ASD group. If global processes were markedly impaired

in the ASD group then performance in the masked condition would be exceptionally poor.

These results are consistent with previous findings of impaired biological motion perception in ASD (Atkinson, 2009; Blake et al., 2003; Price et al., under review) but contrast with those of others (Hubert et al., 2007; Moore et al., 1997; Parron et al., 2008) who have found intact action perception in this population. Our methods differed from these experiments in a number of important ways. First, participants in this study detected the presence or absence of coherent motion with a button-press response. This 2AFC task provides a more stringent measure of perceptual processing without a significant reliance on language production abilities. Secondly, the contradictory studies did not utilize scrambled displays of human movement. Instead, while ASD groups in past studies may have performed as well as control groups, it is unclear whether they were utilizing the same perceptual processes to do so. In the current study, the use of masked displays indicates that observers with and without ASD or AS can use global motion processes to detect human motion.

While positionally scrambling the starting location of the dots is a useful means of disrupting global processing, another method would be to invert them. Stimulus inversion is thought to disrupt global or configural processing as observers demonstrate significantly greater visual sensitivity to upright than to inverted displays of point-light walkers (Sumi, 1984; Bertenthal & Pinto, 1994). However, we have chosen to use the scrambling technique as there is some controversy regarding the exact effects of inversion on stimulus processing in face stimuli (Sekular, Gaspar, Gold, & Bennett, 2004) and biological motion displays (Troje & Westoff, 2006). Furthermore,

neurophysiological data indicate that scrambling might disrupt the typical processing underlying the perception of canonical coherent walkers more so than simple inversion. As noted above, the STSp reacts strongly to point-light depictions of coherent human movement but less so to scrambled (Bonda et al., 1996; Grossman et al., 2000) or inverted versions of these displays (Grossman & Blake, 2001). Importantly, though, a study by Grossman and Blake (2001) compared neural activity during the perception of canonical, scrambled, and inverted displays and found that STS activity was greatest for upright compared to scrambled or inverted. But activity in the brain region was also greater for inverted walkers compared to scrambled walkers, perhaps suggesting that the latter is a greater disruption of typical processing mechanisms.

In conclusion, Experiment 1 showed that observers with ASD differ from chronological age matched controls in their visual sensitivity to human movement. Whereas typical adult observers demonstrated heightened detection performance for human movement as compared to object movement, the ASD group did not. Instead, observers with ASD were equally as sensitive to human and object movement in unmasked and masked displays. Are these results associated with the autistic traits of the ASD group or might they reflect differences in ability to complete the task? This is unlikely, because performance on the tractor condition was comparable across experimental groups. Still, due to the limitation of our matching criteria, it is unclear whether the decrease in sensitivity to human movement is associated with observers' autistic traits. Are observers' social abilities related to their perceptual sensitivity to human movement? This question is addressed in Experiment 2.

2.2 Experiment 2: Autistic Traits in Typical Adults

2.2.1 Hypotheses and Design

The results of Experiment 1 indicate that individuals with autism do not demonstrate enhanced visual sensitivity to human movement. However, given the complexity of this disorder and difficulty matching control groups, it is unclear whether or not autistic traits, per se, are responsible for the above results. Matching experimental groups is especially difficult with individuals with ASD for two main reasons. First, this disorder is often accompanied by comorbid diagnoses including obsessive-compulsive disorder, depression, specific phobia, and ADHD (Leyfer et al., 2006). Also, up to half of the individuals diagnosed with autism are functionally nonverbal (Leyfer et al., 2006) and essentially all individuals with a diagnosis of autism present some degree of communication impairment (Lord & Paul, 1997), which renders comorbid psychiatric disorders difficult to diagnose. It is interesting to note that some of these comorbid disorders have been associated with abnormal social perception, such as impaired perception of human motion in obsessive-compulsive disorder (Kim et al., 2008). This finding strengthens the case that comorbidity introduces a variety of potentially unseen factors influencing the performance of individuals with ASD on different experimental tasks. Chronological age matching is typically used in studies of ASD, although ideally, it is accompanied by an intelligence measure.

Second, while researchers usually match experimental groups on scales of intelligence, recent evidence suggests that these measures assess individuals with ASD somewhat differently than their typically developing counterparts. Although the Raven matrices and Wechsler scale are both designed to measure intelligence accurately and are

thought to function interchangeably, there is a difference of thirty percentiles in the assessment of individuals with ASD but no language impairment (Dawson, Soulieres, Gernsbacher, & Mottron, 2007). This calls for more stringent and exhaustive matching in future studies to fairly compare experimental groups. Of course, this does not answer the question of which criteria are the most important to match. As suggested by Kaiser and Shiffrar (2009), supplementing intelligence measures with assessment of motor abilities may provide more suitable matching criteria especially for studies of motion perception in ASD. Finally, due to the difficulties of matching experimental groups, adequate control tasks are essential. For example, an object control for the human motion condition allows us to isolate the processes specific to each kind of motion processing.

The goal of the current study was to investigate the connection between impaired social function and perception of socially relevant (human) and irrelevant (tractor) motion. The ASD and control groups demonstrated markedly different patterns of performances in Experiment 1. However, it is unclear if this difference is the result of their autism or another factor such as task difficulty or attentional issues. If the results of Experiment 1 reflect an association between social difficulties associated with autism, then we should see a similar pattern of performance in typical adults who display many autistic traits.

The concept of a broader autism phenotype is supported by findings of autistic tendencies in parents and siblings of individuals diagnosed with ASD (for review see Bailey, Palferman, Heavey, & Le Couteur, 1998). In an extension of this concept, researchers have argued for a continuum of the autism spectrum into the general population. Indeed, autistic traits are normally distributed in the general population

(Constantino & Todd, 2003; Ronald, Happé, Price, Baron-Cohen, & Plomin, 2006), and their presence varies continuously across clinical and non-clinical populations (Baron-Cohen, Wheelwright, Skinner, Martin, & Clubley, 2001). Several questionnaires have been developed that support the continuum hypothesis of autism including third-party report measures, like the Social Responsiveness Scale (SRS; Constantino & Todd, 2003), and self-report questionnaires, such as the Autism-Spectrum Quotient, or AQ. The AQ is a measure of autistic tendencies in adults of normal intelligence. The AQ can be used to assess preferences and behaviors consistent with autistic traits (Appendix 1; Baron-Cohen et al., 2001). Broadly speaking, items on this questionnaire address one's preferences for social events (e.g., "I would rather go to a library than a party") and attention to detail (e.g., "I tend to notice details that others do not"). There are five subscales to the full AQ score including attention switching, attention to detail, communication, imagination, and social skill. This measure has been shown to be reliable and valid as it discriminates individuals with ASD from unaffected individuals (Baron-Cohen et al., 2001; Woodbury-Smith, Robinson, Wheelwright, & Baron-Cohen, 2005).

Experiment 2 compared visual sensitivity the human and object motion by typical observers to investigate the relationships between each typical participant's perceptual sensitivities and the magnitude of that participant's autistic traits as measured by the AQ.

2.2.2 Methods

Participants

Fifty-five Rutgers University – Newark undergraduates took part in this study for credit towards a course requirement. Thirty-six participants were female and the mean

age was 20.3 years ($SD = 2.8$, Range = 18 – 29). All provided informed written consent before the start of this experiment. All participants were naive to the hypothesis under investigation, had normal or corrected to normal visual acuity, and provided written informed consent. The Rutgers University Institutional Review Board approved this study.

Apparatus

Participants completed the task on the desktop computer from Experiment 1, in the visual cognition laboratory at Rutgers University – Newark.

Stimuli

The stimuli were the masked displays from Experiment 1.

Procedure

Participants individually completed the Autism-Spectrum Quotient (Baron-Cohen et al., 2001) in a quiet testing room and then the detection task with the masked displays from Experiment 1. As before, in a blocked, within subjects design, each participant saw coherent and scrambled point-light person and tractor motion. Participants completed two blocks of human trials and two blocks of tractor trials, with order counterbalanced across subjects. In the human motion blocks, participants reported with a button press whether some of the dots were “stuck” to a person. In the tractor blocks, participants reported whether some of the dots were “stuck” to a tractor. No feedback was provided.

2.2.3 Results

AQ scores ranged from 8 – 26 with a mean of 16.7 ($SD = 4.8$). This distribution is consistent with that of the control group in the original AQ study by Baron-Cohen and

colleagues (2001). For each participant, d-primes were calculated for the accurate detection of coherent human motion and the accurate detection of coherent tractor motion. Mean detection accuracy was significantly above chance in both the human movement condition, $t(54) = 10.00, p < .0001$, and the tractor movement condition, $t(54) = 11.94, p < .0001$. As in Experiment 1, a paired samples t-test revealed that these typical participants demonstrated greater visual sensitivity to the presence of coherence human motion than to the presence of coherent tractor motion, $t(54) = -5.01, p < .0001$ (Figure 3-A).

In a secondary analysis, we used Pearson Product Moment Correlation to test for correlations between AQ score and d-primes for human motion or tractor motion (Figure 3-B). There was a significant correlation between AQ and detection accuracy for human movement, $r(55) = -.332, p < .05$. This negative correlation indicated that visual sensitivity to human motion increased as AQ score decreased (fewer autistic traits). Conversely, there was no significant relationship between AQ scores and the ability to detect coherent tractor movement, $r(55) = -.135, p = .326$. Comparison of the correlation of AQ and sensitivity human movement with the correlation of AQ and sensitivity to tractor movement indicated that these two correlations moderately differed from each other (Chi Square = 6.085, $p = .014$).

Further analysis of correlations between detection accuracy and AQ subscales yielded one significant correlation. Detection accuracy for human movement was negatively correlated with Attention Switching, $r(55) = -.30, p < .05$. The other AQ subscales did not yield any significant correlation to visual sensitivity to human or tractor motion (Table 1).

We examined the internal reliability of the subscales and found that all of the Cronbach's α 's were below .6 (Social, Cronbach's α = .48; Attention Switching, Cronbach's α = .42; Attention to Detail, Cronbach's α = .53; Communication, Cronbach's α = .58; Imagination; Cronbach's α = .39). This lack of internal reliability is likely due to a lack of power in our sample size. Therefore, we did not include further subscales analyses in the experiments reported below and the omnibus, full AQ measure is used.

2.2.4 Discussion

The presence of autistic traits varies normally within the typically developing population (e.g., Hurst, Mitchell, Kimbrel, Kwapil & Nelson-Gray, 2007). The goal of this experiment was to investigate the relationship, if any, between the magnitude of an individual's autistic traits, as measured by the AQ, and the magnitude of that individual's enhanced visual sensitivity to human movement relative to object movement. The results of this experiment replicate Experiment 1 as typical adults demonstrated greater visual sensitivity to coherent human movement than to coherent object movement within masked point-light displays. Importantly, participants' performance in the human motion condition correlated with their AQ score while their performance in the object motion condition did not. Specifically, visual sensitivity to human motion dropped with increases in AQ score. Visual sensitivity to object motion was flat across increases in AQ score. Because AQ score is a reliable measure of social ability in the typical population (Hurst et al., 2007), this combination of correlations suggests that visual sensitivity to human movement, rather than visual sensitivity to coherent movement in general, is related to

social behavior as measured by full AQ scores.

Analysis of the AQ subscales did not reveal a significant correlation between the social skill questions although there was a significant correlation between the attention to detail subscale and detection of human movement (Table 1). This correlation is difficult to interpret. Given the small sample size, we did not expect to find strong effects of subscales as each subscale only contains ten questions on the AQ questionnaire.

The current results contrast with previous findings of a correlation between the magnitude of autistic traits and the perception of static form (Grinter, Van Beek, Maybery, & Badcock, 2008). Grinter and colleagues (2008) reported that autistic traits were associated with enhanced local processing. In that study, a sample of non-clinical adult participants completed the AQ, the Embedded Figures task, and the Block Design task. As predicted by a local processing bias in ASD as discussed above, those scoring high on the AQ (who displayed more autistic traits) were faster and more accurate on both of these tasks. Successful performance on the Embedded Figures task and the Block Design task favors local processing. The researchers interpreted these results as supporting the WCC. In the current study, both task performance with the human motion stimuli and tractor motion stimuli depended upon global processing as the masking elements severely limited the usefulness of motion information from individual point-lights. AQ scores correlated with the detection of coherent human movement but not tractor motion. Therefore, the current results argue for a reinterpretation of the results of Grinter and colleagues. Rather, the current finding that AQ correlates with accurate perception of human movement but not tractor movement suggests that there might be a direct relationship between autistic traits and the perception of human movement, either

as opposed to, or in addition to, global perceptual deficits.

Using the AQ to measure the magnitude of autistic traits in typical adults provides a means of circumventing many of the difficulties associated with matching clinical and non-clinical experimental groups. In the current comparison between visual sensitivity to human and object movement, only the perception of human movement correlated with the magnitude of observers' autistic traits. Given the social importance of other peoples' movements, these results suggest that autistic traits, and their phenotypic expression in the general population, are related to the ways in which observers perceive dynamic social information. Future developmental studies are needed to determine the causal mechanism of this relationship. Neural atypicalities in the STSp may result in the deficits in social perception that characterize ASD or disrupted social perception may impact neural development in an interactive manner, derailing the processing of social stimuli, such as moving people (Pelphrey & Shultz, in press). In particular, studies on infants in the first years of life will be critical to clarify the causes of disrupted social perception that is associated with the autism spectrum (Pelphrey & Shultz, in press).

2.3 Experiment 3: Typically Developing Children

2.3.1 Hypotheses and Design

A small, but growing, collection of developmental studies has demonstrated that visual sensitivity to human motion arises early in life. In a preferential looking paradigm, 2-day-old (Simion, Regolin, & Bulf, 2008) and 3- to 6-month-old (Bertenthal, 1993; Fox & McDaniel, 1982) infants look longer at upright versus scrambled or inverted biological motion. In addition, 8-month-old infants exhibit differences in amplitude of event-related

potentials (ERPs) during the perception of upright versus scrambled (Hirai & Hiraki, 2005) or inverted (Reid, Hoehl, & Striano, 2006) point-light displays of human movement. Although these results do not necessarily indicate that infants understand what point-light walkers actually depict, they do suggest that even in the first year of life, infants, like adults, detect and show neural responses to the manipulations that affect the form of biological motion portrayed by point-light sequences (see also Bertenthal 1993; Pavlova & Sokolov, 2000).

Despite findings of impressive sensitivity to biological motion in early infancy, there is evidence that processing continues to develop within the first year of life and beyond. For instance, in a series of studies comparing preferential looking time to human and animal point-light displays, Pinto (1997, 2006) found an attunement to the perception of human movement between 5 and 7 months of age. In the upright orientation, 3-, 5-, and 7-month-old infants discriminated canonical and phase-perturbed human point-light displays. Yet, only the 3-month-old infants showed sensitivity to phase perturbations in inverted human movement.

A few studies have examined the perception of human movement by older children using recognition and detection measures and unmasked point-light stimuli. Pavlova and colleagues have shown that children as young as 3 years of age can recognize (as measured by verbal report) point-light displays of human movement with substantial improvement up to 5 years of age where ceiling performance, comparable to that of adults, was observed (Pavlova et al., 2001). This is consistent with Blake and colleagues' (2003) finding, in a similar age group, of no relationship between age and discrimination performance with point-light displays of intact (biological) and scrambled

(non-biological) motions. In both of these studies it is likely that ceiling performance masked any performance differences.

There are two compelling reasons that the visual analysis of human movement might not reach adult levels in early childhood. First, the detection of coherent motion in random dot kinematograms does not reach adult levels until observers reach 7 to 10 years of age (Parrish, Giaschi, Boden, & Dougherty, 2005; Spencer et al., 2000; for review see Kaiser & Shiffrar, 2009). The ability to detect rigid translation may occur before the ability to detect non-rigid human and object motion. Second, an fMRI study revealed developmental changes in the neural areas associated with the perception of human movement (Carter & Pelphrey, 2006). When typically developing children between 7 and 10 years of age viewed biological and non-biological motion displays, area STS was more responsive to biological motion and the specificity of this response increased with age. Because this study used confounded human and robot motion and did not involve point-light displays, the results may not be specific to the perception of human motion, *per se*. Nonetheless, this study supports the hypothesis that visual sensitivity to human movement continues to evolve as observer age increases beyond 5 years. Indeed, a recent study by Hirai and colleagues showed that the neural response to point-light displays of human movement (as measured by ERPs) develops until about 11 years of age (Hirai, Watanabe, Honda, & Kakigi, 2009).

More recent studies of visual sensitivity to point light displays of human motion suggest that when point-light displays of human movement are masked, the detection of human motion improves linearly as observer age changes from 6 years, to 9 years, and again to adulthood (Freire et al., 2006). Comparable findings have been obtained with

masked stimuli in 4-7 year old (Jordan, Reiss, Hoffman, & Landau, 2002) and 14 year-old children (Pavlova, Krageloh-Mann, Sokolov, & Birnbaumer, 2000). It is tempting to speculate that increased resilience to masking elements (Freire et al., 2006) indicates a tuning of the typical visual system for the detection of human movement. However, due to the lack of a control task in the study by Freire and colleagues (2006), these results may simply reflect a general increase in sensitivity to any meaningful, coherent motion. The use of an object control stimulus is needed to determine whether visual sensitivity to human motion, *per se*, or coherent motion, in general, increases during childhood.

Experiment 3 compared visual sensitivity to coherent human and object motion in point-light displays by typically developing (TD) young observers aged 7 to 12 years old. This is a similar age range to that used in previous studies with unmasked (Blake et al., 2003) and masked (Freire et al., 2006) displays of point-light walkers. Although we cannot directly compare the performance of these participants with the ASD group from Experiment 1, or with the typical observers from Experiments 1 or 2, the performance of the TD children is a useful data set to guide the interpretation of the previous studies. Since mental age and chronological age are identical in typically developing children of normal intelligence (Thurstone, 1926), this age range is comparable to the mental age range for past studies of biological motion perception in ASD (e.g., Blake et al., 2003; Price et al., under review). These data will help us to understand whether the results of participants with ASD in Experiment 1 can be explained simply by the use of participants with younger mental ages. As in Experiments 1 and 2, the use of these two types of stimuli (human and object motions) allows us to draw stronger conclusions regarding the

type of processing that children are performing. The object motion condition allows us to compare visual sensitivity to human and object motions.

Will children in this experiment demonstrate the same pattern of results as typical adults in Experiments 1 and 2, namely, a heightened sensitivity to human versus object motion? According to past studies with TD participants in this age range, we should predict no improvement with age in detection sensitivity in the unmasked condition (Blake et al., 2003; Freire et al., 2006; Pavlova et al., 2000) but a significant improvement with age in the masked condition (Freire et al., 2006). We test this hypothesis here. Finally, no study to date has actually compared the detection of coherent human and object motion in unmasked and masked displays along a developmental trajectory so this study aims to fill that gap in the literature as well.

2.3.2 Methods

Participants

Eighty-three typically developing children (TD), including forty males, took part in this study as an activity at a summer camp located at the University of Victoria in British Columbia, Canada. The mean age was 8.8 years ($SD = 1.4$, Range = 7 – 12). All participants were naïve to the hypothesis under investigation and had normal or corrected to normal visual acuity. Parents of all participants provided written consent before the start of this experiment and the children provided informed verbal assent. All participants were naïve to the hypothesis under investigation and had normal or corrected to normal visual acuity. The Rutgers University Institutional Review Board approved this study.

Apparatus

Stimuli appeared on 17-inch monitors including two Sony CPD-E240 monitors and one LG F700P monitor (all three with 85Hz, 1024x768 pixel resolution) controlled by Pentium 4 computers.

Stimuli

The stimuli consisted of the unmasked and masked point-light displays of human and object motion from Experiment 1. Each participant completed one block from each condition of Experiment 1. Each block contained 32 movies (8 coherent and 8 scrambled movies each shown twice). Block order was counterbalanced across participants within each condition.

Procedure

As in the previous studies, participants completed the unmasked trials and then the masked trials and responses were entered by key press. Each child completed the task with an experimenter seated next to him or her. In the rare case that the child could not complete a response by him or her-self, the experimenter entered it according to the child's verbal indication. Encouragement was provided periodically during the task although it was not contingent on the accuracy of responses.

2.3.3 Results

A repeated measures ANOVA was conducted, with Masking and Stimulus as within subject factors. There was a significant main effect of Masking, $F(1,82) = 355.611$, $p < .001$, and Stimulus, $F(1,82) = 40.628$, $p < .001$. Participants were better at detecting the person than the tractor in the unmasked, $t(82) = 5.14$, $p < .0001$, and

masked, $t(82) = 4.90$, $p < .0001$, conditions. There was no interaction of Stimulus and Masking, $F(1,82) = .738$, $p = .393$, indicating that masking equally influenced detection accuracy in the human and tractor conditions (Figure 4).

A Pearson Correlation analysis found significant correlations between participant age and detection accuracy in all conditions (Table 2) including the unmasked human movement condition, $r(83) = .25$, $p < .05$, unmasked tractor, $r(83) = .377$, $p < .01$, masked human, $r(83) = .323$, $p < .01$ and masked tractor conditions, $r(83) = .345$, $p < .01$ (Figure 5). The difference between detection accuracy of person and tractor motions did not correlate with age in the unmasked, $r(83) = -.153$, $p = .17$, or masked, $r(83) = .071$, $p = .53$, conditions. In line with the difference analysis, a comparison of the correlation of age and sensitivity to human movement with the correlation of age and sensitivity to tractor movement in the unmasked condition indicated that there was no difference in these correlations (Chi Square = 0.837, $p = .36$). There was no difference in these correlations in the masked condition (Chi Square = 0.020, $p = .89$).

2.3.4 Discussion

The results of Experiment 3 reveal that typically developing children are more sensitive to the presence of coherent human motion than object motion. Participants detected coherent human motion better than coherent tractor motion in the unmasked and masked conditions. The current results support the hypothesis that enhanced visual sensitivity to human movement develops early in life (Bertenthal, 1993; Simion et al., 2008), as the difference between sensitivity to human and object motion did not increase with age. Thus, these results are not consistent with neural evidence for maturation of the

neural networks involved in the processing of biological motion during childhood (Carter & Pelphrey, 2006). The difference in behavioral and neurophysiological measures may simply reflect a more precise sensitivity of the latter measure. Because performance on the detection task improved with age for both the human and tractor conditions, the current results are consistent with the hypothesis that the visual analysis of coherent motion, in general, continues to mature during childhood (e.g., Freire et al., 2006; Spencer et al., 2000). It is also possible that children are simply improving at the performance of this task independent of what the task actually measures.

Notably, the result that detection sensitivity to unmasked human movement improved with age contradicts previous findings of adult levels of performance in similar tasks in young children (Blake et al., 2003; Freire et al., 2006; Pavlova et al., 2001). What might explain this conflicting finding? In the current experiment, performance was very good in the unmasked condition (Mean d' = 2.34) but not at ceiling. It is likely, therefore, that ceiling performance in the studies by Freire et al. (2006) and Blake et al. (2003) hid developmental trends that were detectable in the present study.

In conclusion, Experiment 3 showed that children between the ages of 7 and 12 years of age are more sensitive to coherent human motion than to coherent object motion. This was true even when masking significantly reduced the utility of local motion processes. Due to differences in the number of trials performed in both the masked and unmasked conditions and a lack of matching criteria, we cannot directly compare the TD children's performance to the ASD group in Experiment 1. Nonetheless, the current results suggest that equivalent sensitivity to human and object motion by observers with

ASD in Experiment 1 does not simply reflect some perceptual standard or non-differentiated motion processing by observers with mental ages between 7 to 12 years.

Chapter 3: Biological Motion or Human Motion?

The studies conducted thus far have compared the visual analysis of human and object motions and suggested that children and adults are more sensitive to coherent human movement than to coherent tractor movement. However, the movements of tractors and people differ in many ways including the pendularity of motion trajectories and the degrees of freedom. As a result, it remains unclear whether the results of the previous studies reflect visual sensitivity to complex pendular motion, in general, or sensitivity to human motion, in specific. That problem is addressed here by a comparison of visual sensitivity to point-light displays of dog, human, and tractor motions.

3.1 Experiment 4: Typical Adults and Observers with ASD

3.1.1 Hypotheses and Design

Typical observers can accurately detect (Pinto, 1994; Pinto, 1997; Pinto & Shiffrar, 2009), categorize (Mitkin & Pavlova, 1990), and identify (Mather & West, 1993; Pavlova et al., 2001) point-light defined animals in motion. Infants as young as 6-months of age can distinguish point-light quadrupeds from vehicles (Arterberry & Bornstein, 2002). These studies demonstrate clear sensitivities to animal motion and call for further examination of what differentiates human from non-human biological motion.

Typically developing infants and children are remarkably sensitive to the ways in which living beings and objects move. Infants differentiate inanimate objects and animate people as well as appropriate and inappropriate actions (for review see Johnson, 2000; Spelke, Phillips, & Woodward, 1995). Indeed, by 6-months of age, infants distinguish

between natural and unnatural interactions between two people or a person and an inanimate object (Molina, Van de Walle, Condry, & Spelke, 2004). Of course, the accurate perception of people and objects is a necessary first step in distinguishing such complex interactions.

There is debate as to whether the animate-inanimate distinction includes a differentiation between humans and animals. For example, the results from two preferential looking tasks with infant observers aged 5 to 7 months suggest an increasing ability to differentiate static images of people and animals as observers age (Pauen, 2000). Others have argued that the animate-inanimate distinction does not include a significant differentiation between humans and non-human animals for adults. Recent support for this hypothesis comes from a change detection task in which adult observers detected changes to animals and people more quickly and accurately than changes to inanimate objects including cars and coffee mugs (New, Cosmides, & Tooby, 2007). This result suggests that humans possess a broad animate-inanimate classification system in which animals and humans are grouped together (New et al., 2007; see also Quinn & Eimas, 1998).

Observers with ASD have demonstrated a similar classification system. A recent study with child and young adult observers with ASD revealed the typical pattern of prioritized social attention in a change detection task. Like control observers, change detection was best for animate (human and animal) versus inanimate (object) components in a static image of a naturalistic scene (New et al., 2009). This somewhat surprising finding indicates that observers with ASD can exhibit “intact categorical prioritization of social agents,” but visual processing impairments may follow such typical social

attention. Also, it is important to note that performance was near ceiling for both control groups and the ASD group in this study. The ease of the task may have resulted in the lack of a differentiation between change detection in the human and animal conditions. Thus, as noted by the authors of this study, the typical performance in this “case-study experiment” (New et al., 2009) should be considered a preliminary result that may be task and participant specific rather than unequivocal proof of intact social orienting in ASD. Indeed, impairments in recognizing human and animal (monkey) faces have been documented in 2-year olds with ASD (Chawarska & Volkmar, 2007).

Research on configural form processing by typical observers highlights both similarities and differences between the perception of humans and animals. For example, psychophysical performance in a same-difference form discrimination task was orientation dependent with images of people and dogs but orientation independent with images of cats and birds (Minnebusch, Suchan, & Daum, 2009). In the same article, ERP data suggested differences in neural processing during the perception of upright and inverted people but not during the perception of upright and inverted dogs, cats, or birds. These results indicate some divergence in the neural mechanisms supporting the visual analyses of static pictures of humans and dogs. Consistent with this, there is substantial evidence that human and animal motion is processed differently in typically developing children and adults. Behaviorally, the perception of human and animal motions has been shown to differ as early as 5-months of age (Pinto, 1994, 1997, 2006). Furthermore, adults demonstrate heightened, although not categorically differentiated, sensitivity to human motion compared to horse motion (Pinto & Shiffrar, 2009). Interestingly, adult observers appear to process both human and horse motions globally.

Brain imaging studies provide clues to why the perception of human and animal motions might differ. EEG data indicate that the visual perception of human locomotion, but not horse locomotion, engages the observer's motor system (Martineau & Cochin, 2003). Furthermore, fMRI data indicate that STSp activity during the perception of point-light human movement is greater than activity during the perception of point-light creature motion (Pyles et al., 2007). Differences in visual experience cannot account for differences in visual sensitivity across these conditions (Cohen, 2002; Calvo-Merino, Grezes, Glaser, Passingham, & Haggard, 2006). Nonetheless, we investigate the role of exposure to dogs and tractors on task performance in this experiment since visual experience has been shown to influence visual analysis of biological motion in point-light displays. This issue is discussed in greater detail in the General Discussion.

Dogs, like people, have four limbs organized about a central axis. If visual sensitivity to human movement simply reflects 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 ASD is associated with compromised abilities to analyze socially relevant information, per se, then autistic traits should correlate significantly with visual sensitivity to human motion relative to dog motion. These predictions are tested with adult observers in Experiment 4. Three groups of participants completed this task including a two groups of typically developed adults and a small group of children and adolescents with a confirmed diagnosis of ASD. The ASD group provides a preliminary measure of ASD performance on the task but future studies will match ASD and typical observers. The second group of typically developed adults completed the psychophysical task and a familiarity questionnaire.

3.1.2 Methods

Participants

Three groups of participants completed this task. Typical Group 1 consisted of fifty-four Rutgers University – Newark undergraduates. Twenty-eight participants were female and the mean age was 20.46 years ($SD = 3.67$, Range = 17 – 36). Another group of six observers with a confirmed diagnosis of ASD also completed the task. Four of the ASD participants were male and the mean age was 10.17 ($SD = 2.86$, Range = 7 – 13). A third group of typically developed adults completed the psychophysical task and a familiarity questionnaire (described below). This Typical Group 2 consisted of fifty-five Rutgers University – Newark undergraduates. Thirty-one participants were female and the mean age was 20.82 years ($SD = 3.14$, Range = 18 – 32). All participants were naïve to the hypothesis under investigation, had normal or corrected to normal visual acuity, and provided informed written consent (typical adult participants) or parental consent (ASD participants) before participation. Typical participants received credit towards a course requirement and participants with ASD received a small monetary compensation as compensation for their participation. The Rutgers University Institutional Review Board approved this study.

Stimuli

Point-light dog stimuli were created in the same manner as the stimuli in the previous experiments (Figure 6). Nine sensors were attached to a mid-sized dog (head (1), paws (4), elbow (1), shoulder (1), knee (1), hip (1)). The dog repeatedly performed three actions: (1) walking a linear 3m path (2) bending down to pick something up with its mouth and (3) walking 1.5m and then bending down to pick something up with its

mouth. The dimensions and presentation of the points in the dog stimuli were equated to the tractor stimuli from the previous experiments. As before, we created a set of 8 coherent and 8 scrambled point-light dog stimuli and the masked versions of these stimuli were used in the experimental task.

Apparatus and Procedure

Typical participants were tested on the desktop computer from Experiment 1 and the participants with ASD were tested on the laptop computer from Experiment 2. Overall, the methods were a modified replication of Experiment 2, with the addition of blocks of trials depicting coherent and scrambled point-light dogs. Following the detection task with masked displays, Typical Group 1 completed the Autism-Spectrum Quotient survey. For the observers with ASD, a parent completed the appropriate Autism-Spectrum Quotient survey (Appendices 2 and 3; Auyeung, Baron-Cohen, Wheelwright, & Allison, 2008; Baron-Cohen, Hoekstra, Knickmeyer, & Wheelwright, 2006) while the child completed the psychophysical task with an experimenter. Group 2 of the typical participants completed a questionnaire to assess their familiarity with dogs and tractors (Appendix 4).

Before completing the psychophysical detection task, all participants performed a practice task with unmasked displays of human, dog, and tractor stimuli. This practice task was a modified replication of the unmasked task in Experiment 1, with the addition of blocks of trials depicting coherent and scrambled point-light dogs. The practice session was implemented to boost the typical observers' performance from Experiment 2 with the goal of producing a broader range of d-prime scores and thus, greater possibility of investigating individual differences in performance as related to AQ scores. Similarly, for

the younger observers with ASD, the unmasked practice trials were included to encourage above chance performance in the masked condition.

A trained tester administered the ADOS and WASI IQ (Wechsler, 1999) test to the participants in the ASD group to confirm autism diagnosis and measure intelligence. These tests are commonly used to characterize and match experimental groups in studies of ASD. The IQ scores, in particular, will be used to match to chronological and mental age controls in future studies. All participants were naive to the hypothesis under investigation, had normal or corrected to normal visual acuity, and provided written informed consent. The Rutgers University Institutional Review Board approved this study.

3.1.3 Results

For the Typical Group 1, AQ scores ranged from 8 to 28 with a mean of 18.33 (SD = 4.71). This falls within the typical range of scores in the original AQ paper (Baron-Cohen et al., 2001). Once again, task performance in each of the stimulus conditions (human, dog, and tractor motion) was assessed with d-prime measures. Mean detection accuracy was significantly above chance the human motion condition, $t(53) = 17.78$, $p < .0001$, the tractor motion condition, $t(53) = 16.06$, $p < .0001$, and the dog motion condition, $t(53) = 14.62$, $p < .0001$. Also, presumably due to practice with unmasked point-light displays, overall performance was significantly better than in Experiment 2 ($p < .001$).

A repeated measures ANOVA with Stimulus (human, dog, tractor) as the within subject dependent variable revealed a main effect of Stimulus, $F(2,53) = 17.842$, $p <$

.0001 (Figure 7-A). As in Experiment 2, we conducted Pearson Correlations between AQ scores and performance on the detection task (Figure 7-B). AQ correlated significantly with detection of human motion, $r(54) = -.299, p < .05$, but not with dog motion, $r(54) = -.206, p > .10$, or tractor motion, $r(54) = -.062, p > .10$. We compared the correlations for AQ and sensitivity to each type of motion. The correlations for AQ with dog and human movement did not differ (Chi Square = 0.237, $p = 0.63$), nor did the correlations of AQ with human and tractor movement (Chi Square = 1.587, $p = 0.21$), or dog and tractor movement (Chi Square = 0.598, $p = 0.44$).

We then examined the effect of familiarity on performance in the dog and tractor conditions, in Typical Group 2. Participants' exposure and familiarity to dogs and tractors were assessed with the familiarity questionnaire (Appendix 4). Results from this measure showed that none of the participants owned a tractor but 18 out of 50 participants reported that they owned a dog. Thus, the dog condition in particular provides a window into the influence of visual experience on task performance. To examine the impact of exposure to dogs we created two groups based on responses to item 4 in which participants report how often they see dogs (every day, once a week, once a month, or never). We combined the participants who reported that they see dogs once a week or less into one group so the number of observers in each group was more equivalent for statistical analyses. This yielded two groups of participants with different levels of Exposure to Dogs: one with daily exposure to dogs ($N=23$) and another with infrequent exposure, or visual experience, with dogs ($N=27$). An ANOVA with Exposure to Dogs (every day vs. infrequent) as the between subject independent variable and performance in the dog, tractor and human conditions as the dependent variable revealed a marginally

significant effect of exposure to dogs on task performance in the dog condition, $F(1) = 4.011, p = .051$), but not in the human, $F(1) = .072, p > .10$, or tractor, $F(1) = 1.075, p > .10$, conditions. Thus, daily exposure to dogs is associated with, and likely leads to, elevated sensitivity to the presence of coherent dog motion in point-light displays (Figure 7-C).

For the ASD group, a repeated measures ANOVA with Stimulus (human, dog, tractor) as the within subject dependent variable revealed no main effect of Stimulus, $F(2,5) = 1.545, p = .26$ (Figure 8-A). One sample t-tests explored whether performance in each condition was above chance. Interestingly, only performance in the human motion condition was significantly above chance, or a d-prime of zero, $t(5) = 5.29, p < .01$. Performance in the dog and tractor conditions did not differ from chance, $t(5) = 2.543, p > .05$ and $t(5) = 1.866, p > .10$, respectively. We also conducted paired-samples t-tests to examine if there were differences in performance in sensitivity to the human motion and dog motion conditions. Since the ASD group is small and only a preliminary group of subjects, these analyses were exploratory. Still, observers with ASD demonstrated equivalent sensitivity to human and dog movements, $t(5) = -.707, p = .511$.

Participants in the ASD group completed the child and adolescent AQ surveys. The child survey is out of 150 possible points while the adolescent survey is out of 50 possible points. The small sample size of this group rendered analysis of the AQ data weak in power and statistical. Individual participants' AQ and d-prime scores are shown in Table 3.

3.1.4 Discussion

Replicating the results from Experiments 1, 2, and 3, typical observers exhibited superior performance in the human motion condition relative to the tractor motion condition. The critical result is that typical observers also demonstrated greater sensitivity to human motion than to dog motion. This pattern of results supports the existence of distinct mechanisms underlying the perception of human and non-human biological motion (e.g., Pinto, 1997, 2006; Pinto & Shiffrar, 2009; Pyles et al., 2007). This finding is in contrast to the prediction of equivalent levels of visual sensitivity to human and dog motions which would have supported the hypothesis that the visual system is tuned for the detection of animate motion rather than specifically human motion (e.g., Minnebusch et al., 2009; New et al., 2007; Quinn & Eimas, 1998). Despite elevated detection of human movement, it is important to note that typical observers used global processes to detect coherent human, dog and tractor motion (since all displays were masked), highlighting a similarity in the perception of each stimulus category. Finally, since detection accuracy was best in the human motion condition followed by the dog condition and then the tractor motion conditions, these results support the hypothesis that motor processes may contribute to the perception of human and animal motion in a graded fashion. The greater the similarity between perceived actions and the observer's repertoire of possible motor actions, the greater the contributions of motor processes to perceptual analyses and as a result, the greater the visual sensitivity to the perceived action (e.g., Bosbach, Cole, Prinz, & Knoblich, 2005; Jacobs & Shiffrar, 2005; Loula et al., 2005; Prinz, 1997; Viviani, 2002).

Consistent with the results of Experiment 2, a significant relationship was found between the presence of autistic traits in typical observers, as measured by the AQ, and changes in visual sensitivity to other people's actions. The correlation between AQ and visual sensitivity to human movement was greater than the correlation between AQ and visual sensitivity to dog motion. This pattern of results supports the hypothesis that social behavior is directly related to social perception. While human and dog motion are both classified as biological, moving people are of the utmost social import. This validates an assumption of many studies of the visual perception of human movement; namely, that successful social behavior requires the accurate and rapid perception of other people's actions (e.g., Blake & Shiffrar, 2007; Shiffrar et al., 2009). Finally, the AQ correlations suggest that the visual analyses of human and animal motion are differentially related to autistic traits despite previous reports that observers with and without autism group these categories together in static displays (New et al., 2009).

We also found preliminary evidence that visual experience plays a role in heightened sensitivity to specific types of motion. Namely, the results of the familiarity questionnaire reveal that the amount of exposure an observer has to dogs in his or her daily routine influences their visual sensitivity to coherent dog motion in point-light displays. This pattern of results indicates that visual experience is a likely contributor to the typical pattern of elevated sensitivity to human movement (e.g., Giese & Poggio, 2003). Furthermore, this preliminary finding adds support to theories that observers with ASD fail to develop typical levels of sensitivity to human movement due to lack of visual experience with this type of motion (e.g., Klin et al., 2009). We will return to this topic in section 5.1 below.

Performance of the ASD group in this experiment serves as preliminary results since we were unable to complete proper matching to chronological and mental age matched controls. That is, the small sample size and lack of a main effect temper the strength of the conclusions that can be drawn from this group's performance. Nonetheless, the ASD group did demonstrate equivalent sensitivity to all three types of motion in this task. Performance in the tractor motion condition was not above chance. However, the important comparison in this study was between performance in the human motion condition and dog motion condition. Since the ASD group exhibited equivalent sensitivity to similar human and animal motions, the current results support the hypothesis that a selective dysfunction in social perception is associated with this pervasive developmental disorder.

Chapter 4: The Detection of Emotional Human Action

Experiments 1 to 4 examined the relationship between social abilities and social perception by assessing the connection between detection of coherent human motion in point-light displays and observers' autistic traits. But these studies do not fully examine this putative relationship. Successful social function relies on more than the accurate detection of other people in the environment. It also requires the extraction of socially relevant information from other people's actions (Shiffrar et al., 2009). 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). A growing number of studies have highlighted the impaired perception of emotional information in ASD (e.g., Adolphs, Sears, & Piven, 2001; Wang, Dapretto, Hariri, Sigman, & Bookheimer, 2004). The majority of this work has focused on face processing tasks. A small number of studies with point-light displays of emotional human movement have been conducted, but they involved labeling tasks. Together, these studies motivate Experiment 5 below, which aims to examine the perception of emotional human movement as it relates to the magnitude of typical observers' autistic traits.

4.1 Experiment 5: Autistic Traits in Typical Adults

4.1.1 Hypotheses and Design

Some scientists have theorized that amygdala dysfunction is at the core of the social impairments in ASD (Baron-Cohen et al., 2000; Schultz, 2005). Originally put forward by Simon Baron-Cohen and colleagues, the amygdala theory of autism is based on this region's importance as a social brain structure (Adolphs, 2002; Brothers, 1990;

LaBar, Crupain, Voyvodic, & McCarthy, 2003) and its dysfunction in ASD (e.g., Baron-Cohen et al., 2000). Lesions of the primate (e.g., Bachevalier, 1991, 1994; Kluver, & Bucy, 1939) and human (e.g., Adolphs, 2008) amygdala affect social behavior. In typical observers, the amygdala is important for detecting stimuli related to threat and fear, or more broadly, salient and biologically relevant information (for review see Adolphs, 2008; Whalen, 1998). Much of this research has focused on studies of face perception. And, indeed, individuals with ASD demonstrate abnormal processing of social information from faces in behavioral tasks such as judging emotion (Baron-Cohen et al., 2000) or trustworthiness (Adolphs et al., 2001), and matching emotions between faces (Wang et al., 2004). Moreover, several neuroimaging studies indicate that observers with ASD, relative to typical observers, recruit different neural networks and rely on different strategies in processing facial emotions (e.g., Baron-Cohen et al., 2000; Kleinhans et al., 2008; Wang et al., 2004; Wicker et al., 2008).

In contrast, other research suggests that emotion processing is not entirely dysfunctional in ASD. For example, Rosset and colleagues established that children with ASD have deficits categorizing static images of actual emotional faces but are able to categorize emotional cartoon faces in the same way as typically developing children matched on CA and MA (Rosset et al., 2008). Castelli (2005) found that children with ASD performed as well as matched controls on basic emotion recognition tasks with realistic face stimuli. Such variability in the results of perceptual studies of observers with ASD is not uncommon. It is likely that variability within the disorder and in matching to control groups across studies contributes to contradictory assessments of emotion processing in ASD (Hobson, 2005).

Previous behavioral studies have shown that typical observers can reliably identify the emotions conveyed in point-light actions (e.g., Atkinson et al., 2004; Chouchourelou et al., 2006; Clarke et al., 2005; Dittrich et al., 1996). Even just a few points of biological motion, such as three points defining an arm knocking, can convey the emotional state of an actor (Pollick et al., 2001). While the above studies indicate that observers can recognize the emotional state of a point-light actor, they do not indicate whether the emotional content of an action influences visual sensitivity to that action. Chouchourelou and colleagues tested the influence of perceived emotion on the visual detection of coherent human motion (Chouchourelou et al., 2006). In this detection task, observers reported when they saw a coherent point-light walker hidden within a mask or cloud of identically moving points. Across trials, the point-light walkers could express anger, fear, happiness, neutral emotional state or sadness. Importantly, emotion was never mentioned in the instructions to the participants nor was it explicitly judged by the observers. The results showed that typical adult observers were most sensitive to the presence of a coherent point-light walking person when that person expressed anger. Thus, the results supported an anger-superiority effect for bodily motion. This finding suggests that a person's affective state is automatically, rapidly and proficiently monitored during the analysis of that person's actions (Adolphs, 2008; Whalen, 1998). These results are consistent with neurophysiological connections between the STS, known to be involved in the visual analysis of point-light displays of walking people (e.g., Grossman et al., 2000), and the limbic system including the amygdala (e.g., Peelen, Atkinson, Andersson, & Vuilleumier, 2007; Sato, Yoshikawa, Kochiyama, & Matsumura, 2004; Wheaton, Pipingas, Silberstein, & Puce, 2001).

Enhanced perceptual sensitivity to potentially threatening stimuli has been documented in a variety of empirical settings including face stimuli (e.g., Hansen & Hansen, 1988; Öhman, Lundqvist, & Esteves, 2001; Öhman, Flykt, & Esteves, 2001). When asked to detect a novel target face amongst a set of otherwise identical faces, typical observers are most efficient at detecting an angry face within a crowd of happy or neutral faces (Hansen & Hansen, 1988; Hortsmann & Bauland, 2006; Öhman, Lundqvist, & Esteves, 2001). This pattern of results fits nicely into a more general concept of threat detection. Typically, humans are exceptionally sensitive to potential threat in the environment. Indeed, threatening stimuli, such as snakes and spiders, are detected more rapidly and accurately than non-threatening stimuli (Öhman, Flykt, & Esteves, 2001).

A neural area that is likely involved in the above anger-superiority effect is the amygdala. This brain area has been shown to respond to potential threat indicated by angry faces (e.g., Britton, Shin, Barrett, Rauch, & Wright, 2008). A recent fMRI study with typical adult observers found that the amygdala and STS were more active in the perception of point-light displays of negative emotion (fear) compared to neutral emotion (Grezes, Pichon, & de Gelder, 2007). In addition, other neuroimaging studies in humans have shown that passively viewing caricatured silhouettes, point-of-light displays or whole-body postures symbolizing an emotion engages regions in the STS and the amygdala (Bonda et al., 1996; Hadjikhani and de Gelder, 2003; de Gelder, Snyder, Greve, Gerard, & Hadjikhani, 2004).

Notably, the amygdala has been shown to play an especially important role in the perception of fearful *and* angry face stimuli. For example, Adams and colleagues (Adams, Gordon, Baird, Ambady & Kleck, 2003) reported that typical observers'

exhibited equivalent amygdala response to fearful faces with averted gaze and angry faces with direct gaze. LaBar and colleagues also provided evidence that the amygdala is important for the perception of anger, anger/fear blends, and fear portrayed in facial expressions (Graham, Devinsky, & LaBar, 2007). Such findings raise the question as to why an anger-superiority effect is present in behavioral tasks with point-light displays of human movement (Chouhourelou et al., 2006). Why not a fear-superiority effect? The simple answer is that faces and bodies convey distinct emotional signals, although they often go together (Darwin, 1872). Angry body actions, as opposed to fearful body movements, typically have high velocity movements (Pollick et al., 2001), which might be easy to detect. Although fearful body actions have been shown to recruit the amygdala (Grezes et al., 2007), we predict that angry body actions would do so to the same extent, if not more. Nonetheless, this prediction remains to be tested because, to date, no laboratory has conducted a neuroimaging study of the walker detection task described above (Chouhourelou et al., 2006).

These social brain areas involved in perceiving human movement (STS) and emotion (amygdala) have been highly implicated in ASD. As reviewed above, these regions have anatomical and functional abnormalities in ASD. Furthermore, social deficits have been associated with impaired function in both the STS (Boddaert et al., 2004; Zilbovicius et al., 2006) and the amygdala (e.g., Dalton, Nacewicz, Alexander, & Davidson, 2007; Munson et al., 2006; Nacewicz et al., 2006). Thus, it is likely that individuals with ASD might not show the typical modulation to their visual analysis of human action as a function of the emotional content of that action, as shown by Chouhourelou and colleagues (2006).

Studies have consistently found that observers with ASD have a deficit in their ability to accurately label the emotions depicted in point-light displays of human movement (Atkinson, 2009; Hubert et al., 2007; Moore et al., 1997; Parron et al., 2008). The first such study by Moore, Hobson, and Lee (1997), included unmasked displays of human and object movement. Participants verbally described each point-light display and response time was the dependent measure. Human displays could be action specific (e.g., running, jumping) or emotional (e.g., happy, angry, sad and fearful) in content. Observers with ASD took longer than controls to label the emotions in the displays but performed as quickly as the control groups in labeling actions. In later studies using a slightly modified paradigm, free-choice verbal labeling accuracy was the dependent variable. These studies found that adolescent (Parron et al., 2008) and adult (Hubert et al, 2007) observers with ASD were specifically impaired in emotion recognition compared to age and gender matched control groups. In a recent study by Atkinson (2009), adults with ASD performed worse than age and IQ matched controls on emotion recognition in a forced-choice detection task in which the emotion labels were listed on the bottom of the screen and subjects chose a label for each point-light movie. Taken together, these categorization studies demonstrate that the perception of human movement is abnormal in ASD and that response type influences observer's performance on action and emotion recognition tasks.

In the final experiment described below, the nature of emotion processing deficits associated with ASD will be further investigated. The evidence for impairments in labeling emotion in point-light displays is less variable than that of action recognition, although the specificity of this impairment is not fully understood. For instance, while

Atkinson (2009; Atkinson, personal communication) reported impaired recognition of anger and happiness, other researchers (Losh et al., 2009; Losh, personal communication) found particularly compromised recognition of positive emotions in observers with ASD. The current study examined the relationship between autistic traits and sensitivity to human actions depicting angry, fearful, happy, neutral and sad emotions. This is the first study to utilize a detection task with emotional walkers, rather than a labeling task, and therefore has less of a verbal requirement than past investigations of this type of emotion processing in ASD. Since people with ASD frequently experience difficulties with language (American Psychiatric Association, 2001), it is particularly important to avoid the use of labels, especially labels describing psychological states as complex as emotions.

In Experiment 5, typical participants were asked to complete a detection task similar to that of Chouchourelou and colleagues (2006). This task assessed whether typically developed adults demonstrate the anger-superiority effect with point-light walkers as a function of the magnitude of their autistic traits. As a control task, participants were also asked to complete a detection task with inverted emotional walkers. Since inversion disrupts typical, global, processing of point-light displays (Sumi 1984), we do not expect a significant relationship between autistic traits and performance in this condition. To the extent that AQ relates to the visual analysis of upright, coherent human movement, we should find no relationship between AQ and performance in the inverted condition. Given that the neural correlates of the anger-superiority effect, specifically the amygdala and the STS, are compromised in observers with ASD (e.g., Pelphrey & Carter, 2008; Schultz, 2005), we predict a negative correlation between

observer's autistic traits and enhanced detection accuracy for angry walkers. The past studies of emotion recognition with point-light displays by observers with ASD have all included labeling tasks (Atkinson, 2009; Hubert et al., 2007; Losh et al., 2009; Moore et al., 1997; Parron et al., 2008). The aim here is to use a more rigorous psychophysical detection task to examine the perception of emotional action with limited verbal requirements. Finally, this study aims to clarify the emotion processing deficits associated with ASD. This study will include typical adult observers, as a preliminary step in establishing how autistic traits modify the influence of emotion on walker detection. Future studies will include observers with ASD to further clarify the relationship.

4.1.2 Methods

Apparatus

Participants completed this task on the desktop computer from Experiment 1.

Participants

A group of fifty-eight Rutgers University undergraduate students completed the experiment for partial credit towards a course requirement. Thirty-six participants were female and the mean age was 20.74 years ($SD = 4.85$, Range = 18 – 48). All subjects were naïve to the hypothesis, provided informed consent prior to the study and had not participated in any of the studies reported above. This study was approved by the Rutgers Institutional Review Board.

Stimuli

The stimuli were a modified set from Chouchourelou and colleagues (2006). The stimulus set consisted of 60 displays of coherent point-light walkers expressing five different emotional states: angry, sad, fearful, happy, and neutral and 60 displays that were positionally scrambled versions of the coherent set. Each display consisted of 13 points that defined the walker and 13 points that defined the Mean age = 20.5, Range = 17-36 years mask. Each walker had its own unique mask, since the mask was constructed from the point-light walker. To ensure that performance was not at chance, the masking elements were modified from the original study (Chouchourelou et al., 2006). The masking elements were placed within a five to ten point radius of the original dots of the coherent and scrambled walkers used in Chouchourelou et al. (2006). The stimuli were presented in a 15 X 15 cm window positioned in the center of the computer screen. In half the trials, a coherent point-light walker was present in the mask. These were “walker present” trials. In the other half of trials, the points defining the walker were positionally scrambled in a similar manner as the mask (but placed within a 5 point radius of the original point). This scrambling destroyed the structure of the walker’s body and rendering the walker unidentifiable. These “walker absent” trials were otherwise identical to the “walker present” trials.

In a slight modification of Chouchourelou and colleagues study, participants completed one block of trials. So, each subject viewed a total of 120 trials (60 “target present” and 60 “target absent” trials). All displays were 3 seconds in duration.

We also created a set of inverted point-light movies that were identical to the emotional point-light displays described above (60 “target present and 60 “target absent”)

except for a 180-degree inversion in the picture plane. Participants completed the same walker detection task in a block of inverted movies after completing the upright task.

Procedure

Participants sat approximately 57 cm in front of the computer screen and were informed that they would see a sequence of brief point-light movies. Participants' task was to report, by pressing one of two buttons (Yes/No), whether they saw a walking point-light person within a cloud of moving points. In the inverted block of trials, participants' task was to report, by pressing one of two buttons (Yes/No), whether they saw an upside-down walking point-light person within a cloud of moving points. No mention of emotion was included in the instructions. Participants had to respond during the three-second duration of each movie. No practice trials were administered nor feedback provided.

Each trial began with the presentation of a white fixation cross in the center of a black screen for one second. Then, a randomly selected point-light movie appeared for three seconds. Immediately after the participant responded, the next fixation window appeared, followed by another point-light movie. In the case that the participant did not respond within the three-second window in which the movie was shown, the next trial started at the completion of the movie. These 'missed trials' were coded as 'no' responses because a person was not detected.

All participants completed the task with upright displays followed by the same task with inverted displays, no practice trials were administered nor feedback provided. After the psychophysical task, all participants completed the AQ to assess the magnitude of their autistic traits.

4.1.3 Results

As in the past studies, d -prime was computed to assess detection accuracy in each emotion condition. Mean performance was above chance for all emotions in the upright (all p 's < .001) and inverted (all p 's < .001) conditions.

First, we conducted repeated measures ANOVA to determine if the typical adults demonstrated a similar pattern of results to that of the participants from the original study by Chouchourelou et al. (2006). For the upright displays, there was a main effect of emotion (Angry, Fear, Happy, Neutral, Sad), $F(4,57) = 6.87, p < .0001$ (Figure 9-A). For the inverted displays, the repeated measures ANOVA indicated no effect of emotion on detection accuracy, $F(4,57) = .441, p = .441$ (Figure 9-B). To examine the main effect of emotion in the upright condition, we conducted post-hoc paired t-tests for detection of angry walkers relative to the other emotions. Detection of angry walkers was significantly better than that of fearful walkers, ($p < .001$) but equivalent to happy, neutral and sad walkers. Hence, overall we did not find an anger-superiority effect.

Further analyses examined whether sensitivity to emotional movement varied as a function of the magnitude of observer's autistic traits. AQ scores ranged from 9 to 30 (Mean = 17.48, SD = 4.79), which falls within the typical range of scores (Baron-Cohen et al., 2001). We conducted Pearson Product Correlations for detection accuracy in each emotion condition and AQ score (Table 4). Since there were five emotions per condition (upright, inverted), statistical significance was adjusted to .01 to control for multiple comparisons. Thus, the only significant correlation for the upright displays was with AQ and sensitivity to angry walkers, $r(58) = -.359, p < .01$ (Figure 10-A). There was a

marginal correlation of sensitivity to upright happy walkers and observer's AQ score, $r(58) = -.322, p < .05$. The correlations for AQ score and all other emotions in the upright condition were not significant (all p 's $> .05$). We also conducted Pearson Product Correlations in the inverted condition (Figure 10-B) and found that none of the correlations was significant at the $p < .01$ level.

4.1.4 Discussion

This study examined the relationship between autistic traits and sensitivity to the presence of human action as a function of the emotional content of that action. Typical observers have demonstrated a heightened detection of potentially threatening, angry, human movement (Chouchourelou et al., 2006). Surprisingly, overall, the typical observers in this task failed to demonstrate elevated detection accuracy for upright angry walkers compared to the other emotions. This finding contrasts with Chouchourelou et al. (2006) and may reflect the range of autistic traits in this larger group of participants. Indeed, we found that observers with fewer autistic traits were significantly more sensitive to the presence of angry walkers than observers with more autistic traits. A possible explanation for the difference in findings between our study and the original is that we did not include practice trials and only used one block of experimental trials in the upright condition. However given the documented efficiency of a threat-detection mechanism in typical observers (e.g., Whalen et al., 2004), it is difficult to imagine why practice would be necessary to garner the effect. Thus, it is somewhat concerning that the anger-superiority effect did not emerge in the upright block in this study and future research should attempt to replicate Chouchourelou and colleagues' finding.

Typical observers vary in their sensitivity to the presence of emotional human movement. We showed that detection accuracy of angry walkers was directly associated with the magnitude of an observer's autistic traits. This relationship was only present in the upright condition. Since inversion is thought to disrupt typical processing of human action in point-light displays, these results likely reflect a meaningful connection between social skills, as measured by autistic traits, and the typical global analysis of these displays rather than a low level perceptual bias to angry movement in point-light movies of human action. While researchers have often assumed that sensitivity to emotional content is important for social interactions, this empirical evidence is relatively novel. In particular, the result of a negative correlation between autistic traits and detection of angry walkers on this task supports the hypothesis that social abilities are linked to social perception. Indeed, the detection of potential threat is a critical perceptual skill that serves to promote one's survival (e.g., Whalen, 1998).

The above results are not limited to individual differences in the anger-superiority effect. Indeed, we found individual differences in sensitivity to the presence of upright angry *and* happy point-light walkers. The association between observer's social skills and detection accuracy to walkers of various emotions compliments previous studies that found impaired labeling of angry and happy point-light and full-light (video) displays of human action (Atkinson, 2009). Although, as described above, we find strong support for the predicted relationship of autistic traits and diminished sensitivity to angry human movement, the decreased sensitivity to angry and happy human movement may not be fully explained by the amygdala theory of autism (but see Yang et al., 2002). Decreased sensitivity to happy point-light walkers may reflect a more general emotion-processing

deficit associated with ASD. Alternatively, these results may reflect similarities between angry and happy human movement. In particular these basic emotions have been associated with similar movement kinematics (Pollick et al., 2001). Atypical sensitivity to fast motion has been documented in observers with ASD (Gepner & Mestre, 2002). Thus, the diminished sensitivity to angry and happy walkers may reflect a decreased sensitivity to the rapid, kinematic information depicted in those displays. Finally, because there was no significant relationship between AQ score and detection of *inverted* angry or happy emotional human movement, the current results likely reflect a genuine connection between social abilities and detecting emotional human movement.

Future studies can investigate how observers with an actual diagnosis of ASD perform on such a detection task. Given the above findings, we predict that observers with ASD may not show a heightened sensitivity to the angry walkers compared to mental and chronological age matched controls. This pattern of results would provide behavioral support for the amygdala theory of autism (Baron-Cohen et al., 2001) and also for theories of a specific deficit in emotional processing in ASD (e.g. Schultz, 2005). Lack of enhanced sensitivity to angry human movement, which indicates a potential threat, would fit nicely with historical reports that individuals with ASD exhibit diminished fear of environmental danger (e.g., Wing & Wing, 1971).

While observers with ASD did not complete this task, the results of the AQ correlations indicate that autistic traits are associated with a particular pattern of sensitivity to emotional human movement. Namely, sensitivity to angry human movement decreased as a function of observer's autistic traits. This pattern of results provides evidence against the hypothesis that basic emotion processing is intact in ASD

(e.g., Castelli, 2005; Rosset et al., 2008). It contrasts with findings of an anger-superiority effect with face stimuli in observers with ASD but is concordant with reaction time differences found on such tasks (Ashwin, Wheelwright, & Baron-Cohen, 2006; Krysko & Rutherford, 2008). Certainly, the AQ results in the current experiment provide a prediction of how observers with ASD might perform on this task. Future studies are needed to address this issue.

Observers with ASD consistently demonstrate decrements in their ability to label the emotional content of human actions in studies that use both free-response (Hubert et al., 2007; Moore et al., 1997; Parron et al., 2008) and 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 et al., 1996; Hadjikhani & de Gelder, 2003; de Gelder et al., 2004). In line with these findings, atypical neural response to moving emotional faces has also been reported in ASD (Pelphrey et al., 2007). Hence, these 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).

Chapter 5: General Discussion

The experiments in this dissertation support the hypothesis of a tight coupling between social perception and social behavior, as autistic traits are associated with decreased visual sensitivity to human action. Specifically, decreased social capabilities in typical observers are associated with (1) decrements in the detection of human movement and (2) reduced perceptual sensitivity to the emotional content of such movement. These findings reveal a meaningful relationship between real-world social capabilities and the perception of point-light displays of human movement. These results validate a long-standing assumption in vision research, namely, that studying the perception of such displays is actually relevant to how we see and act outside of the laboratory (for review see, Blake & Shiffrar, 2007). Furthermore, this research can help inform our understanding of social perception in ASD. It also illustrates the extension of autistic traits into sub-clinical populations thus bolstering the continuum theory of autism, which emphasizes that autism is not a dichotomous phenomenon (e.g., Baron-Cohen et al., 2001).

The experiments reported above provide a unique contribution to the literature. They include novel and critical control conditions including animal and object movement. Whereas other research groups have drawn conclusions about human motion perception in ASD, the specificity of their results to human movement were often questionable (e.g. Blake et al., 2003). The control conditions included in the current experiments specifically target alternative explanations of past studies, namely, that impaired perception of human motion in point-light displays might simply reflect deficits

in the perception of meaningful coherent motion. In addition, whereas other researchers have compared the perception of action and emotion (Atkinson, 2009; Hubert et al., 2007; Moore et al., 1997; Parron et al, 2008), such reports always included labeling tasks. Experiment 5 is the first study to examine autistic traits and sensitivity to emotional point-light walkers in a detection task. This task has proven to be a more finely tuned measure of sensitivity and provides a template for future research with ASD populations. While past reports of emotion-labeling impairments are undisputed, the current experiment provides a picture of the relationship between the perception of different emotions and autistic traits. Finally, all of the studies reported above included masked displays. This is an important contribution to the literature given that past studies of observers with ASD have included unmasked displays while typical observers utilize global processes to detect coherent human movement.

Why are autistic traits associated with the objectification or object-like processing of human movement? The direction of causality in this relationship is unclear since Pearson Product Moment Correlations were used in all of the AQ studies reported above. Of course, such analyses simply measure the degree to which two things vary together (Rodgers & Nicewander, 1988). What does the inverse correlation between decreased sensitivity to human movement and autistic traits reflect? Is it an example of a perceptual *contribution* to the social impairments associated with ASD, a perceptual *consequence* of the social impairments, or both? An examination of what shapes typical observers' sensitivity to human movement may shed some light on these questions. Visual experience, motor abilities, and social-emotional processes all influence typical adults' sensitivity to human movement (Shiffrar, 2008). Each of these mechanisms may be

altered along the autism spectrum. We will review them each here briefly in individuals with and without ASD.

5.1 Visual Experience

It is not surprising that visual experience contributes to typical adults' visual sensitivity to human movement. Indeed, in his original point-light studies, Johansson argued that our clear and rapid perception of human action resulted from extensive visual experience with other people's movements (1973; see also Giese & Poggio, 2003). A good example of the role of visual experience in defining the visual analysis of human movement comes from studies in which observers exhibit heightened sensitivity to point-light displays of a friend compared to a stranger (Loula et al., 2005; Prasad & Shiffrar, 2009). Also, typical observers are best able to discriminate between two point-light walkers when they have visually familiar as opposed to visually rare gait styles (Jacobs et al., 2004).

The effect of visual experience goes beyond action recognition and impacts action processing as well. Visual sensitivity to deceptive intent may be influenced by visual experience. Sebanz and Shiffrar (2009) found that observer's ability to detect whether a point-light basketball player intends to fake a pass depends upon the observer's visual (and motor) experience playing the game of basketball. It can be difficult to separate motoric and visual influences on the analysis of human movement. But a study that did just that compared the abilities of professional basketball players (visual and motor experience), professional basketball coaches and sports journalists (only visual experience), and novices (neither visual nor motor experience) to judge whether a

basketball free throw would be successful (Aglioti, Cesari, Romani & Ugresi, 2008). While professional players were more accurate in their predictions than coaches or journalists, all three groups showed more motor system activation while watching basketball than while watching soccer. Taken together, these studies illustrate an influence of visual experience on perceptual analyses of human action in addition to contributions of motor experience, which is discussed in section 5.2 below.

5.1.1 Observers with ASD: Looking at People Less

The evidence presented above suggests that visual sensitivity to human motion increases as a result of visual experience. That is, observers are good at perceiving other people's actions in part because they see so much of it. Importantly, there is growing evidence that, early in life, observers with ASD do not gain the same levels of visual experience with human action as do typical observers. This may in turn decrease their visual sensitivity to human action. For example, preferential looking paradigms and eye-tracking data suggest that children and adults with ASD exhibit atypically low levels of visual attention to people's bodies and actions. Typically developed infants are sensitive to manipulations of human movement and this sensitivity becomes specialized during the first year of life (e.g., Pinto, 1997). 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; Frankenhuys et al., in press). Toddlers with ASD, on the other hand, do not exhibit a preference for upright versus inverted displays of human movement (Klin et al., 2009). Eye-tracking data does not directly indicate what an observer comprehends 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 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 et al., 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.

As described above, observers with ASD seem to look less at other people. Atypical gaze behavior is documented in real life settings, such as home videos, by one year of age (Osterling & Dawson, 1994). 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 young observers with ASD result in atypical percepts of human movement later in life or whether dysfunction in social attention (and social brain areas) cause atypical gaze and impaired human motion perception (Pelphrey & Carter, 2008). Do infants, later diagnosed with ASD, demonstrate atypical gaze from birth?

5.1.2 Predisposition for Biological Motion

Typically, human infants may come into the world predisposed to attend to biological motion. A striking example of this comes from a study with 2-day-old infants (Simion et al., 2008). In this study, exceptionally young observers, who obviously have absolutely no experience watching hens, preferentially attended to the motion of coherent point-light hens compared to random motion or inverted hen motion. These results support the hypothesis that infants possess an innate preference for biological motion. Consistent with this, newly hatched chicks, who have been reared in the dark, display a preference for point-light displays of biological motion (Vallortigara, Regolin, & Marconato, 2005). Taken together, these studies suggest an evolutionary mechanism for processing biological motion that is at least initially triggered independently of visual experience. Although further development occurs after birth, studies of the perception of faces and biological motion strongly indicate a typical readiness to process socially-relevant information without extensive visual experience (Frankenhuis, Barrett, & Johnson, in press).

Do children diagnosed with ASD come into the world attentive to socially relevant information? At this time, it is unknown if 2-day-old infants, later diagnosed with ASD, would demonstrate a preference for canonical biological motion. Unfortunately, even if they did, the meaning of this pattern of performance would not be entirely clear. For instance, the study by Simion and colleagues (2008) does not address the question of whether the reported preferential gaze is specialized to the perception of human movement or biological movement in general. As described above, there are similarities in the perception of human and animal movement and no study to date has

compared the perception of human and animal movement in such young infants. Also, adult observers are sensitive to the walking direction of point-light displays of humans and animals and the discrimination of walker direction seems to primarily rely on the motion of the feet (Troje & Westhoff, 2006). The gaze behavior that (presumably typical) 2-day-old infants show to point-light hens may reflect a sensitivity to biological motion in general, rather than human motion per se.

Although it is unclear at exactly what age the perception of human motion is distinct from other types of biological motion, this type of visual analysis is meaningfully related to social behavior early in life. A recent study showed that point-light displays of human movement, just like fully lit depictions of human movement, elicit social behavior in typically developing 12-month old infants (Yoon & Johnson, 2009). This study provides encouraging motivation to continue to study how developing infants look at point-light displays of human and animal motion. Future studies with infant siblings of children with ASD, so-called ‘at risk infants’, can determine whether observers later diagnosed with ASD demonstrate a preference for biological motion, or maybe human motion, in the first days and year of life. These studies will help to determine the developmental trajectory of social perception in ASD (e.g., Schultz, 2005).

5.2 Motoric Contributions

There is also evidence that motoric representations of human actions typically influence action perception. While so-called perception-action coupling is thought to bolster visual sensitivity to other people’s movements, this pathway may be abnormal in ASD. Studies of perception-action coupling in typical observers and non-autistic patients

have demonstrated the existence of strong linkages between an observer's motoric abilities and that observer's visual sensitivity to motion (e.g., Bosbach et al., 2005; Jacobs & Shiffrar, 2005; Loula et al., 2005; Prinz, 1997; Viviani, 2002). Perception-action coupling is thought to play a particularly important role in social behavior (e.g., Knoblich & Sebanz, 2006). This raises the possibility that individual differences in motor system impairment, or perception-action coupling, may also contribute to visual sensitivity to movement and impairments of social behavior. Research investigating the relationships between motor ability, visual sensitivity, and social abilities is needed to fully address this issue.

A growing literature on the mirror neuron system (MNS) in ASD might elucidate motoric influences on action perception in this population. This proposed system in humans is based, in part, on the finding of premotor cells in the macaque that fire during the execution and observation of the same action (e.g., Rizzolatti, Fadiga, Fogassi & Gallese, 1996). Dysfunction of this system in ASD may contribute to or correlate with the social deficits in the disorder. In recent years, several groups have focused on the functionality of the MNS in observers with ASD (e.g., Dapretto et al., 2006; Gallese, 2006; Iacoboni & Dapretto, 2006; Nishitani, Avikainen, & Hari, 2004; Oberman & Ramachandran, 2007; Williams, Whiten, & Singh, 2004; Williams, 2008). The MNS is located in the central premotor cortex (area F5) in the macaque (Rizzolatti, Fogassi & Gallese, 2001) and in Brodmann's area 44/45 in the human (Iacoboni et al., 1999) and receives input from the STS (e.g., Pineda, 2008). Significant correlations have been found between atypical cortical thinning in MNS areas and ASD symptom severity (Hadjikhani, Joseph, Snyder, & Tager-Flusberg, 2006). In EEG measures of MNS

function, typical observers show significant mu suppression during the observation of other peoples' movements while observers with ASD do not (Oberman et al., 2005). To the extent that the MNS links the production and perception of actions (Rizzolatti & Craighero, 2004), these and other results are consistent with the hypothesis that ASD involves dysfunction of the mirror neuron system (see Williams, 2008 for review).

Other researchers, however, dispute the claim that dysfunctions of the MNS are involved in the social and perceptual difficulties associated with ASD (e.g., Leighton, Bird, Charman, & Heyes, 2008). For example, while imitation is thought to rely on MNS function (e.g., Iacoboni et al., 1999; Iacoboni, 2005), equivalent levels of performance have been reported on four different imitation tasks by observers with ASD and controls (Hamilton, Brindley & Frith, 2007).

Action perception and action production obviously involve neural mechanisms other than, or in addition to, the MNS. Nonetheless, the MNS is part of the motor system, and ASD is associated with motor difficulties including clumsiness (Burgoine & Wing, 1983; Wing, 1981), atypical posture (Burgoine & Wing, 1983), deviant reach-to-grasp movement (Mari, Castiello, Marks, Marraffa, & Prior, 2003), compromised manual dexterity, balance, and ball skills (Manjivioni & Prior, 1995), and abnormal gait (e.g., Hallett et al., 1993; Jansiewicz, Goldberg, Newschaffer, Denckla, & Mostofsky, 2006; Rinehart et al., 2006). Such motor difficulties, whether or not they depend on MNS damage, will necessarily limit any individuals' abilities to link their visual percepts of another person's actions with their own motor repertoire (e.g., Serino et al., 2009). To the extent to which movement perception relies on the processes underlying movement production, and conversely, movement production relies upon movement perception,

disruption of perception-action coupling should give rise to decrements in the ability to perceive and produce movement.

While MNS disruption in ASD is equivocal, examination of the heterogeneity in motor capabilities in ASD can provide some insight into the functionality of perception-action coupling in this population. Is autism associated with dysfunctional perception-action coupling? Or, do motor atypicalities result in decrements in perception, which would indicate intact perception-action linkage? Rather than taking a dichotomous perspective of such questions and of the autism diagnosis, we can examine these issues with the spectrum in mind. The heterogeneity along the autism spectrum provides clues as to what mechanisms are altered and how (Jones & Klin, 2009). For example, individual differences in motor abilities exist along the autism spectrum. Investigations of these differences reveal that motoric contributions (per se) to motion perception may be intact in ASD because variability in motor capabilities predicts performance on several visual perception tasks. While some observers with ASD demonstrate typical motion sensitivity thresholds, others do not (Kaiser & Shiffrar, 2009). Milne and colleagues (2006) found a significant relationship between visual motion coherence thresholds with random dot kinematograms and fine motor control in both children with ASD and matched controls. In observers with AS, Dean-Woodcock measures of motor system function correlate with visual sensitivity to coherent motion in random dot displays and point-light displays of human motion (Price, 2006; Price et al., under review). Finally, neural activity in area STS during the observation of point-light depictions of human movement correlates with gross motor skills in observers with ASD (Freitag et al., 2008). These findings are consistent with Gepner and Mestre's (2002) suggestion that visual

motion perception deficits might be related to, or result from, deficits in the motor system. Taken together, these studies suggest that motoric abilities may actually *contribute* to individual differences in sensitivity to human movement in individuals along the clinical and non-clinical tails of the autism spectrum. A complete malfunction of the perception-action coupling in ASD would predict no relationship between motor capabilities and visual sensitivity to coherent motion in RDKs and point-light displays.

In conclusion, motoric contributions to typical visual analyses of human movement may be altered in observers with ASD. The coupling of action and perception may be intact and the disruption may stem from heterogeneous impairments of various motor skills. Alternatively, the perception-action connection itself may be altered resulting in a lack of motor resonance during action perception (e.g., Williams, 2008). Some have argued that the MNS or perception-action coupling is typically present at birth (Lepage & Theoret, 2007) and this system is disrupted in ASD. Clarification of these issues will help to define motoric involvement, or lack thereof, in the objectification of human motion by observers with autistic traits.

5.3 Social-Emotional Constraints

Decreased visual experience and disrupted perception-action coupling may play a role in the lack of an enhanced sensitivity to human movement in the ASD population. But, it still is not clear why observers with ASD or observers with more autistic traits look less at people or have atypical motor resonance during action perception. Exploration of a third influence on typical observers' visual sensitivity to human action may help to explain why observers with more autistic traits exhibit decreased sensitivity

to human action. Social-emotional processes have been shown to facilitate the perception of human movement (Shiffrar, 2008), and this is thought to result from sensitivity to the abundance of social information conveyed by human movement.

Social processes impact the perception of human movement in typical adult observers. In one study, Chouchourelou and colleagues (Chouchourelou, 2006) asked observers to judge the strength of apparent human motion in which alternating images of a person performing an action, such as punching, were shown in one of four different contexts. The person could be shown in isolation, with a single object, with a human partner (social), or with an object related to the action (e.g., a punching bag). Observers' judgments of apparent motion depended on the context of the action. Specifically, participants rated apparent motion displays as yielding the strongest motion percepts when the person was shown in a social context with a human partner. Furthermore, emotion modulates the detection of human movement in point-light displays (Experiment 5; Chouchourelou et al., 2006). Also, emotion has been shown to influence early visual processes, such as contrast sensitivity (Phelps, Ling, & Carrasco, 2006), suggesting that the above results are not limited to the perception of human movement. Taken together, these studies support the hypothesis that, in typical observers, social processes have a significant influence on the visual analysis of human action.

Social processes may not automatically influence perception in observers with ASD. The results of Experiment 5 suggest that the influence of social-emotional processes on visual perception of human action may be less robust in observers with more autistic traits. Future studies will determine whether this relationship is further disrupted in observers with a clinical diagnosis of ASD. In addition, a recent study

showed that while typical observers automatically interpret social cues in static displays of human bodies, observers with ASD do not (Jellema et al., 2009). The performance of the ASD group in this task revealed intact perceptual processing, but a lack of influence of the social context on the perception of the displays. It can be difficult to separate the influence of social-emotional processes from visual and motor influences but the evidence to date supports the disruption of all of these systems in ASD.

5.4 Beyond Moving Bodies: ASD and the STS

The basic components of social vision may be altered in ASD. While typical observers seem predisposed to perceive and interpret social meaning, observers with ASD do not. For example, the classic Heider and Simmel (1944) displays of moving geometrical shapes evoke strong percepts of human interaction in typical observers but not in observers with ASD (Castelli, Frith, Happé & Frith, 2002; Klin, 2000; but see Abell, Happé & Frith, 2000). Furthermore, these two groups of observers exhibit distinct levels of engagement of the STS during the perception of Heider and Simmel-like displays (Castelli et al., 2002). Is this neural response to the visual perception of moving shapes meaningfully related to the neural underpinnings of the visual perception of moving human bodies?

The short answer is a hesitant, “Yes” (Pyles, personal communication). There is growing evidence that the STS codes actions at a basic and abstract level and is especially influenced by the context of an action (for thoughtful discussion see Pyles & Grossman, in press). Based on evidence from single-unit recordings in monkeys (Perret et al., 1985) and imaging studies with humans (Grossman, Jardine & Pyles, under review),

some researchers argue that cells within the STS encode actions from a basic level of body kinematics to more abstract properties, such as those seen in the anthropomorphized moving shapes. To date, only one peer-reviewed article has compared neural activation during the perception of Heider and Simmel-like displays and point-light displays of human action (Gobbini, Koralek, Bryan, Montgomery & Haxby 2007; see also Pyles, 2009). Gobbini and colleagues reported a high degree of overlap in the pSTS during the perception of both types of displays suggesting a role for this region in representing perceived actions and the implied intentions of those actions. The behavioral and neural results reviewed above indicate that action interpretation, for human motion in particular and social action in general, is typically encoded by the STS.

Observers with ASD exhibit marked abnormalities in their behavioral and neural response to socially relevant visual stimuli, from moving shapes to moving human bodies. In accordance with this notion, psychophysical and neuroimaging data have revealed individual differences in behavior and brain activity by observers with ASD in social perception tasks. There is a significant relationship between severity of autism, as measured by the ADOS, and the ability to detect point-light human movement (Blake et al., 2003). Toddlers with ASD lack of attention to eye gaze correlates with their level of social impairments as measured by the ADOS (Jones, Carr, & Klin, 2008). Furthermore, fMRI 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 et al., 2006). Finally, the magnitude of activity in the (right) STS during the perception of direct versus averted eye gaze correlates with the severity of observer's

social difficulties (Pelphrey & Carter, 2008). In summary, diagnostic measures of social impairments in ASD have consistently predicted variations in performance and neural response in a range of person perception experiments. Therefore, there is growing evidence for a direct connection between the social impairments associated with ASD and disrupted social perception.

Various explanations have been suggested for the abnormal social perception and cognition exhibited by individuals on the autism spectrum. For instance, Pelphrey and others have suggested that social categories, such as faces and bodies, are unpredictable and complex and that these characteristics might contribute to more substantial processing requirements compared, for example, to scenes of places (Pelphrey, Lopez, & Morris, 2009). Schultz (2005) focused on face processing impairments and argued that deficits in social brain networks, such as connections between the amygdala and the fusiform, result in a derailment of typical social development in autism. Pelphrey and Carter (2008) examined the perception of biological motion and posited that dysfunction in the STS region, as well as reduced connectivity between this region and other social brain structures including the fusiform gyrus and amygdala, significantly contribute to the social perception deficits in autism. These theories emphasize that, early in life, individuals with ASD are not tuned to social information in the same way as typically developing children. But, what exactly causes this inattention to socially relevant stimuli? When does it occur? Future research will seek to clarify the specific mechanisms and timing underlying atypicalities in the social brain and social perception in ASD.

The derailment of social perception in ASD may occur in the first years of life, but perhaps not in the first days of life. In a thorough review of the infant sibling

literature, Rogers reported that “contrary to current views that autism is a disorder that profoundly affects social development from the earliest months of life, the data... presents a picture of autism as a disorder... with a gradual onset that changes both ongoing developmental rate and established behavioral patterns across the first 2-3 years of life” (Rogers, 2009). This raises the possibility that individuals with ASD come into the world with typical predispositions for social stimuli but then fail to develop a normal preference for seeking out such stimuli.

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., Pelphrey & Carter, 2008; 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.

5.5 Considering Other Populations

Researchers have begun to examine the perception of human movement in point-light displays in various developmental disorders, to clarify 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 sensitivity to coherent human motion in point-light displays. For instance, Virji-Babul and colleagues reported that 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). Further, these same children are impaired in identifying emotional states and distinguishing 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 et al., 2002). Notably, William's syndrome is associated with hypersociability (or overfriendliness) (Meyer-Lindenberg, Mervis, & Berman, 2006). This combination of intact perception of human movement and preserved social abilities contrasts with the opposite pattern in ASD. It is likely that in the case of ASD, and other social disorders, impairments in the perception of human action have a significant impact on the detection and interpretation of social information (e.g., Kim et al., 2008).

Difficulties in social function can also arise from neglect or maltreatment early in life. Studies of these populations can also inform our understanding of social capabilities and how individuals perceive their world. Children with early global deprivation include those reared in Romanian orphanages with limited caregivers and resources. Interestingly, elevated levels of autistic traits have been documented in children from these orphanages who were adopted in the United Kingdom (Rutter et al., 1999). While

these children did not necessarily receive a diagnosis of ASD, this finding suggests a strong role of experience in the development of social behavior. Of course, this example of abnormal social development stems from environmental influences as opposed to the postulated gene-environment interaction postulated to result in the social derailment in ASD (e.g., Pelphrey & Shultz, in press). However, similarities and differences between such groups can undoubtedly inform our understanding of the effects of early experience on social development and social perception.

Behavioral and neurophysiological studies have begun to elucidate the derailment of social function in a variety of domains including the perception of faces. Children who were neglected or abused exhibit abnormal recognition and discrimination of emotional facial expressions (Pollak, Cicchetti, Hornung, & Reed, 2000). Those who were physically abused demonstrate hyper-sensitivity to threatening facial expressions in behavioral and ERP measures (Shackman, Shackman, & Pollak, 2007). Taken together, these and other studies (e.g., Moulson, Nathan, Zeanah, & Nelson, 2008) suggest that to the extent that children's experience with the world varies, so too will their interpretation and understanding of social information. Recovery can be limited and many researchers have suggested a sensitive period in cognitive development (e.g., Nelson et al., 2007) as early aversive experience has a lasting impact on the developing brain and social-emotional processes (e.g. Tottenham et al., 2009). As researchers continue to compare different populations with social difficulties, we will refine our grasp on the influences and outcomes of early experience and genetics on the development of social perception and social behavior.

5.6 Implications & Future Directions

The studies in this dissertation serve several purposes. (1) They provide a foundation for studying the visual perception of human movement in ASD. These studies improved upon past methodologies with the addition of important control and masking conditions. (2) The measurement of autistic traits in typical observers provides a window into the relationship between social perception and social behavior. The results support a tight coupling of these processes, thus validating a long-held assumption that typical robust sensitivity to human movement in point-light displays reflects social functioning in the real world. (3) While future studies need to extend the current results to observers with ASD, these findings have potential applications to intervention and treatment programs.

What kind of treatment could the current results inform? First, there is the issue of visual experience. If observers with ASD spend less time looking at other people, this is an obvious place to begin treatment programs. Namely, if young children with ASD can be trained to look more at other people, they may be able to get back ‘on track’ to more typical social perception that has the potential to cascade into more typical social capabilities. Second, given the motoric contributions to action perception (e.g. Bosbach et al., 2005; Prinz, 1997) in typical observers and suggested disruption of this mechanism in ASD (e.g., Williams, 2008), treatment programs might target motor abilities in observers with ASD to boost the resonance of one’s own movement. Such a boost could provide a first and necessary step towards a stronger activation of one’s own motor repertoire during the perception of other people’s movements. Finally, the issue of social-emotional impairments is perhaps the most difficult and most important area to focus on in

treatment programs. The first step in this area will be to clarify the complex relationships between brain, genes, and behavior. These influences on social function are thought to interact to determine the developmental course of autism spectrum disorders (e.g., Pelphrey & Shultz, in press). Indeed, even in typical observers, the visual, motor and social constraints on visual sensitivity to human action work in concert throughout development (Shiffrar, 2008).

5.7 Caveats

The experiments reported above provide clear evidence for a coupling of autistic traits and visual sensitivity to the presence of human movement, per se, as well as it's emotional content. However, there are several limitations to these studies that future research can improve upon.

5.7.1 Observers with ASD

In Experiments 1 and 4, the size and characterization of the ASD groups leave open interpretive caveats regarding the data. The sample size of 6 in each of these experiments is certainly small and, therefore, these groups' performance can be treated as preliminary at best. It remains to be determined whether larger samples of observers with ASD will exhibit equivalent levels of sensitivity to human and non-human movement.

Yet, in both of these experiments, participants completed hundreds of trials. Thus, the ASD groups completed thousands of total trials which is far more data than previously reported in related studies. The observers with ASD in Experiment 4 were all administered the ADOS to confirm their clinical diagnoses. However, the ASD group in

Experiment 1 did not undergo any clinical assessment, which raises questions as to the quality of the ASD group in this study although all participants were recruited through special programs for individuals on the autism spectrum. Given our limited resources while these studies were being conducted, we made every effort to account for alternative explanations for our results. First, Experiment 2 helped to strengthen the conclusions of Experiment 1 as autistic traits were found to directly correlate with sensitivity to human movement. Second, the performance of typically developing children in Experiment 3 suggest that mental age differences are unlikely to account for group differences found in Experiment 1 and 4. Finally, overall above chance performance by the ASD groups is a strong indication that they understood the task. Therefore, even without comparing these data to other groups, the pattern of performance is still informative. Nonetheless, additional studies are currently underway with well-characterized samples of observers with ASD and age and IQ matched controls. Indeed, proper matching to mental-age matched controls is essential to fully define the performance of children and adults with ASD on such psychophysical tasks.

5.7.2 Non-human Motion Controls

The use of tractor motion in the object control condition, while novel and well thought out, is obviously limited. Although tractors, like humans, move in complex, globally non-rigid ways, they are also less familiar and less ecologically relevant than other types of motion including that of humans, animals, and some other objects. Certainly, the detection of coherent tractor motion in the above experiments may have been worse than that of human or dog motion simply because it is less coherent. This

may be the case, since typical observers analyze human motion over larger spatio-temporal windows than object motion (Shiffrar, Lichtey, Heptulla-Chatterjee, 1997). For instance, studies of the ability to integrate simple motion signals across space indicate that observers typically rely on local motion signals during the analysis of object motion (Shiffrar & Pavel, 1991). Conversely, global motion cues are especially important during the perception of biomechanically possible human actions (Shiffrar et al., 1997). Notably, both local and global processes are used in the detection of coherent human and tractor motion in the tasks reported above, as evidenced, for example, by a significant effect of masking on performance by the typical observers in Experiment 1. However, if tractor motion is processed in a more local fashion than biological motion, it is possible that this may contribute to differences in AQ correlations in each of the conditions. Indeed, high AQ scores have been associated with local processing tendencies in motion coherence tasks (Grinter et al., 2009). In summary, there is ample support for the notion that tractor motion is processed in a less global manner than human motion and this may partially explain differences in detection accuracy in these conditions.

The use of non-human, animal motion was an important control condition and an improvement in many respects on the tractor condition. The dog provided a biological motion control that is generally more familiar than tractor motion. Quadruped motion, like human motion, in point-light displays is detected via global analyses (Pinto & Shiffrar, 2009), which addresses some of the limitations of the tractor stimuli. Still, dogs are not as socially relevant or visually familiar as people and different neural mechanisms support the perception of human and creature motion (Pyles et al., 2007). Alas, as in all

studies of face or body processing, a perfect control stimulus is difficult to find and we inevitably compare “apples and oranges” (Tanaka, LeGrand & Kaiser, 2007).

5.7.3 Age of Participants

Another caveat to the experiments in this dissertation is that they primarily include adult observers. Since autism is a developmental disorder, charting the developmental trajectory of atypical social perception in clinical and non-clinical populations is essential. Researchers and clinicians have posited an early derailment of social processes in ASD that have “cascading effects on subsequent development” as brain and behavior impact each other throughout development (e.g., Jones & Klin, 2009; Pelphrey & Shultz, in press). Such theories highlight the need for investigations of typical and atypical social perception in early childhood. Indeed, studies of typical human development can provide “important clues on the type and timing of interventions with atypical development” (Casey, Tottenham, Liston, & Durston, 2005).

However, the use of adult observers was more than a result of convenience. We specifically conducted studies with adult observers because the perception of human motion in point-light displays is best understood in this age group (Blake & Shiffrar, 2007). There is a growing literature on the developmental origins of biological motion perception (for a review see Frankenhuys et al., in press). Yet, while studies have increasingly reported an early preference for biological motion (e.g., Simion et al., 2008) the exact nature of these preferences is unclear at this time. For instance, a recent report with 3-day-old infants indicated that in human neonates the so-called preference for human locomotion movements is partially explained by a preference for translational

displacement (Kitromilides-Salerio, Bidet-Ildei1, Orliaguet, & Gentaz, under revision). Since more is known about the visual analysis of human motion by adult observers, the studies in this dissertation focused on this age group.

5.7.4 Measuring Autistic Traits

Finally, the Autism-Spectrum Quotient is only one measure of autistic traits. The use of additional surveys and questionnaires would likely strengthen the conclusions of the reported studies. For example, the use of an alternative measure such as the Social Responsiveness Scale for children or adults (SRS; Constantino & Todd, 2003; Constantino & Todd, 2005) might substantiate our conclusions if SRS scores correlated with detection accuracy of human movement. We did not utilize the SRS, though, because it requires a third-party report of an individual's behaviors and tendencies. Limited time and resources to recruit appropriate dyads rendered addition of this questionnaire impossible. Another issue is the respondent in surveys of social behavior or autistic traits. For instance, a recent study showed that compared to their parents, individuals with ASD underestimated the magnitude of their autistic traits on the AQ (Johnson, Filliter, & Murphy, 2009). This finding suggests that use of both self- and third-party report measures, such as the AQ and SRS, might be the best method to assess autistic traits.

An additional potential problem with the AQ questionnaire is the jump from measuring 'autistic traits' to conclusions about general social capabilities. Do autistic traits actually reflect social capabilities? Not only do autistic traits exist in the typical population, but also these traits have been associated with "deviant social behavior" (for a

thoughtful discussion of this topic, see Scheeren & Stauder, 2008). Such findings may raise questions as to the specificity of such ‘autistic traits’ to those found in a clinical diagnosis of ASD. Yet, these questions are quickly refuted by substantial evidence of the validity of this measure and its reliability in distinguishing individuals with ASD from those with sub-clinical levels of autistic traits (e.g., Baron-Cohen et al., 2001; Woodbury-Smith et al., 2005). Nonetheless, the results of the AQ correlations reported above should be replicated with other measures of social capabilities or autistic traits to validate the conclusion that social skills are directly related to observers’ sensitivity to the presence and emotional content of human movement. Furthermore, the AQ is a screening instrument, not a diagnostic instrument, and research has emphasized the importance of using multiple measures for screening clinical populations (e.g., Mattila et al., 2009). That is, since the AQ is only a screening measure we must be cautious in the conclusions we draw from its measurement.

The reasoning behind using the AQ in the reported studies is as follows. 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, these surveys are helping to clarify the relationship between autistic tendencies and

performance on an assortment of psychophysical tasks (e.g. Grinter et al., 2008; Grinter et al., 2009; Stewart, Watson, Allcock, & Yaqoob, 2009), neurophysiological measures (Di Martino et al., 2009; von dem Hagen, Yu, Ewbank, & Calder, 2008), and genetic variability (e.g., Chakrabarti et al., 2009). These studies clearly illustrate the possibilities of examining individual differences in autistic traits in the study of genes, brain and behavior. The studies presented above are an example of the promise of examining the relationship between social perception and the continuation of the autistic spectrum.

5.8 Summary and Conclusions

An ecological approach describes perception as functionally defined by affordances. That is, observers perceive the world based on what they can do with what they see (Gibson, 1979). It is suggested that social affordances might define our sensitivity to human movement. Specifically, an observer's social capabilities seem to define their visual analysis of human movement. Those with better social skills, or fewer autistic traits, can 'do' more with the people in their environment. Therefore, these observers exhibit exceptional sensitivity to the ways in which other people move their bodies. This body of work supports the Gibsonian notion of social affordances, and their disruption along the autism spectrum. Since the objectification of human movement is associated with decrements in social abilities, observers with more autistic traits do not seem to be coding the socially relevant information conveyed by other people's movements as special. Perhaps these observers are less socially capable and, thus, can 'do' less with the people before them. Sensitivity to the information conveyed by others' actions is thought to support successful function in the social world (Shiffrar et al., 2009).

While this assumption has historically motivated empirical investigations of the perception of human action (Blake & Shiffrar, 2007), 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*.

Since ASD is essentially a social disorder, it is important to determine how observers with ASD, or autistic traits, see the social world around them. Some theories of visual perception in observers with ASD emphasize a local processing tendency (e.g., Frith, 1989; Happé & Frith, 2006; Mottron & Burack, 2001), a processing bias for featural and local information at the expense of extracting the gist or seeing the big picture. Other theories suggest that compromised social perception may characterize the pervasive developmental disorder (Klin et al., 2003; Pelphrey & Carter, 2008; Schultz, 2005). The experiments reported above provide strong support for theories of a specific deficit in social perception in ASD. Observers with more autistic traits demonstrate decrements in their visual sensitivity to the presence of human movement. Furthermore, while observers with less autistic traits exhibit a modulation of their visual sensitivity to the presence of human movement based on the emotional content of that movement, observers with more autistic traits do not. These behavioral findings are likely associated with atypicalities in the social brain in ASD including the STS.

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.

We have focused our discussion on the role of the STS in the perception of human movement and associated atypicalities in ASD. However, it is unsurprising, and worth noting, that abnormalities in the autistic brain are not limited to the STS. For example, disordered connectivity (Rippon, Brock, Brown, & Boucher, 2007), atypical early brain development (Courchesne et al., 2007), and reduced structural integrity of white matter (Keller, Kana, & Just, 2007) have all been reported in individuals with ASD. Indeed, autism research, like imaging technology, is moving from a ‘region of interest’ approach to whole brain studies (Rapin & Tuchman, 2008), integrating better temporal and spatial resolution with new technologies. Finally, while social impairments are central to the autistic diagnoses, researchers are seeking to define the range of behavioral symptoms associated with ASD such as attentional and executive dysfunctions (Bowler & Thomme, 2000).

In conclusion, the results from five psychophysical studies have provided substantial empirical evidence for a tight coupling of social abilities and visual sensitivity to human action. However, 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? It seems that diminished visual experience contributes to the objectification of human movement in ASD, but motor capabilities and perception-action coupling may also interfere. In addition, social-emotional constraints are probably atypical in observers with ASD and along the autism spectrum. Yet, future research is needed to determine the contribution and interaction of these various sources of typical sensitivity to human movement.

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Figures

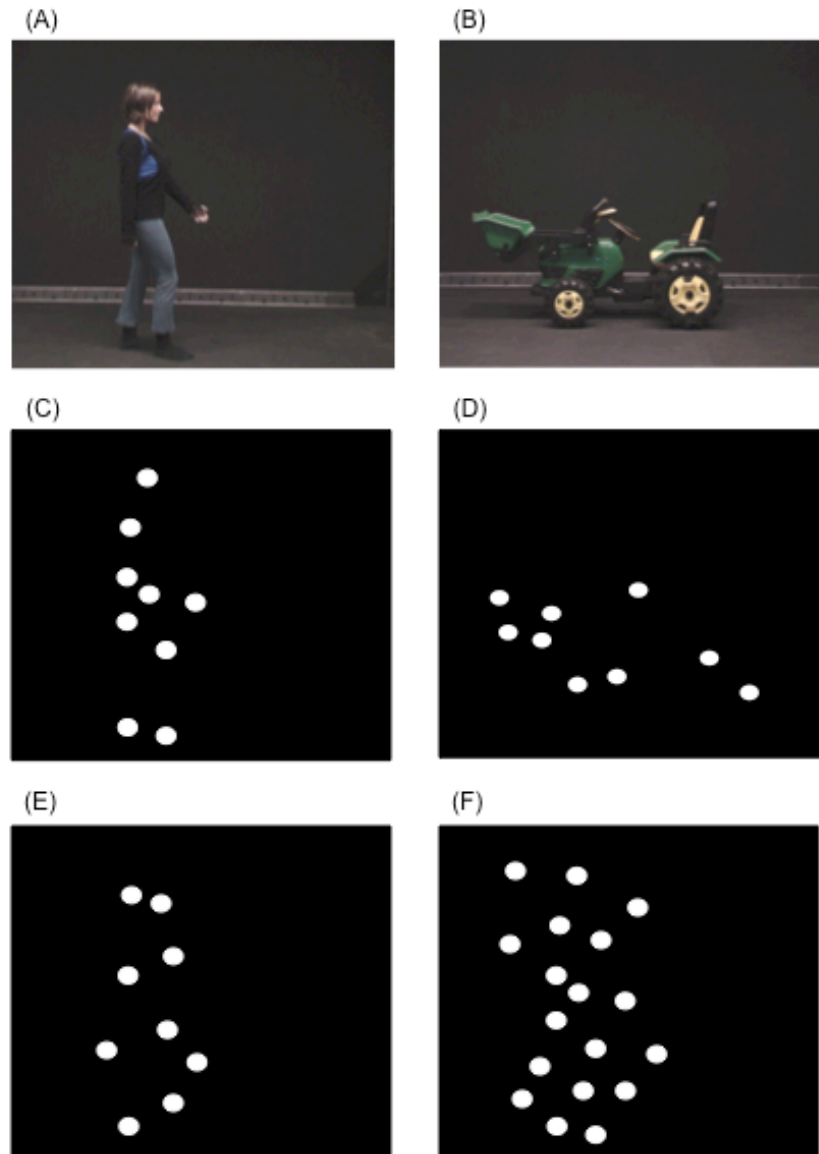


Figure 1. Photographs of the person (A) and tractor (B) within the motion capture system. Static images taken from the resultant point-light movies of the person (C) and tractor (D). While point-light displays are difficult to recognize when static (Johansson, 1973), observers readily detect these displays when set in motion. A scrambled human movie (E). Coherent human motion in a mask (F). Masks were constructed by scrambling the initial locations of the points from a duplicate stimulus. Then the walker is hidden within the mask. Global analyses are needed to detect masked stimuli.

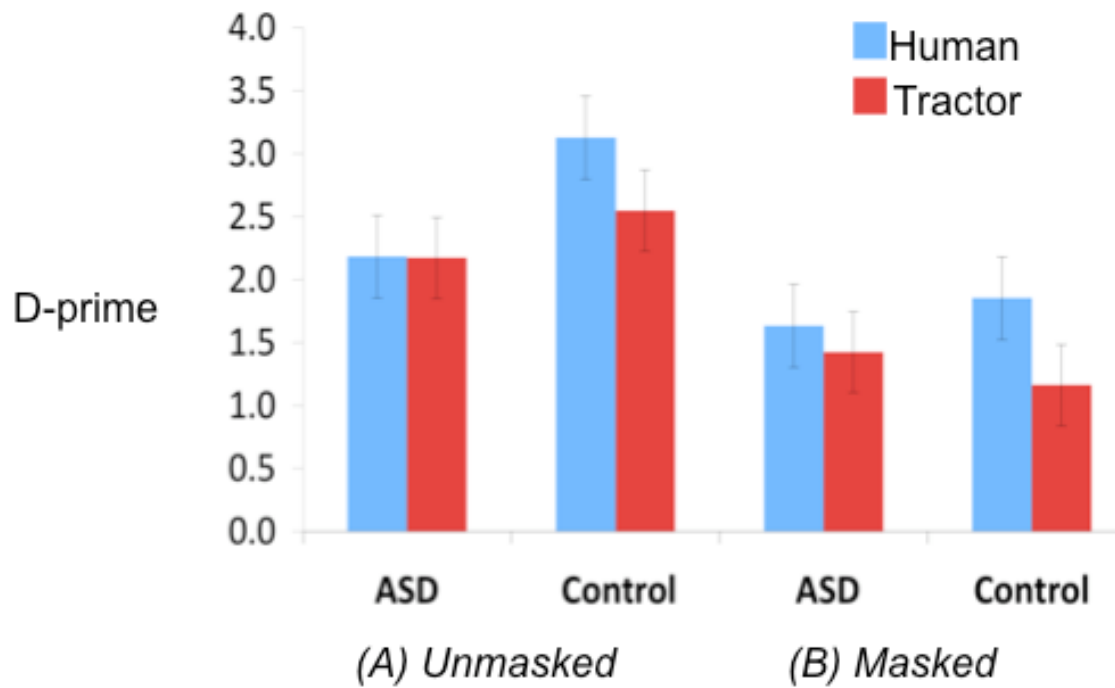


Figure 2. Results from Experiment 1. (A) Unmasked condition: Typical adult observers demonstrate significantly greater visual sensitivity to the presence of coherent human motion than to the presence of coherent tractor motion. Observers with ASD demonstrate equivalent sensitivity. (B) Masked condition: When point-light targets are hidden within point-light masks, typical observers detect human motion coherence better than tractor motion coherence. Observers with ASD exhibit equivalent performance to both types of motion. Error bars indicate the standard error.

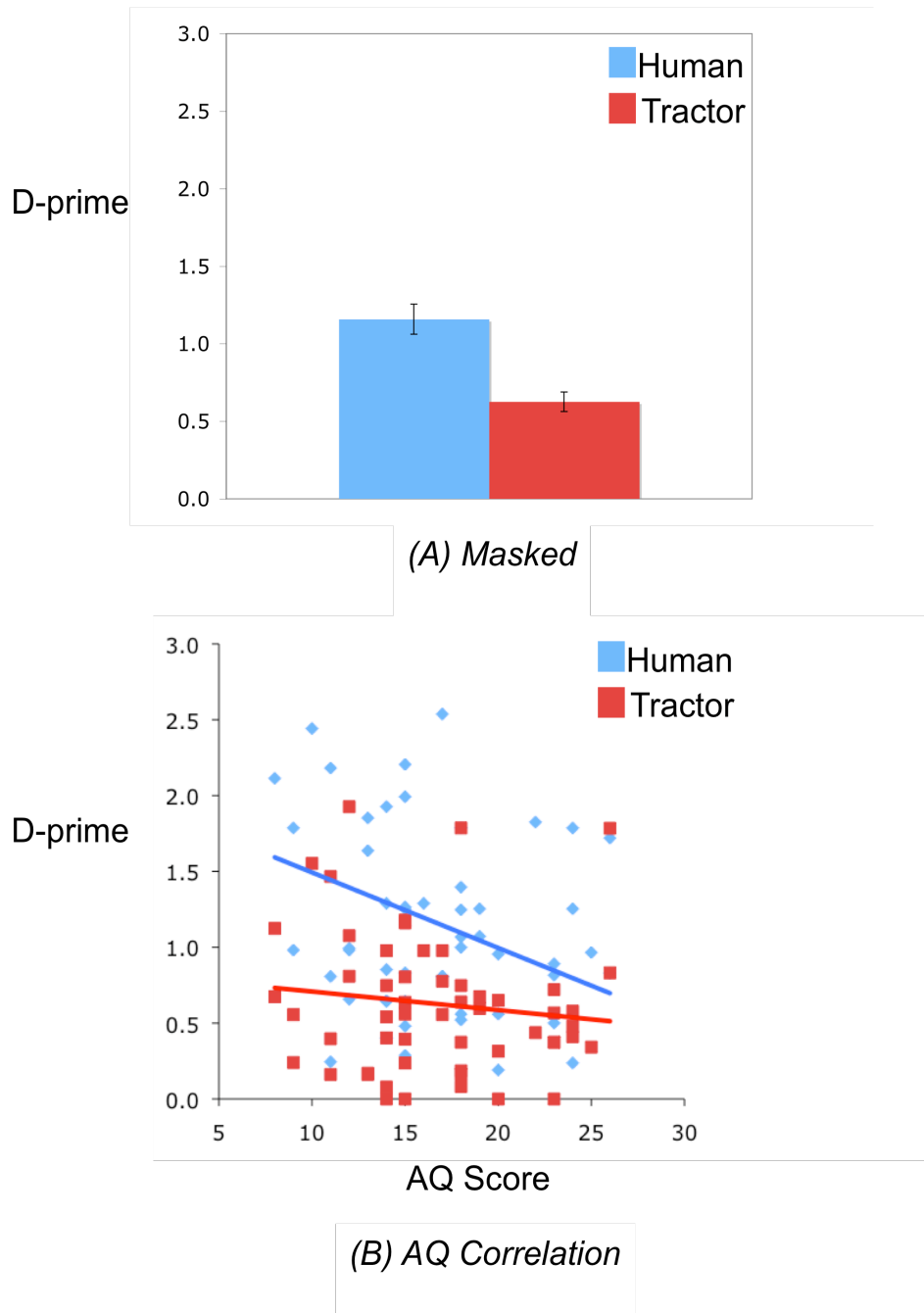


Figure 3. Results from Experiment 2. (A) Observers demonstrate significantly greater visual sensitivity to the presence of coherent human motion than to the presence of coherent tractor motion in masked displays. Error bars indicate the standard error. (B) Typical observers' detection of human motion varies as a function of the magnitude of autistic traits, as measured by the AQ. There is no significant relationship between observers' visual sensitivity to the presence of coherent tractor motion and the magnitude of their autistic traits. Trendlines indicate the correlation between AQ Score and visual sensitivity to human (blue line) and tractor (red line) motions.

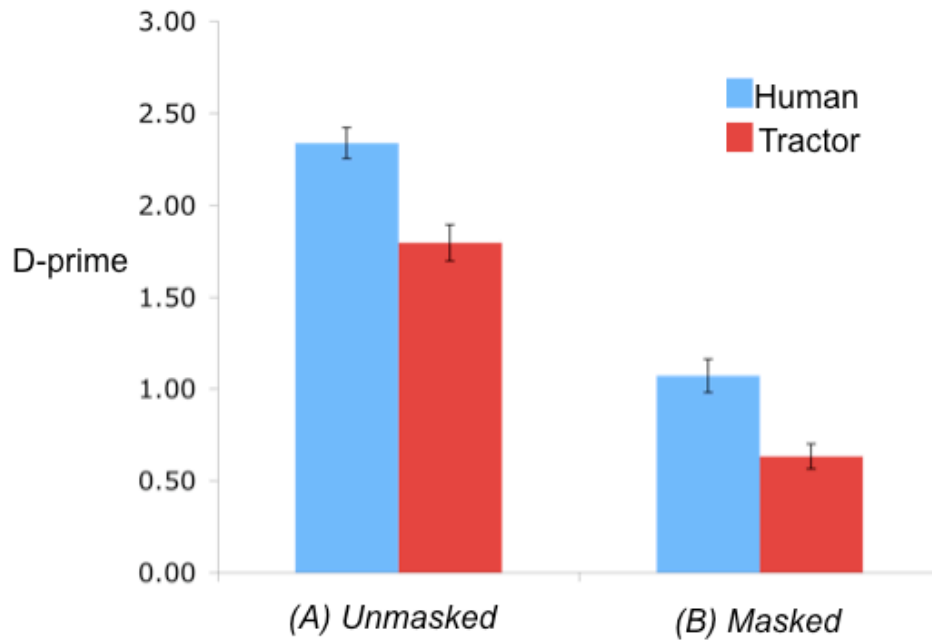
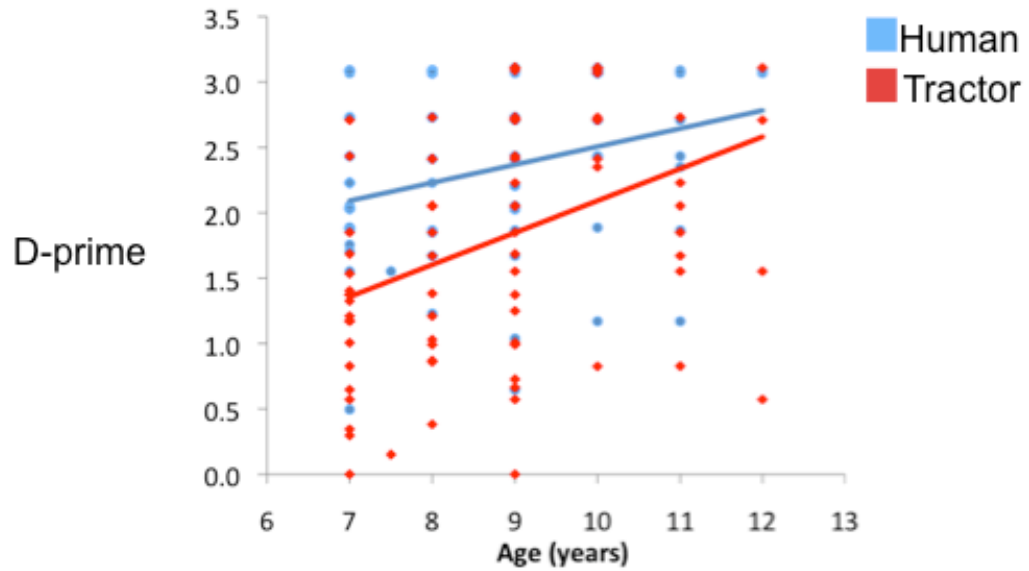
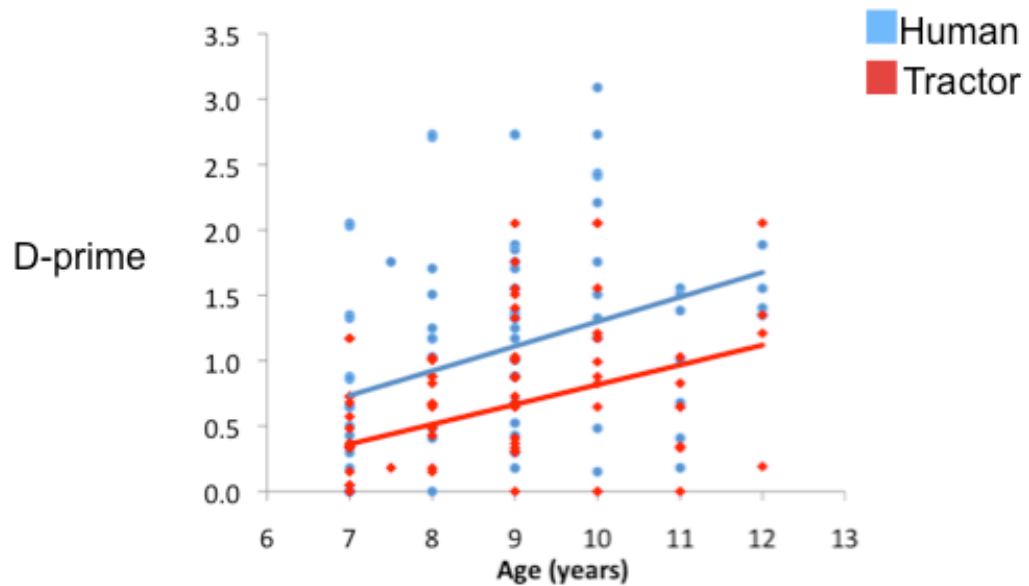


Figure 4. Results from Experiment 3. (A) Unmasked condition: Typically developing child observers demonstrate significantly greater visual sensitivity to the presence of coherent human motion than to the presence of coherent tractor motion. (B) Masked condition: When point-light targets are hidden within point-light masks, typical developing child observers detect human motion coherence better than tractor motion coherence. Error bars indicate the standard error.



(A) Unmasked



(B) Masked

Figure 5. Results from Experiment 3. (A) Unmasked condition: Typically developing child observers improve in the detection of coherent human and tractor motions with an increase in age. (B) Masked condition: Typically developing child observers improve in the detection of coherent human and tractor motions in masked displays with an increase in age. Trendlines indicate the correlation between Age and visual sensitivity to human (blue lines) and tractor (red lines) motions.



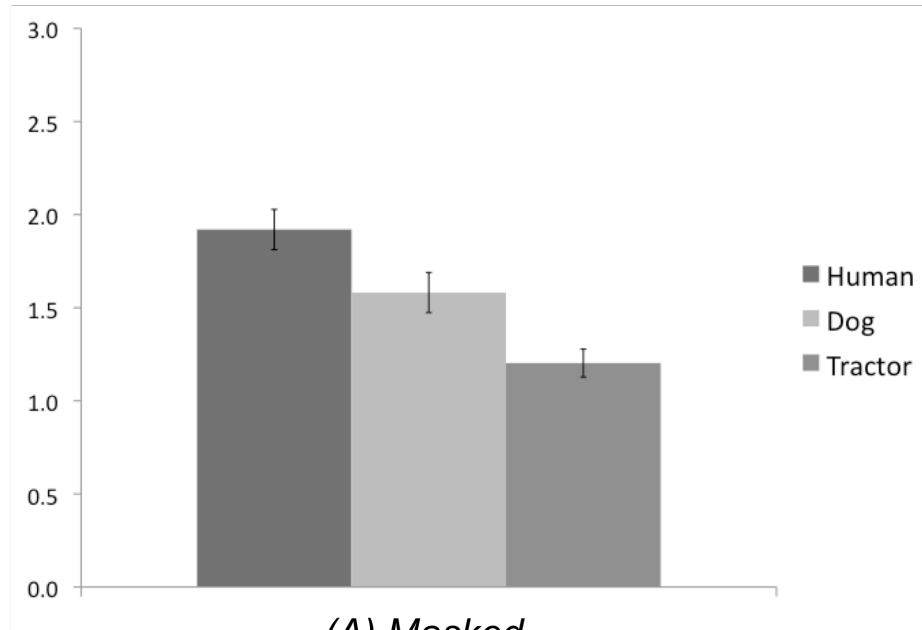
(A)



(B)

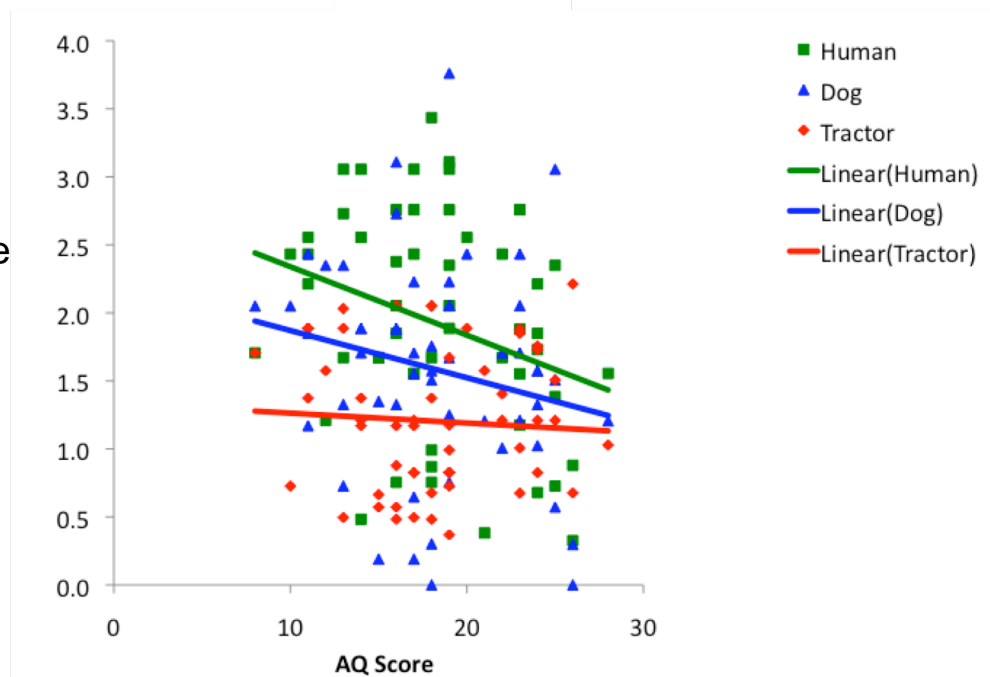
Figure 6. Static image taken from a point-light movie of a dog in the unmasked (A) and masked (B) conditions.

D-prime



(A) Masked

D-prime



(B) AQ Correlation

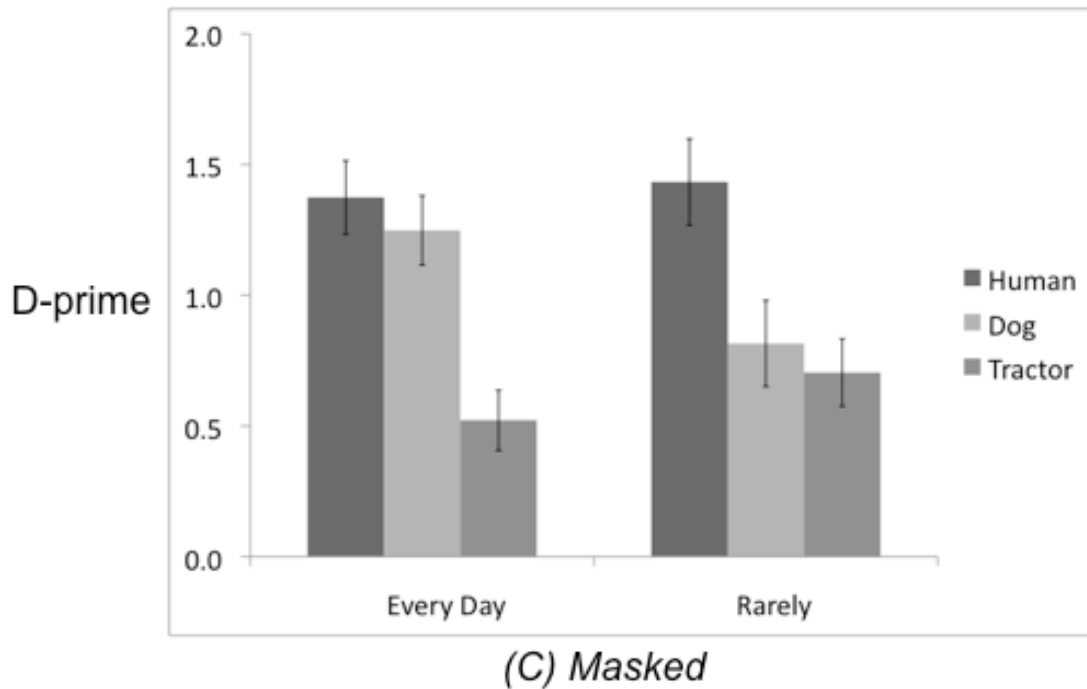


Figure 7. Results from Experiment 4. (A) Masked condition: Typical adult observers (Group 1) demonstrate significantly greater visual sensitivity to the presence of coherent human motion compared to dog and tractor motion. Also, visual sensitivity is greater to the presence of coherent dog motion relative to tractor motion in masked displays. Error bars indicate the standard error. (B) Typical observers' (Group 1) visual sensitivity to the presence of coherent human motion varies as a function of the magnitude of autistic traits, as measured by the AQ. There is no significant relationship between observers' visual sensitivity to the presence of coherent dog or tractor motions and the magnitude of their autistic traits. Trendlines indicate the correlation between AQ Score and visual sensitivity to human (green line), dot (blue line) and tractor (red line) motions. (C) Typical adult observers (Group 2) with greater visual experience with dogs and see them every day (N=23) exhibit heightened sensitivity to the presence of coherent dog motion relative to observers who see dogs once a week (N=15) or once a month or never (N=12).

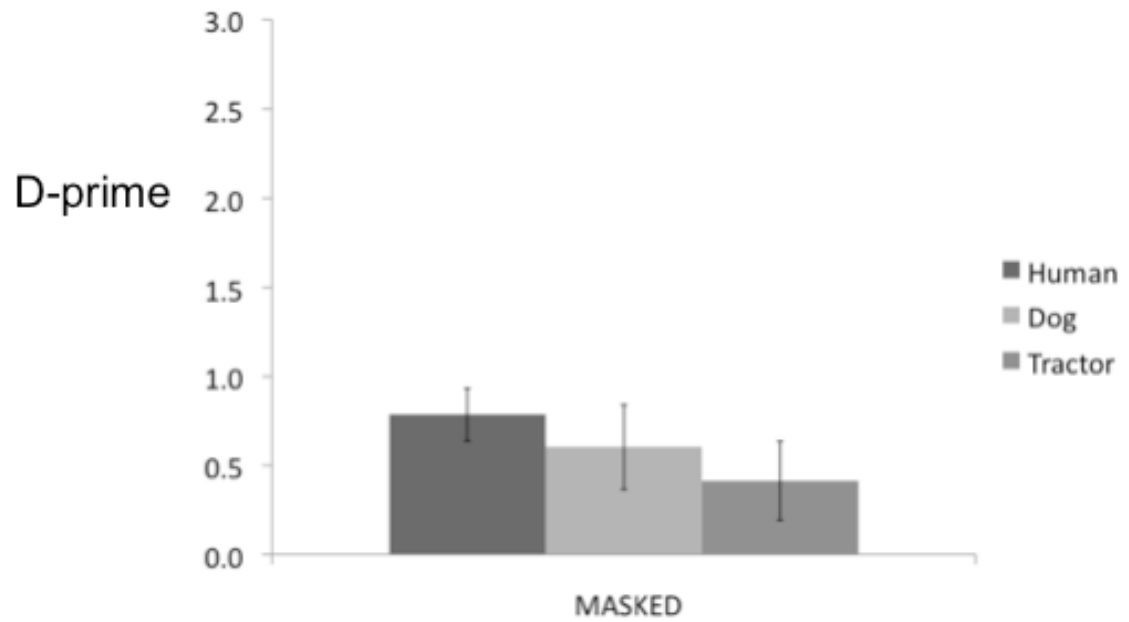
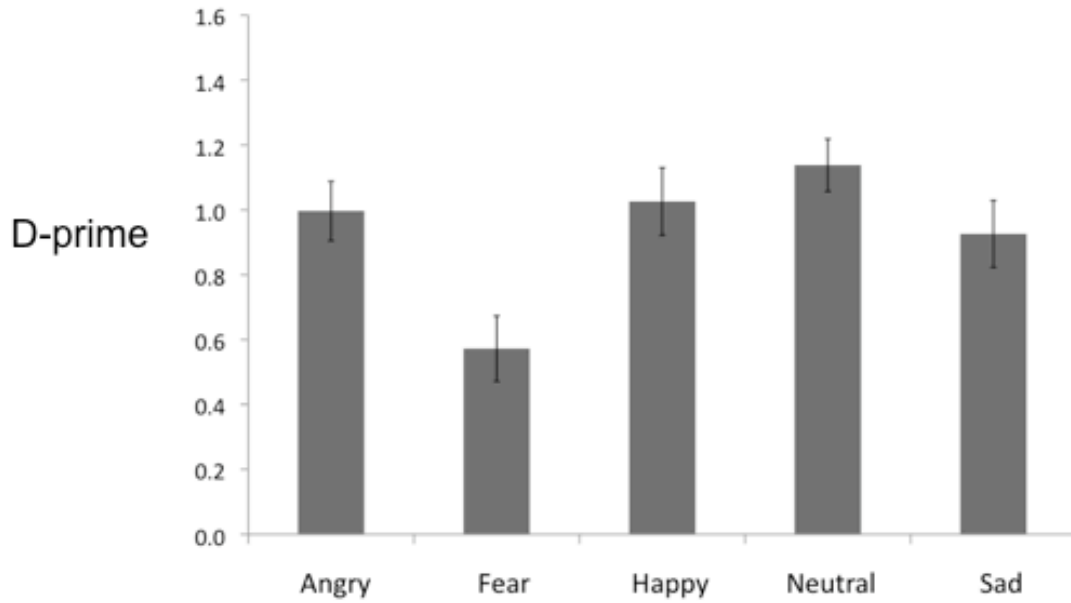
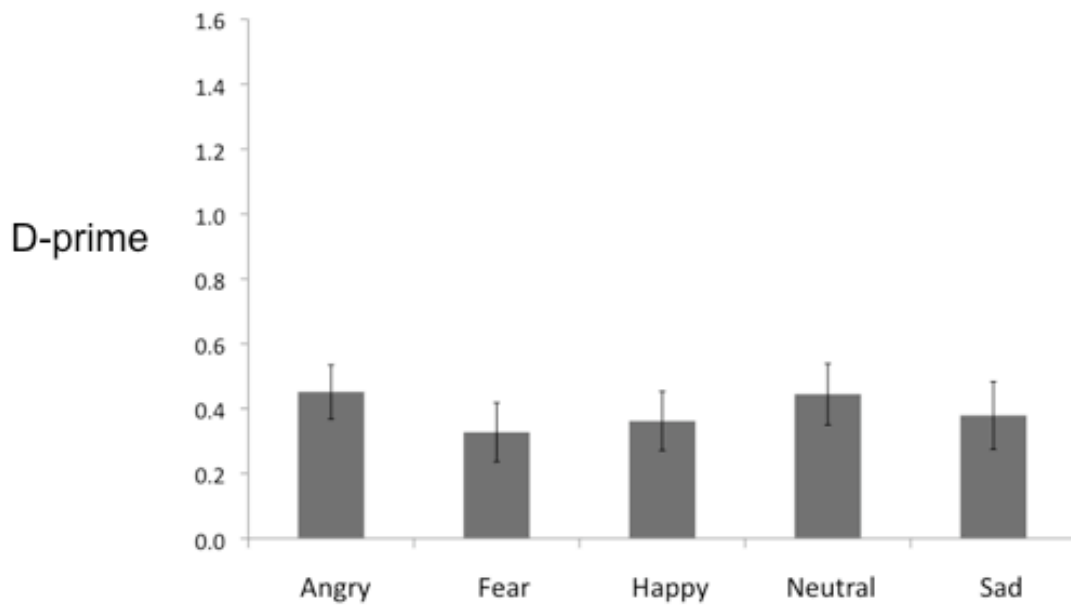


Figure 8. Results from the ASD group in Experiment 4. Masked condition: Preliminary results (N=6) indicate that observers with ASD demonstrate equivalent sensitivity to human, dog and tractor motions. Error bars indicate the standard error.



(A) Upright



(B) Inverted

Figure 9. Results for Experiment 5. (A) Overall sensitivity to the presence of upright human movement for each emotion. There was no anger-superiority effect but observers detected the presence of angry movement better than fearful movement ($p < .001$). (B) Typical observers demonstrated equivalent sensitivity to the presence of inverted human movement of various emotions.

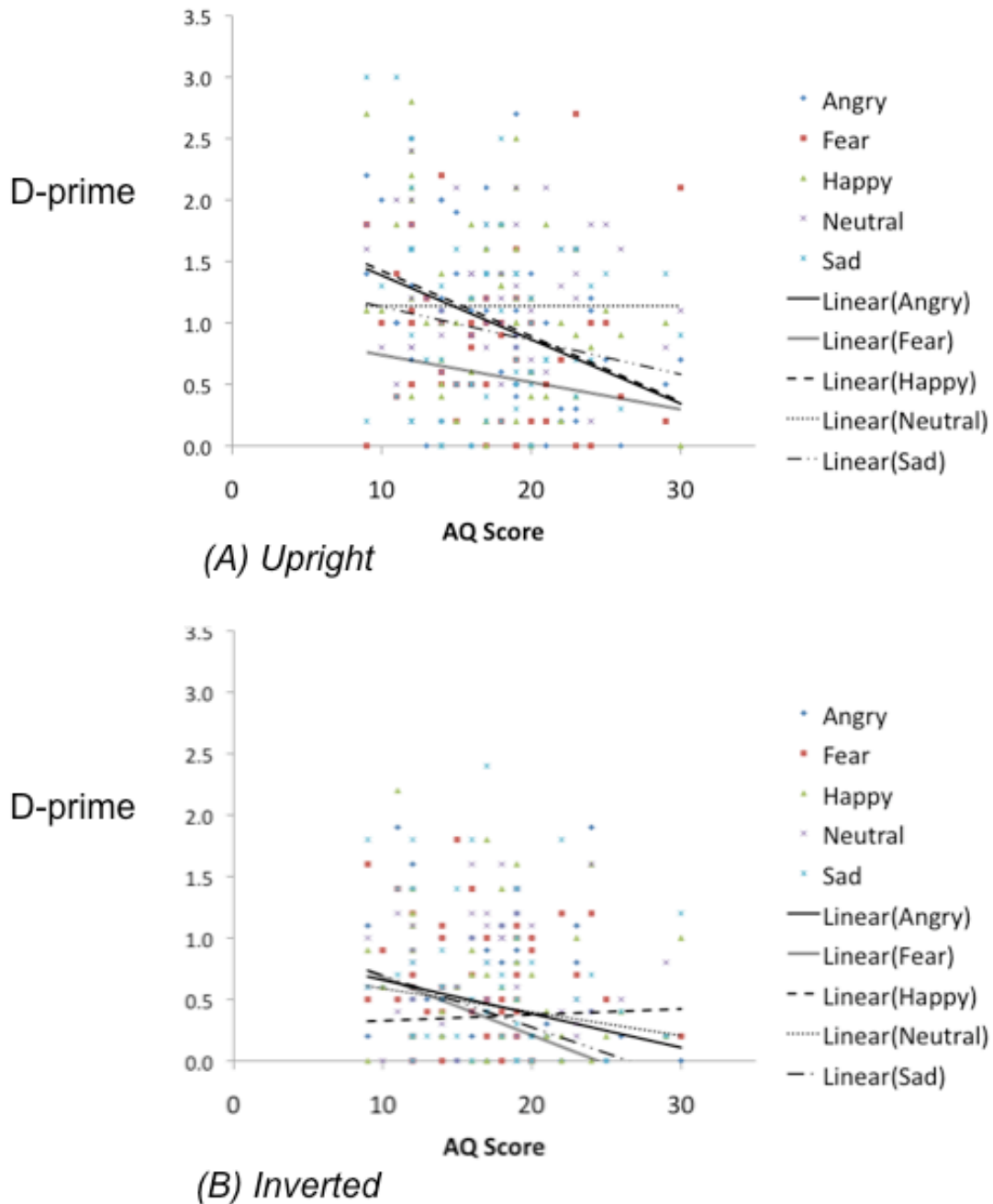


Figure 10. Results for Experiment 5. (A) Typical observers sensitivity to the presence of upright human movement varies as a function of the emotional content of that movement. Trendlines show the correlation between AQ Score and detection performance for each emotion condition. Observers' visual sensitivity to angry human movement varies as a function of the magnitude of their autistic traits. The correlations for AQ and the other emotions are not significant. (B) Typical observers sensitivity to the presence of inverted human movement does not vary as a function of the emotional content of their autistic traits. Trendlines indicate the correlation between AQ Score and visual sensitivity to emotional human movement.

Tables

	AQ	Social Skill	Attention Switch	Attention To Detail	Communication	Imagination
Human	-.33*	-.11	-.30*	-.13	-.14	-.20
Tractor	-.11	.20	-.07	-.24	.06	-.16

Table 1. Experiment 2: Pearson Correlations of AQ Score and sensitivity to human and tractor movement (N = 55). There was an inverse relationship between the magnitude of autistic traits and observer's visual sensitivity to the presence of coherent human motion. The relationship is not significant for coherent tractor motion. The AQ subscales are also shown (social skill, attention switching, attention to detail, communication, and imagination). The only significant relationship for a subscale was between visual sensitivity to human motion and Attention Switching. *. Correlation is significant at the 0.05 level (2-tailed).

	Unmasked		Masked	
	Human	Tractor	Human	Tractor
Age	.25*	.377**	.32**	.35**

Table 2. Experiment 3. Pearson Correlations of age and visual sensitivity to human and tractor movement (N = 83). Visual sensitivity to human and tractor motion in the unmasked and masked conditions improved with participant age. * = Correlation is significant at the 0.05 level (2-tailed). ** = Correlation is significant at the 0.01 level (2-tailed).

Subject	1	2	3	4	5	6
AQ score/ possible points	77/150	80/150	83/150	114/150	26/50	34/50
Dog	0.66	0.65	-0.50	0.83	0.73	1.25
Human	0.15	0.83	0.83	0.66	1.03	1.21
Tractor	-0.34	0.83	0.03	0.15	0.83	0.99

Table 3. Experiment 4: ASD Group individual participant's AQ scores and detection accuracy (d-prime) in the dog, human and tractor conditions. Due to the small sample size, statistical analyses lack sufficient power and limits the conclusions that can be drawn from this data. Nonetheless, a lack of heightened sensitivity to human movement is evident in individual subject's performance. Only two participants (3 & 5) were more sensitive to human motion relative to dog motion.

Orientation	Angry	Fearful	Happy	Neutral	Sad
Upright	-.359 *(.006)	-.138 (.301)	-.322 (.014)	.000 (.999)	-.167 (.209)
Inverted	-.208 (.118)	-.327 (.012)	.033 (.805)	-.128 (.339)	-.255 (.059)

Table 4. Experiment 5: Pearson Correlations of AQ Score and visual sensitivity to emotional human movement in the upright and inverted conditions (N = 58). Visual sensitivity to angry human movement in the upright condition correlated with observer's AQ score. * = Correlation is significant at the 0.01 level (2-tailed). Note that there is a trend towards significant correlation of AQ Score and detection of upright happy walkers. However, this is not considered significant since statistical significance was adjusted to .01 to account for multiple comparisons.

Appendix 1.

The Adult Autism Spectrum Quotient (AQ)

Ages 16+

SPECIMEN, FOR RESEARCH USE ONLY.

Name:..... Sex:.....

Date of birth:..... Today's Date.....

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 MISS 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

Developed by:
The Autism Research Centre
University of Cambridge

Appendix 2.

The Adolescent Autism Spectrum Quotient (AQ)

Ages 12-15 years

SPECIMEN, FOR RESEARCH USE ONLY.

Name:..... Sex:.....

Date of birth:..... Today's Date:.....

How to fill out the questionnaire

Below is a list of statements about your child. Please read each statement very carefully and rate how strongly you agree or disagree by selecting the appropriate option opposite each question.

DO NOT MISS ANY STATEMENT OUT.

Examples

E1. S/he is willing to take risks.	definitely agree	slightly agree	slightly disagree	definitely disagree
E2. S/he likes playing board games.	definitely agree	slightly agree	slightly disagree	definitely disagree
E3. S/he finds learning to play musical instruments easy.	definitely agree	slightly agree	slightly disagree	definitely disagree
E4. S/he is fascinated by other cultures.	definitely agree	slightly agree	slightly disagree	definitely disagree

	Definitely Agree	Slightly Agree	Slightly Disagree	Definitely Disagree
1. S/he prefers to do things with others rather than on her/his own.				
2. S/he prefers to do things the same way over and over again.				
3. If s/he tries to imagine something, s/he finds it very easy to create a picture in her/his mind.				
4. S/he frequently gets so strongly absorbed in one thing that s/he loses sight of other things.				
5. S/he often notices small sounds when others do not.				
6. S/he usually notices car number plates or similar strings of information.				
7. Other people frequently tell her/him that what s/he has said is impolite, even though s/he thinks it is polite.				
8. When s/he is reading a story, s/he can easily imagine what the characters might look like.				
9. S/he is fascinated by dates.				
10. In a social group, s/he can easily keep track of several different people's conversations.				
11. S/he finds social situations easy.				
12. S/he tends to notice details that others do not.				
13. S/he would rather go to a library than a party.				
14. S/he finds making up stories easy.				
15. S/he finds her/himself drawn more strongly to people than to things.				

	Definitely Agree	Slightly Agree	Slightly Disagree	Definitely Disagree
16. S/he tends to have very strong interests, which s/he gets upset about if s/he can't pursue.				
17. S/he enjoys social chit-chat.				
18. When s/he talks, it isn't always easy for others to get a word in edgeways.				
19. S/he is fascinated by numbers.				
20. When s/he is reading a story, s/he finds it difficult to work out the characters' intentions.				
21. S/he doesn't particularly enjoy reading fiction.				
22. S/he finds it hard to make new friends.				
23. S/he notices patterns in things all the time.				
24. S/he would rather go to the theatre than a museum.				
25. It does not upset him/her if his/her daily routine is disturbed.				
26. S/he frequently finds that s/he doesn't know how to keep a conversation going.				
27. S/he finds it easy to "read between the lines" when someone is talking to her/him.				
28. S/he usually concentrates more on the whole picture, rather than the small details.				
29. S/he is not very good at remembering phone numbers.				
30. S/he doesn't usually notice small changes in a situation, or a person's appearance.				
31. S/he knows how to tell if someone listening to him/her is getting bored.				

	Definitely Agree	Slightly Agree	Slightly Disagree	Definitely Disagree
32. S/he finds it easy to do more than one thing at once.				
33. When s/he talks on the phone, s/he is not sure when it's her/his turn to speak.				
34. S/he enjoys doing things spontaneously.				
35. S/he is often the last to understand the point of a joke.				
36. S/he finds it easy to work out what someone is thinking or feeling just by looking at their face.				
37. If there is an interruption, s/he can switch back to what s/he was doing very quickly.				
38. S/he is good at social chit-chat.				
39. People often tell her/him that s/he keeps going on and on about the same thing.				
40. When s/he was younger, s/he used to enjoy playing games involving pretending with other children.				
41. S/he likes to collect information about categories of things (e.g. types of car, types of bird, types of train, types of plant etc.)				
42. S/he finds it difficult to imagine what it would be like to be someone else.				
43. S/he likes to plan any activities s/he participates in carefully.				
44. S/he enjoys social occasions.				
45. S/he finds it difficult to work out people's intentions.				
46. New situations make him/her anxious.				

	Definitely Agree	Slightly Agree	Slightly Disagree	Definitely Disagree
47. S/he enjoys meeting new people.				
48. S/he is a good diplomat.				
49. S/he is not very good at remembering people's date of birth.				
50. S/he finds it very to easy to play games with children that involve pretending.				

Appendix 3.

Please answer each of the following questions about your child or the person who is under your care by indicating the most appropriate answer 1. Definitely Agree, 2. Slightly Agree, 3. Slightly Disagree, or 4. Definitely Disagree. If there is any question that you feel not able to comment, please ask your son, daughter, partner or the person to answer

1. S/he prefers to do things with others rather than on her/his own.
2. S/he prefers to do things the same way over and over again.
3. If s/he tries to imagine something, s/he finds it very easy to create a picture in her/his mind.
4. S/he frequently gets so strongly absorbed in one thing that s/he loses sight of other things.
5. S/he often notices small sounds when others do not.
6. S/he usually notices house numbers or similar strings of information.
7. S/he has difficulty understanding rules for polite behaviour.
8. When s/he is read a story, s/he can easily imagine what the characters might look like.
9. S/he is fascinated by dates.
10. In a social group, s/he can easily keep track of several different people's conversations.
11. S/he finds social situations easy.
12. S/he tends to notice details that others do not.
13. S/he would rather go to a library than a birthday party.
14. S/he finds making up stories easy.
15. S/he is drawn more strongly to people than to things.

16. S/he tends to have very strong interests, which s/he gets upset about if s/he can't pursue.
17. S/he enjoys social chit-chat.
18. When s/he talks, it isn't always easy for others to get a word in edgewise.
19. S/he is fascinated by numbers.
20. When s/he is read a story, s/he finds it difficult to work out the characters' intentions or feelings.
21. S/he doesn't particularly enjoy fictional stories.
22. S/he finds it hard to make new friends.
23. S/he notices patterns in things all the time.
24. S/he would rather go to the cinema than a museum.
25. It does not upset him/her if his/her daily routine is disturbed.
26. S/he doesn't know how to keep a conversation going with her/his peers.
27. S/he finds it easy to "read between the lines" when someone is talking to her/him.
28. S/he usually concentrates more on the whole picture, rather than the small details.
29. S/he is not very good at remembering phone numbers.
30. S/he doesn't usually notice small changes in a situation, or a person's appearance.
31. S/he knows how to tell if someone listening to him/her is getting bored.
32. S/he finds it easy to go back and forth between different activities.
33. When s/he talk on the phone, s/he is not sure when it's her/his turn to speak.

34. S/he enjoys doing things spontaneously.
35. S/he is often the last to understand the point of a joke.
36. S/he finds it easy to work out what someone is thinking or feeling just by looking at their face.
37. If there is an interruption, s/he can switch back to what s/he was doing very quickly.
38. S/he is good at social chit-chat.
39. People often tell her/him that s/he keeps going on and on about the same thing.
40. When s/he was in preschool, s/he used to enjoy playing games involving pretending with other children.
41. S/he likes to collect information about categories of things (e.g. types of car, types of bird, types of train, types of plant, etc.).
42. S/he finds it difficult to imagine what it would be like to be someone else.
43. S/he likes to plan any activities s/he participates in carefully.
44. S/he enjoys social occasions.
45. S/he finds it difficult to work out people's intentions.
46. New situations make him/her anxious.
47. S/he enjoys meeting new people.
48. S/he is good at taking care not to hurt other people's feelings.
49. S/he is not very good at remembering people's date of birth.
50. S/he finds it very to easy to play games with children that involve pretending.

Appendix 4.

Magnificent Movies Questionnaire

Circle the most appropriate answer.

1. Do you currently have a dog? Y N

2. Have you ever had a dog? Y N

3. Do you like dogs? (rate number between 1 and 7).

(Y) 1 2 3 4 5 6 7 (N)

4. How often do you see dogs in your typical routine?

EVERY DAY ONCE/WEEK ONCE/MONTH RARELY/NEVER

5. Do you currently have a tractor? Y N

6. Have you ever had a tractor? Y N

7. Do you like tractors? (rate number between 1 and 7).

(Y) 1 2 3 4 5 6 7 (N)

8. How often do you see tractors in your typical routine?

EVERY DAY ONCE/WEEK ONCE/MONTH RARELY/NEVER

VITA

Martha D. Kaiser

- | | |
|-----------|---|
| 1980 | Born May 29 in Montreal, Canada. |
| 1998 | Graduated from Scarsdale High School, Scarsdale, New York. |
| 1998 | Attended Oberlin College, Oberlin, Ohio. |
| 2003 | B.A. in Psychology, Oberlin College, Oberlin, Ohio. |
| 2003-2005 | Research Assistant, University of Victoria, Canada. |
| 2005-2009 | Graduate work in Psychology, Rutgers University, Newark, New Jersey. |
| 2008 | Article: "Preservation of mouth region processing in two cases of prosopagnosia," <i>Journal of Neuropsychology</i> , vol. 2, p. 227-244 |
| 2008 | Article: "OPAM 2008 Report: Individual differences in visual sensitivity to emotional human movement," <i>Visual Cognition</i> , vol. 16, p. 1115-1119. |
| 2008 | Article: "Specific impairment of face processing abilities in children with autism spectrum disorder using the Let's Face It! Skills Battery," <i>Autism Research</i> , vol. 6, p. 329-340. |
| 2009 | Article: "Is the loss of diagnosticity of the eye region of the face a common aspect of acquired prosopagnosia?" <i>Journal of Neuropsychology</i> , vol. 3, p. 69-78. |
| 2009 | Article: "Integrating the visual perception of motion by observers with autism spectrum disorder: A review," <i>Psychonomic Bulletin & Review</i> , vol. 16, p.761-777. |
| 2010 | Ph.D. in Psychology. |