Social Cognition and Social Outcomes in Children Born at Very Low Birth Weight

by

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ABSTRACT

Social cognition is a broad construct that refers to the fundamental abilities to perceive, store, analyze, process, categorize, reason with, and behave towards other conspecifics (Pelphrey & Carter, 2008). Two important aspects of social cognition are the ability to perceive and interpret body movements (biological motion perception) and the ability to infer the mental states of others (theory of mind reasoning) (Allison, Puce & McCarthy, 2000). In my thesis, these and other aspects of social cognition are explored in a group known to be at high risk for poor social outcomes, namely children born prematurely at very low birth weight (VLBW: < 1500 grams). Results showed that 8-11 year old VLBW children had difficulties processing both realistic and stylized life motion displays. These impairments were associated with increased evidence of autistic-like traits. Finally, poor performance on tests requiring life motion perception was linked to complications related to premature birth. These results could inform the development of screening, diagnostic, and intervention tools.

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DEDICATION

This thesis is dedicated to my mom, dad, sister, and brother.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABBREVIATIONS

ADHD	Attention Deficit and Hyperactivity Disorder
APGAR	Appearance, Pulse, Grimace, Activity, Respiration
AQ	Autism Spectrum Quotient - Child Version
ASD	Autism Spectrum Disorder
ASI	Adaptive Symptoms Index in BASC-2
BASC-2	Behavioral Assessment System for Children - Second Edition
BSI	Behavioral Symptoms Index in BASC-2
CASP	Child and Adolescent Social Perception
DWMI	Diffuse White Matter Injury
DSD	Developmental Social Disorder content score in BASC-2
EPI	Externalizing Problems Index in BASC-2
FT	Full-term Children
IPI	Internalizing Problems Index in BASC-2
IVH	Intraventricular Hemmorhage
NVLD	Nonverbal Learning Disability
PT	Preterm Children
PPVT-4	Peabody Picture Vocabulary - Fourth Edition
PVL	Periventricular Leukomalacia
ROP	Retinopathy of Prematurity
STS	Superior Temporal Sulcus
ToM	Theory of Mind
VLBW	Very Low Birth Weight (<1500 g)

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Fig. 1.1 Experimental paradigms used to investigate perception of life motion

Reprinted from *Social perception: Detection and interpretation of animacy, agency, and intention,* Troje, N. F. (2013). What is biological motion?: Definition, stimuli and paradigms. In M. D. Rutherford, & V. A. Kuhlmeier, (Eds.), (pp. 13-38), Cambridge, with permission from MIT Press.

Appendix H. Scoring criteria and examples for verbal descriptions of animations
Appendix I. Five stills taken from the Animated Triangles Task - Theory of Mind "coaxing" condition

Reprinted from *NeuroImage*, 12, Castelli, F., Happe, F., Frith, U., & Frith, C. (2000). Movement and mind: A functional imaging study of perception and interpretation of complex intentional movement patterns, 323, Copyright (2013), with permission from Elsevier.

LIST OF ACCEPTED PUBLICATIONS

Slightly modified versions of referenced articles (full citations included below) are part of said dissertation thesis (Chapter 2 and 3, respectively). Printed with permission from publishers: Wiley Journals via RightsLink ® and Cambridge University Press, respectively.

Williamson, K. E. & Jakobson, L. S. (2014). Social perception in children born at very low birth weight and its relationship to social/behavioural outcomes. *Journal of Child Psychology and Psychiatry*.

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CHAPTER 1 - GENERAL INTRODUCTION

Over the last 20 years, there has been a steady rise in the number of children in the population who have a history of preterm birth (Joseph, Allen, Dodds, Vincer, & Armson, 2001a; Joseph et al., 2001b; World Health Organization, 2012), defined as delivery before 37 weeks of gestation. By recent estimates, the rate of premature birth in Canada is now at 8.1% (Canadian Institute for Health Information, 2009). Joseph et al. (1998) suggested that the rise in preterm birth can be attributed to increased rates of multiple birth, improved obstetrical care, and changes in the way that gestational age is estimated by ultrasound. Several factors have been associated with increased risk for preterm birth, including demographic, psychosocial, genetic, and environmental factors, factors related to the mothers' obstetric history and prenatal care, and medical complications during pregnancy (for review, see Berkowitz & Papiernik, 1993).

Complications of prematurity account for 75% of all perinatal mortality in Canada (Silins et al., 1985), and mortality rates increase as birth weight and gestational age decrease (Stevenson et al., 1998). However, enhanced management of high risk pregnancies and advances in medical care, such as improved mechanical ventilation and the use of exogenous surfactants to aid in respiration, have resulted in increased survival rates for those born at the youngest gestational ages (Allen, Donohue, & Dusman, 1993; Hoekstra, Ferrara, Couser, Payne, & Connett, 2004; Horbar, Wright, & Onstad, 1993; Schwartz, Luby, Scanlon, & Kellogg, 1994).

Survivors of preterm birth are often classified according to whether they were low birth weight (LBW: <2500 g), *very* low birth weight (VLBW: <1500 grams), or *extremely* low birth weight (ELBW: <1000 grams). The care of these children is extremely costly. In fact, the in-hospital costs are approximately 11 times higher for a low-birth-weight baby compared to a baby born at term (Canadian Institute for Health Information, 2009). Of great concern is the fact that the smallest of these babies are being born during a period in which their brains are still in a very early stage of development. At 28 weeks gestation, for example, the cortical volume of the brain of the child born preterm is only 13% of that of a child born at term (Hüppi et al., 1998). The weight of the neonatal brain increases by 90% during weeks 20-40 of gestation (Guihard-Costa & Larroche, 1990). This period marks a time when the brain is particularly vulnerable, as dramatic changes associated with the maturation of the cerebral gray and white matter are occurring -- including development of gyri and sulci, and major developments of neurons and glia at the cellular and molecular level (for review, see Kinney, 2006).

The neonatal brain is susceptible to many forms of insults which, in addition to their primary effects, can alter the subsequent development of grey and white matter (Hüppi et al., 1998). According to MRI studies, the majority of infants born preterm show some evidence of brain injury (Maalouf et al., 1999). The various kinds of brain injury include infective, ischaemic, and inflammatory insults (Counsell, Rutherford, Cowan, & Edwards, 2003a). Common brain injuries include (a) germinal matrix/intraventricular haemorrhage (IVH), which is a hemorrhagic injury resulting from rupture of fragile blood vessels in tissue near the ventricles, (b) periventricular leukomalacia (PVL), which is a hypoxic injury that results from lack of oxygen to the white matter surrounding the ventricles, and (c) diffuse white matter injury (DWMI), in which one sees alterations in maturation of the white matter and a disruption of cortical organization and/or myelination. Research has shown that the former two types of brain injuries are on the decline, and that DWMI is the most common type of brain injury seen in children born preterm (Counsell et al., 2003a; Heuchan, Evans, Smart, & Simpson, 2002). Indeed, it is estimated that 20-50% of children born very preterm have DWMI, compared to 3-11% with IVH and 3-9% with PVL (Horsch et al., 2007; Larroque et al., 2003; Volpe, 2003). In one recent study, abnormalities in white matter were found in up to 68% of children born very prematurely (Back, 2006; Counsell et al., 2003b). The areas most vulnerable to DWMI are in the periventricular region (Counsell et al., 2003a).

Survivors of very premature birth are at risk for a variety of adverse, long-term consequences including medical disabilities such as cerebral palsy, blindness or low vision, hearing loss, and epilepsy (Moster, Lie, & Markestad, 2008; Wood, Marlow, Costeloe, Gibson, & Wilkinson, 2000). Interestingly, even those who escape severe disability often score lower on tests of intelligence than full-term peers (Johnson, 2007). Children born very prematurely are also at heightened risk to experience difficulties on measures of academic performance (reading, spelling, and mathematics), executive function, working memory, and both expressive and receptive language (Aarnoudse-Moens, Weisglas-Kuperus, van Goudoever, & Oosterlaan, 2009; Anderson & Doyle, 2003; Foster-Cohen, Edgin, Champion, & Woodward, 2007; Gallagher & Watkin, 1998; Hutchinson, De Luca, Doyle, Roberts, & Anderson, 2013; Johnson, 2007; Luciana, Lindeke, Georgieff, Mills, & Nelson, 1999; Luu, Ment, Allan, Schneider, & Vohr, 2011; Saigal et al., 2003a).

Of particular relevance for this thesis is the fact that children born very prematurely are at increased risk for social, emotional and behavioral problems. Not only do they display more internalizing problems (Aarnoudse-Moens et al., 2009; Bhutta, Cleves, Casey, Cradock, & Anand, 2002; Dahl et al., 2006; Farooqi, Hagglof, Sedin, Gothefors, & Serenius, 2007; Johnson, 2007) and experience more social rejection and lower self-esteem (Rickards, Kelly, Doyle, & Callanan, 2001) than their full-term peers, but they also have a higher rate of psychiatric disorders, such as attention deficit hyperactivity disorder (ADHD) (Johnson, 2007; Nosarti et al., 2012). In adolescents born at VLBW an association has been found between psychiatric problems and variables such as low birth weight, lower gestational age, and the presence of IVH (Indredavik et al., 2010).

In addition, there is growing support for a connection between autism spectrum disorders (ASDs) and preterm birth (Buchmayer et al., 2009; Burd, Severud, Kerbeshian, & Klug, 1999; Eaton, Mortensen, Thomsen, & Frydenberg, 2001; Hack et al., 2009; Hultman, Sparen, & Cnattingius, 2002; Indredavik et al., 2010; Johnson et al., 2010; Johnson & Marlow, 2009; Kolevzon, Gross, & Reichenberg, 2007; Kuban et al., 2009; Lampi et al., 2012; Limperopoulos et al., 2008; Maimburg & Væth, 2006; Pinto-Martin et al., 2011; Stephens et al., 2012). Matsuishi et al. (1999) found that the incidence of ASD is higher in neonatal intensive care unit survivors than in the general population. Unfortunately, no *consistent* pattern of perinatal and prenatal risk factors has been identified for ASDs (Hultman et al., 2002; Nelson, 1991). Despite this, many factors have been associated with a higher incidence of autistic-like traits, including characteristics of the mother (e.g., maternal birth outside of Europe and North America, maternal age, daily smoking), factors associated with the pregnancy and delivery (e.g., gravidity, multiple pregnancies, pregnancies complicated by hypertensive disease or bleeding, and caesarean or vaginal breech delivery), and infant characteristics (e.g., fetal distress, length of hospital stay, gender, low Apgar score, congenital malformations, abnormal findings in brain imaging, being small for gestational age, and -- of greatest relevance to the current study -- birth weight and gestational age) (Eaton et al., 2001; Glasson et al., 2004; Hultman et al., 2002; Juul-Dam, Townsend, & Courchesne, 2001; Indredavik et al., 2010).

Recent research suggests that up to 21-26% of very premature children screen positively for autistic-like traits (Kuban et al., 2009; Limperoloulos et al., 2008). However, these statistics come from studies utilizing autism screening measures, which can produce a high rate of false positives (Stephens et al., 2012). When formal diagnostic criteria have been used, the risk of a child born weighing < 2000 g receiving a diagnosis of ASD is five times higher than the risk seen in the general population (Pinto-Martin et al., 2011). It is important to note, however, that some suggest that the causal pathway leading to the "autistic phenotype" in children born preterm may be slightly different from that seen in full-term children with ASDs (Johnson & Marlow, 2011). Indeed, some authors are careful to describe the clinical presentation in children born preterm as an "… atypical social-behavioral profile strongly suggestive of an autism spectrum disorder" (Limperopoulos, 2009, p. 792). Johnson and Marlow (2011, p. 11R) referred to "… a 'preterm behavioral phenotype' characterized by an increased risk for symptoms and disorders associated with inattention, anxiety and social difficulties."

Given the dramatically elevated incidence of social difficulties and other autistic-like features seen in children born preterm, it is imperative that further investigations take place to explore the underlying core deficits that may contribute to poor social outcomes in this high-risk population. The main aim of the research described in this dissertation is to contribute to the emerging literature on this topic. Before describing the research, I would like to provide some general background relating to current conceptualizations of, and current approaches to the assessment of, social competence and social cognition.

Social Competence

Social competence is critical for the formation of lasting relationships and an important determinant of social outcomes, more broadly defined (Cacioppo, 2002). It is a construct readily understood by clinicians and the lay public. In research, however, the construct is not always clearly operationalized. Many different definitions of social competence exist (Bierman & Welsh, 2000; Dodge, 1985; Hubbard & Coie, 1994; Rose-Krasnor, 1997; Waters & Sroufe 1983; Yeates & Selman, 1989). Some proposed definitions focus on behavior related to successful functioning (Howes, 1987), effectiveness in social interactions (Rose-Krasnor, 1997), or the development of social-cognitive skills and knowledge (Yeates & Selman, 1989). A recent definition of social competence proposed by Semrud-Clikeman (2007) is the ability of an individual to take another person's perspective, to learn from experience, and to utilize this learning in daily social interactions.

Part of the difficulty in defining social competence comes from the fact that it is a complex and multidimensional construct. It consists of social, emotional, behavioral and cognitive skills (for review, see Semrud-Clikeman, 2007). In addition, this concept frequently includes other constructs such as social skills, social communication and interpersonal communication. Socially competent behaviors vary with situation and interactional partner. Thus, for example, behaviors appropriate for one setting may not be appropriate for another. Socially competent behavior may also differ depending on characteristics of the individuals involved, such as their age or gender. Finally, when defining social competence one must consider the context for understanding social interaction (i.e., culture, relationships, timing, perceptions, integration, and behaviors involved in social relationships).

Although definitions of social competence vary, most would agree that the defining feature of social competence is social success (Rose-Krasnor, 1997). The skills necessary for social competence develop at various time points, and build on previously learned skills and knowledge (Semrud-Clikeman, 2007). A breakdown of any of these skills at any point can result in a ripple effect that will affect subsequent development. Difficulties in social competence can have long-lasting effects on an individual. Specifically, having limited social competence has been associated with mental and physical health problems (Spitzberg, 2003). As a result, early detection and intervention are important to minimize the impact of poor social skills.

The assessment of social competence is not straightforward (Semrud-Clikeman, 2007). According to Hayes and Sharif (2009), the most common clinical questionnaires used in its assessment include the Child Behavior Checklist (Achenbach, 1991), the Behavioral Assessment System for Children (BASC; Reynolds & Kamphaus, 1998) and the Strengths and Difficulties Questionnaire (Goodman, 1997). These measures are beneficial in quantifying long-term outcomes. However, exclusive use of self-report and questionnaire-style measures provides an incomplete picture of the child. Specifically, it does not establish the nature of the problem, and can provide a potentially misleading assessment of social competence (Foster & Ritchey, 1979; Perrin, Stein, & Drotar, 1991;

Sattler & Hoge, 2006; Semrud-Clikeman, 2007). For example, when used with children who have a chronic illness, the Child Behavior Checklist has limited sensitivity to mild adjustment problems, and may lead to a possible bias when interpreting physical symptoms experienced by this population (Perrin et al., 1991).

Because of these difficulties, Semrud-Clikeman (2007) argued that a comprehensive assessment of emotional, behavioral, and social outcomes should include a multimodal, multi-method, and multi-source approach (Semrud-Clikeman, 2007). Such an approach is particularly important given that even children with appropriate social skills do not always respond effectively across situations, and do not always show similar behaviors in the school, home, and neighbourhood. In addition to gathering information through clinical interviews and questionnaires, clinicians and researchers should strive, wherever possible, to assess social skills in real-life (through direct observation), and through direct assessment of a child's social cognitive/perceptual skills. Having these multiple sources of information will help examiners gain a better appreciation for how a given child is functioning in social environments.

Social Cognition

Beginning in the 1980s, research has shown a relationship between measures of social competence and social cognition (Ford, 1982; Pellegrini, 1985). Social cognition is a broad construct that refers to the fundamental abilities to perceive, store, analyze, process, categorize, reason with, and behave towards other conspecifics (Pelphrey & Carter, 2008). One aspect of social cognition is social perception. Social perception refers to the initial stages of information processing involved in social cognition that result in accurate evaluation of others' dispositions and intentions (Allison et al., 2000).

In 1986, Dodge proposed a model of social competence using a social-information-processing approach. It was based on the idea that the study of maladaptive behavior should involve an examination of cognitive processes. In the most recent version of this model, the authors suggested six steps that an individual undergoes in order to process and respond to a social situation (Crick & Dodge, 1994). The first four steps involve encoding the relevant social cues, interpreting those cues, determining what one wants to achieve from the interaction, and determining how the interaction compares to past experiences. The final two steps involve selecting a response and evaluating its effectiveness. Maladaptive social behavior can result from impairments at any step -- even in the earliest stages in which social perceptual cues are encoded.

Successful encoding requires the ability to selectively attend to and extract verbal and nonverbal cues relevant to a situation (Allison et al., 2000; Archer & Akert, 1977; Doble & Magill-Evans, 1992; Fichten, Tagalakis, Judd, Wright, & Amsel, 1992; McDonald et al., 2006). Of particular relevance to the present research are nonverbal cues such as facial expressions, gestures, and prosodic vocal cues. Much of the research on nonverbal social cues has examined these cues separately, and has involved the use of static stimuli that do not specify the situational context (Chan, 2009; Cheal & Rutherford, 2011; Grossman, 2010; Little, Jones, & DeBruine, 2011; Mosconi, Mack, McCarthy, & Pelphrey, 2005; Nowicki & Duke, 1994; Sauter, Panattoni, & Happé, 2013). As such, it is difficult to know how well the findings from these studies reflect the ability to process cues available in real-life social situations. It is important to remember that during naturalistic social interactions people's faces and bodies *move*. Having these dynamic cues available can be beneficial (e.g., Ambadar, Schooler, & Cohn, 2005; Fiorentini &

Viviani, 2011; Lander, Christie, & Bruce, 1999). It is important for researchers to extend work on social perception by studying children's ability to process and interpret "life motion," broadly defined.

Troje (2013) has recently provided an overview of the types of displays that have been used in research into the perception of life motion. These have varied from displays that are realistic (live action, or depictions of same in video/film or computer animations), to ones that are degraded and stylized (see Figure 1.1). Through the use of stylized displays, researchers have attempted to isolate variables that contribute to life motion perception in a way that is not possible with realistic stimuli. Troje describes two general categories of stylized displays. First are displays featuring the movements of one or more objects which signal, to typical viewers, characteristics of agency or intentionality ("extrinsic" stylized life motion). Examples are the "animate motion" displays first introduced by Heider and Simmel (1944). The second type of stylized displays are those depicting non-rigid movements of humans or other animals ("intrinsic" stylized life motion). Examples include moving stick figures and the biological motion displays (point-light walkers) popularized by Johansson (1973).

Jones et al. (2011) have shown relationships between the processing of different kinds of life motion. These researchers found that, in adolescents with and without ASDs, lower thresholds for the detection of motion-mediated body structure in masked point-light displays were seen in individuals who used more mental state words to describe Theory of Mind (ToM) animations in the Frith-Happé Animated Triangles test (an adapted version of the Heider and Simmel test). This observation fits with the

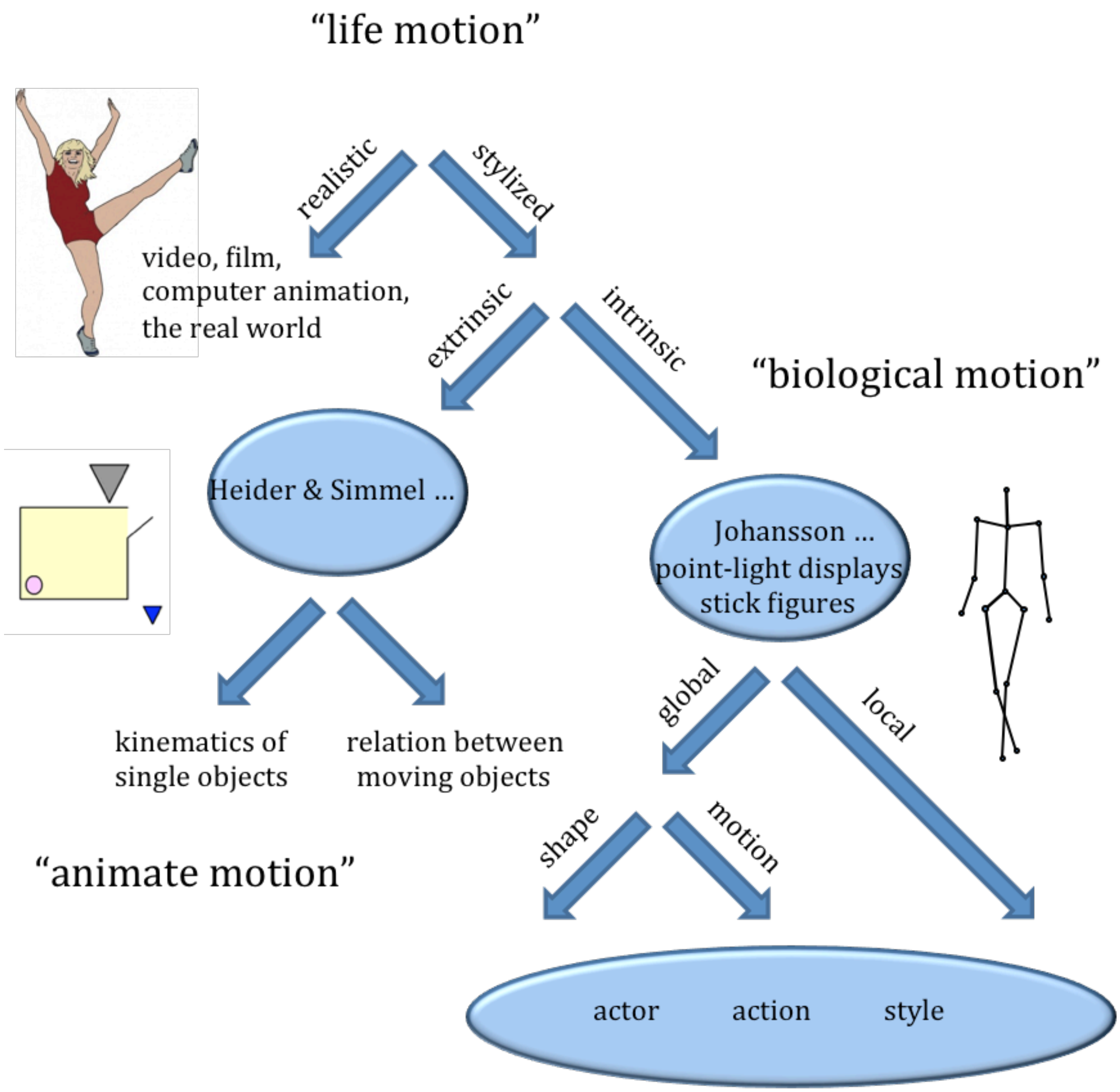

Figure 1.1 Experimental paradigms used to investigate perception of life motion. Reprinted from *Social perception: Detection and interpretation of animacy, agency, and intention,* Troje, N. F. (2013). What is biological motion?: Definition, stimuli and paradigms. In M. D. Rutherford, & V. A. Kuhlmeier, (Eds.), pp. 13-37, with permission from MIT Press.

suggestion that life motion perception is a precursor to higher-order processes involved in ToM reasoning (Allison et al., 2000; Frith & Frith, 2003), which allows us to attribute beliefs, intentions and desires to ourselves and others (Premack & Woodruff, 1978). In typical development, ToM, or mentalizing, abilities significantly increase between the ages of three to five years, and continue to develop and be refined over time (Flavell, 2004; Perner & Lang, 1999; Perner & Wimmer, 1985; Walper & Valtin, 1992). Impairments in these abilities have been found in individuals with ASDs, schizophrenia, traumatic brain injury and various forms of dementia (Baron-Cohen, Leslie, & Frith, 1985; Baron-Cohen, Jolliffe, Mortimore, & Robertson, 1997a; Bibby & McDonald, 2005; Brune, 2005; Gregory et al., 2002).

The Present Study

Studying deficits in social perception and cognition in groups characterized by problems in social functioning may increase our understanding of these important processes, and help us to fine-tune our assessment and intervention efforts. Despite the importance of this research, to date there has been limited research examining social perception and cognition in children born at VLBW -- a group known to be at high risk for social problems. The main goal of the present research was to fill this gap.

An increasing amount of research is examining the neural bases of social cognition and social perception. This work suggests that specialized brain processes are involved in various aspects of these skills. Key brain areas that have been implicated include the lateral fusiform gyrus, amygdala, extrastriate body area, orbitofrontal cortex, medial prefrontal cortex, and posterior superior temporal sulcus (for review see, Pelphrey & Carter, 2008). Of particular interest for my dissertation is research showing that abnormalities in one of these areas -- the superior temporal sulcus -- have been found in both children with ASD (Pelphery & Carter, 2008; Zilbovicius et al., 2006) and those born very prematurely (Dubois et al., 2008; Zubiaurre-Elorza et al., 2009). This area is known to be involved in the perceptual analysis of many different kinds of social stimuli (including static images of the face and body, and movements of the eyes, mouth and hands), and in mentalizing (Adolphs, 2003; Allison et al., 2000; Pelphrey & Carter, 2008; Wright, Pelphery, Allison, McKeown, & McCarthy, 2003). Given the evidence of atypical morphology in this area in children born preterm, one might expect to find that they would show impairments in these aspects of social perception and cognition.

The results of several recent studies suggest that children born very prematurely have problems with both face recognition and emotion recognition that could reflect the effects of damage to or atypical development in parts of the social brain. Fazzi et al. (2009) found that 18% of their sample of children born very preterm had impaired face recognition abilities. Potharst et al. (2013) reported problems with both face and emotion recognition in children born very preterm. In addition, Wocadlo and Rieger (2006) found that children born preterm who had problems recognizing facial expressions were more likely to have parent-reported social skills deficits. In other work, Olivieri et al. (2012) found that children born at ELBW showed impaired affect recognition and ToM reasoning on a normed neuropsychological assessment tool. Hood (2009) also identified subtle problems with ToM reasoning in four-year-old children born very prematurely, although in this case the differences between full-term and preterm children were not statistically significant. Despite these interesting results, in several cases (Fazzi et al., 2009; Wocadlo & Rieger 2006), the absence of a control group or normative data limited the conclusions that could be drawn. Another key limitation of all of these studies was their utilization of static photographs or line drawings.

Only a handful of studies have used dynamic stimuli to explore social perceptual processing in children born preterm. Several investigators have used realistic displays to assess infants' responses to moving faces. In early work, Field (1979) examined the looking behaviors of preterm and full-term infants as they viewed their mother's face (moving spontaneously, or imitating the infant's facial expressions), a rigidly moving doll's face, and a still doll's face. In both groups, viewing times were longest when they viewed the static doll's face, followed by the moving doll's face, the mother's imitative movements, and finally the mother's spontaneous facial movements. However, preterm infants spent less time looking at their mother's spontaneously moving face than full-term infants did, and showed higher arousal levels during this condition, suggesting that they had more difficulty modulating their arousal levels and/or processing dynamic face information. In related research, Hsu and Jeng (2007) compared the responses of two-month-old Taiwanese infants with birthweights falling below 2000 g to those of full-term controls as the infants underwent the maternal "still face" procedure. In this procedure, a parent suddenly stops interacting with their infant and looks away for a short period. Both the infant's reaction to the parent's withdrawal of attention and changes in the infant's behavior when interaction resumes are studied. In the Hsu and Jeng study, the authors reported that preterm infants became distressed faster, and remained in a negative affective state longer, than full-term infants did when their mothers stopped interacting with them. In other work using the still face paradigm, Segal et al. (1995) reported that seven-month-old preterm infants exhibited fewer big smiles than term infants during baseline testing, and showed a less pronounced decrease in big smiles during the still face phase of testing. Together, these results suggest that, even in infancy, preterm children respond differently to dynamic social cues than their full-term peers do.

The only other investigations that have explored aspects of life motion perception in preterm children are a series of studies utilizing stylized, biological motion displays (e.g., Pavlova et al., 2005; Taylor, Jakobson, Lewis, & Maurer, 2009). While the results of theses studies suggest that children born very prematurely have impaired biological motion perception, it is important to note that, in all of this work, only the ability to extract motion-mediated cues to global body structure was assessed. Other aspects of biological motion perception -- including the ability to extract important invariants from local biological motion cues, the ability to identify particular actions, and the ability to recognize individuals based on their unique movement styles -- have yet to be examined in children born prematurely.

Given the findings described above, the purpose of the current study was to use a multi-method and multi-sourced approach (i.e., direct assessment of social cognitive and perceptual skills, combined with parent report measures) to assess the social competence of a group of 8-to 11-year-old children born very prematurely. In three experiments, I investigated the effects of prematurity and associated complications on the processing of life motion in realistic displays (Chapter 2), in extrinsic stylized (animate motion) displays (Chapter 3), and in intrinsic stylized displays depicting either point-light walkers or moving stick figures (Chapter 4). I used dynamic stimuli to more accurately mimic real life demands. In each case, I investigated relationships between deficits in life motion perception and both social outcomes and autistic-like traits, as reported by parents. To remedy limitations in Wocadlo and Rieger (2006), a control group of full-term children was included to allow me to document impairments in my preterm sample. Overall, I hypothesize that children born at low birth weight will have impaired abilities to process all three aspects of life motion perception.

The data for all three studies were collected from the same group of participants during a single testing session that lasted approximately two hours (with a small reduction in sample size in the work described in Chapter 4, due to missing data resulting from computer error)[1]. The battery of tests included several screening measures: three visual screening measures (used to assess visual acuity, stereoacuity, and fusion); a letter cancellation task (used to assess processing speed/visual attention); the Peabody Picture Vocabulary Test - Fourth Edition (PPVT-4, Dunn & Dunn, 2007) (used to estimate verbal intelligence). In addition, parents provided demographic information (through a general information questionnaire), and completed two rating scales that provided measures of their children's social/behavioural outcomes (including the number of autistic-like traits they displayed), namely, the Autism Spectrum Quotient - Child Edition

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[1] The work described in Chapters 2-4 has already been accepted or submitted for publication, in slightly modified forms. The study described in Chapter 2 was accepted for publication in the *Journal of Child Psychology and Psychiatry,* and the study described in Chapter 3 was accepted for publication in *Development and Psychopathology*. Permission to include the modified versions of the manuscripts in my thesis was obtained from Wiley Journals via RightsLink ® and Cambridge University Press. Both of these papers are co-authored by my advisor, Dr. Lorna Jakobson, who provided advice on the study design and analysis, and played a role in editing the manuscripts. A manuscript based on the work described in Chapter 4 is currently under review for the journal *Child Neuropsychology*. In addition to Dr. Jakobson and me, this paper was co-authored by Dr. Nikolaus Troje (Queen's University) and Dr. Daniel Saunders (Harvard University). Dr. Saunders developed the biological motion test battery that was used in the experiment while he was a graduate student in Dr. Troje's laboratory. Both Dr. Saunders and Dr. Troje provided feedback on an earlier draft of the manuscript.

(Auyeung, Baron-Cohen, Wheelwright, & Allison, 2008) and the Behavior Assessment for Children - Second Edition (Reynolds & Kamphaus, 2004). All of these measures are described in detail in Chapter 2. In addition, participating children also completed several experimental measures. In Chapter 2, I describe results of testing with the Child Adolescent Social Perception Measure (CASP; Magill-Evans, Koning, Cameron-Sadava, & Manyk, 1995). In Chapter 3, I describe the results of testing with the Animated Triangles task (Abell, Happé, & Frith, 2000; Castelli, Happé, Frith & Frith, 2000). Finally, in Chapter 4, I describe the results of testing on a biological motion perception test battery comprised of four subtests (Saunders, 2011).

Each child was tested individually. After informed consent was obtained, the child's parent completed the previously mentioned questionnaires in one room, while the child completed the test battery in another. All participating children first completed the visual screening measures, followed by the cancellation task. The order of administration for the remaining measures was counterbalanced, with the exception that the subtests comprising the biological motion test battery were always administered in the following order: Detection, Direction, Action, and Identity (see Chapter 4 for details). Short rest breaks were inserted between tests to prevent fatigue. The majority of the children completed the experiment in a single two-hour testing period. The exception was one preterm male who completed the CASP during a second testing session. All families received an honorarium of $40 in appreciation of their time and research contribution.

This dissertation was written using the "*sandwich method*" in which each chapter is presented as a stand-alone paper. As such, there is some redundancy in the information provided across chapters.

CHAPTER 2 - SOCIAL PERCEPTION IN CHILDREN BORN AT VERY LOW BIRTH WEIGHT AND ITS RELATIONSHIP TO SOCIAL/BEHAVIOURAL OUTCOMES

Recently, there has been an increase in research examining emotional, behavioral, and social outcomes in children born prematurely at VLBW. Much of this work has relied on questionnaires, and while the findings generally suggest that very preterm birth is associated with problems in these areas, the results are somewhat mixed. In some studies utilizing self-report measures, children born prematurely and full-term peers have reported similar levels of attention deficit and hyperactivity disorder (ADHD), depression, delinquency/conduct disorder, low-self-esteem, and impaired peer relationships (Dahl et al., 2006; Gardner et al., 2004; Hack et al., 2005; Saigal et al., 2003b), while in others children born preterm have reported higher rates of emotional problems and depression, reduced competence in scholastic, athletic, and employment situations, and a lack of self-confidence in the context of romantic partnerships (Farooqi et al., 2007; Gardner et al., 2004; Grunau, Whitefield, & Fay, 2004). A more consistent pattern is seen in studies utilizing parent and teacher reports. Here, very premature birth has been associated with higher rates of internalizing problems (anxiety, depression, withdrawal, and somatization problems), externalizing problems (particularly attention problems), and peer/social problems (Dahl et al., 2006; Delobel-Ayoub et al., 2009; Farooqi et al., 2007; Gardner et al., 2004; Gray, Indurkhya, & McCormick, 2004; Grunau et al., 2004; Reijneveld et al., 2006; Saigal et al., 2003b).

In addition, a growing body of literature suggests an increased incidence of autistic-like traits in children born prematurely compared to full-term controls (e.g., Eaton et al., 2001; Hultman et al., 2002; Indredavik, et al., 2010; Johnson et al., 2010; Johnson & Marlow, 2009; Kuban et al., 2009; Lampi et al., 2012; Maimburg & Væth, 2006; Pinto-Martin et al., 2011; Stephens et al., 2012). Indeed, Pinto-Martin et al. (2011) suggested that there is a 5% prevalence rate of ASD within children born weighing less than 2000 g -- a rate approximately five times higher than that seen in the general population. While it is still unclear what underlies this increased risk, a range of maternal and perinatal/neonatal risk factors have been implicated (Buchmayer et al., 2009; Gardner, Spiegelman, & Buka, 2009; Glasson et al., 2004; Limperopoulos et al., 2008).

It is important for researchers, clinicians, and educators to understand the core deficits that underlie impaired the social difficulties, and other "autistic-like" symptoms, displayed by certain children born preterm. In this regard, an obvious candidate is an impairment in social perception -- the initial stage where information needed to assess another person's mental state or intentions is received, processed and interpreted (Allison et al., 2000). Social perception involves the ability to selectively attend to (Doble & Magill-Evans, 1992) and extract those verbal and nonverbal social cues most relevant in the current situation (Archer & Akert, 1977; Fichten, Tagalakis, Judd, Wright, & Amsel, 2001; McDonald, Bornhofen, Shum, Long, Saunders, & Neulinger, 2006). If an individual is unable to process and interpret these cues accurately, difficulties may arise. Indeed, research supports a link between social perceptual skills and social competence (Blanck, Buck, & Rosenthal, 1986; Custrini & Feldman, 1989; Feldman, White, & Lobato, 1982; McDonald et al., 2006).

Of particular interest in the present research are nonverbal social cues present in real life social situations, such as facial expression, body language, and vocal tone. Past research indicates that these cues are essential to interpret a verbal message (Smith, Archer, & Costanzo, 1991; Trimboli & Walker, 1993). Consider, for example, the following scenarios:

Scenario 1: *It is a sunny day and the children have gone outside for recess. James is very excited because he got a new ball for his birthday. He runs up to Allison and says, "Let's play catch". Allison's eyes open wide; she smiles and claps her hands as she says, "Sure, I would just love to play catch!"*

Scenario 2: *It is a sunny day and the children have gone outside for recess. James is very excited because he got a new ball for his birthday. He runs up to Allison and says, "Let's play catch". Allison rolls her eyes; she sighs and crosses her arms as she says, "Sure, I would just love to play catch!"*

Although the words Allison uses are exactly the same in these two scenarios, her feelings and intentions are drastically different. In scenario 1 she is very excited to play catch with James, while in scenario 2 she is not. James's ability to respond appropriately depends on how he processes and interprets the multiple nonverbal social cues Allison provides.

Despite the obvious importance of this ability, much of the research in the area of social perception has examined our ability to process cues such as facial expressions (Chan, 2009; Cheal & Rutherford, 2011; Little, Jones, & DeBruine, 2011; Grossman, 2010; Mosconi, Mack, McCarthy, & Pelphrey, 2005), gestures (Norwiki & Duke, 1994), and vocal cues (Imaizumi, Furya, & Yamazaki, 2009; Sauter, Panattoni, & Happé, 2013) individually, rather than exploring how these cues are combined with each other and additional situational cues in order to help understand an unfolding social situation. As such, more research is needed exploring how we process multiple nonverbal cues in situations that more closely approximate the real life demands placed on individuals (Koning, 1997; Trimboli & Walker, 1993).

The Present Study

Only limited research exists examining the social perceptual skills of school-age children born very prematurely. I have shown recently that children born at VLBW under-attribute intentionality to triangles that move in ways that typical viewers describe using mental state words (e.g., one triangle “coaxing” the other), and that their scores on this test are related to the number of autistic-like traits they display (see Chapter 3). In other work, Pavlova, Sokolov, Birbaumer, & Krägeloh-Mann (2008b) reported that prematurely born children with PVL showed impaired ability to perceive the intentions of others in social interactions as measured by the Event Arrangement task. Children born prematurely have also been shown to have impaired ability to process biological motion (see Chapter 4; see also Pavlova et al., 2005; Taylor et al., 2009) -- a skill widely considered a hallmark of social cognition (Pavlova, 2012).

In one recent report, Wocadlo and Rieger (2006) found that, in children born at VLBW, difficulties with social skills (assessed by parent report) were associated with problems recognizing facial expressions. They suggested that errors in decoding facial emotion might be one factor implicated in poor social skills acquisition. Two major limitations of this study were the absence of a control group of children born at term and the use of static photographs as opposed to more naturalistic, dynamic displays. To address these limitations, I assessed the social perceptual skills of well-matched samples of preterm and full-term children using the Child Adolescent Social Perception Measure

(CASP; Magill-Evans, Koning, Cameron-Sadava, & Manyk, 1995) -- a test in which children are shown videotaped vignettes of realistic social interactions and are then asked to identify the emotions of the characters and describe the nonverbal cues that convey these emotions.

The CASP has been used with a variety of different clinical groups including children with ASD, ADHD, and nonverbal learning disability (NVLD) (Castorina & Negri, 2011; Fine, Semrud-Clikemann, Butcher, & Walkowaik, 2008; Galway & Metsala, 2011; Koning & Magill-Evans, 2001; Koning, Magill-Evans, Volden, & Dick, 2011). Of particular interest for this research, individuals with ASD have been found to have impaired abilities to identify emotions and nonverbal cues, compared to control children (Koning & Magill-Evans, 2001; Koning, Magill-Evans, Volden & Dick, 2011). Here, I used this measure to gain insight into the nature of the social perceptual deficits affecting children born prematurely at VLBW. In addition, by also collecting data from parent report measures of social, behavioral and autistic-like traits I was able to explore links between social perceptual functioning and social competence in these children. Overall, I hypothesize that children born prematurely will have impaired abilities to process emotions and nonverbal cues in scenes depicting realistic life motion. I also hypothesize that these children will exhibit more adverse social/behavioural outcomes than full-term peers. Finally, I hypothesize that that risk for poor outcomes will be highest in preterm children who experienced more severe neonatal medical complications.

Materials and Methods

Participants

Participants included 34 children aged 8- to 11-years and born at VLBW, and 36 age-matched children born at term. Recruitment took place over a one-year period beginning March 2011. Thirteen of the preterm children were born weighing less than 1000 g, and three were small for gestational age (i.e., birth weight below the third percentile for gestational age). See Table 2.1 for more information concerning characteristics of the participating children.

Recruitment of children born at VLBW took place through the High-Risk Newborn Follow-Up Programs at Children's Hospital and at St. Boniface Hospital (both in Winnipeg, Manitoba), please see Appendix A for recruitment letter. The following medical variables were obtained with parental consent from neonatal medical records: birthweight, gestational age, Apgar score at 5 min, duration of mechanical ventilation and supplemental oxygen therapy (days), history of bronchopulmonary dysplasia (at 28 days), length of hospital stay (days), information regarding the presence/severity of retinopathy of prematurity (ROP), and results of neonatal cranial ultrasound and any other available brain imaging studies. Exclusion criteria used for the preterm sample included a history of major sensory impairment (e.g., blindness or deafness), and/or ventriculo-peritoneal shunting for posthemorrhagic hydrocephalus.

Full-term children were recruited through elementary schools and the community, as well as through word-of-mouth. Please see Appendix B for the full-term recruitment letter sent to elementary schools and Appendix C for the poster used for community recruitment. Inclusion criteria for the full-term children included being born within two

Table 2.1

Demographic and Screening Measures for the Full-term and Preterm Samples

	Full-term Children (*n* = 36)		Preterm Children (*n* = 34)	
Gestational Age (weeks)	Inclusion criteria specified a range of 38-42		28 (*SD* 2), range of 25-33	
Birthweight (g)	3626 (*SD* 443), range of 2523-4730		1081 (*SD* 247), range of 600-1467	
Age (years: months)	10:2 (*SD* 14.7 months), range of 8:1 to 11:11		10:0 (*SD* 15.0 months), range of 8:0 to 11:9	
Gender Distribution	17 Female; 19 Male		18 Female; 16 Male	
Handedness	5 Left; 31 Right		4 Left; 30 Right	
Parental Education (mode)	Partial or completed college/university or specialized training		Partial college/ university or specialized training	
Family Income (mode)	Over CAD $75,000		Over CAD $75,000	
Visual Acuity	20/20: 33	20/50: 0	20/20: 28	20/50: 1
	20/25: 2	20/63: 1	20/25: 5	20/63: 0
Binocular Fusion	34 Passed; 2 Failed		32 Passed; 2 Failed	
Stereoacuity	34 Passed; 2 Failed		31 Passed; 3 Failed	
Cancellation (time in s)	37.6 (*SD* 16.6)		37.3 (*SD* 14.7)	
Cancellation (errors)	0.8 (*SD* 1.1)		1.4 (*SD* 1.4)	
PPVT-4 (standard score)[a]	112.5 (*SD* 11.2)		108.4 (*SD* 12.3)	
AQ (total score)	53.7 (*SD* 12.2)		60.3 (*SD* 14.5)*	

[a] Age-corrected standard scores on the Peabody Picture Vocabulary Test, 4th edition were used to estimate verbal intelligence; see *Intellectual screening* and *Results* sections for further details.
* $p < 0.05$

weeks of their due date, without medical complications, at an appropriate size for their gestational age, and with no known history of developmental problems.

General Procedure

Before testing began, informed written consent was obtained from the parent (or legal guardian) (see Appendices D & E) and verbal consent was obtained from the participating child. The parent was then asked to complete a general information questionnaire and two questionnaires designed to assess social and behavioral outcomes in children, as described below. The participating child was asked to complete a series of screening tests, the CASP, and several other tests used for separate purposes. All tests were administered individually in a quiet room. Descriptions of each measure included in the test battery used are provided below. The Psychology/Sociology Research Ethics Board (P2010:091) at the University of Manitoba approved the research protocol.

Demographic and Screening Measures

General information questionnaire. A general information questionnaire was completed for each participating child by a parent (or legal guardian) (see Appendix F). The questionnaire asked about the child's early developmental history, and about demographic variables (such as parental education and family income) that have been linked to cognitive development in children born preterm (Braid, Donohue, & Strobino, 2012; Sommerfelt, Ellertsen, & Markestad, 1995; Voss, Jungmann, Wachtendorf, & Neubauer, 2012).

Visual screening. The Lighthouse Distance Acuity Chart was used to measure linear acuity (Lighthouse International, New York, NY). The Worth 4-Dot Test (Richmond Products, Albuquerque, NM) was used to measure binocular fusion. The

Titmus Test of Stereoacuity (Stereo Optical Company, Chicago, IL) was used to measure stereoacuity. The administration and scoring of these tasks followed standardized procedures (see Kniestedt & Stamper, 2003; Taylor et al., 2009).

Letter cancellation task (Geldmacher, 1996). Visual attention and processing speed were assessed using a letter cancellation task. In this task, the child was asked to cross out all 20 instances of a target letter "X" in an array of 100 letters. The time taken to complete the task (in s) and the number of errors were recorded.

Intellectual screening. The Peabody Picture Vocabulary Test - Fourth Edition (PPVT-4; Dunn & Dunn, 2007) was administered to each child in order to estimate verbal intelligence. This test allowed me to determine whether any difficulties experienced by the preterm children on the experimental tasks might be attributable to the presence of a general cognitive delay, or to impaired ability to comprehend task instructions. Scores on the PPVT - Third Edition (Dunn & Dunn, 1997) are highly correlated with both Full Scale IQ (r = .90) and Verbal IQ (r = .91) measured with the Wechsler Intelligence Scale for Children - Third Edition (WISC-III, Wechsler, 1991). In addition, scores on the PPVT-4 correlate highly with a measure of expressive language, the Expressive Vocabulary Test-2 (Williams, 2007). On each trial in the PPVT-4, the child is required to point to one of four pictures that correspond to a word spoken by the examiner. The task is organized into sets of words (12 in each set). Difficulty increases within and across sets. Testing continues until basal (one or no errors) and ceiling (eight or more errors) levels are found. Performance is expressed as an age-corrected standard score (M = 100, SD = 15).

Experimental Materials

Social and behavioral outcomes. Social and behavioral outcomes were assessed using two parent-rating scales: the Behavior Assessment System for Children - Second Edition (BASC-2; Reynolds & Kamphaus, 2004) and the Autism Spectrum Quotient - Child Version (AQ; Auyeung, Baron-Cohen, Wheelwright, & Allison, 2008).

The parent form of the BASC-2 includes 160 items, each rated using a four-point Likert scale (*almost always* to *never*). The BASC-2 reports two sets of outcomes: *behavioral indices* (hyperactivity, aggression, conduct problems, anxiety, depression, somatization, atypicality, withdrawal, and attention problems), and *adaptive indices* (adaptability, social skills, leadership, activities of daily living, and functional communication). Four *composite index scores* can also be derived: externalizing problems (EPI: hyperactivity, aggression and conduct problems); internalizing problems (IPI: anxiety, depression and somatization); overall behavioral symptoms (BSI: atypicality, withdrawal and attention problems) and adaptive skills (ASI: adaptability, social skills, leadership, activities of daily living and functional communication). In addition, six *behavioral content scores* (anger control, bullying, developmental social disorder, emotional self-control, executive function and negative emotionality) and one *adaptive content score* (resiliency) can also be extracted. For purposes of this research, I focused on the four composite index scores and on the developmental social disorder (DSD) content score, which have been shown in other research to be elevated in individuals with ASDs (Reynolds & Kamphaus, 2004). All of these scores are age-sex standardized and are reported as T scores (M = 50, SD =10). *Clinically significant* T scores are defined as scores of 30 and below on the ASI, and 70 and above on the remaining measures. *At-risk* T scores are defined as 31-40 on the ASI, and 60-69 on the remaining measures. The authors of the BASC-2 reported test-retest reliability from 0.87 to 0.94 (Reynolds & Kamphaus, 2004). The internal consistency of the BASC-2 (parent version) ranges from 0.80 to 0.95.

The AQ is a parent-report questionnaire that is designed to measure autistic-like traits in children ages 4-11 years, which has good test-retest reliability ($r = 0.85$, $p < .001$) and a high Cronbach's alpha of 0.97 (Auyeung et al., 2008). It is composed of 50 items assessing five broad areas associated with autism and the broader autistic phenotype. Specifically, the following areas are assessed with 10 items each: social skills, attention switching, attention to detail, communication, and imagination. The questions are answered on a 4-point Likert scale, where the parent indicates the extent to which each trait accurately describes their child, with 0 representing *definitely agree* and 3 representing *definitely disagree*. Full endorsement of all autistic-like traits results in a maximum score of 150. For purposes of the present study, I categorized individuals scoring 76 and higher as falling in the *clinically significant* range, and those with scores of 66-75 as falling in the *at risk* range. These cut-offs were selected based on previous research showing that (a) both cut-offs have excellent sensitivity and specificity (≥ 90); (b) 4.3% of controls, 95.1% of those with high functioning autism/Asperger syndrome, and 94.8% of those with autism obtain scores at or above the cut-off of 76; and (c) 9.7% of controls, 98.9% of those with high functioning autism/Asperger syndrome, and 99.5% of those with autism obtain scores at or above the cut-off of 66 (Auyeung et al., 2008).

Child and Adolescent Social Perception Measure (CASP). The CASP has good internal consistency, test-retest reliability, and inter-rater reliability (all above 0.8)

(Magill-Evans et al., 1995). The test consists of 10 videotaped scenes depicting children, adolescents and adults in typical social interactions. Each scene is audio-filtered, rendering the verbal content unintelligible but still preserving vocal tone and prosodic features. Each scene lasts from 19 to 40 s, with a mean length of 29 s. Two to four characters are presented per scene. The scenes take place in a variety of settings, such as home and school, and characters display a range of emotions (positive, negative, and neutral).

The CASP was administered and scored according to the standard procedure, and the time taken to complete the task was recorded for each child. After viewing each scene, the child was asked to describe what happened during the scene, the feelings of each character, and how they knew each character was feeling this way. From this, two scores were obtained for each child: an *emotion* score and a *nonverbal cues* score. Verbal responses were recorded and scored off-line by the primary researcher and two independent raters who were blind to group membership. After initial scoring by all raters, any discrepancies between scores were discussed and a final score was determined through group consensus. The emotion score provides a measure of the participant's ability to identify and label the emotions displayed by each character. For each emotion identified by the viewer, a nonverbal cues score is derived. The nonverbal score is based on the participant's ability to identify specific face, body, situational, and prosodic voice cues that could be used to determine the character's emotional state. Face cues include facial expressions, such as smiling or rolling the eyes. Body cues include body movements, such as leaning forward or making a hand gesture. Situational cues include aspects of the situation that would be expected to affect the character's emotional state (e.g., he is happy *because his mom gave him a gift*). Voice cues include changes in tone, inflection or rhythm. Not all of these cues are present in each scene; thus, participants' descriptions were scored according to the cues indicated in the scoring manual. In total, there were 43 face cues, 44 body cues, 28 voice cues and 20 situational cues that viewers could use to interpret the emotions displayed by different characters. Subscores were generated for each type of nonverbal cue and were expressed as a percentage of the maximum score possible for that cue. This method allowed for direct comparison across cue types.

In addition to carrying out the standard scoring (as described above), I developed a new measure to assess incidental recall of non-social information presented in the scenes: the incidental memory score. This measure was scored off-line (i.e., was based on children's recorded verbal responses). As such, the collection of these data did not in any way interfere with the standard administration of the CASP. Participants were awarded one point if their verbal description specified the correct number of characters in the scene, and one point for correctly specifying the location in which the scene took place. They could also receive from 3 to 8 additional points (depending on the scene) for correctly recalling specific visual details about the scene, including characteristics about an actor's appearance (e.g., pony tail, white shirt, glasses) or specific objects present in the environment (e.g., table, videogame, salt/pepper shaker). The total maximum score was 76. The score sheet is reproduced in Appendix G.

Results

As can be seen in Table 2.1, the preterm and full-term samples were comparable in terms of age-in-months (independent samples *t* test, $p = .49$), and had similar gender distributions ($\chi^2(1) = .23$, $p = .63$), parental education levels (Mann-Whitney U, Z = -1.82, $p = .07$), and family incomes (Mann-Whitney U, Z = -.43, $p = .67$). The incidence of left-handedness was low and similar between groups (see Table 2.1). The groups performed equally well on the cancellation task (measuring visual information processing speed/attention) and on the PPVT-4 (used to estimate verbal intelligence) (independent samples *t* tests, $p > .06$ for all comparisons). With one exception, all children in the preterm sample obtained standard scores on the PPVT-4 that fell in the average range or above (89-141); the exception was one child who obtained a standard score of 78. Preterm and full-term children had low and comparable rates of problems (5.6-8.8%) with binocular fusion and stereoacuity. Visual acuity was also comparable in the two groups, being 20/25 or better in 97% of participating children. The remaining 3% of participants (one preterm and one full-term child) had visual acuity of 20/63 or better, which is considered adequate for neuropsychological testing (Capruso, Hamsher, & Benton, 1995; Norman, Payton, Long, & Hawkes, 2004).

Child and Adolescent Social Perception

The groups did not differ in incidental memory scores, $t(68) = -1.35$, $p = .18$, but full-term children took slightly longer to complete the CASP than preterm children, $t(68) = -2.03$, $p = .046$. As both measures were positively correlated with emotion scores and with nonverbal subscores for body, voice and situational cue identification ($.28 \leq r \leq .48$) ($p < .01$ in all cases), both variables were included as covariates in subsequent analyses.

A univariate analysis of covariance (ANCOVA) performed on the CASP emotion scores produced a significant main effect of Group, $F(1, 66) = 9.41$, $p = .003$, $\eta^2 = .13$, with full-term children outperforming preterm children ($M_{full\text{-}term} = 36.8$, $SEM = 1.5$ vs.

$M_{preterm}$ = 30.2, *SEM* = 1.5). A separate analysis showed that age (in months) was positively correlated with performance in both groups ($r_{preterm} > .64$, $r_{full\text{-}term} > .69$, $p < .001$ in both cases).

The percentage of nonverbal cues of each type that were correctly identified by participants were entered into a 2 (Group: Preterm, Full-term) x 4 (Cue Type: Face, Body, Situational, Voice) mixed ANCOVA. Significant main effects of Group, $F(1, 66) = 14.08$, $p < .001$, $\eta^2 = .18$ and Cue Type, $F(3, 198) = 9.36$, $p < .001$, $\eta^2 = .12$, were observed, with full-term children outperforming preterm children, and participants being most accurate at identifying available situational cues, followed by face, voice and body cues, in that order ($p < .001$ for all comparisons). These main effects had to be interpreted in light of a significant Group x Cue Type interaction, $F(3, 198) = 2.89$, $p < .05$, $\eta^2 = .04$ (see Figure 2.1). Follow-up tests confirmed that full-term children correctly identified significantly more face, body and situational cues than preterm children did ($p < .01$, in all cases), but the groups did not differ in their ability to identify voice cues. Separate analyses confirmed that, in both groups, the ability to recognize all four cue types improved with age ($r > .34$, $p < .05$).

BASC-2

As noted earlier, for purposes of this study I was interested in comparing T scores obtained for preterm and full-term children on the four composite index scores (EPI, IPI, BSI and ASI) and the DSD content score from the BASC-2. As these scores are age-sex standardized, and as age was not significantly correlated with any of the scores, the full samples of preterm and full-term children were compared on these measures using a series of independent samples *t* tests. While the four composite index scores were

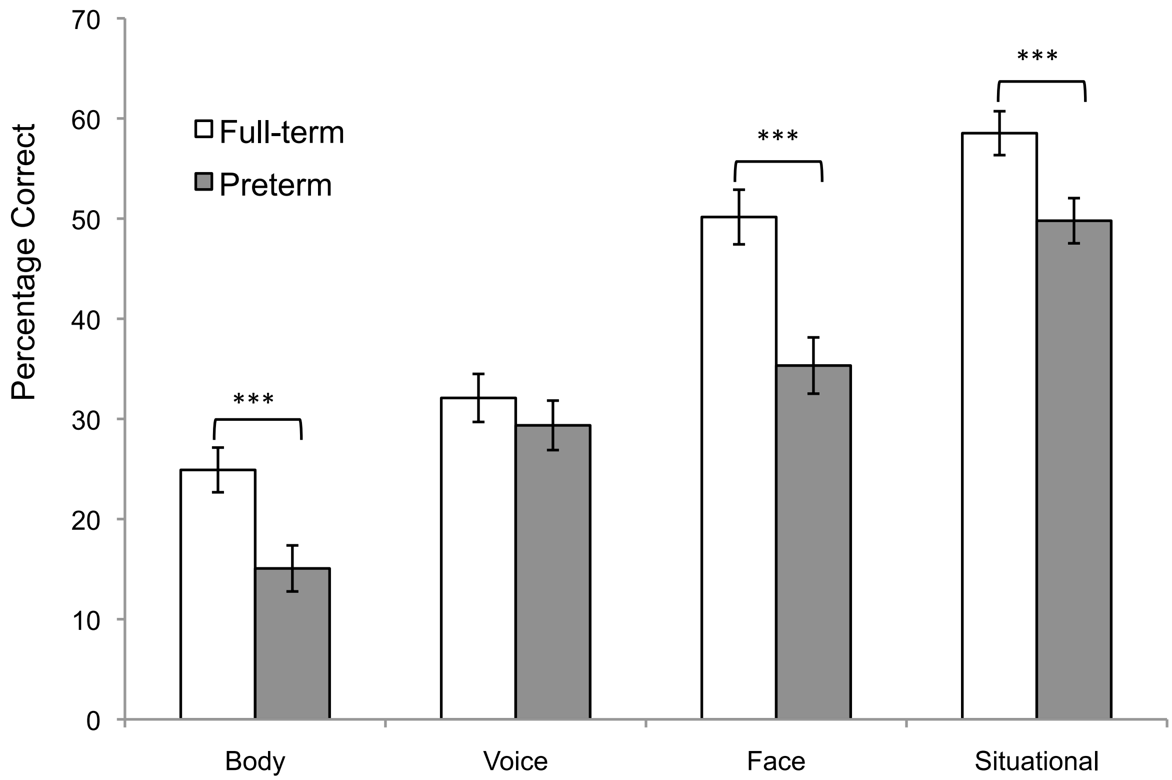

Figure 2.1 Mean percentage correct for each type of nonverbal cue in the CASP (*SEM* indicated), as a function of group membership. Follow-up tests showed group differences in the correct identification of face, body and situational nonverbal cues, with full-term children outperforming preterm children.
*** $p \leq 0.001$ level

comparable in the two groups, preterm children were rated by parents as displaying significantly more symptoms consistent with developmental social disorder than their full-term peers were, $t(68) = 2.30$, $p < .05$; $M_{preterm} = 52.5$, $SEM = 2$ vs. $M_{full\text{-}term} = 47.2$, $SEM = 1.3$.

Although mean scores for the preterm group were fairly close to the expected mean of 50 on all five measures, Mann-Whitney tests confirmed that the distribution of scores falling *within normal limits*, in the *at-risk* range, and in the *clinically significant* range was different for preterm and full-term children for the DSD content score, $Z = -2.74$, $p = .006$, with preterm children showing higher rates of impairment. While in the expected direction, the group difference for the BSI, $Z = -1.94$, $p = .052$, and the ASI, $Z = -1.80$, $p = .072$, were not statistically significant. Rates of impairment on the EPI and IPI scales did not differ in the two groups. (See Figure 2.2.)

Autism Spectrum Quotient

As scores on the AQ were not correlated with age, independent samples *t* tests were used to compare AQ scores in the full samples of preterm and full-term children. As expected, parents of preterm children reported significantly more autistic-like traits in their children than parents of full-term peers, $t(68) = 2.06$, $p < .05$ ($M_{preterm} = 60.3$, $SEM = 2.3$ and $M_{full\text{-}term} = 53.8$, $SEM = 2.3$). Of note, twelve preterm children (35.3%) scored in the *at risk/clinically significant* ranges, compared to 6 (16.7%) of the full-term children (see Figure 2.2). While in the expected direction, the group difference in distribution of scores was not statistically significant, $Z = -1.80$, $p = .072$.

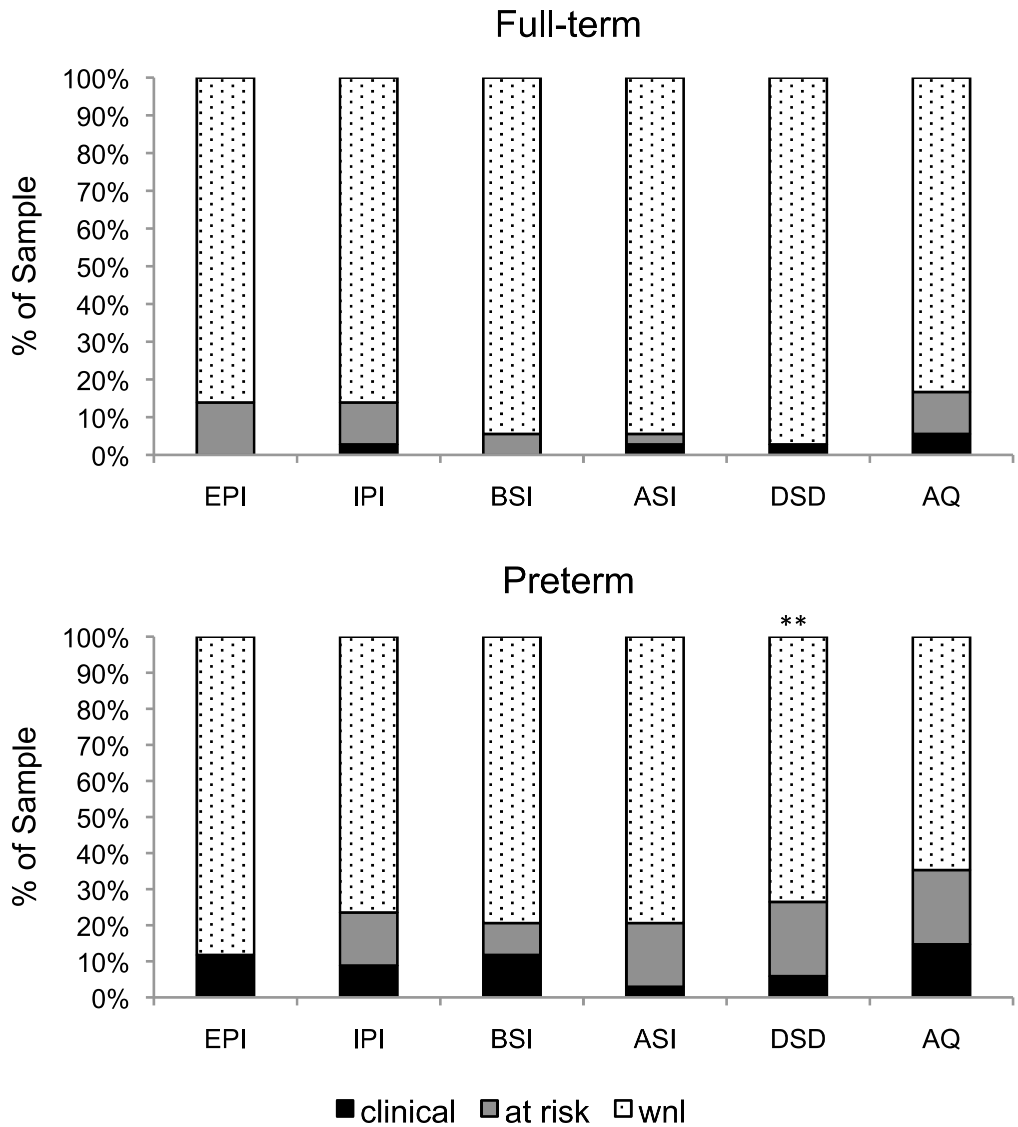

Figure 2.2 Incidence (% of sample) of T scores on the BASC-2 and AQ falling within normal limits (wnl), in the at risk range (at risk), and in the clinically significant range (clinical), for full-term and preterm children. EPI = Externalizing Problems Index score, IPI = Internalizing Problems Index score, BSI = Behavioral Symptoms Index score, ASI = Adaptive Skills Index score, DSD = Developmental Social Disorder content score, and AQ = Autism Spectrum Quotient total score.
** $p \leq 0.01$

Table 2.2

Relationships between AQ, BASC-2, and CASP scores in Full-term and Preterm Children

	DSD	EPI	IPI	BSI	ASI	Emotion	Face	Body	Situation	Voice
Full-term										
AQ	.61***	.30*	.30*	.55***	-.64***	-0.31*	-0.14	-0.38*	-0.11	-0.22
DSD	--	.49***	.33*	.80***	-0.90***	-0.14	0.11	-0.35*	-0.20	-0.31*
EPI		--	.42**	.80***	-.52***	0.18	0.10	-0.15	0.09	-0.18
IPI			--	.56***	-.37*	0.25	0.22	-0.12	-0.06	-0.19
BSI				--	-.75***	0.07	0.05	-0.31*	-0.11	-0.35*
ASI					--	0.11	-0.04	0.42***	0.23	0.23
Emotion						--	0.28	0.51***	0.39*	0.30*
Face							--	-0.03	0.17	-0.07
Body								--	0.36*	0.37*
Situation									--	-0.01
Preterm										
AQ	.75***	.50***	.64***	.75***	-.76***	-0.05	-0.25	0.02	0.45**	-0.06
DSD	--	.67***	.65***	.88***	-.87***	-0.03	-0.25	0.04	0.43**	0.07
EPI		--	.53***	.85***	-.74***	-0.03	-0.24	0.08	0.47**	0.10
IPI			--	.82***	-.74***	-0.06	-0.15	-0.05	0.40*	0.15
BSI				--	-.91***	-0.07	-0.24	0.01	0.51**	0.11
ASI					--	0.02	0.23	0.03	-0.58***	-0.09
Emotion						--	0.25	0.43**	0.38*	0.41*
Face							--	0.16	-0.13	0.17
Body								--	0.18	0.36*
Situation									--	0.24

* $p < .05$, ** $p < .01$, *** $p < .001$

Notes: AQ = Autism Spectrum Quotient total score; DSD = Developmental Social Disorder content score; EPI = Externalizing Problems Index score; IPI = Internalizing Problems Index score; BSI = Behavioral Symptoms Index score; ASI = Adaptive Skills Index score. Correlations with CASP measures control for age-in-months, administration time and incidental memory score. Correlations shown in boxes are significantly different between groups, $p < .05$, Fisher r-to-z transformation test.

Relationships Between Variables

Table 2.2 presents relationships between parent-report measures and CASP scores, in full-term and preterm children. In both groups, children displaying more autistic-like traits (higher AQ and DSD scores) were rated as showing more problems on all indices of the BASC-2, as one might expect given the pervasive nature of ASDs. However, correlations between autistic-like traits and internalizing problems were stronger in preterm than in full-term children. In full-term children, emotional and behavioral problems and autistic-like traits were most evident in those who experienced problems identifying emotions, and body cues in particular. Interestingly, in preterm children these difficulties were especially evident in those who could most *accurately* identify situational cues.

Medical Risk Factors.

By parent report, preterm children with a positive history of bronchopulmonary dysplasia had more autistic-like traits (AQ total score) and more behavioral symptoms (BSI score) than those without such a history, $t(32) > 2.07$, $p < .05$ in both cases. After controlling for age-in-months, administration time, and incidental memory, I found that children with a positive history of retinopathy of prematurity performed more poorly than those without on the CASP emotion and nonverbal situational subscores, $F(1, 25) > 4.34$, $p < .05$ in both cases. Although no differences in performance were seen in subgroups defined by the presence/absence of abnormality in brain imaging studies, it is important to note that in the majority of cases only neonatal cranial ultrasound scans were available; these scans are not sensitive enough to detect some forms of brain damage in this population (e.g., Woodward, Anderson, Austin, Howard, & Inder, 2006). Table 2.3 presents correlations between test scores and continuous medical variables. Lower Apgar scores at 5 min were associated with more parent-rated problems on all

Table 2.3

Relationships between Medical Risk Variables and Performance in the Preterm Sample

		Birth weight	Gestational Age (wks)	Apgar (5 min)	Days on Oxygen	Days on Ventilation	Length of Hospital Stay
	Emotion	0.303*	0.379*	0.453**	-0.518***	-0.434**	-0.481**
	Face	0.019	0.109	0.324*	-0.411**	-0.281	-0.28
CASP	Body	0.266	0.459**	0.052	-0.285	-0.238	-0.400**
	Situational	0.14	0.214	-0.113	-0.049	-0.133	-0.174
	Voice	0.046	0.278	0.264	-0.087	-0.266	-0.229
AQ	Total Score	0.178	-0.128	-0.139	0.169	-0.082	0.104
	DSD	0.117	-0.04	-.291*	0.055	-0.111	0.014
	EPI	0.195	-0.082	-.502***	0.124	-0.081	0.026
BASC-2	IPI	0.166	-0.087	-.308*	0.112	-0.131	0.031
	BSI	0.179	-0.093	-.417**	0.159	-0.111	0.06
	ASI	-0.232	-0.025	.406**	-0.05	0.105	0.007

* $p < .05$, ** $p < .01$, *** $p < .001$

Note: Correlation with CASP measures control for age-in-months, administration time and incidental memory score five BASC-2 measures. After controlling for age-in-months, administration time, and incidental memory, I found that CASP emotion scores and nonverbal face and body subscores were significantly correlated with several of the continuous medical variables, with children at higher medical risk performing more poorly.

Discussion

Similar to results in adolescents with Asperger Syndrome/high-functioning autism (Koning & Magill-Evans, 2001; Semrud-Clikeman, Walkowiak, Wilkinson, & Minne, 2010), children born at VLBW had impaired social perceptual abilities on the CASP. In particular, they were less able than full-term controls to correctly interpret the emotions of others, due largely to a failure to identify key nonverbal cues (facial and body movements, and situational cues) that could be used to make these determinations. It is unlikely that these difficulties are related to lowered intelligence, or to demographic factors (such as gender, family income or parental education), as the groups were matched on these variables. Similarly, they do not seem to arise from general difficulties recalling the details of the CASP scenes, as the groups received comparable scores on the incidental memory measure. I suspect that a key factor underlying these difficulties is that children born at VLBW have problems with the visual analysis of “life motion,” broadly defined. If this were the case, this would explain why these children not only show impaired processing of realistic life motion present in naturalistic, dynamic social scenes (as shown here), but also impaired processing of stylized forms of life motion -- including both the “animate motion” present in Heider-Simmel type displays (see Chapter 3; Williamson & Jakobson, in press), and the biological motion conveyed in point-light displays (see Chapter 4; see also Pavlova et al., 2005; Taylor et al., 2009).

These findings extend previous reports suggesting that preterm children show increased vulnerability in systems involved in processing moving stimuli (e.g., Downie, Jakobson, Frisk, & Ushycky, 2003; Jakobson et al., 2006; MacKay et al., 2005; Taylor et al., 2009).

It will be interesting in future work to determine if children born very prematurely have difficulties interpreting verbally presented social vignettes or whether -- like children with NVLD (Galway & Metsala, 2010) -- their difficulties are most evident with visually presented scenes. Certainly, results from my study showed intact ability to identify nonverbal *vocal* (prosodic) cues. It will also be important to track developmental changes in social perception skills in this clinical group. Although children born preterm performed worse on all visual measures, both preterm and full-term children showed age-related improvement in performance. It is unclear whether social perception skills plateau earlier in preterm children than in full-term peers (which would mean the deficits would persist), or whether they show a developmental lag (which might suggest that catch-up is still possible). Additional research utilizing more age-sensitive measures of social perceptual function, and longitudinal research designs, are needed to shed light on this issue.

An important aspect of the present research is that it included measures of social difficulties and autistic-like traits. On the BASC-2, both AQ total scores and DSD content scores on the BASC-2 (which are elevated in those on the autism spectrum) were significantly higher in preterm than in full-term children. Combined with recent research suggesting that children born prematurely have impaired ToM abilities (see Chapter 3; Williamson & Jakobson, in press), these results strengthen previous claims linking premature birth to a social-behavioral phenotype strongly suggestive of an autism spectrum disorder (Limperopoulos, 2009; Pinto-Martin et al., 2011).

A question that can only be indirectly answered by the present research relates to the nature of the relationship between social perceptual skill deficits and social outcomes in children born preterm. Several CASP measures were correlated with scores on the AQ and with particular composite and content scales on the BASC-2 (BSI, ASI and DSD) that tap into behavioral and adaptive skills deficits seen in children with ASDs. One could speculate that impaired social perceptual skills play a causal role in the social and behavioral problems experienced by children born preterm. Indeed, the fact that emotional and behavioral problems and autistic-like traits were especially evident in children born preterm who could most *accurately* identify situational cues may suggest that social difficulties in preterm children arise, in part, because -- given their impaired ability to decipher face and body cues -- they rely too heavily on situational cues to interpret social interactions. This focus on situational cues could create difficulty if another person's reaction to a given situation is unexpected; for example, if someone gets a birthday present, but finds it disappointing. Given the correlational nature of this research, however, a conclusive statement cannot be made in this regard.

Limitations

There are a number of limitations of the present study. First, my study sample was small, and it is possible that my recruitment process created some selection bias. Second, there was an over-representation of children with relatively well-educated parents from the higher income brackets. Given these factors, it is important to try to replicate the present results in larger samples that are representative of the entire cohort of surviving VLBW children.

A third limitation of the present study concerns the selection of some of the research instruments. I used the PPVT-4 to estimate verbal IQ, and the AQ-Child and the BASC-2 to quantify the number of "autistic-like" traits in study participants. Clearly, it would have been preferable to conduct a more thorough assessment of intellectual and language functions in our study participants. It would also have been beneficial to complete a comprehensive, diagnostic work-up on those children who obtained high DSD and/or AQ scores, given that elevations of these scores could be associated with poor socialization, or with a number of childhood conditions (other than ASD) that are characterized by deficits in social cognition. Nonetheless, the present results are intriguing, and suggest several avenues for future research.

Conclusion

These results of this study demonstrate that children born at VLBW have an impaired ability to extract the emotions of characters in scenes depicting naturalistic (dynamic) social interactions. This difficulty arises primarily from problems processing nonverbal cues from moving faces and bodies, and situational cues. Precisely how/if these problems contribute to, or exacerbate, emotional and behavioral problems (such as anxiety, excessive shyness, or withdrawal) remain to be seen. Further work exploring the links between these problems and the preterm autistic phenotype are warranted.

CHAPTER 3 - SOCIAL ATTRIBUTION SKILLS OF CHILDREN BORN PRETERM AT VERY LOW BIRTH WEIGHT

An increasing number of very premature infants are now surviving due to enhanced management of high risk pregnancies and advancements in neonatal medical care (Allen et al., 1993; Hoekstra et al., 2004; Horbar et al., 1993; Schwartz et al., 1994). As such, we now need, more than ever, to examine the long-term effects of very premature birth in order to improve outcomes of these survivors.

Research has shown that the smallest survivors of preterm birth face many ongoing problems. Some of the impairments with which they are confronted include physical and health-related problems such as cerebral palsy, seizures, sensorineural hearing loss, and blindness (Aylward, 2002; Foreman, Fielder, Minshell, Hurrion, & Sergienko, 1997; Goldenberg & McClure, 2010; Hellgren et al., 2007; Msall & Tremont, 2002; Saigal, Stoskopf, Streiner, & Burrows, 2001). Children born prematurely also exhibit poorer performance on tests of attention, memory, and both expressive and receptive language, and have academic struggles in the areas of reading, spelling, and mathematics (Anderson & Doyle, 2003; Bennett, 1999; Cherkes-Julkowski, 1998; Downie, Frisk, & Jakobson, 2005; Grunau, Whitfield, & Fray, 2004; Rickards et al., 1993). They are also at elevated risk for difficulties in multiple aspects of cortical visual functioning (e.g., Jakobson, Frisk, & Downie, 2006; Taylor et al., 2009), and for a range of cognitive and behavioral problems (Bhutta et al., 2002; Caravale, Tozzi, Albino, & Vicari, 2005; Delobel-Ayoub et al., 2009; Hack et al., 2005; Hille et al., 2001; Litt, Taylor, Klein, & Hack, 2005; Marlow, Wolke, Bracewell, & Samara, 2005; Moster, Lie, & Markestad, 2008; Saigal et al., 2003a).

Of particular relevance to the current study is research showing that children born at low birth weight (Dahl et al., 2006) and/or very prematurely (< 32 weeks gestation; Farooqi et al., 2007; Gardner et al., 2004; Reijneveld et al., 2006; Saigal et al., 2003b) are at greater risk than are full-term controls for social, emotional and mental health difficulties. For example, recent reports suggest that children born preterm are at elevated risk for internalizing problems, such as anxiety, depression, withdrawal and somatic complaints; problems with attention and hyperactivity; thought problems; and social difficulties (Farooqi et al., 2007; Gardner et al., 2004). They have also been shown to be at greater risk for psychiatric hospitalization in young adulthood than their peers are, and to show increased vulnerability to a range of psychiatric diagnoses, such as nonaffective psychosis, depressive disorder, and bipolar affective disorder (Nosarti et al., 2012).

In addition, although there are some contradictory findings (e.g., Bilder, Pinborough-Zimmerman, Miller, & McMahon, 2009; Croen, Grether, & Selvin, 2002), results of a number of recent studies suggest that children born preterm have a higher incidence of autistic-like traits when compared to full-term controls (e.g., Eaton et al., 2001; Hultman et al., 2002; Indredavik et al., 2010; Johnson et al., 2010; Johnson & Marlow, 2009; Kuban et al., 2009; Lampi et al., 2012; Maimburg & Væth, 2006; Pinto-Martin et al., 2011; Stephens et al., 2012). It is likely that a range of maternal and perinatal/neonatal risk factors underlie this relationship (Buchmayer et al., 2009; Gardner, Spiegelman, & Buka, 2009; Glasson et al., 2004; Limperopoulos et al., 2008). Unfortunately, many of the studies supporting an increased incidence of autistic-like traits in preterm children have relied on screening measures administered in retrospective or prospective studies (Pinto-Martin et al., 2011). Some authors caution that use of such tools may lead to high false positive rates, given the increased incidence of other impairments in preterm children (Stephen et al., 2012). It is significant, then, that in a recent study that followed children prospectively and used diagnostic tools, researchers estimated the prevalence of ASD in children born weighing < 2000 g to be 5%, which is approximately five times higher than the rate seen in the general population (Pinto-Martin et al., 2011).

Despite evidence that children born preterm are at increased risk for a behavioral phenotype similar to that seen in autism, Johnson and Marlow (2011) pointed out that the causal pathways may be different in full-term and preterm children. To date, the literature examining links between prematurity and autism has focused very much on findings obtained from behavioral and symptom checklists. It is important to extend this work by studying specific cognitive and perceptual skills in this population, to determine how deficits in particular areas may contribute to the characteristic social and behavioral profile of the preterm child. In this regard, it has been found that 6-month-old infants born prematurely have difficulties engaging in joint play and initiating joint-attention episodes with their mothers, and exhibit more gaze aversion, compared to full-term controls (Landry, 1986, 1995). Joint attention skills are thought to be important precursors to higher-order skills that are fundamental to social development (Baron-Cohen, 1991; Carpenter, Nagell, & Tomasello, 1998; Mundy & Gomes, 1998), including the ability to attribute mental states (such as beliefs, intentions or desires) to oneself and others, and to appreciate that others' mental states may differ from one's own (Premack & Woodruff, 1978). These latter abilities have been termed Theory of Mind (ToM, Premack & Woodruff, 1978), mindreading (Baron-Cohen, 1997), or mentalizing (Abu-Akel, 2003) abilities.

Much of the literature on ToM has centered on children and adults with ASDs, who exhibit a range of impairments in these skills. For example, children with autism produce fewer mental state words in their descriptions of scenarios and stories, and in natural speech patterns, when compared to neurotypical controls (Baron-Cohen, Leslie, & Frith, 1986; Tager-Flusberg, 1992). They also exhibit a lower frequency of symbolic (or pretend) play behaviors in spontaneous play (Baron-Cohen, 1987; Lewis & Boucher, 1988; Ungerer & Sigman, 1981; Wing, Gould, Yeates, & Brierley, 1977), and even high-functioning children with autism have been shown to have difficulties understanding pretense, persuasion, sarcasm, jokes, double bluffs, irony, and lies (Happé, 1994). These latter impairments are evident in a range of tasks requiring an appreciation of first- and second-order false beliefs (Baron-Cohen, 1989; Baron-Cohen, Leslie, & Frith, 1985; Leekam & Perner, 1991; Perner, Frith, Leslie, & Leekam, 1989; Reed & Peterson, 1990; Swettenham, 1996), and in other ToM tasks including, for example, Happé's Strange Stories Task (Happé, 1994), The Eyes Task (Baron-Cohen, Jolliffe, Mortimore, & Robertson, 1997a; Baron-Cohen, Wheelwright, & Jolliffe, 1997b) and the Happé-Frith animated triangles task (e.g., Abell, Happé, & Frith, 2000; Jones et al., 2011; Salter, Seigal, Claxton, Lawrence, & Skuse, 2008; White, Coniston, Rogers, & Frith, 2011; Zwickel, White, Coniston, Senju, & Frith, 2011).

The animated triangles task has been widely used as a non-verbal (visual) measure of ToM abilities. This task was based on research done by Heider and Simmel (1944) in which viewers often attributed intentionality to geometric shapes that appeared to move in a goal-directed fashion. Happé and Frith extended this task by developing three different types of animations that evoked mental state descriptions to varying degrees (Abell et al., 2000). Specifically, their task included animations depicting two triangles moving in a random manner (random displays), engaged in goal-directed activities (e.g., one shape "following" the other; goal-directed displays), or appearing to "interact" with one another or in response to environmental cues in a way that typical viewers often described using mental state words (e.g., one shape "coaxing" the other; ToM displays).

Since its introduction, the animated triangles task has been used with neurotypical viewers across a range of ages (Castelli, Happé, Frith, & Frith, 2000; Klein, Zwickel, Prinz, & Frith, 2009; Knickermeyer, Baron-Cohen, Raggatt, Taylor, & Hackett, 2006; Moriguchi, Ohnishi, Mori, Matsuda, & Komaki, 2007) and with a variety of different clinical populations including individuals with autism, Asperger's syndrome, Turner's syndrome, schizophrenia, medial frontal lobe damage, right hemisphere damage and alexithymia (Bird, Castelli, Malik, Frith, & Husain, 2004; Campbell et al., 2006; Castelli, Frith, Happé, & Frith, 2002; Koelkebeck et al., 2010; Lawrence et al., 2007; Moriguchi et al., 2006; Russel, Reynaud, Herba, Morris, & Corcoran, 2006; Weed, McGregor, Nielsen, Roepstorff, & Frith, 2010). Research involving individuals with autism has produced a fairly consistent pattern of results. Abell and colleagues (2000) found that children with autism who could pass first- and second-order false belief tasks nonetheless used fewer and less appropriate mental state terms than typically developing children when describing ToM displays, specifically. Similar results have been described in more recent work involving children (Salter et al., 2008), adolescents (Jones et al., 2011), and adults

(White et al., 2011) with autism. In addition, Zwickel and colleagues (2011) found that, in addition to offering less appropriate descriptions of ToM displays than controls, adults with autism over-attributed intentionality to the triangles in the random displays, and tended to under-attribute intentionality to the triangles in the goal-directed and ToM displays.

The Present Study

Functional neuroimaging studies have shown that viewing ToM displays is associated with increased activation in areas known to be involved in mentalizing [i.e., medial prefrontal cortex, superior temporal sulcus (STS), basal temporal regions, and extrastriate cortex (Castelli et al., 2000)]. Interestingly, abnormalities in one of these areas, the STS, have been found in both children with ASD (Pelphery & Carter, 2008; Zilbovicius et al., 2006) and those born prematurely (Dubois et al., 2008; Zubiaurre-Elorza et al., 2009). Given, I sought to examine whether children born prematurely show impaired ability to attribute intentionality in the animated triangles task, when compared to full-term, age-matched controls. I also asked whether their ability to attribute intentionality in ToM displays was related to the number of autistic-like traits they displayed, and whether either of these measures was related to specific neonatal risk factors.

Materials and Methods

Participants

The participants in this study were the same as those described in Chapter 2.

Screening Tests and Parent Report Measures

As noted in Chapter 2, as part of a larger test battery participating children completed a series of screening tests (assessing basic visual functions, processing speed/visual attention, and intelligence), and parents completed a demographic measure and the AQ. Scores on the latter questionnaire were used to quantify autistic-like traits in the children. Please see Chapter 2 for details.

Animated Triangles Task

In this task, participants were presented with a series of animations, each depicting one large red triangle and one small blue triangle, moving about within a framed white background (Abell et al., 2000; Castelli et al., 2000). Three different types of animations were presented: random, goal-directed, and ToM. As noted earlier, random displays do not typically evoke descriptions of interactions or mental states. In contrast, goal-directed displays (in which one triangle moves as though intentionally "responding" to the other's behaviour) typically evoke descriptions of specific interactions (e.g., following, fighting, chasing, dancing), while ToM displays (in which one triangle appears to intentionally act in a way designed to affect the other's "mental state") typically evoke descriptions that include mental state terms describing the action (e.g., persuading, mocking, coaxing, surprising) and/or the mental state of one or both triangles (e.g., happy, afraid). See Appendix H for an example for a ToM display.

Children completed familiarization and experimental trials, which were presented in a fixed order. A random number generator determined the fixed sequence of animations; with the provision that no more than two trials in a row were from the same condition. For the familiarization task, one practice animation of each type was presented. Participants described each scenario and corrective feedback was given. A second administration was allowed if necessary. For the experimental task, four animations were presented in each condition (12 trials in total), each lasting from 26-48 seconds. After viewing each animation the child was asked "What happened in the cartoon?" The child's verbal description of the scenario was recorded verbatim and then scored using Castelli and colleagues' (2000) protocol (see Appendix I). Responses were initially scored on three different dimensions: certainty (0-3 Likert scale, where 0 represents *long hesitations or silence*, and 3 represents *no hesitations*), appropriateness (0-3 Likert scale, where 0 represents *no answer or an answer of 'I don't know'*, and 3 represents an *appropriate and clear answer*), and intentionality (0-5 Likert scale, where 0 represents a *nondeliberate (i.e., non-goal-oriented) action*, 3 represents *a deliberate action in response to another's actions*, and 5 represents *a deliberate action taken with the explicit goal of affecting another's mental state*). It is important to note that, even though the movements of the triangles in both goal-directed and ToM displays appear to be *interactive* and *intentional*, it is only in the latter case that one triangle appears to act in a way intended to affect the *mental state* of the other. For this reason, descriptions of ToM displays would normally be expected to include mental state terms, and to receive higher "intentionality" scores than goal-directed displays (as defined in the scoring protocol). In addition to the measures mentioned above, I also recorded total word count for each participant. The primary researcher and two raters who were blind to group membership scored responses, and any discrepancies in scoring were resolved through discussion between all three raters.

Results

As noted in Chapter 2, the demographics of the two study groups were similar, as was their performance on a range of screening measures used to assess basic visual functions, processing speed/visual attention, and intellectual ability. As expected, the groups differed with regard to scores they obtained on a screening test used to measure autistic-like traits (the AQ), with parents of preterm children reporting more symptoms associated with autism in their children than parents of full-term peers. Please refer to Table 2.1 for details regarding sample demographics and the results of the screening tests.

Animated Triangles Task

It is important to note that the descriptions provided by children in the preterm sample were shorter than those provided by their peers, overall [total word count: $M_{preterm} = 488.0$, $SD = 210.58$ vs. $M_{full\text{-}term} = 632.5$, $SD = 286.48$; $t(68) = 2.39$, $p < .05$]. This variable was significantly correlated with both appropriateness and intentionality scores ($p < .05$ in both cases). For this reason, appropriateness and intentionality scores were analyzed using separate 2 (Group: Preterm, Full-term) x 3 (Display Type: Random, Goal-directed, ToM) analysis of covariance (ANCOVA) tests that controlled for total word count.

The ANCOVA on appropriateness ratings produced significant main effects of Group, $F(1,67) = 4.01$, $p < .05$, $\eta^2 = .06$, and Display Type, $F(2,134) = 5.83$, $p < 0.005$, $\eta^2 = .08$. Full-term children provided more appropriate descriptions of the animations overall ($M_{preterm} = 1.50$, $SD = .35$ vs. $M_{full\text{-}term} = 1.67$, $SD = .36$), but both groups of children found the ToM displays the hardest to describe appropriately (see Figure 3.1). The Group x Display Type interaction was not significant.

The ANCOVA on intentionality ratings produced a significant main effect of Display Type, $F(2,134) = 38.07$, $p < .001$, $\eta^2 = .36$ and a significant interaction between Display Type and Group, $F(2,134) = 9.54$, $p < .001$, $\eta^2 = .13$ (see Figure 3.2). Follow-up tests of simple main effects showed that intentionality scores increased from random to goal-directed, and from goal-directed to ToM, for both groups ($p < .001$ in all cases), as would be expected. But, more importantly, preterm children were found to over-attribute intentionality to random displays ($p = .05$), and under-attribute intentionality to ToM displays ($p < .01$), relative to full-term peers. The two groups performed similarly on the goal-directed displays ($p = .49$).

Certainty ratings on the animated triangles task were entered into a 2 (Group: Preterm, Full-term) x 3 (Display Type: Random, Goal-directed, ToM) analysis of variance (ANOVA). Total word count was not included as a covariate in this analysis as it was not correlated with certainty scores. Mean certainty ratings were very similar in the two groups ($M_{preterm} = 2.82$, $SD = .29$ vs. $M_{full\text{-}term} = 2.94$, $SD = .24$). Indeed, no significant main effects or interactions were found, suggesting that descriptions of the animations provided by children in the two groups were equally fluent (i.e., one group was not more hesitant, or prone to long pauses, than the other).

Relationships Between Variables

After controlling for total word count in the animated triangles task, I found that AQ total scores were negatively correlated with ToM intentionality scores in the full sample, $r(67) = -.24$, $p = .025$, one-tailed. This result indicates that children who

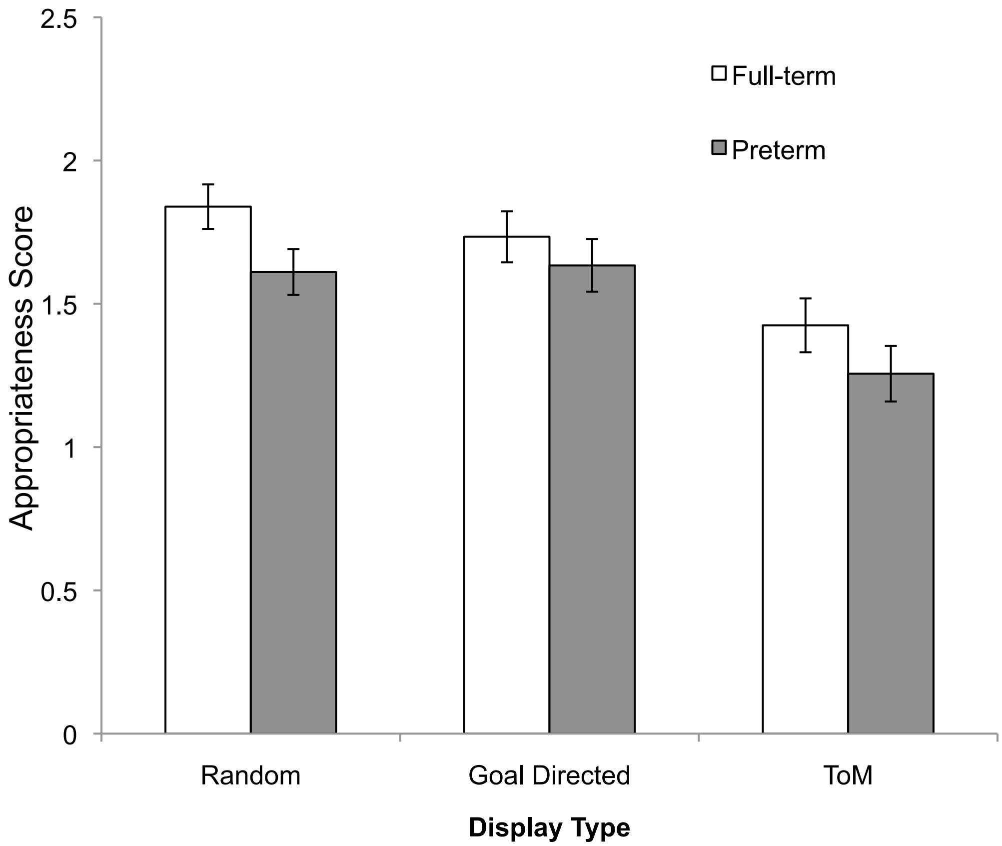

Figure 3.1 Mean (± *SEM*) appropriateness scores displayed as a function of display type (random, goal-directed and ToM) and group membership (full-term and preterm samples). Although descriptions provided by preterm children were less appropriate than those of their peers, overall, both groups found the ToM displays the most difficult to describe.

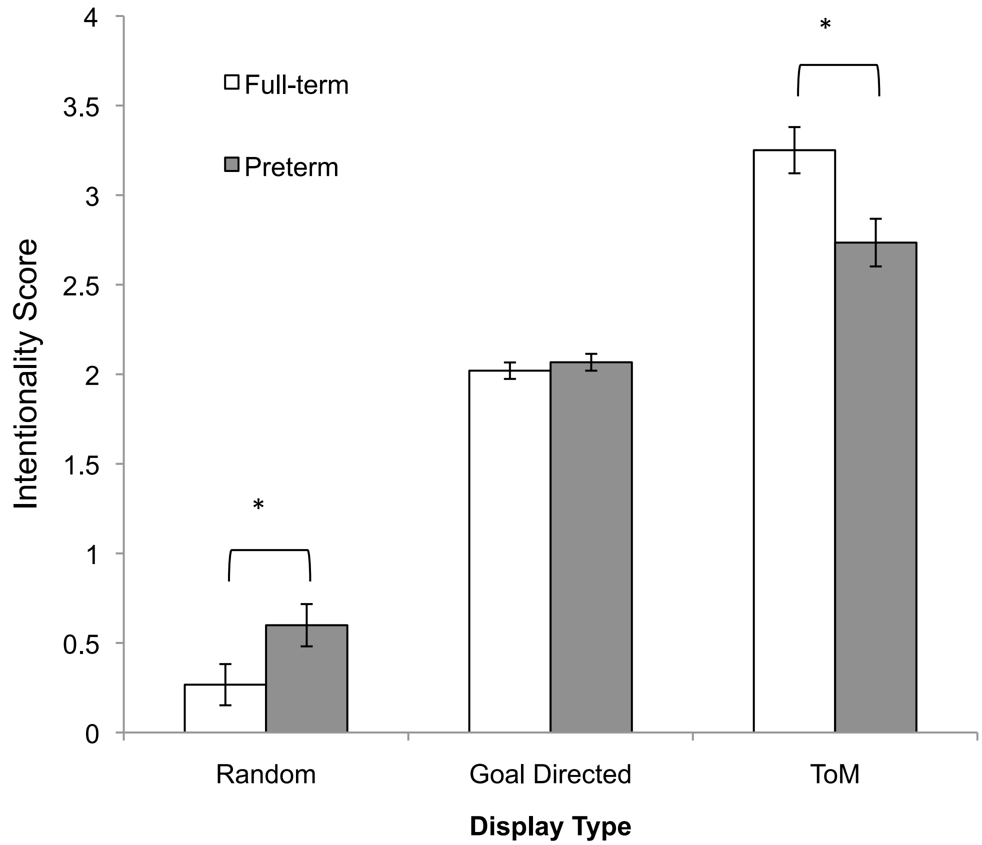

Figure 3.2 Mean (± *SEM*) intentionality scores displayed as a function of display type (random, goal-directed and ToM) and group membership (full-term and preterm samples). Preterm children over-attributed intentionality to the random displays and unattributed intentionality to the ToM displays.
* $p < 0.05$ level

displayed more autistic-like traits tended to under-attribute intentionality to the ToM displays, relative to those who displayed few autistic-like traits. Correlations between AQ total scores and intentionality scores for the random and goal-directed displays were not significant.

Age-Related Changes in the Ability to Interpret ToM Displays

To examine possible within-group, age-related changes in children's ability to interpret the ToM displays, I assessed correlations between age (in months) and both appropriateness and intentionality scores for full-term and preterm children separately. Both correlations were significant in the full-term sample [appropriateness: $r(36) = .35$, $p < .05$; intentionality: $r(34) = .65$, $p < .001$], with performance improving as a function of age. In contrast, neither correlation was significant in the preterm sample [appropriateness: $r(34) = .02$, $p = .91$; intentionality: $r(34) = -.14$, $p = .42$]. One-tailed, Fisher z tests confirmed that the difference in the strength of the correlations measured in the two groups was significant for the intentionality scores, $z = 3.66$, $p < .0001$, and was not significant for the appropriateness scores, $z = 1.38$, $p = .08$.

Medical Risk Factors

To investigate relationships between medical variables and the ability to interpret ToM displays in preterm children, I computed correlations between ToM intentionality scores and each of the continuous medical variables (birthweight, gestational age, Apgar score at 5 min, days on ventilation, days on supplemental oxygen, and length of hospital stay). Given the small sample size and the large number of correlations that were run, these results should be interpreted with caution. For the remaining dichotomous medical variables (presence/absence of bronchopulmonary dysplasia at 28 days, abnormality in brain imaging studies, and retinopathy of prematurity), I compared ToM intentionality scores of children with and without complications using independent samples *t* tests. The same sets of analyses were undertaken to explore the relationship between medical risk and AQ total scores. Even within this sample of very prematurely born children, birthweight was positively correlated with ToM intentionality scores, $r(34) = .30$, $p < .05$, one-tailed. In addition, preterm children who showed evidence of bronchopulmonary dysplasia at 28 days displayed more autistic-like traits on the AQ than those who did not, $t(32) = -2.26$, $p < .05$. No significant differences in performance were found between groups defined by the presence/absence of abnormalities in brain imaging studies or history of retinopathy of prematurity.

Discussion

The present results lend support to earlier reports indicating that children born at VLBW are at increased risk for displaying autistic-like traits (Eaton et al., 2001; Hultman et al., 2002; Indredavik et al., 2010; Johnson et al., 2010; Johnson & Marlow, 2009; Kuban et al., 2009; Lampi et al., 2012; Maimburg & Væth, 2006; Pinto-Martin et al., 2011; Stephens et al., 2012). They also extend this work by showing an association between the number of autistic-like traits identified through parental report measures, and impaired ability to attribute intentionality in a performance-based test of mentalizing skills (the animated triangles task).

The specific problems with inferring intentionality seen in the preterm sample were similar to those that have been described in individuals with ASD when completing the animated triangles task (Abell et al., 2000; Jones et al., 2011; Zwickel et al., 2011). Specifically, when compared to matched full-term controls, children born preterm used fewer mentalizing words when describing socially relevant ToM displays and more interactional terms when describing random displays. Children born preterm received comparable intentionality scores to peers when describing goal-directed displays. They also used more mentalizing words as the social meaning of the interactions increased, suggesting an underlying understanding that the scenes varied in the amount of interactional content. These observations are important as they suggest that children in the preterm sample were not completely insensitive to the manipulation. However, the fact that their descriptions were less appropriate, overall, suggests that, like children with ASD (see Zwickel et al., 2011), they use mentalizing words in a somewhat indiscriminate manner, perhaps in an effort to fulfill the assumed task requirements.

While it seems likely that problems inferring intentionality underlie the difficulties that children born preterm experienced, it is important to rule out alternative explanations for these findings. The literature suggests that processing speed, verbal intelligence and demographic variables (such as gender, family income, and maternal education) can affect performance on ToM tasks (Buitelaar, Wees, Swaab-Barneveld, & van der Gaag, 1999; Cutting & Dunn, 1999; De Sonneville et al., 2002; Happé, 1995; Milligan, Astington, & Dack, 2007; Pears & Moses, 2003). As such, it is important to highlight that the two groups in my study were matched on these variables, making it unlikely that the group differences observed were attributable to these factors. Similarly, by controlling for total word count in the analyses of intentionality and appropriateness scores, reduced the likelihood that group differences emerged simply because children born preterm offered more succinct descriptions of the animations.

Another possibility that should be considered is that the observed group differences reflect underlying problems with memory in children born preterm, as difficulties in working, spatial and episodic memory have been described in this population (e.g., Anderson & Doyle, 2004; Isaacs et al., 2000; Luciana et al., 1999; Woodward, Edgin, Thompson, & Inder, 2005). In this regard, one should note that, as part of a separate investigation, I assessed how well participants recalled details about specific objects that appeared in short video clips (19-40 s in length) depicting social interactions (see Chapter 2 for further details). Not only did children born preterm recall just as many details about objects in these scenes as their full-term peers in that study, but I confirmed that these visual memory scores were not correlated with the ToM intentionality scores they obtained in the present study, $r(34) = .19$, $p = .28$. Given this, it is unlikely that the group differences observed in the animated triangles task arose from group differences in the ability to recall details about the animations.

It will be interesting in future work to determine if/how problems with executive function contribute to difficulties in social attribution in children born preterm. Deficits in both executive function and ToM are often seen in individuals with ASD (e.g., Ozonoff, Pennington, & Rogers, 1991), but whether these deficits are linked or simply co-occur is not clear. Interestingly, Hu, Chan and McAlonan (2010) have recently shown that typical children's performance on social attribution tasks similar to the animated triangles task used here is *not* related to their performance on tests of executive function, after controlling for age and verbal IQ.

Hu et al. (2010) tested the social attribution skills of typically developing 6- to 13-year olds using a task similar to the animated triangles task used here, and a modified version of the task in which the moving figures were animals rather than geometric shapes. While the modified task was sensitive to developmental changes across the full age range of participants, performance on the conventional task only showed age-related improvement in children over the age of 9. The authors concluded that social attribution tasks involving animated shapes may be too abstract for young children, or those with developmental problems, and that difficulties appreciating the symbolic nature of the stimuli may compromise the performance of these groups. In the present study, which involved children between the ages of 8 and 11 years, I found evidence of age-related improvement in the ability to interpret ToM displays in full-term but not preterm children. Given this, it is possible that problems with symbolic representation may have contributed to the difficulties children born preterm experienced in attributing social meaning to the animations. It is also possible, however, that in these children, social attribution skills simply follow a different developmental trajectory than that seen in typical development. Longitudinal research is needed to address this question. Investigators undertaking such research should consider using less abstract social attribution tasks, such as the modified Social Attribution Task described by Hu and colleagues (2010).

A variety of other factors could contribute to difficulties with social attribution in children born preterm. For example, recent work shows that children born at VLBW are at risk for experiencing difficulties with low-level and more complex forms of motion perception (Jakobson et al., 2006; Mackay et al., 2005; Taylor & Jakobson, 2010; Taylor et al., 2009). An important focus of future research should be to determine the extent to which such problems contribute to difficulties with social attribution in this population.

One approach to this question might be to study the performance of children born preterm on a visual ToM task that uses static stimuli, such as The Eyes test (Baron-Cohen et al., 1997a). Another might be to study ToM skills in verbal tasks, such as Happé's Strange Stories Task (Happé, 1994).

Even within this sample of children born at VLBW, birth weight was related to social attribution skills, and children with a positive history of bronchopulmonary dysplasia showed more signs of autism by parent report than children without such a history. Additional research involving children born preterm across a broader range of birthweights and gestational ages may help to identify important risk markers for poor social outcomes. Research incorporating sophisticated brain-imaging techniques that can detect subtle damage or dysfunction in the preterm brain will also help in this regard. For instance, future research could map similarities and differences in brain activation patterns as preterm and full-term children watch random, goal-directed, and ToM animations. Studies of this nature may provide important insights into the causal pathway leading to problems with social perception and social cognition in children born preterm.

The results of this study make an important contribution to a growing literature showing that preterm children are at risk for social and behavioral problems similar to those seen in children with autism. More research is needed to identify the causal pathway behind these functional impairments, and to determine if it is the same as that operating in full-term children with ASD (Johnson & Marlow, 2011). The long-term goal of the present research is to improve our understanding of the development and functioning of the social brain, and to improve screening tools and clinical interventions used with populations at risk for impaired social functioning.

CHAPTER 4 - LOCAL AND GLOBAL ASPECTS OF BIOLOGICAL MOTION PERCEPTION IN CHILDREN BORN VERY PRETERM

Children born at VLBW are at increased risk for impairments in cerebral (central) visual function (e.g., Atkinson & Braddick, 2007; Atkinson et al., 2008; Cooke, Foulder-Hughes, Newsham, & Clarke, 2004; Hård, Niklasson, Svensson, & Hellstrom 2000; Jakobson, Frisk, Knight, Downie, &Whyte, 2001; Ramenghi et al., 2010). Research in the Jakobson laboratory has revealed difficulties with multiple aspects of motion perception, including reduced sensitivity to first- and second-order local motion, to global motion in random dot kinematograms (MacKay et al., 2005; Taylor et al., 2009), and to 2D motion-defined forms (Downie et al., 2003; Jakobson et al., 2006). These difficulties can co-occur with other problems associated with dysfunction in the dorsal cortical visual stream, including impaired visual search, stereopsis, visuoconstructive, and visuomotor skills (Jakobson et al., 2006). Interestingly, despite these problems, children born very prematurely often perform relatively well on tasks requiring static form perception (e.g., Jakobson et al., 2001; Taylor et al., 2009). These results are consistent with the view that the dorsal stream is more susceptible to developmental perturbations than the ventral stream -- a conclusion that gains support from numerous behavioral and neuroimaging studies (e.g., Atkinson & Braddick, 2007; Jakobson et al., 2006).

Dynamic cues are important for on-line visuomotor control and other dorsal stream functions, but they also contribute to a range of social perceptual/cognitive functions that help us understand the actions and intentions of others. In this regard, one area of visual function that has received some attention in children born preterm is biological motion perception -- the ability to recognize the movements of human and other animals based purely on information available from the movements of lights attached to the head and major joints of the body. In his pioneering research into this ability, Johansson (1973, 1976) demonstrated that human observers can recognize human actions even with exposure durations under 200 ms. Subsequent work has shown that they can also readily extract socially relevant attributes such as gender, age, and mental states (Barclay, Cutting, & Kozlowski, 1978; Bassili, 1978; Blakemore & Decety, 2001; Dittrich, 1993; Dittrich, Troscianko, Lea, & Morgan, 1996; Pollick, Paterson, Bruderline, & Sanford, 2001; Troje, 2002a, 2002b), and identify familiar individuals such as friends or family members (Cutting & Kozlowski, 1977) from these degraded displays. The saliency of these displays makes sense from an evolutionary perspective, given the importance of being able to detect conspecifics and potential predators or prey within the environment, and to identify and appropriately respond to their actions and intentions (Mather & West, 1993; Troje & Westhoff, 2006).

To date, studies examining the effects of prematurity and associated complications on the processing of biological motion stimuli have focused exclusively on the question of whether preterm children are impaired in their ability to perceptually organize point-light displays using structure-from-motion cues (Pavlova, Bidet-Ildei, Sokolov, Braun, & Krageloh-Mann, 2008a; Pavlova et al., 2006a; Pavlova, Sokolov, Birbaumer, & Krageloh-Mann, 2006b; Pavlova et al., 2005; Pavlova, Staudt, Sokolov, Birbaumer, & Krageloh-Mann, 2003; Taylor et al., 2009). In a recent study examining global processing of form and motion cues, 5- to 9-year-old preterm children born at <32 weeks gestation had higher coherence thresholds for global motion and global form perception, and reduced sensitivity to global motion cues signaling body structure in point-light displays, relative to full-term children (Taylor et al., 2009). Impairments were most marked in the tasks involving dynamic stimuli -- a result consistent with the idea of dorsal stream vulnerability.

Pavlova et al. (2003) suggested that deficits shown by preterm children in processing structure-from-motion in point-light displays are related to the presence of periventricular leukomalacia (PVL) -- the most common ischemic brain injury affecting premature infants (Volpe, 2001). Indeed, in their work, impairment in the ability to use global, structure-from-motion cues to detect a point-light walker within a field of masking dots was specifically correlated with the extent of damage to the parieto-occipital white matter (Pavlova et al., 2003). These authors suggested that PVL could interfere with performance on this task by disrupting (a) a cortical-subcortical network involved in visual binding and spatial attention; (b) white matter pathways connecting regions involved in biological motion perception, specifically; or (c) the development of the posterior cerebral cortex. One cortical region that may be implicated is the superior temporal sulcus (STS) -- an area involved in biological motion perception (e.g., Wright et al., 2003), and which shows atypical morphology in many very premature children (Zubiaurre-Elorza et al., 2009).

Despite this interesting research, it is important to note that being able to extract structure-from-motion is only one important feature of biological motion perception (Troje & Westhoff, 2006). Indeed, Troje (2008) hypothesized that four key processes are involved. The first of these is the ability to extract the local motion present in the ballistic movements of the limbs of terrestrial animals. This information provides the visual system with cues that allow us to orient towards and distinguish a moving animal from its environment quickly, without undertaking a detailed analysis of its shape (Thompson, Hansen, Hess, & Troje, 2007; Troje & Chang, 2013; Troje & Westhoff, 2006). It is suggested that once a creature is detected, the structure-from-motion mechanism comes into operation, organizing the movements of individual body parts to allow perception of an animal's structure or shape. At the next level -- action recognition -- classification and categorization of actions are achieved through the integration of structural and kinematic information. Troje proposed that the mechanism supporting these operations is designed to detect invariants and that, as such, it should operate well regardless of the particular agent, viewing conditions, or style of action. Lastly, a style recognition mechanism has been proposed to operate after the agent and action have been perceived. This mechanism is involved in pattern recognition at a subordinate level (cf. Rosch, 1988) and is used to retrieve specific information about the agent and action, such as individual identity, gender, age, emotional state, or personality traits (Troje, 2002a, 2002b; Troje, Sadr, Geyer, & Nakayama, 2006; Troje, Westhoff, & Lavrov, 2005; Westhoff & Troje, 2007). Although, to date, only the operation of the structure-from-motion mechanism has been studied in children born at VLBW, research has examined all four aspects of biological motion perception in full-term infants and children.

Biological Motion Perception in Typical Development

Developmental studies have shown that even infants are sensitive to biological motion (Arterberry & Bornstein, 2001; Bardi, Regolin, & Simion, 2011; Bertenthal, Profitt, & Cutting, 1984; Bertenthal, Profitt, Kramer, & Spetner, 1987; Bertenthal, Profitt, Spetner, & Thomas, 1985; Fox & McDaniel, 1982; Kuhlmeier, Troje, & Lee, 2010; Moore, Goodwin, George, Axelsson, & Braddick, 2007; Simion, Regolin, & Bulf, 2008).

In the first study of biological motion processing in infants, Fox and McDaniel (1982) showed that by 4 months infants prefer to view upright biological motion displays compared to inverted displays or displays depicting randomly moving dots, suggesting that they are tuned to the natural movement in these displays. Indeed, Kuhlmeier et al. (2010) have shown that 6-month-old infants can use information contained in upright (but not inverted) biological motion displays to discern the facing direction of a walker. Whether infants in these two studies were focusing on the local or the global cues present in the displays, or both, cannot be determined as both types of cues were present. Recently, however, Bardi et al. (2011) have shown that newborns spontaneously prefer biological motion sequences to rigid non-biological motion, even if the biological motion has been spatially scrambled. Similar observations have been reported in visually naïve chicks reared and hatched in darkness, who prefer displays depicting both coherent and scrambled biological motion over those depicting rigidly rotating hens or randomly moving dots (Vallortigara, Regolin, & Marconato, 2005). The preference for scrambled biological motion is significant in these studies, as it suggests an innate sensitivity to invariants contained in the local motion that support "life detection." It is not yet known when the processing of these local invariants reaches adult levels. There is, however, some evidence to suggest that the ability to use global motion cues to retrieve the shape of a moving body does not reach adult levels until 5 years of age (Pavlova, Krageloh-Mann, Sokolov, & Birbaumer, 2001).

Several studies have explored infants' and young children's ability to recognize specific actions from information contained in biological motion displays (Booth, Bertenthal, & Pinto, 2002; Golinkoff et al., 2002). Booth et al. (2002) showed that 3-

month-olds can use differences between the local movements of the limbs to discriminate between displays depicting walking and running. Golinkoff et al. (2002) showed that 3-year-olds looked longer at point-light displays depicting actions named by the investigators (e.g., walking and dancing) in a preferential looking paradigm, and were also able to supply labels for these actions. The ability to map perceived actions onto one's own body also begins to emerge early in life. Thus, Sanefuji, Ohgami, and Hashiya (2008) showed that infants could not only discriminate between point-light displays depicting walking and crawling, but also preferred actions similar to those they themselves could produce.

The fourth process that Troje (2008) described is the ability to extract information about style characteristics. Amazingly, infants aged 4-8 months have been shown to discriminate different facial expressions using information from facial point-light displays (Soken & Pick, 1992), and to discriminate between different individuals depicted in computer-generated faces differing only in their motion sequences (Spencer, O'Brien, Johnston, & Hill, 2006). But while the ability to extract information about this kind of stylistic information is clearly apparent early in life, other work suggests that this skill is still not fully developed in 4-year-olds (Doi, Kato, Hashimoto, & Masataka, 2008). These results suggest that studies charting the developmental trajectory of this ability would be useful.

The Present Study

The primary goal of the present research was to assess the impact of prematurity and associated complications on the development of all four of the processes described by Troje (2008), including not just structure-from-motion processing, but also local motion processing, action recognition and style recognition. This is important as past research suggests that distinctive patterns of intact and impaired biological motion perception abilities can be identified in certain clinical groups. For example, Parron et al. (2008) recently reported that the ability to extract emotion from whole-body point-light displays is impaired in children with autism, even though their ability to recognize specific actions and subjective states (such as feeling itchy or cold) from these displays appears to be intact.

A secondary goal of the present research was to determine whether deficits in particular aspects of biological motion perception are related to the presence of autistic-like traits. Recent reports suggest that in children born weighing < 2000 g the prevalence of ASD is 5% -- a value approximately five times higher than that seen in the general population (Pinto-Martin et al., 2011). It is important to determine how/if core deficits in social perception/cognition contribute to the development of the symptoms of autism in preterm children. Research examining these questions will not only provide important insights into the typical and atypical development of the social brain, but may also provide useful information for those involved in designing diagnostic tests and intervention strategies for use with this specific population.

Materials and Methods

Participants

With two exceptions, the participants in this study were the same as those described in Chapter 2. Data from the biological motion tasks (described below) were not collected from one full-term child due to a computer error, and data from one preterm child could not be included because that child completed a different version of the tasks than the other participants. This left a final sample of 33 children born at VLBW, and 35 age-matched controls born at term.

Screening Tests and Parent Report Measures

As noted in Chapter 2, all children completed a series of screening tests (assessing basic visual functions, processing speed/visual attention, and intelligence). In addition, parents completed a demographic measure and a measure used to assess autistic-like traits in children (the AQ). Please see Chapter 2 for details.

Biological Motion Perception Test Battery

Biological motion stimuli were presented on a PC computer, using custom-made software (http://www.biomotionlab.ca). The database includes motion-captured data from 50 male and 50 female walkers (for further information about the data acquisition and the creation of the stimuli, see Troje, 2002a). Four tasks were administered in a fixed order: Detection, Direction, Action and Identity (for full details on test construction, see Saunders, 2011).

Detection task. The walker used for this task was an 11-dot point-light figure with single dots representing the head, one shoulder, one hip, and each of the two elbows, wrists, knees and ankles. The walker was shown facing either left or right and walking in place, as if on a treadmill. Here and in the subsequent tasks, the walker's height was 4º degrees of visual angle, and it was presented on a black background using white dots that subtended 0.1º of visual angle. In each trial of the detection task, two displays were presented sequentially for 1 s each, with an inter-stimulus interval of 0.5 s. One contained a coherent walker (the target), presented within a mask derived from similarly oriented point-light figures that had been spatially scrambled. The position of the coherent walker was randomized within a 5 x 5º display window across trials. The other (non-target) display contained the same number of dots as the target display, but in this case all dots were derived from scrambled walkers. The display that contained the target (first or second) and the target's facing direction (left or right) were randomized over a total of 40 trials. On each trial, the child's task was to indicate which of the two displays contained the coherent walker. Responses were made via a key press, using the child's preferred hand. Each response was followed by a 1 s interstimulus interval, after which the next trial began. Because the scrambled-walker mask renders local motion cues uninformative, viewers must be able to extract motion cues to reveal global body structure in order to determine which display contains the target.

The number of masking dots was varied trial by trial based on the QUEST method (Watson & Pelli, 1983), an established staircase procedure that allows one to estimate a perceptual threshold in a relatively small number of trials[2]. This feature makes it useful when testing children and clinical populations, especially in cases where the viewer may have difficulty maintaining attention. In the present task, the threshold was defined as the number of noise dots that could be tolerated while maintaining an 82% correct detection rate (a performance criterion shown to result in efficient threshold estimation; King-Smith, Grigsby, Vingrys, Bene, & Supowit, 1994). Higher dot counts at criterion represent better performance.

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[2] Compared to the method of constant stimuli or staircase methods that use fixed step sizes, the QUEST procedure requires less prior knowledge of the distribution of thresholds in a given population (Watson & Fitzhugh, 1990). Test level intensity for each trial is based on a set of assumptions regarding the psychometric function, and on the participant's performance on preceding trials (see Saunders, 2011).

Direction task. The walker used for this task was a 15-dot point-light figure. This walker contained the dots used in the 11-dot figure described above, plus an additional four dots representing the sternum, the second shoulder, the center of the pelvis, and the second hip. On each trial, the walker was presented in the center of the screen and was horizontally scrambled, meaning that the location of the each dot was randomly reassigned from trial-to-trial, keeping the dot trajectory in the same vertical position but varying its position in the horizontal plane. The stimuli were also phase scrambled (i.e., the point in the step cycle was randomized). This method of scrambling was used because it disrupts any horizontal asymmetries that can be used as structural cues to direction, while maintaining the vertical structure and all the local motion features. The only cues that provide information about the walker's facing direction are contained in the local motion of individual dots (Hirai, Chang, Saunders, & Troje, 2011).

On each of 40 test trials, a walker was presented for 1 s, and the child was asked to indicate its facing direction (left or right) quickly and accurately, using a key press. The next trial began 1 s later. The direction the scrambled walker was facing was chosen between 0º (frontal view) to ± 90º (sagittal view) across trials, as determined by the QUEST procedure. Here, a sagittal walker had maximum stimulus intensity as it provided the strongest directional cues. Thus, smaller viewing angles at criterion indicated better performance. As past researchers have found this task to be more challenging than the detection task (Saunders, 2011), the criterion used to determine threshold-level performance was set at 75% correct (rather than 82% correct, as in the detection task).

Action task. In this task, stick figures displaying 10 different actions were presented, one at a time, in the center of the display. Stick figures were used instead of point-light walkers because the goal of this task was not to assess viewers' ability to perceptually organize the dots into a coherent figure, but rather to determine whether they could extract information about specific actions from degraded stimuli. The actions depicted in the task were catching a ball, climbing stairs, jumping, jumping jacks, kicking, lifting, running, sitting, throwing a ball and walking. Each action was shown from three different viewing angles [0º (frontal view), 30º, and 90º (sagittal view)], for a total of 30 randomly ordered trials. On each trial, the child chose the label that best described the action from a list of 10 descriptors. Stimuli were presented for 1 s, and responses were followed by a 1 s inter-trial interval. Proportion correct was the dependent variable.

Identity task. This test was designed to measure the child's ability to recognize and name different individuals by their unique walking styles. The task involved a memorization phase, followed by two acquisition blocks, each of which consisted of learning trials (naming) and test trials (old-new discrimination). In the memorization phase, participants were shown three different stick figures, each associated with a unique name (Lee, Joe, Raj). Each was presented for 5 s at 0º (frontal view) and at 45º, for a total of 6 trials, which were separated by inter-trial intervals of 1 s. During the naming trials of each acquisition block, the child had to indicate (with a key press) which of the three walkers was being presented. The walker remained on the screen until a button was pressed. Corrective feedback was given on each trial, and the next trial began 1 s later. The child completed 18 naming trials. During each of the 45 old-new discrimination trials comprising each acquisition block, a figure was presented in the center of the screen, and the child was asked to indicate (through a button press) if the walker currently being viewed was from the original (memorization) set or was new. Overall, during old-new discrimination testing, half of the walkers were new (with no repeats) and half were from the original set (with each walker presented an equal number of times from each viewing angle). No feedback was given during old-new discrimination testing. Hits and false alarms on the old-new discrimination trials were used to compute *d'*, which provided a measure of the child's sensitivity in this recognition task.

Results

Given that the final sample of participants was different than that taking part in the studies described in Chapters 2 and 3, I re-assessed the comparability of the two subgroups of children on the demographic and screening measures (as described below). Preterm and full-term children were similar in terms of age-in-months (independent samples *t* test), and showed similar gender distributions (Chi-squared test), parental education levels, and family incomes (Mann-Whitney U tests). Rates of left-handedness were low and similar across preterm and full-term children. Children in the two groups also showed comparable speed and accuracy on the letter cancellation task (used to assess processing speed and visual attention), and had comparable verbal intelligence, as estimated by standard scores on the PPVT-4 (independent samples *t*-tests). In addition, the groups showed comparable performance on the visual screening tests. The majority of children had 20/25 visual acuity or better (66/68 participants). The remaining two participants had adequate vision for neuropsychological testing, according to standards suggested by Capruso et al. (1995). Results of the other two visual screening measures showed both low and comparable rates of problems with binocular fusion and stereoacuity in the two groups. As before, it was only in the analysis of AQ total scores that the two groups differed significantly, with preterm children being rated by their parents as showing more autistic-like traits than full-term peers, $F(1, 66) = 5.22$, $p = .03$, $\eta^2 = .07$. See Table 4.1 for group means.

Biological Motion Perception Test Battery

As noted above, I computed thresholds for detecting biological motion in noise in the detection task (number of masking dots to achieve 82% correct detection), thresholds for discerning facing direction in the direction task (left/right deviation from the frontal view needed to achieve 75% correct discrimination of facing direction), accuracy (% correct) in the action recognition task, and sensitivity for individual walkers (*d'*) in the old-new discrimination trials of the identity task. I first looked for age-related changes in task performance by correlating age (in months) with each score; these correlations were run in each group, separately. As can be seen in Table 4.2, full-term (but not preterm) children showed age-related improvement in performance in the Action and Identity tasks, but age was not related to performance in either group in the Detection or Direction tasks. For this reason, age was considered as a second grouping factor when analyzing the data from the Action and Identity tasks only (see below). Note that, due to a computer error, data for the identity task were not collected for one 10-year-old, full-term child.

Detection task. A one-way analysis of variance (ANOVA) confirmed that full-term children were more sensitive to the presence of masked walkers than preterm children

Table 4.1

Demographic and Screening Measures for the Full-term and Preterm Samples

	Full-term Children (*n* = 35)		Preterm Children (*n* = 33)	
Gestational Age (weeks)	Inclusion criteria specified a range of 38-42		28.3 (*SD* 2.3), range of 25-33	
Birthweight (g)	3624 (*SD* 449), range of 2523-4730		1079 (*SD* 251), range of 600-1467	
Age (years: months)	10:3 (*SD* 14.8 months), range of 8:0 to 11:9		10:0 (*SD* 14.9 months), range of 8:3 to 11:11	
Gender Distribution	17 Female; 18 Male		18 Female; 15 Male	
Handedness	5 Left; 30 Right		4 Left; 29 Right	
Parental Education (mode)	Partial or completed college/university or specialized training		Partial college/ university or specialized training	
Family Income (mode)	Over CAD $75,000		Over CAD $75,000	
Visual Acuity	20/20: 32	20/50: 0	20/20: 28	20/50: 1
	20/25: 2	20/63: 1	20/25: 4	20/63: 0
Binocular Fusion	33 Passed; 2 Failed		31 Passed; 2 Failed	
Stereoacuity	33 Passed; 2 Failed		30 Passed; 3 Failed	
Cancellation (time in s) [a]	37.1 (*SD* 16.6)		37.2 (*SD* 14.9)	
Cancellation (errors) [a]	0.8 (*SD* 1.1)		1.4 (*SD* 1.4)	
PPVT-4 (standard score) [a]	112.7 (*SD* 11.3)		108.1 (*SD* 12.4)	
AQ (total score)	52.7 (*SD* 11.0)		59.8 (*SD* 14.4)*	

[a] Age-corrected standard scores on the Peabody Picture Vocabulary Test, 4th edition were used to estimate verbal intelligence; see *Intellectual screening* and *Results* sections for further details.
* $p < 0.05$

Table 4.2

Inter-correlations between Biological Motion Tasks and Age/AQ Total Scores

		Detection	Direction	Action	Identity
Age (in months)	Full-term	0.217	0.118	.315*	.560***
	Preterm	0.204	-0.058	-0.009	-0.126
AQ total	Full-term	-0.241	-0.255	-0.246	-0.137
	Preterm	-.369*	0.215	-0.105	.448**

* $p < .05$, ** $p < .01$, *** $p < .001$

Notes: Correlation with Action and Identity scores control for age (in months). Bolded box indicates significant difference between full-term and preterm correlations, $p < .05$, Fisher r-to-z transformation test.

were (i.e., they achieved the 82% correct detection threshold at higher levels of mask density) ($M_{preterm}$ = 31.9 dots, *SEM* = 3.2 vs. $M_{full\text{-}term}$ = 41.0 dots, *SEM* = 3.1), $F(1, 66) = 4.11$, $p < .05$, $\eta^2 = .06$.

Direction task. Children found the direction task quite challenging. Indeed, only 53% of the study participants were able to achieve threshold levels of performance (75% correct direction discrimination). Importantly, however, the proportion of children who were able to achieve threshold was similar in all four subgroups, $\chi^2(3) = 0.36$, $p = .95$ ($\text{Preterm}_{8\text{-}9\ years}$ = 50%; $\text{Preterm}_{10\text{-}11years}$ = 59%; $\text{Full-term}_{8\text{-}9\ years}$ = 53%; $\text{Full-term}_{10\text{-}11\ years}$ = 50%). As the analyses described below were restricted to data obtained from those children who met this performance criterion (Preterm n = 18, Full-term n = 18), I assessed whether these subgroups were well matched on all demographic measures, had comparable estimated verbal intelligence, and showed similar accuracy and completion times on the letter cancellation task; this was indeed the case. A one-way ANOVA on direction thresholds produced a significant main effect of Group, $F(1, 34) = 5.02$, $p < .05$, $\eta^2 = .13$, with preterm children needing stronger directional cues than full-term children to assess facing direction from local motion cues ($M_{preterm} = 43.0^{o}$, *SEM* = 6.1 vs. $M_{full\text{-}term} = 23.8^{o}$, *SEM* = 6.1).

Action task. To investigate age-related differences in performance on the Action task, each sample was split into subgroups of younger children (8- to 9-year olds; Full-term n = 16; Preterm n = 16) and older children (10- to 11-year olds; Full-term n = 19; Preterm n = 17). I confirmed that, with one exception, the four subgroups were well matched on all demographic and screening measures. The exception was that older children had faster processing speeds than younger children did (as measured by the cancellation task), $F(1, 64) = 8.16$, $p < .01$, $\eta^2 = .11$. Given this, I analyzed the data from the Action task using a 2 (Group: Preterm, Full-term) x 2 (Age Category: 8-9 year olds, 10-11 year olds) analysis of covariance (ANCOVA) that controlled for processing speed. This analysis only produced a significant main effect of Group, $F(1, 63) = 5.64$, $p < .05$, $\eta^2 = .08$, with preterm children being less accurate than full-term controls at identifying the actions of moving stick figures ($M_{preterm}$ = 83.5% correct, *SEM* = 1.2% vs. $M_{full\text{-}term}$ = 87.3% correct, *SEM* = 1.1%).

Identity. A 2 (Group) x 2 (Age Category) ANCOVA controlling for processing speed was conducted on *d'* scores in the Identity task. This analysis produced only a significant Group x Age Category interaction, $F(1, 62) = 12.04$, $p = .001$, $\eta^2 = .16$ (see Figure 4.1). Follow-up tests of simple main effects showed that only in the full-term samples did sensitivity to the identities of individual walkers show age-related change ($p = .002$). This resulted in a group difference in the older age category, with full-term children outperforming preterm children ($p = .001$).

Relationships Between Variables.

As can be seen in Table 4.2, AQ total scores were not correlated with scores on any of the tasks in the full-term sample. In the preterm sample, they were negatively correlated with thresholds in the Detection task and positively correlated with *d'* scores in the Identity task. In the latter case, the correlation was significantly stronger than that seen in the full-term children. These results indicate that preterm children who displayed more autistic-like traits had more difficulties detecting global biological motion but, interestingly, were *more* sensitive to idiosyncratic movement styles.

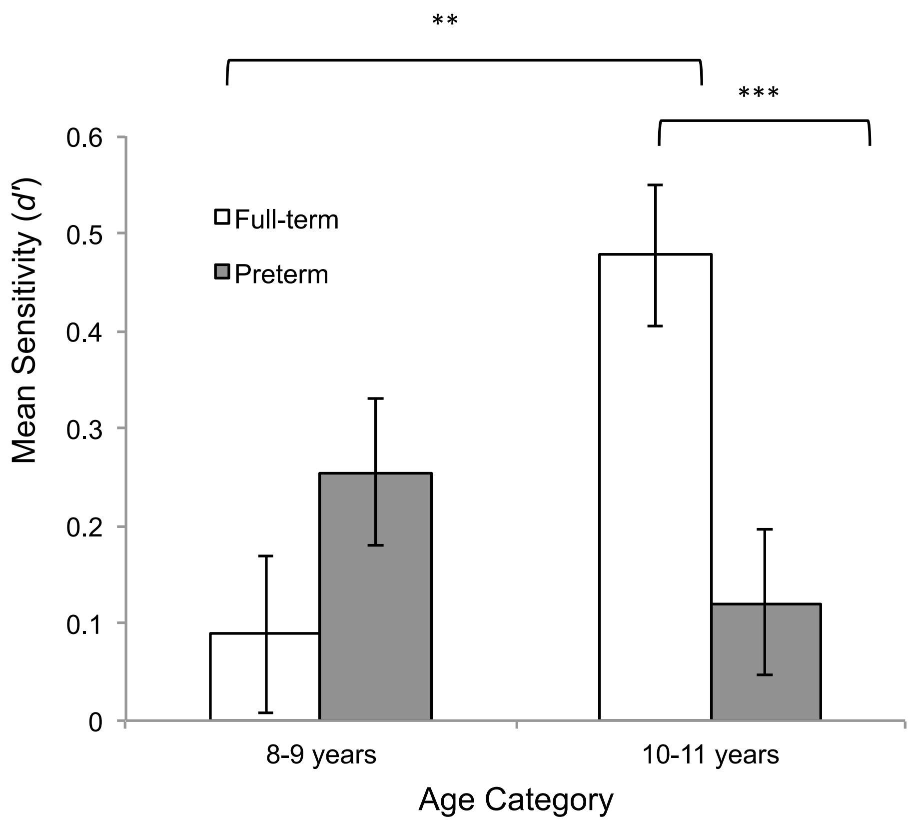

Figure 4.1 Mean *d'* scores (± *SEM*), on the Identity task displayed as a function of age and group membership. Follow-up tests of simple main effects showed age-related improvement in sensitivity in full-term children only.
** $p < 0.01$ level, *** $p < 0.001$ level

Medical Risk Factors.

To investigate relationships between medical variables and the ability to process biological motion in preterm children, I computed correlations between performance measures on the biological motion tasks and each of the continuous variables extracted from the children's medical records (birthweight, gestational age, Apgar score at 5 min, days on ventilation, days on supplemental oxygen, and length of hospital stay). For the remaining dichotomous medical variables (presence/absence of bronchopulmonary dysplasia at 28 days, abnormality in brain imaging studies, and retinopathy of prematurity), I compared scores on the biological motion tasks for children with and without complications using independent samples *t* tests. Given the small sample size and the large number of analyses that were run, these results should be interpreted with caution. However, even within this sample of very prematurely born children, days on oxygen were negatively correlated with detection threshold, $r(33) = -.31$, $p < .05$; thus, as neonatal oxygen requirements went up, sensitivity to masked walkers in childhood decreased. In the action task, better performance was seen in children who had spent fewer days on oxygen, $r(33) = -.41$, $p < .01$, or on mechanical ventilation, $r(33) = -.34$, $p < .05$, or who had shorter hospital stays, $r(33) = -.36$, $p < .05$. In addition, preterm children with a history of abnormal findings in brain imaging were less accurate at identifying actions than those with no atypical findings, $t(31) = 2.73$, $p = .01$.

Discussion

The present study examined the ability of children born preterm at VLBW to process biological motion. As has been reported in earlier work (Pavlova et al., 2003, 2005, 2006a, 2006b, 2008a; Taylor et al., 2009), children born preterm had more difficulty than full-term controls detecting a coherent walker amongst a field of scrambled walkers -- a task that requires the extraction of motion-mediated body structure. But in addition, this research extends the literature by showing that children born preterm are also impaired in their sensitivity to the visual filters that signal the presence of articulated animals and their locomotion independently of their particular shape. Furthermore, they demonstrate deficits in action recognition and they are impaired in using stylistic cues -- at least in the context of person recognition. Group differences in performance across the four biological motion tasks were not due to group differences in several key demographic variables (parental education, family income). They could also not be attributed to differences related to variables such as gender, handedness, processing speed, or verbal abilities/estimated intelligence as the groups were well matched on these variables. However, while these results suggest that premature birth and associated complications are risk factors for atypical development of the systems involved in processing biological motion, it is important to consider the potential impact of other potentially relevant variables when interpreting these results.

Although perceptual organization (structure-from-motion processing) is essential for success in the detection task, difficulties on this task could also arise from impairments in processing speed, selective attention, visual working memory, and/or figure-ground segregation. One can be fairly confident that the first three of these factors did not play a large role in the problems observed in children born preterm, as their performance on the letter cancellation task was comparable to that of full-term controls. This task requires an individual to keep a target in mind while quickly searching for instances of it within a cluttered visual display; as such, it involves all three skills noted above. At this point, it cannot be ruled out that problems with figure-ground segregation may have contributed to preterm children's poor performance on this particular task, especially given previous reports of impaired figure-ground segregation in this population (Amicuzii et al., 2006; Davis, Burns, Wilkerson, & Steichen, 2005; Hård et al., 2000). However, it is important to note that past research suggests that children born preterm are at risk for experiencing problems with a wide range of motion processing tasks, many of which do not require figure-ground segregation (Downie et al., 2003; Jakobson et al., 2006; MacKay et al., 2005; Taylor et al., 2009). This ability was also not required in the direction, action, and identity tasks included in the present test battery, in which preterm children were also impaired. Together, these observations suggest that difficulties with figure-ground segregation, if present, are unlikely to fully account for the problems this sample of preterm children experienced in the detection task, and that these reflect instead difficulties extracting motion-mediated cues to global body structure.

Tasks that examine our ability to discern the direction a walker is facing can often be solved using two very different and, to a large degree, independent sources of information, namely, motion-defined cues to body shape, and specific local motion cues (in the case of terrestrial animals with legs, the local motion of the feet appears to be critical; see Saunders, Suchan, & Troje, 2009; Troje & Chang, 2013). In the direction task, scrambled walkers were used and, as a result, participants were forced to rely solely on local motion cues present in the displays to make their directional judgments. For reasons outlined above, I suspect that many children born at VLBW in this sample had problems processing these motion cues. It is possible, however, that problems with left/right confusion and/or with distinguishing between stimuli that are mirror-images of one another may also have played a role. Indeed, research in the Jakobson laboratory does suggest that some preterm children may have subtle problems with mirror-normal discrimination (Taylor, 2008; Taylor & Jakobson, 2009, 2013). Further exploration of the role these problems may play in the processing and interpretation of biological motion, or in the ability to copy the movement of others (an important component of observational learning), would be an interesting avenue for future research.

Both local motion invariants and global (configural) motion cues convey semantic, socially relevant information that contributes to our ability to identify particular actions and individuals. In the present study, a solitary (unmasked) stick figure was used in both the action and the identity tasks. Observers were not required to perceptually organize the dots into a coherent articulated shape (as would be required with a point-light figure), or to engage in figure-ground segregation. The fact that preterm children showed impairments on these two tasks, relative to full-term controls, suggests they have difficulty detecting invariants that define particular actions, and performing the type of pattern recognition needed to retrieve specific information about the identity of the agent. However, while these skills are essential for successful performance in these tasks, the identity task also involves visual learning and memory. It is possible that problems in this area may have contributed to poor performance on the identity task, above and beyond any problems associated with pattern recognition.

Although one cannot rule out the possibility that problems in the areas described above contributed to the difficulties I observed in my preterm sample, the most parsimonious explanation for the present set of findings is that (perhaps in addition to these problems) preterm children have generalized difficulties in processing the movements of living entities. Additional support for this hypothesis comes from the fact that the same group of VLBW children studied here also show impairments on tasks requiring the analysis and interpretation of animate motion displays of the sort introduced by Heider and Simmel (1944), and naturalistic social interactions depicted in videotaped scenes (see Chapter 2 and 3 for further details). These findings extend previous reports of vulnerability in systems involved in processing dynamic cues in children born preterm (e.g., MacKay et al., 2005; Taylor et al., 2009).

One question that remains is whether preterm children improve or, indeed, "catch-up" to their peers in these areas of visual function over time. It seems unlikely that this would be the case, as age-related improvement was not evident in the present sample of VLBW children on any of the four tasks. This result complements findings from an earlier study from the Jakobson laboratory (Downie et al., 2003), which showed that deficits in 2-D structure-from-motion processing persist at least into early adolescence in children born at extremely low birthweight (< 1000 g). It would be interesting, in future work, to examine the developmental trajectory for biological motion perception abilities in children born preterm in more detail, using a longitudinal research design. As persisting impairments in this area may have important implications for the development of a range of higher-order social skills, studying how children born preterm process and utilize these social cues in everyday situations may help to explain some of the social difficulties for which they are known to be at increased risk. In support of this hypothesis, Wocadlo and Rieger (2006) found that, in children born at VLBW, problems recognizing facial expressions were associated with social skill deficits. Additional support comes from the present finding that autistic-like traits were most evident in preterm children who displayed more difficulties on the detection task. The fact that sensitivity to individual movement styles was *better* in preterm children who displayed more autistic-like traits is interesting, and may relate to the fact that autistic-like traits in children born preterm are strongly related to internalizing problems, such as anxiety and depression (see Chapter 2). It may be that children who focus heavily on the details of others' movements are also those who are most anxious, and that this places them at increased risk for social difficulties. Future research could also explore possible links between early problems with attachment and the later appearance of autistic-like traits in this population.

These results suggest that, even within a restricted sample of children born at VLBW, those with more complicated medical histories are at increased risk for deficits in different aspects of biological motion perception. At this point, it is unclear how atypical neurodevelopment and/or early brain damage contribute to these difficulties, although it seems likely that atypical development of the STS (Zubiaurre-Elorza et al., 2009), or damage to the parieto-occipital white matter (Pavlova et al., 2003), may play an important role. For the majority of children born preterm who participated in this study, the available brain imaging data consisted of results from routine, neonatal cranial ultrasound scans which are not detailed enough to reveal subtle disruptions in brain structure (Ramenghi et al., 2010). In future work, it would be interesting to apply more sophisticated brain imagining techniques in order to elucidate the neural basis of the functional impairments in biological motion perception seen in this population.

Limitations

As noted earlier, my preterm sample was small and relatively homogeneous in the sense that most of the children were right handed, came from families in the higher income brackets, and had relatively well-educated parents. They had also all escaped major intellectual disabilities. These factors may limit the generalizability of some of the findings.

A positive feature of the local motion task is that the stimuli were created using motion capture technology and, as such, the local motion cues are more naturalistic than those present in displays created using computer algorithms. Indeed, algorithms such as that originally employed by Cutting (1978) have been shown to lack invariants in the motion of the feet that are present in real walkers (Saunders et al., 2009), and that supply critically important information for making facing judgments (Troje & Westhoff, 2006). Unfortunately, the local motion task proved to be too difficult for many of the participating children, making it impossible for them to achieve threshold levels of accuracy. By limiting my analyses to data from children who reached criterion, our ability to explore relationships between task performance and other measures was limited.

I did not incorporate measures that would allow me to determine if/how problems with executive function, which affect many children born prematurely (e.g., Aarnoudse-Moens, Weisglas-Kuperus, van Goudoever, & Oosterlaan, 2009), may have contributed to difficulties in task performance. Deficits in both executive function and social perception/cognition are often seen in individuals with autism spectrum disorders (e.g., Ozonoff, Pennington, & Rogers, 1991), but whether these deficits are linked or simply co-occur in this population is not clear. Interestingly, work with typical children suggests that performance on social attribution tasks is *not* related to performance on tests of executive function, after controlling for age and verbal IQ (Hu, Chan, & McAlonan, 2010).

I controlled for individual differences in visual attention and processing speed by including processing efficiency as a covariate in our analyses. The cancellation task I used to assess processing efficiency (from Geldmacher, 1996) had a target-to-distractor ratio of 1:4. In his work with adults, Geldmacher has found that performance (errors/s) was worse for displays with a 1:4 ratio than for those with a 1:9 ratio. It is possible that my results would have changed if processing efficiency had been assessed using a different measure, but it is interesting to note that in the SFM task the children I tested achieved 82% correct detection when the target-to-noise dot ratio was close to 1:4.

Conclusion

This study makes an important contribution to the literature by demonstrating that preterm birth and associated complications put children at risk for problems with multiple aspects of biological motion processing, and that problems in this area of social perception are related to the presence of autistic-like traits. The ultimate goals of this research are to increase our understanding of the long-term consequences of prematurity, and to gain new insights into the typical and atypical development of the social brain. Advances in these areas may help to shape the development of more effective screening tools and clinical interventions for use with this and other clinical populations.

CHAPTER 5 - GENERAL DISCUSSION

Results from this doctoral thesis add to the growing body of literature examining the long-term consequences of very preterm birth, particularly with regard to outcomes related to social competence. As previously stated, children born very prematurely are at risk for emotional and behavioral problems (Aarnoudse-Moens et al., 2009; Bhutta et al., 2002; Dahl et al., 2006), peer rejection and low self-esteem (Rickards et al., 2001), and psychiatric symptoms and disorders associated with inattention, anxiety and social difficulties (Johnson, 2007). Most alarming is the fact that this group shows a high rate of ASDs (Pinto-Martin et al., 2011). The over-arching goal of my research was to examine social perception and cognition in this group in an effort to shed light on core deficits that may underlie some of these difficulties.

In the current research, I sought to further examine the ability of children born preterm to process aspects of life motion (i.e., movements of objects or people that signal animacy or agency), and how this ability relates to social outcomes. Extending previous research, the present studies have shown that children born at VLBW have impairments in various aspects of life motion perception. First, they show difficulties using nonverbal cues from moving faces and bodies to identify emotions depicted in realistic life motion displays. Second, they show a deficit in their ability to attribute intentionality on the basis of extrinsic, stylized life motion cues. Third, they show impairments not just in their ability to extract global form from biological motion in point light displays (a finding that replicates earlier results, Pavlova et al., 2003, 2005, 2006a, 2006b, 2008; Taylor et al., 2009), but also in their ability to extract directional (heading) information from local biological motion cues, to recognize actions, and to recognize particular individuals based on their familiar movement patterns. Finally, the present sample of children born preterm not only had more autistic-like traits and social difficulties than their full-term peers did, but these impairments were also associated with difficulties in the ability to process each of the different aspects of life motion mentioned above. This finding complements that of Wocadlo and Rieger (2006), who reported that impairments in the ability to recognize emotions in static facial displays were associated with social difficulties in children born preterm.

One of the strengths of this thesis is that it used a variety of research paradigms to test social cognitive abilities in the same group of children. The stimuli presented varied with respect to the number and type of cues that were available. Specifically, in the CASP, a variety of different cues were present including not only structure and motion cues from the faces and bodies of individual actors, but also voice cues, situational cues, and cues arising from the interactions *between* actors. In the animated triangles task, the rigid movement patterns of the triangles conveyed information about interactions between the shapes. Finally, in the biological motion displays, situational and interactional cues are stripped away, and form cues are either absent (direction task), degraded (in the stick figure displays used in the action and identity tasks), or must be inferred from motion-mediated cues (detection task). The motion cues, moreover, are ones derived from non-rigid motion of different body parts. By systematically manipulating the type of cues that are available, one can gain insight into the core deficits that may contribute to difficulties in social functioning in children born preterm. A larger sample size would be required to investigate interrelationships between scores on the various tasks thoroughly, but the present data suggest that carrying out this kind of investigation would be worthwhile.

The neurological basis of the problems with social perception and cognition affecting children born preterm are unclear. However, some insights may be provided by the present finding of significant relationships observed between performance on tests of life motion perception and indicators of medical risk (such as birth weight, Apgar scores, days on supplemental oxygen, etc.). In the present study, only impaired ability to recognize actions in stylized (stick figure) displays was related to the presence of a documented brain injury. Despite this result, it is reasonable to suggest that common brain insults, such as DWMI, may play a role in poor performance on many of the tests in the present battery. As previously noted, DWMI is difficult to detect using cranial ultrasound and may have been missed in many of the present cases. Indeed, it is estimated that up to 50% of children born very prematurely have DWMI (Horsch et al., 2007; Larroque et al., 2003; Volpe, 2003). In addition, previous research has shown that different aspects of motion perception are particularly vulnerable to DWMI and other insults (Back et al., 2001; Goto, Ota, Iai, Sugita, & Tanabe, 1994). In future work, it will be important to examine the impact that DWMI and other insults have on the functioning of the social brain in children born preterm, using more sophisticated brain imaging techniques (see below).

Previous research has suggested links between a range of medical variables and autistic-like traits in children born preterm (Indredavik et al., 2010; Johnson et al., 2010; Moore, Johnson, Hennessy, & Marlow, 2012). In the current investigation, lower Apgar scores were related to DSD scores on the BASC-2 and a positive history of bronchopulmonary dysplasia was related to autistic-like traits (AQ total score) and more behavioral symptoms on the BASC-2. Although the remaining medical variables were not strong predictors of autistic-like traits, they did predict deficits in social perception and cognition that, in turn, were related to AQ and DSD scores. This finding suggests that there is a complex relationship between these variables that should be further explored in larger samples.

There is a gradient of risk for autistic symptomatology in children born preterm, with those who are more likely to screen positive also being at higher risk for other difficulties, such as motor and cognitive impairments (Kuban et al., 2009; Luyster et al., 2011; Moore et al., 2012). In this regard, it is important to note that all but one of the children born at VLBW in the present sample performed in the normal range for their age on the PPVT-4, and that their intelligence (as estimated from this test) was similar to that of children in the control sample. As such, the conclusions that can be drawn from this research study are limited to children born preterm who do not have significant intellectual impairment. More research is needed to investigate social perceptual and social cognitive functioning in more globally compromised children, and to design ways to support their development. The impact of sociodemographic variables is also difficult to determine in this research, as the majority of children in both the preterm and full-term samples had well-educated parents with family incomes in the higher income brackets. This demographic limits the conclusions that can be drawn from the study..

Clinical Implications

Assessment and screening. Once the preterm infant is stabilized, efforts focus on reducing the likelihood of future disability and improving quality of life. A key aspect of this involves identifying infants who are particularly vulnerable to adverse outcomes in a timely fashion. As such, assessment and screening tools are needed that will allow us to detect even subtle impairments in preterm infants that predict poor social outcomes. In this regard, several well-established paradigms with minimal motor requirements are widely used to assess the perceptual and cognitive abilities of full-term infants. One of these, the preferential looking paradigm, involves measurement of the proportion of time that an infant devotes to a certain object of interest relative to another. This paradigm has been used successfully with full-term infants to assess sensitivity to biological motion (Bardi et al., 2011; Fox & McDaniel, 1982). Habituation paradigms have also been employed to study infants' sensitivity to biological motion (Kuhlmeier et al., 2010). In other work, changes in infants' looking preferences, and in their affect, have been measured to assess sensitivity to the gaze shifts (Symons, Hains, & Muir, 1998) and facial expressions (Montague & Walker-Andrews, 2001) of other people. Applying these different approaches to assess the early development of social information processing in infants born preterm might allow clinicians and researchers to detect early disruptions in this high-risk group.

Because many social perceptual and cognitive functions have long developmental trajectories, assessing preterm children's cerebral visual function, including their ability to process life motion, should be an important part of *preschool* and *school-age* screening or assessment batteries, as well. Developing new tools that allow for a fine-grained assessment of these skills, or applying tools that have been utilized with other groups, should be an important goal for clinicians working with children born preterm. In this regard, recently investigators have used point-light facial or whole-body displays to study how typically developing individuals and those with ASD use motion cues to enhance speech comprehension and to extract emotions or mental states (Hubert et al., 2007; Nackaerts et al., 2012; Rosenblum, Johnson, & Saldana, 1996). It would be interesting to see how children born prematurely perform on these tasks. The benefit of using point-light stimuli to access emotion recognition is that these displays allow one to isolate the impact of motion-processing problems. This could have important implications not just for clinical interpretation, but also for future test development and intervention efforts. It may be that using dynamic displays allows for more accurate assessment of, or greater sensitively to, problems in social perception in this population.

Early detection is important, as research suggests that even minor difficulties with visual function in children born prematurely can affect social competence in the long-term (Butcher, Kalverboer, Geuze, & Stremmelaar, 2002; Geva & Feldman, 2008). The ability to process animate motion, accurately attribute intentionality, and recognize and interpret nonverbal cues correctly can affect the social success of the child. If the child has problems in these areas, social situations may be difficult to navigate because they may not make sense, and/or the child may not have the tools necessary to encode and respond to the full complement of available contextual cues in an effective way. Difficulties such as these could potentially lead these children to become more socially anxious or to withdraw from social interactions, which may lead to social rejection/isolation. Problems processing life motion could also have cascading effects on the development of other skills, such as those acquired through observational learning, for example. It is important to understand the underlying basic and higher-order difficulties that these high-risk children face in order to improve the quality of their lives.

Early intervention. Research suggests that early intervention for children with developmental disabilities enhances developmental competence by preventing or minimizing developmental delays (Kirby, Swanson, Kelleher, Bradley, & Casey, 1993; Majnemer, 1998). It is thought that the timing of interventions is important. In particular, beginning intervention soon after the infant's birth has been suggested to have the most impact because the brain is very plastic at this time (Blackman, 2002; Katusic, 2011). Interventions begun when the child is already showing clear symptoms of a condition have been shown to be less beneficial than programs started earlier (Shonkoff & Hauser-Cram, 1987; Sharkey et al. 1990). Early intervention programs have been developed to enhance cognitive, motor and behavioral impairments in children at risk for developmental disability (Kirby et al., 1993; Spittle et al., 2009). Spittle et al. (2009) suggested that these interventions should be multi-faceted. In addition, it has been suggested that interventions that include psychosocial support for caregivers are associated with improved outcomes (Benzies, Magill-Evans, Hayden, & Ballantyne, 2013; Spittle et al., 2009).

Research assessing the effectiveness of interventions in children born prematurely is mixed. Specifically, Orton, Spittle, Doyle, Anderson, and Boyd (2009) reviewed early intervention programs to determine if cognitive and motor outcomes are maintained after discharge. They found that early interventions have limited effects on motor outcomes at any age. In contrast, early interventions have a positive effect on cognitive development in the short term, but the benefits of the interventions they studied were not maintained at school age. Vanderveen, Bassler, Robertson, and Kirpalani (2009) found similar results, showing clinically meaningful effects on neurodevelopment up to 24 months of age, but no difference at 5 years. Despite this finding, they argued that early intervention for at-risk children is very important, and that lasting results may be present in other outcomes not assessed, such as social interaction, health status, and the emotional functioning of parents and families.

The *Infant Health and Developmental Program* is one of the largest, multi-center randomized controlled trials that has evaluated the long-term outcomes of preterm children from two birth weight strata (Lighter LBW $\leq$ 2000g, and Heavier LBW 2001-2500g). Children participated in an educational intervention until age 3 years, and long-term outcomes were assessed at ages 5, 8 and 18 years (Brooks-Gunn, Klebanov, Liaw, & Spiker, 1993; Brooks-Gunn et al., 1994; Hill, Brooks-Gunn, & Waldfogel, 2003; McCormick et al., 2006). At 18 years, results from this study revealed overall modest benefit for children born at heavier LBW (McCormick et al., 2006). Specifically, when comparisons were adjusted for attrition, heavier LBW youth in the intervention group showed favourable outcomes on math achievement scores and verbal IQ, and self-reported fewer risky behaviors. Lower LBW youth in the intervention group were shown to have higher reading scores.

Although I am unaware of any studies examining social interventions in children born prematurely, a large body of literature has examined the benefits of early intervention on social outcomes in other clinical groups, particularly in children with ASD. For example, comprehensive intervention strategies involving Applied Behavior Analysis produce positive (medium or large) effects on the acquisition of a range of skills, including daily living skills and social functioning, in children with autism (Virués-Ortega, 2010). Other intervention approaches specifically target social skills.

Barnhill, Cook, Tebbenkamp, and Myles (2002) examined the effectiveness of social skills training in a group of adolescents with Asperger syndrome and related pervasive developmental delays. Social skills training included instruction focused on identification of facial expressions, and utilized pictures, videos without sound, the use of mirrors (to teach mimicking of facial expressions), role-playing, modeling, and reinforcement. Results revealed minimal improvements on nonverbal communication and paralanguage communication; however, it should be noted that performance was assessed using the DANVA-2, which utilizes static photographs for visual stimuli. It is possible that the use of dynamic stimuli may have provided a more sensitive measure. However, Barnhill et al. did find that the intervention led to improved development and maintenance of social relationships.

Tanaka et al. (2010) developed a program called "Let's Face It!" which is a comprehensive, interactive computer-based program consisting of static face and object stimuli. Results from a relatively short-term intervention program using this program showed improved face recognition skills in children with autism. Despite this, it has yet to be determined if these gains will be maintained and/or generalize to other settings or more naturalistic stimuli. It has only been recently that intervention tools have used dynamic and more naturalistic stimuli. Golan et al. (2010) developed an intervention tool, entitled "The Transporters," that features animated vehicles with realistic, dynamic human faces that display different emotions. Results from this study showed children who completed the intervention had better emotional comprehension and recognition skills than matched control children did. The use of such a tool within the preterm population may prove advantageous.

Future Directions

In the future, an important goal of research in this area should be to incorporate longitudinal designs. In particular, two key questions could be addressed using this approach. First, longitudinal research could address the question of whether deficits in basic visual skills predict poor long-term social outcomes, such ASD diagnoses. It would be reasonable to speculate from the findings in the current study and past research (Butcher et al., 2002; Geva & Feldman, 2008) that impairments seen in life motion perception would impact later social competence. Second, longitudinal research could determine the course of development of various aspects of visual function (as well as other functions, such as attention, processing speed, working memory, and executive functions) across time. It is presently unclear whether the impairments seen in children born prematurely are the result of delayed development, or represent true (i.e., persisting) deficits in the ability to process life motion.

Another promising area of future research involves the use of auditory/verbal measures of social cognition, such as Happé's Strange Stories Task (Happé, 1994). I have emphasized problems with life motion perception in this dissertation, but it would be important to determine whether social attribution problems in children born preterm are evident in verbal ToM tasks as well. As previously suggested, children born preterm are at risk for impairments in various aspects of receptive and expressive language (Aarnoudse-Moens et al., 2009; Anderson & Doyle, 2003; Foster-Cohen, et al., 2007; Gallagher & Watkin, 1998; Saigal et al., 2003a). It would be interesting to see if these difficulties extend to higher-level aspects of language, including those requiring ToM reasoning (e.g., the ability to understand sarcasm, irony). In addition, it will be important to investigate further preterm children's ability to process and produce nonverbal auditory cues, conveyed through changes in vocal tone, inflection or rhythm. I observed that preterm and full-term children had comparable performance when extracting prosodic voice cues in the CASP (see Chapter 2 for further details). It is possible that this ability may be less impacted by prematurity than the ability to extract visually based cues. If this were the case, then it might be worthwhile to promote the enhanced use of auditory/verbal cues as a compensation strategy for extracting social cues in children at risk for impaired social outcomes.

It would also be of interest to carry out studies directly comparing preterm and full-term children who screen positive for, or are diagnosed with, an ASD. Johnson and Marlow (2011) suggested that the "autistic phenotype" of preterm children is different from that seen in full-term children who have ASD. It is suggested that the ASD profile in preterm children is a milder form, and that these children have particular difficulties encoding and interpreting subtle social cues (Indredavik, Vik, Skranes, & Brubakk, 2008). It has also been suggested that they exhibit excessive shyness, increased withdrawal, and more difficulties establishing social contact (Elgen, Sommerfelt, & Markestad, 2002; Hille et al., 2008; Nadeau, Boivin, Tessier, Lefebvre, & Robaey, 2001). Early findings suggest that the causative pathway in preterm children may be different from that in full-term children with ASD, involving brain insults and altered neurodevelopment associated with premature birth (Johnson & Marlow, 2011; Limperopoulos, 2009). However, more research is needed to confirm this hypothesis.

Finally, as noted earlier, an extremely important area for future research would be to incorporate more sophisticated brain imaging techniques. For instance, the use of diffusion tensor imaging (DTI) might prove valuable given that it has been shown to be more sensitive than other imaging techniques to disruptions in white matter (Neil, Miller, Mukherjee, & Hüppi, 2002). This is important because research using neonatal ultrasound suggests that in children born at very low birth weight are at high risk for white matter injuries (e.g., Volpe, 2003), and the presence of such injuries significantly increases the risk that a child born at low birth weight will screen positive for, or be diagnosed with, an ASD, (Movsas et al., 2013). Other work utilizing DTI methods suggests that, even in neurotypical adults, there is a significant correlation between AQ total scores and measures of connectivity between the STS and amygdala (Iidaka, Miyakoshi, Harada, & Nakai, 2012). Using DTI would allow researchers to better understand the relationship between the location/extent of white matter pathology in preterm children and impairments in social perception. Use of structural and functional magnetic resonance imaging techniques may also shed light on how/if damage or dysfunction in areas of the social brain, such as the STS, contribute to social difficulties in preterm children. The role that cerebellar damage or dysfunction plays in the preterm "autistic phenotype" should also be further explored, given that Limperopoulos et al. (2009) have suggested that damage in this area is linked to pervasive neurodevelopmental disabilities in preterm children (such as severe motor disability, expressive and receptive language delays, cognitive deficits, severe functional limitations in daily activities, internalizing behavioral problems, and autistic-like symptoms).

Humans are innately social creatures. As such, examining the processes that allow them to function successfully in social situations is critical. In particular, understanding the differences between those individuals who have effective social skills and those who do not can provide insights into the typical processes involved in social perception and social cognition (Pelphery & Carter, 2008). In the present research, the social perceptual and cognitive skills of children born at VLBW were examined. Overall, the results from this study suggest that (a) preterm children are at risk for impairments in processing various forms of life motion, (b) these deficits are related to increased risk for atypical social development. It is particularly important to utilize this information to advance diagnostic, assessment and screening tools in an effort to improve the quality of life for these at-risk children.

References

Aarnoudse-Moens, C. S. H., Weisglas-Kuperus, N., van Goudoever, J. B., & Oosterlaan, J. (2009). Meta-analysis of neurobehavioral outcomes in very preterm and/or very low birth weight children. *Pediatrics*, *124*, 717-728. doi: 10.1542/peds.2008-2816

Abell, F., Happé, F., & Frith, U. (2000). Do triangles play tricks? Attribution of mental states to animated shapes in normal and abnormal development. *Cognitive Development, 15*, 1-16. doi: 10.1016/S0885-2014(00)00014-9

Abu-Akel, A. (2003). A neurobiological mapping of theory of mind. *Brain Research Reviews, 43*, 29-40. doi: 10.1016 / S0165-0173(03)00190-5

Achenbach T. (1991). *Manual for the Child Behavior Checklist/4-18 and 1991 Profile*. Burlington, VT: University of Vermont.

Adolphs, R. (2003). Cognitive neuroscience of human social behavior. *Nature Reviews Neuroscience, 4*, 165-178. doi: 10.1038/nrn1056

Allen, M. C., Donohue, P. K., & Dusman, A. E. (1993). The limit of viability: Neonatal outcome of infants born at 22 to 25 weeks gestation. *New England Journal of Medicine. 329*, 1597-1601. doi: 10.1056/NEJM199311253292201

Allison, T., Puce, A., & McCarthy, G. (2000). Social perception from visual cues: Role of the STS region. *Trends in Cognitive Sciences*, *4*, 267-278. doi: 10.1016/S1364-6613(00)01501-1

Ambadar, Z., Schooler, J. W., & Cohn, J. F. (2005). Deciphering the enigmatic face the importance of facial dynamics in interpreting subtle facial expressions. *Psychological Science*, *16*, 403-410. doi: 10.1111/j.0956-7976.2005.01548.x

Amicuzii, I., Stortini, M., Petrarca, M., Di Giulio, P., Di Rosa, G., Fariello, G., … Castelli, E. (2006). Visual recognition and visually guided action after early bilateral lesion of occipital cortex: A behavioral study of a 4.6-year-old girl. *Neurocase, 12*, 263-279. doi: 10.1080/13554790601026106

Anderson, P. J., & Doyle, L. W. (2003). Neurobehavioral outcomes of school-age children born extremely low birth weight or very preterm in the 1990s. *JAMA, 289*, 3264-3272. doi: 10.1001/jama.289.24.3264

Anderson, P. J., & Doyle, L. W. (2004). Executive functioning in school-aged children who were born very preterm or with extremely low birth weight in the 1990s. *Pediatrics*, *114*, 50-57. doi:10.1542/peds.114.1.50

Archer, D., & Akert, R. M. (1977). Words and everything else: Verbal and nonverbal cues in social interpretation. *Journal of Personality and Social Psychology*, *35*, 443-449. doi: 10.1037/0022-3514.35.6.443

Arterberry, M. E., & Bornstein, M. H. (2001). Three month old infants' categorization of animals and vehicles based on static and dynamic attributes. *Journal of Experimental Child Psychology, 80*, 333-346. doi: 10.1006/jecp.2001.2637

Atkinson, J., & Braddick, O. (2007). Visual and visuocognitive development in children born very prematurely. *Progress in Brain Research, 164,* 123-149. doi: 10/1016/S0079-6123(07)64007-2

Atkinson, J., Braddick, O., Anker, S., Nardini, M., Birtles, D., Rutherford, M. A., ... & Cowan, F. M. (2008). Cortical vision, MRI and developmental outcome in preterm infants. *Archives of Disease in Childhood-Fetal and Neonatal Edition*, *93*, F292-F297. doi: 10.1136/adc.2007.116988

Auyeung, B., Baron-Cohen, S., Wheelwright, S., & Allison, C. (2008). The autism spectrum quotient: Children's version (AQ-Child). *Journal of Autism and Developmental Disorders*, *38*, 1230-1240. doi: 10.1007/s10803-007-0504-z

Aylward, G. P. (2002). Cognitive and neuropsychological outcomes: More than IQ scores. *Mental Retardation and Developmental Disabilities Research Reviews, 8*, 234-240. doi: 10.1002/mrdd.10043

Back, S. A. (2006). Perinatal white matter injury: The changing spectrum of pathology and emerging insights into pathogenetic mechanisms. *Mental Retardation and Developmental Disabilities Research Reviews*, *12*, 129-140. doi: 10.1002/mrdd.20107

Back, S. A., Luo, N. L., Borenstein, N. S., Levine, J. M., Volpe, J. J., & Kinney, H. C. (2001). Late oligodendrocyte progenitors coincide with the developmental window of vulnerability for human perinatal white matter injury. *Journal of Neuroscience, 21,* 1302-1312.

Barclay, C. D., Cutting, J. E., & Kozlowski, L. T. (1978). Temporal and spatial factors in gait perception that influence gender recognition. *Perception & Psychophysics, 23*, 145-152. doi: 10.3758/BF03208295

Bardi, L., Regolin, L., & Simion, F. (2011). Biological motion preference in humans at birth: Role of dynamic and configural properties. *Developmental Science*, *14*, 353-359. doi: 10.1111/j.1467-7687.2010.00985.x

Barnhill, G. P., Cook, K. T., Tebbenkamp, K., & Myles, B. S. (2002). The effectiveness of social skills intervention targeting nonverbal communication for adolescents with Asperger syndrome and related pervasive developmental delays. *Focus on*

Autism and Other Developmental Disabilities, *17*, 112-118. doi: 10.1177/10883576020170020601

Baron-Cohen, S. (1987). Autism and symbolic play. *British Journal of Developmental Psychology, 5*, 139-148.

Baron-Cohen, S. (1989). The autistic child's theory of mind: A case of specific developmental delay. *Journal of Child Psychology and Psychiatry, 30*, 285-297. doi: 10.111/j.1469-7610.1989.tb00241.x

Baron-Cohen, S. (1991). *Precursors to a theory of mind*: *Understanding attention in others*. In A. Whiten (Ed.), Natural theories of mind: Evolution, development and simulation of everyday mindreading. (pp. 233-251). Cambridge, MA: Basil Blackwell.

Baron-Cohen, S. (1997). *Mindblindness: An essay on autism and Theory of Mind.* London: MIT Press.

Baron-Cohen, S., Leslie, A. M., & Frith, U. (1985). Does the autistic child have a "theory of mind"? *Cognition, 21,* 37-46. doi: 10.1016/0010-0277(85)90022-8

Baron-Cohen, S., Leslie, A. M., & Frith, U. (1986). Mechanical, behavioral and intentional understanding of picture stories in autistic children. *British Journal of Developmental Psychology, 4*, 113-125.

Baron-Cohen, S., Jolliffe, T., Mortimore, C., & Robertson, M. (1997a). Another advanced test of theory of mind: Evidence from very high functioning adults with autism or Asperger Syndrome. *Journal of Child Psychology and Psychiatry, 38*, 813-822.

Baron-Cohen, S., Wheelwright, S., & Jolliffe, T. (1997b). Is there a "language of the eyes"? Evidence from normal adults and adults with autism or Asperger syndrome. *Visual Cognition, 4*, 311-331. doi: 10.1080/713756761

Bassili, J. N. (1978). Facial motion in the perception of faces and of emotional expression. *Journal of Experimental Psychology: Human Perception and Performance, 4*, 373-379. doi: 10.1037/0096-1523.4.3.373

Bennett, F. C. (1999). Developmental outcome. In G. B. Avery, M. A. Fletcher, & M. G. MacDonald (Eds.), *Neonatology: Pathophysiology and management of the newborn* (5th ed., pp. 1479-1497). Philadelphia: Lippincott Williams & Wilkins.

Benzies, K. M., Magill-Evans, J. E., Hayden, K. A., & Ballantyne, M. (2013). Key components of early intervention programs for preterm infants and their parents: A systematic review and meta-analysis. *BMC Pregnancy and Childbirth*, *13*(Suppl 1), S10. doi: 10.1186/1471-2393-13-S1-S10

Berkowitz, G. S., & Papiernik, E. (1993). Epidemiology of preterm birth. *Epidemiologic Reviews*, *15*, 414-443.

Bertenthal, B. I., Profitt, D. R., & Cutting, J. E. (1984). Infant sensitivity to figural coherence in biomechanical motions. *Journal of Experiment Child Psychology, 37*, 213-230. doi: 10.1016/0022-0965(84)90001-8

Bertenthal, B. I., Profitt, D. R., Kramer, S. J., & Spetner, N. B. (1987). Infants' encoding of kinetic displays varying in relative coherence. *Developmental Psychology, 23*, 171-178. doi: 10.1037/0012-1649.23.2.171

Bertenthal, B. I., Profitt, D. R., Spetner, N. B., & Thomas, M. A. (1985). The development of infant sensitivity to biomechanical motions. *Child Development, 56*, 531-543. http://www.jstor.org/stable/1129742

Bhutta, A. T., Cleves, M. A., Casey, P. H., Cradock, M. M., & Anand, K. J. (2002). Cognitive and behavioral outcomes of school-aged children who were born preterm: A meta-analysis. *JAMA, 288*, 728-737. doi: 10.1001/jama,288.6.728

Bibby, H., & McDonald, S. (2005). Theory of mind after traumatic brain injury. *Neuropsychologia*, *43*, 99-114. doi: 10.1016/j.neuropsychologia.2004.04.027

Bierman, K. L., & Welsh, J. A. (2000). Assessing social dysfunction: The contributions of laboratory and performance-based measures. *Journal of Clinical Child Psychology, 29*, 526-539. doi: 10.1037/0003-066X.57.11.819

Bilder, D., Pinborough-Zimmerman, J., Miller, J., & McMahon, W. (2009). Prenatal, perinatal, and neonatal factors associated with autism spectrum disorders. *Pediatrics*, *123*, 1293-1300. doi: 10.1542/peds.2008-0927

Bird, C. M., Castelli, F. Malik, O., Frith, U., & Husain, M. (2004). The impact of extensive medial frontal damage on 'Theory of Mind' and cognition. *Brain, 127*, 914-928. doi: 10.1093/brain/awh108

Blackman, J. A. (2002). Early intervention: A global perspective. *Infants and Young Children, 15*, 11-19.

Blakemore, S. J., & Decety, J. (2001). From the perception of action to the understanding of intention. *Nature Reviews Neuroscience, 2*, 561-567. doi: 10.1038/35086023

Blanck, P. D., Buck, R. W., & Rosenthal, R. (1986). *Nonverbal communication in the clinical context*. University Park, PA: University of Pennsylvania Press.

Booth, A. E., Bertenthal, B. I., & Pinto, J. (2002). Perception of the symmetrical patterning of human gait by infants. *Developmental Psychology, 38*, 554-563. doi: 10.1037//0012-1649.38.4.554

Braid S., Donohue P. K., & Strobino D. M. (2012). The impact of wealth on the cognitive development of children who were preterm infants. *Advances in Neonatal Care, 2*(4), 225-231. doi: 10.1097/ANC.0b013e3182624636

Brooks‐Gunn, J., Klebanov, P. K., Liaw, F. R., & Spiker, D. (1993). Enhancing the development of low‐birthweight, premature infants: Changes in cognition and behavior over the first three years. *Child Development*, *64*, 736-753. doi: 10.1111/j.1467-8624.1993.tb02940.x

Brooks-Gunn, J., McCarton, C. M., Casey, P. H., McCormick, M. C., Bauer, C. R., Bernbaum, J. C., ... & Whitley, M. (1994). Early intervention in low-birth-weight premature infants. *The Journal of the American Medical Association*, *272*, 1257-1262. doi: 10.1001/jama.1994.03520160041040

Brüne, M. (2005). “Theory of mind” in schizophrenia: A review of the literature. *Schizophrenia Bulletin*, *31*, 21-42. doi: 10.1093/schbul/sbi002

Buchmayer, S., Johansson, S., Johansson, A., Hultman, C. M., Sparen, P., & Cnattingius, S. (2009). Can association between preterm birth and autism be explained by maternal or neonatal morbidity? *Pediatrics, 124*, e817-e825. doi: 10.1542/peds.2008-3582

Buitelaar, J. K., Wees, M. V. D., Swaab-Barneveld, H., & Gaag, R. J. V. D. (1999). Verbal memory and performance IQ predict theory of mind and emotion recognition ability in children with autistic spectrum disorders and in psychiatric control children. *Journal of Child Psychology and Psychiatry*, *40*, 869-881. doi: 10.1111/1469-7610.00505

Burd, L., Severud, R., Kerbeshian, J., & Klug, M. G. (1999). Prenatal and perinatal risk factors for autism. *Journal of Perinatal Medicine*, *27*, 441-450.

Butcher, P. R., Kalverboer, A. F., Geuze, R. H., & Stremmelaar, E. F. (2002). A longitudinal study of the development of shifts of gaze to a peripheral stimulus in preterm infants with transient periventricular echogenicity. *Journal of Experimental Child Psychology, 82*, 116-140. doi: 10.1016/S0022-0965(02)00006-1

Cacioppo, J. T. (2002). Social neuroscience: Understanding the pieces fosters understanding the whole and vice versa. *American Psychologist, 57,* 819-831. doi: 10.1037/0003-066X.57.11.819

Campbell, R., Lawrence, K., Mandy, W., Mitra, C., Jeyakuma, L., & Skuse, D. (2006). Meanings in motion and faces: Developmental associations between the processing of intention from geometrical animations and gaze detection accuracy. *Development and Psychopathology, 18*, 99-118. doi: 10.10170S0954579406060068

Canadian Institute for Health Information (2009). Too early, too small: A profile of small babies across Canada. Ottawa, Ontario: CIHI.

Capruso, D.X., Hamsher, K. deS., & Benton, A. L. (1995). Assessment of visuocognitive processes. In R. L. Mapou & J. Spector (Eds.), *Clinical neuropsychological* *assessment: A cognitive approach* (pp.137-169). New York: Plenum Press.

Caravale, B., Tozzi, C., Albino, G., & Vicari, S. (2005). Cognitive development in low risk preterm infants at 3-4 years of life. *Archives of Diseases in Childhood: Fetal and Neonatal Edition, 90,* F474-F479. doi: 10.1136/adc.2004.070284

Carpenter, M., Nagell, K., & Tomasello, M. (1998). *Social cognition, joint attention, and communicative competence from 9 to 15 months of age*. Monographs of the Society for Research in Child Development, 63, No. 4 (Serial No. 255). http://www.jstor.org/stable/1166214

Castelli, F., Frith, C., Happé, F., & Frith, U. (2002). Autism, Asperger syndrome and brain mechanisms for the attribution of mental states to animated shapes. *Brain*, *125*, 1839-1849. doi: 10.1093/brain/awf189

Castelli, F., Happé, F., Frith, U., & Frith, C. (2000). Movement and mind: A functional imaging study of perception and interpretation of complex intentional movement patterns. *NeuroImage, 12*, 314-325. doi: 10.1006/nimg.2000.0612

Castorina, L. L., & Negri, L. M. (2011). The inclusion of siblings in social skills training groups for boys with Asperger syndrome. *Journal of Autism and Developmental Disorders*, *41*, 73-81. doi: 10.1007/s10803-010-1023-x

Chan, V. (2009). The perception and recognition of emotions and facial expression. *University of Toronto Journal of Undergraduate Life Sciences*, *3*, 70-72.

Cheal, J. L., & Rutherford, M. D. (2011). Categorical perception of emotional facial expressions in preschoolers. *Journal of Experimental Child Psychology*, *110*, 434-443. doi: 10.1016/j.jecp.2011.03.007

Cherkes-Julkowski, M. (1998). Learning disability, attention-deficit disorder, and language impairments as outcomes of prematurity: A longitudinal descriptive study. *Journal of Learning Disabilities, 31*, 294-306. doi: 10.1177/002221949803100309

Cooke, R. W. I., Foulder-Hughes, L., Newsham, D., & Clarke, D. (2004). Ophthalmic impairment at 7 years of age in children born very preterm. *Archives of Disease in Childhood-Fetal and Neonatal Edition*, *89*, F249-F253. doi: 10.1136/adc.2002.023374

Counsell, S. J., Rutherford, M. A., Cowan, F. M., & Edwards, A. D. (2003a). Magnetic resonance imaging of preterm brain injury. *Archives of Disease in Childhood-Fetal and Neonatal Edition*, *88*, F269-F274. doi: 10.1136/fn.88.4.F269

Counsell, S. J., Allsop, J. M., Harrison, M. C., Larkman, D. J., Kennea, N. L., Kapellou, O., ... & Rutherford, M. A. (2003b). Diffusion-weighted imaging of the brain in preterm infants with focal and diffuse white matter abnormality. *Pediatrics*, *112*, 1-7.

Custrinic, R. J., & Feldman, R. S. (1989). Children's social competence and nonverbal encoding and decoding of emotions. *Journal of Clinical Child Psychology, 18*, 336-342. doi: 10.1207/s15374424jccp1804_7

Cutting, A. L., & Dunn, J. (1999). Theory of mind, emotion understanding, language, and family background: Individual differences and interrelations. *Child Development*, *70*, 853-865. doi: 10.1111/1467-8624.00061

Cutting, J. E. (1978). A program to generate synthetic walkers as dynamic point-light displays. *Behavior Research Methods and Instrumentation*, *10*, 91-94.

Cutting, J. E., & Kozlowski, L. T. (1977). Recognizing friends by their walk: Gait perception without familiarity cues. *Bulletin of the Psychonomic Society, 9*, 353-356.

Crick, N. R., & Dodge, K. A. (1994). A review and reformulation of social information-processing mechanisms in children's social adjustment. *Psychological Bulletin*, *115*, 74-101. doi: 10.1037/0033-2909.115.1.74

Croen, L. A., Grether, J. K., & Selvin, S. (2002). Descriptive epidemiology of autism in a California population: who is at risk? *Journal of Autism and Developmental Disorders*, *32*, 217-224. doi: 10.1023/A:1015405914950

Dahl, L. B., Kaaresen, P. I., Tunby, J., Handegard, B. H., Kvernmo, S., & Ronning, J. A. (2006). Emotional, behavioral, social and academic outcomes in adolescents born with very low birth weight. *Pediatrics, 118*, e449-459. doi: 10.1542/peds.2005-3024

Davis, D. W., Burns, B. M., Wilkerson, S. A., & Steichen, J. J. (2005). Visual perceptual skills in children born with very low birth weights. *Journal of Pediatric Health Care*, *19*, 363-368. doi: 10.1016/j.pedhc.2005.06.005

De Sonneville, L. M. J., Verschoor, C. A., Njiokiktjien, C., het Veld, V. O., Toorenaar, N., & Vranken, M. (2002). Facial identity and facial emotions: Speed, accuracy, and processing strategies in children and adults. *Journal of Clinical and Experimental Neuropsychology*, *24*, 200-213. doi: 10.1076/jcen.24.2.200.989

Delobel-Ayoub, M., Arnaud, C., White-Koning, M., Casper, C., Pierrat, V., Garel, M., … Larroque, B. (2009). Behavioral problems and cognitive performance at 5 years of age after very preterm birth: The EPIPAGE study. *Pediatrics, 123*, 1485-1492. doi: c10.1542/peds.2008-1216

Dittrich, W. H. (1993). Action categories and the perception of biological motion. *Perception, 22*, 15-22. doi: 10.1068/p220015

Dittrich, W. H., Troscianko, T., Lea, S. E. G., & Morgan, D. (1996). Perception of emotion from dynamic point-light displays represented in dance. *Perception, 25*, 727-738. doi: 10.1068/p250727

Doble, S. E., & Magill-Evans, J. (1992). A model of social interaction to guide occupational therapy practice. *Canadian Journal of Occupational Therapy*, *59*, 141-150. doi: 10.1177/000841749205900304

Dodge, K. A. (1985). Facets of social interaction and the assessment of social competence in children. In B. Schneider, K.H. Rubin, & J. Ledingham (Eds.), *Children's peer relations: Issues in assessment and intervention* (pp. 3-22). New York: Springer-Verlag. doi: 10.1007/978-1-4684-6325-5_1

Dodge, K. A. (1986). A social information processing model of social competence in children. In *The Minnesota Symposium on Child Psychology (Vol. 18, pp. 77-125)*, Hillsdale, NJ: Lawrence Erlbaum Associates.

Doi, H., Kato, A., Hashimoto, A., & Masataka, N. (2008). Role of biological-motion information in recognition of facial expressions by young children. *Perception, 37*, 1399-1411. doi: 10.1068/p5673

Downie, A. L. S., Frisk, V., & Jakobson, L. S. (2005). The impact of periventricular brain injury on reading and spelling abilities in late elementary and adolescent years. *Child Neuropsychology, 11*, 479-495. doi: 10.1080/09297040591001085

Downie, A. L., Jakobson, L. S., Frisk, V., & Ushycky, I. (2003). Periventricular brain injury, visual motion processing, and reading and spelling abilities in children who were extremely low birthweight. *Journal of the International Neuropsychological Society*, *9*, 440-449. doi: 10.1017/S1355617703930098

Dubois, J., Benders, M., Cachia, A., Lazeyras, F., Leuchter, R. H-V., Sizonenko, S. V., … Huppi, P. S. (2008). Mapping in early cortical folding process in the preterm newborn brain. *Cerebral Cortex, 18*, 1444-1454. doi:10.1093/cercor/bhm180

Dunn, L. M., & Dunn, D. M. (1997). *Peabody Picture Vocabulary Test - Third Edition*. Bloomington, MN: Pearson Assessments.

Dunn, L. M., & Dunn, D. M. (2007). *Peabody Picture Vocabulary Test - Fourth Edition*. Bloomington, MN: Pearson Assessments.

Eaton, W. W., Mortensen, P. B., Thomsen, P. H., & Frydenberg, M. (2001). Obstetric complications and risk for severe psychopathology in childhood. *Journal of Autism and Developmental Disorders*, *31*, 279-285. doi: 10.1023/A:1010743203048

Elgen, I., Sommerfelt, K., & Markestad, T. (2002). Population based, controlled study of behavioral problems and psychiatric disorders in low birthweight children at 11 years of age. *Archives of Disease in Childhood-Fetal and Neonatal Edition*, *87*, F128-F132.

Farooqi, A., Hagglof, B., Sedin, G., Gothefors, L., & Serenius, F. (2007). Mental health and social competencies of 10- to 12-year-old children born at 23 to 25 weeks of gestation in the 1990s: A Swedish national prospective follow-up study. *Pediatrics, 120*, 118-133. doi: 10.1542/peds.2006-2988

Fazzi, E., Bova, S., Giovenzana, A., Signorini, S., Uggetti, C., & Bianchi, P. (2009). Cognitive visual dysfunctions in preterm children with periventricular leukomalacia. *Developmental Medicine & Child Neurology*, *51*, 974-981. doi: 10.1111/j.1469-8749.2009.03272.x

Feldman, R. S., White, J. B., & Lobato, D. (1982). Social skills and nonverbal behavior. In R. S. Feldman (Ed.), *Development of nonverbal behavior in children* (pp. 259-277). New York: Springer-Verlag. doi: 10.1007/978-1-4757-1761-7_10

Fichten, C. S., Tagalakis, V., Judd, D., Wright, J., & Amsel, R. (1992). Verbal and nonverbal communication cues in daily conversations and dating. *The Journal of Social Psychology*, *132*, 751-769. doi: 10.1080/00224545.1992.9712105

Field, T. M. (1979). Visual and cardiac responses to animate and inanimate faces by young term and preterm infants. *Child Development*, *50*, 188-194. http://www.jstor.org/stable/1129055

Fine, J. G., Semrud-Clikeman, M., Butcher, B., & Walkowiak, J. (2008). Brief report: Attention effect on a measure of social perception. *Journal of Autism and Developmental Disorders*, *38*, 1797-1802. doi: 10.1007/s10803-008-0570-x

Fiorentini, C., & Viviani, P. (2011). Is there a dynamic advantage for facial expressions?. *Journal of Vision*, *11*, 17. doi: 10.1167/11.3.17

Flavell, J. H. (2004). Theory-of-mind development: Retrospect and prospect. *Merrill-Palmer Quarterly*, *50*, 274-290. doi: 10.1353/mpq.2004.0018

Ford, M. E. (1982). Social cognition and social competence in adolescence. *Developmental Psychology*, *18*, 323-340. doi: 10.1037/0012-1649.18.3.323

Foreman, N., Fielder, A., Minshell, C., Hurrion, E., & Sergienko, E. (1997). Visual search, perception, and visual-motor skill in "healthy" children born at 27-32 weeks' gestation. *Journal of Experimental Child Psychology, 64,* 27-41. doi: 10.1006/jecp.1996.2326

Foster, S. L., & Ritchey, W. L. (1979). Issues in the assessment of social competence in children. *Journal of Applied Behavior Analysis, 12*, 625-638. doi: 10.1901/jaba.1979.12-625

Foster-Cohen, S., Edgin, J. O., Champion, P. R., & Woodward, L. J. (2007). Early delayed language development in very preterm infants: Evidence from the MacArthur-Bates CDI. *Journal of Child Language*, *34*, 655-675.

Fox, R., & McDaniel, C. (1982). The perception of biological motion by human infants. *Science, 218,* 486-487. http://www.jstor.org/stable/1689485

Frith, U., & Frith, C. D. (2003). Development and neurophysiology of mentalizing. *The Royal Society of London B, 358,* 459-473. doi: 10.1098/rstb.2002.1218

Gallagher, T. M., & Watkin, K. L. (1998). Prematurity and language developmental risk: Too young or too small?. *Topics in Language Disorders*, *18*, 15-25.

Galway, T. M., & Metsala, J. L. (2011). Social cognition and its relation to psychosocial adjustment in children with nonverbal learning disabilities. *Journal of Learning Disabilities*, *44*, 33-49. doi: 10.1177/0022219410371680

Gardner, F., Johnson, A., Yudkin, P., Bowler, U., Hockley, C., Mutch, L., & Wariyar, U. (2004). Behavioral and emotional adjustment of teenagers in mainstream school who were born before 29 weeks' gestation. *Pediatrics, 114*, 676-682. doi: 10.1542/peds.2003-0763-L

Gardener, H., Spiegelman, D., & Buka, S. L. (2009). Prenatal risk factors for autism: Comprehensive meta-analysis. *The British Journal of Psychiatry*, *195*, 7-14. doi: 10.1192/bjp.bp.108.051672

Geldmacher, D. S. (1996). Effects of stimulus number and target-to-distractor ratio on the performance of random array letter cancellation tasks. *Brain and Cognition, 32*, 405-415. doi: 10.1006/brcg.1996.0073

Geva, R., & Feldman, R. (2008). A neurobiological model for the effects of early brainstem functioning on the development of behavior and emotion regulation in infants: Implications for prenatal and perinatal risk. *Journal of Child Psychology and Psychiatry, 49*, 1031-1041. doi: 10.1111/j.1469-7610.2008.01918.x

Glasson, E. J., Bower, C., Petterson, B., de Klerk, N., Chaney, G., & Hallmayer, J. F. (2004). Perinatal factors and the development of autism: A population study. *Archives of General Psychiatry*, *61*, 618-627. doi: 10.1001/archpsyc.61.6.618

Golan, O., Ashwin, E., Granader, Y., McClintock, S., Day, K., Leggett, V., & Baron-Cohen, S. (2010). Enhancing emotion recognition in children with autism spectrum conditions: An intervention using animated vehicles with real emotional faces. *Journal of Autism and Developmental Disorders*, *40*, 269-279. doi: 10.1007/s10803-009-0862-9

Goldenberg, R. L., & McClure, E. M. (2010). The epidemiology of preterm birth. In V. Berghella (Ed.), *Preterm birth: Prevention & management* (pp. 22-38). West Sussex: Blackwell Publishing Ltd.

Golinkoff, R. M., Chung, H. L., Hirsh-Pasek, K., Liu, J., Bertenthal, B.I., Brand, R., … Hennon, E. (2002). Young children can extend motion verbs to point-light displays. *Developmental Psychology, 38*, 604-614. doi: 10.1037//0012-1649.38.4.604

Goodman R. (1997). The strengths and difficulties questionnaire: A research note. *Journal of Child Psychology and Psychiatry,* 38, 581-586. doi: 10.1111/j.1469-7610.1997.tb01545.x

Goto, M., Ota, R., Iai, M., Sugita, K., & Tanabe, Y. (1994). MRI changes and deficits of higher brain functions in preterm diplegia. *Acta Paediatrica, 83,* 506-511. doi: 10.1111/j.1651-2227.1994.tb13068.x

Gray, R. F., Indurkhya, A., & McCormick, M. C. (2004). Prevalence, stability, and predictors of clinically significant behavior problems in low birth weight children at 3, 5, and 8 years of age. *Pediatrics*, *114*, 736-743. doi:10.1542/peds.2003-1150-L

Gregory, C., Lough, S., Stone, V., Erzinclioglu, S., Martin, L., Baron-Cohen, S., & Hodges, J. R. (2002). Theory of mind in patients with frontal variant frontotemporal dementia and Alzheimer's disease: Theoretical and practical implications. *Brain*, *125*, 752-764. doi: 10.1093/brain/awf079

Grossmann, T. (2010). The development of emotion perception in face and voice during infancy. *Restorative Neurology and Neuroscience*, *28*, 219-236. doi: 10.3233/RNN-2010-0499

Grunau, R. E., Whitfield, M. F., & Fray, T. B. (2004). Psychological and academic characteristics of extremely low birth weight (≤800g) adolescents who are free of major impairment compared with term-born control subjects. *Pediatrics, 114*, e725-e732. doi: 10.1542/peds.2004-0932

Guihard-Costa, A. M., & Larroche, J. C. (1990). Differential growth between the fetal brain and its infratentorial part. *Early Human Development*, *23*, 27-40. doi: 10.1016/0378-3782(90)90126-4

Hack, M., Taylor, H. G., Drotar, D., Schluchter, M., Cartar, L., Andreias, L., …. Klein, N. (2005). Chronic conditions, functional limitations, and special health care needs of school-aged children born with extremely low-birth-weight in the 1990s. *The Journal of the American Medical Association, 294*, 318-325. doi: 10.1001/jama.294.3.318

Hack, M., Taylor, H. G., Schluchter, M., Andreias, L., Drotar, D., & Klein, N. (2009). Behavioral outcomes of extremely low birth weight children at age 8 years. *Journal of Developmental and Behavioral Pediatrics, 30*, 122-130. doi: 10.1097/DBP.0b013e31819e6a16

Happé, F. G. (1994). An advanced test of theory of mind: Understanding of story characters' thoughts and feelings by able autistic, mentally handicapped, and normal children and adults. *Journal of Autism and Developmental Disorders, 24,* 129-154. doi: 10.1007/BF02172093

Happé, F. G. (1995). The role of age and verbal ability in the theory of mind task performance of subjects with autism. *Child Development*, *66*, 843-855. doi: 10.111/j.1467-8624.1995.tb00909.x

Hård, A. L., Niklasson, A., Svensson, E., & Hellström, A. (2000). Visual function in school-aged children born before 29 weeks of gestation: A population-based study. *Developmental Medicine & Child Neurology*, *42*, 100-105. http://journals.cambridge.org/abstract_S0012162200000207

Hayes, B., & Sharif, F. (2009). Behavioral and emotional outcome of very low birth weight infants: Literature review. *The Journal of Maternal-Fetal & Neonatal Medicine, 22*, 1-8. doi: 10.1080/14767050902994507

Heider, F., & Simmel, M. (1944). An experimental study of apparent behavior. *American Journal of Psychology, 57*, 243-259. http://www.jstor.org/stable/1416950

Hellgren, K., Hellstrom, A., Jacobson, L., Flodmark, O., Wadsby, M., & Martin, L. (2007). Visual and cerebral sequelae of very low birth weight in adolescents. *Archives of Diseases in Childhood: Fetal and Neonatal Edition, 92,* F259-F264. doi: 10.1136/adc.2006.101899

Heuchan, A. M., Evans, N., Smart, D. H., & Simpson, J. M. (2002). Perinatal risk factors for major intraventricular haemorrhage in the Australian and New Zealand Neonatal Network, 1995-97. *Archives of Disease in Childhood-Fetal and Neonatal Edition*, *86*, F86-F90.

Hill, J. L., Brooks-Gunn, J., & Waldfogel, J. (2003). Sustained effects of high participation in an early intervention for low-birth-weight premature infants. *Developmental psychology*, *39*, 730-744. doi: 10.1037/0012-1649.39.4.730

Hille, E., Dorrepaal, C., Perenboom, R., Gravenhorst, J.B., Brand, R., & Verloove-Vanhorick, S.P. (2008). Social lifestyle, risk-taking behavior, and psychopathology in young adults born very preterm or with a very low birthweight. *The Journal of Pediatrics*, *152*, 793-800.

Hille, E. T., den Ouden, A. L., Saigal, S., Wolke, D., Lambert, M., Whitaker, A., … Paneth, N. (2001). Behavioral problems in children who weigh 1000 g or less at birth in four countries. *Lancet, 357*, 1641-1643. doi: 10.1016/S0140-6736(00)04818-2

Hirai, M., Chang, D. H., Saunders, D. R., & Troje, N. F. (2011). Body configuration modulates the usage of local cues to direction in biological-motion perception. *Psychological Science*, *22*, 1543-1549. doi: 10.1177/0956797611417257

Hoekstra, R. E., Ferrrara, T. B., Couser, R. J., Payne, N. R., & Connett, J. E. (2004). Survival and long-term neurodevelopmental outcome of extremely premature infants born at 23-26 weeks' gestational age at a tertiary center. *Pediatrics, 113*, e1-6.

Hood, K. M. (2009). Social competence at age 4 years, of children born very preterm. Unpublished manuscript. University of Canterbury.

Horbar, J. D., Wright, E. C., & Onstad, L. (1993). Decreasing mortality associated with the introduction of surfactant therapy: An observational study of neonates weighing 601 to 1300 grams at birth. *Pediatrics, 92*, 191-196.

Horsch, S., Hallberg, B., Leifsdottir, K., Skiold, B., Nagy, Z., …. Aden, U.(2007). Brain abnormalities in extremely low gestational age infants: A Swedish population based MRI study. *Acta Paediatrica, 96,* 979-984. doi: 10.111/j.1651-2227.2007.00294.x

Howes, C. (1987). Social competence with peers in young children: Developmental sequences. *Developmental Review, 7*, 252-272. doi: 10.1016/0273-2297(87)90014-1

Hsu, H. C., & Jeng, S. F. (2008). Two-month-olds' attention and affective response to maternal still face: a comparison between term and preterm infants in

Taiwan. *Infant Behavior and Development*, *31*, 194-206. doi: 10.1016/j.infbeh.2007.10.008

Hu, Z., Chan, R. C., & McAlonan, G. M. (2010). Maturation of social attribution skills in typically developing children: An investigation using the social attribution task. *Behavioral and Brain Functions*, *6*, 10-18. doi: 10.1186/1744-9081-6-10

Hubbard, J., & Coie, J. (1994). Emotional correlates of social competence in children's peer relationships. *Merrill-Palmer Quarterly, 40*, 1-20.

Hubert, B., Wicker, B., Moore, D. G., Monfardini, E., Duverger, H., Da Fonseca, D., & Deruelle, C. (2007). Brief report: Recognition of emotional and non-emotional biological motion in individuals with autistic spectrum disorders. *Journal of Autism and Developmental Disorders*, *37*, 1386-1392. doi: 10.1007/s10803-006-0275-y

Hultman, C. M., Sparén, P., & Cnattingius, S. (2002). Perinatal risk factors for infantile autism. *Epidemiology*, *13*, 417-423. doi: 10.1097/01.EDE.0000016968.14007.E6

Hüppi, P. S., Warfield, S., Kikinis, R., Barnes, P. D., Zientara, G. P., Jolesz, F. A., ... & Volpe, J. J. (1998). Quantitative magnetic resonance imaging of brain development in premature and mature newborns. *Annals of Neurology*, *43*, 224-235. doi: 10.1002/ana.410430213

Hutchinson, E. A., De Luca, C. R., Doyle, L. W., Roberts, G., & Anderson, P. J. (2013). School-age outcomes of extremely preterm or extremely low birth weight children. *Pediatrics*, *131*, e1053-e1061. doi: 10.1542/peds.2012-2311

Iidaka, T., Miyakoshi, M., Harada, T., & Nakai, T. (2012). White matter connectivity between superior temporal sulcus and amygdala is associated with autistic trait in healthy humans. *Neuroscience Letters*, *510*, 154-158.

Imaizumi, S., Furuya, I., & Yamasaki, K. (2009). Voice as a tool communicating intentions. *Logopedics Phoniatrics Vocology*, *34*, 196-199. doi: 10.3109/14015430903311192

Indredavik, M. S., Vik, T., Evensen, K. A. I., Skranes, J., Taraldsen, G., & Brubakk, A. M. (2010). Perinatal risk and psychiatric outcome in adolescents born preterm with very low birth weight or term small for gestational age. *Journal of Developmental & Behavioral Pediatrics*, *31*, 286-294. doi: 10.1097/DBP.0b013e3181d7b1d3

Indredavik, M. S., Vik, T., Skranes, J., & Brubakk, A. M. (2008). Positive screening results for autism in ex-preterm infants. *Pediatrics*, *122*, 222.

Isaacs, E. B., Lucas, A., Chong, W. K., Wood, S. J., Johnson, C. L., Marshall, C., … Gadian, D. G. (2000). Hippocampal volume and everyday memory in children of very low birth weight. *Pediatric Research, 47*, 713-720. doi: 10.1203/00006450-200006000-00006

Jakobson, L. S., Frisk, V., & Downie, A. L. (2006). Motion-defined form processing in extremely premature children. *Neuropsychologia, 44*, 1777-1786. doi: 10.1016/j.neuropsychologia.2006.03.011

Jakobson, L. S., Frisk, V., Knight, R. M., Downie, A. L., & Whyte, H. (2001). The relationship between periventricular brain injury and deficits in visual processing among extremely-low-birthweight (< 1000 g) children. *Journal of Pediatric Psychology*, *26*, 503-512. doi: 10.1093/jpepsy/26.8.503

Johansson, G. (1976). Spatio-temporal differentiation and integration in visual motion perception. *Psychological Research, 38*, 379-393. doi: 10.1007/BF00309043

Johansson, G. (1973). Visual perception of biological motion and a model for its analysis. *Perception & Psychophysics, 14,* 202-211.

Johnson, S. (2007, October). Cognitive and behavioral outcomes following very preterm birth. *Seminars in Fetal and Neonatal Medicine, 12*, 363-373. doi: 10.1016/j.siny.2007.05.004

Johnson, S., Hollis, C., Kochhar, P., Hennessy, E., Wolke, D., & Marlow, N. (2010). Autism spectrum disorders in extremely preterm children. *The Journal of Pediatrics, 156*, 519-521. doi: 10.1016/j.jpeds.2009.10.041

Johnson, S., & Marlow, N. (2009). Positive screening results on the modified checklist for autism in toddlers: Implications for very preterm populations. *The Journal of Pediatrics, 154*, 478-480. doi: 10.1016/j.jpeds.2008.11.028

Johnson, S., & Marlow, N. (2011). Preterm birth and childhood psychiatric disorders. *Pediatric Research, 69(5-2),* 11R-8R. doi: 10.1203/PDR.0b013e318212faa0

Jones, C. R. G., Swettenham, J., Charman, T., Marsden, A.J.S., Tregay, J., Baird, G., … Happé, F. (2011). No evidence for a fundamental visual motion processing deficit in adolescents with autism spectrum disorder. *Autism Research, 4*, 347-357. doi: 10.1001/aur.209

Joseph, K. S., Allen, A. C., Dodds, L., Vincer, M. J., & Armson, B. A. (2001a). Causes and consequences of recent increases in preterm birth among twins. *Obstetrics and Gynecology, 98,* 57-64.

Joseph, K. S., Kramer, M. S., Marcoux, S., Ohlsson, A., Wen, S. W., Allen, A., & Platt, R. (1998). Determinants of preterm birth rates in Canada from 1981 through 1983 and from 1992 through 1994. *New England Journal of Medicine*, *339*, 1434-1439. doi: 10.1056/NEJM199811123392004

Joseph, K. S., Marcoux, S., Ohlsson, A., Liu, S., Allen, A. C., Kramer, M. S. … & Wen, S. W. (2001b). Changes in stillbirth and infant mortality associated with increases in preterm birth among twins. *Pediatrics, 108,* 1055-1061. doi: 10.1542/peds.108.5.1055

Juul-Dam, N., Townsend, J., & Courchesne, E. (2001). Prenatal, perinatal, and neonatal factors in autism, pervasive developmental disorder-not otherwise specified, and the general population. *Pediatrics*, *107*, e63.

Katusic, A. (2011). Early brain injury and plasticity: Reorganization and functional recovery. *Translational Neuroscience, 2*, 33-42. doi:10.2478/s13380-011-0006-5

Kinney, H. C. (2006). The near-term (late preterm) human brain and risk for periventricular leukomalacia: A review. *Seminars in Perinatology, 30*, 81-88. doi: 10.1053/j.semperi.2006.02.006

Kirby, R. S., Swanson, M. E., Kelleher, K. J., Bradley, R. H., & Casey, P. H. (1993). Identifying at-risk children for early intervention services: lessons from the Infant Health and Development Program. *The Journal of Pediatrics*, *122*, 680-686. doi: 10.1016/S0022-3476(06)80004-1

Klein, A. M., Zwickel, J., Prinz, W., & Frith, U. (2009). Animated triangles: An eye tracking investigation. *The Quarterly Journal of Experimental Psychology*, *62*, 1189-1197. doi:10.1080/17470210802384214

King-Smith, P. E., Grigsby, S. S., Vingrys, A. J., Benes, S. C., & Supowit, A. (1994). Efficient and unbiased modifications of the QUEST threshold method: Theory, simulations, experimental evaluation and practical implementation. *Vision Research*, *34*, 885-912. doi: 10.1016/0042-6989(94)90039-6

Knickermeyer, R., Baron-Cohen, S., Raggatt, P., Taylor, K., & Hackett, G. (2006). Fetal testosterone and empathy. *Hormones and Behavior, 49*, 282-292. doi: 10.1016/j.yhbeh.2005.08.010

Kniestedt, C., & Stamper, R.L. (2003). Visual acuity and its measurement. *Ophthalmology Clinics of North America*, *16*, 155-170.

Koelkebeck, K., Pedersen, A., Suslow, T., Kueppers, K.A., Arolt, V. & Ohrmann, P. (2010). Theory of mind in first-episode schizophrenia patients: Corrections with cognition and personality traits. *Schizophrenia Research, 119*, 115-123. doi: 10.1016/j.schres.2009.12.015

Kolevzon, A., Gross, R., & Reichenberg, A. (2007). Prenatal and perinatal risk factors for autism: A review and integration of findings. *Archives of Pediatrics & Adolescent Medicine*, *161*, 326-333. doi: 10.1001/archpedi.161.4.326

Koning, C. (1997). Validation and application of the CASP. (unpublished thesis). University of Alberta, Edmonton, AB.

Koning, C., & Magill-Evans, J. (2001). Social and language skills in adolescent boys with Asperger syndrome. *Autism, 5*, 23-36. doi: 10.1177/1362361301005001003

Koning, C., Magill-Evans, J., Volden, J., & Dick, B. (2011). Efficacy of cognitive behavior therapy-based social skills intervention for school-aged boys with autism spectrum disorders. *Research in Autism Spectrum Disorders*, *7*, 1282-1290 doi: 10.1016/j.rasd.2011.07.011

Kuban, K. C. K., O'Shea, M., Allred, E. N., Tager-Flusberg, H., Goldstein, D.J., & Leviton, A. (2009). Positive screening on the modified checklist for autism in toddlers (M-CHAT) in extremely low gestational age newborns. *The Journal of Pediatrics, 154*, 535-540. doi: 10.1016/j.jpeds.2008.10.011

Kuhlmeier, V. A., Troje, N. F., & Lee, V. (2010). Young infants detect the direction of biological motion in point-light displays. *Infancy, 15,* 83-93. doi: 10.111/j.1532-7078.2009.00003.x

Lampi, K. M., Lehtonen, L., Tran, P. L., Suominen, A., Lehti, V., Banerjee, P. N., … Sourander, A. (2012). Risk of autism spectrum disorders in low birth weight and small for gestational age infants. *Journal of Pediatrics, 161*, 830-836. doi: 10.1016/j.jpeds.2012.04.058

Lander, K., Christie, F., & Bruce, V. (1999). The role of movement in the recognition of famous faces. *Memory & Cognition*, *27*, 974-985. doi: 10.3758/BF03201228

Landry, S. H. (1986). Preterm infants' responses in early joint attention interactions. *Infant Behavior and Development, 9*, 1-14.

Landry, S. H. (1995). The development of joint attention in premature low birth weight infants: Effects of early medical complications and maternal attention-directing behaviors. In C. Moore, P. J. Dunham, & P. Dungam (Eds.), *Joint attention: Its origins and role in development* (pp. 223-250). Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.

Larroque, B., Marret, S., Ancel, P. Y., Arnaud, C., Marpeau, L., Supernant, K., ... &

Bréart, G. (2003). White matter damage and intraventricular hemorrhage in very preterm infants: The EPIPAGE study. *The Journal of Pediatrics*, *143*, 477-483. doi: 10.1067/S0022-3476(03)00417-7

Lawrence, K., Jones, A., Oreland, L., Spektor, D., Mandy, W., Campbell, R., & Skuse, D. (2007). The development of mental state attributions in women with X-monosomy, and the role of monoamine oxidase B in the sociocognitive phenotype. *Cognition, 102*, 84-100. doi: 10.1016/j.cognition.2005.12.003

Leekam, S., & Perner, J. (1991). Does the autistic child have a metarepresentational deficit? *Cognition, 40*, 203-218. doi: 10.1016/0010-0277(91)90025-Y

Lewis, V., & Boucher, J. (1988). Spontaneous, instructed and elicited play in relatively able autistic children. *British Journal of Developmental Psychology, 6*, 325-339.

Limperopoulos, C. (2009). Autism spectrum disorders in survivors of extreme prematurity. *Clinics in Perinatology*, *36*, 791-805. doi: 10.1016/j.clp.2009.07.010.

Limperopoulos, C., Bassan, H., Sullivan, N. R., Soul, J. S., Robertson, R.L., Moore, … du Plessis, A. J. (2008). Positive screening for autism in ex-preterm infants: Prevalence and risk factors. *Pediatrics, 121*, 758-768. doi: 10.1542/peds.2007-2158

Litt, J., Taylor, H. G., Klein, N., & Hack, M. (2005). Learning disabilities in children with very low birthweight: Prevalence, neuropsychological correlates, and educational interventions. *Journal of Learning Disabilities, 38*, 130-141. doi: 10.1177/00222194050380020301

Little, A. C., Jones, B. C., & DeBruine, L. M. (2011). The many faces of research on face perception. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *366*, 1634-1637. doi: 10.1098/rstb.2010.0386

Luciana, M., Lindeke, L., Georgieff, M., Mills, M., & Nelson, C. A. (1999). Neurobehavioral evidence for working-memory deficits in school-aged children with histories of prematurity. *Developmental Medicine and Child Neurology, 41,* 521-533. doi: 10.1111/j.1469-8749.1999.tb00652.x

Luu, T. M., Ment, L., Allan, W., Schneider, K., & Vohr, B. R. (2011). Executive and memory function in adolescents born very preterm. *Pediatrics*, *127*, e639-e646. doi: 10.1542/peds.2010-1421

Luyster, R. J., Kuban, K. C., O'Shea, T. M., Paneth, N., Allred, E. N., & Leviton, A. (2011). The Modified Checklist for Autism in Toddlers in extremely low gestational age newborns: individual items associated with motor, cognitive, vision and hearing limitations. *Paediatric and Perinatal Epidemiology*, *25*, 366-376. doi: 10.1111/j.1365-3016.2010.01187.x

Maalouf, E. F., Duggan, P. J., Rutherford, M. A., Counsell, S. J., Fletcher, A. M., Battin, M., ... & Edwards, A. D. (1999). Magnetic resonance imaging of the brain in a cohort of extremely preterm infants. *The Journal of Pediatrics*, *135*, 351-357. doi: 10.1016/S0022-3476(99)70133-2

MacKay, T. L., Jakobson, L. S., Ellemberg, D., Lewis, T. L., Maurer, D. & Casiro, O. (2005). Deficits in the processing of local and global motion in very low birthweight children. *Neuropsychologia, 43,* 1738-1748. doi: 10.1016/j.neuropsychologia.2005.02.008

Magill-Evans, J., Koning, C., Cameron-Sadava, A., & Manyk, K. (1995). The child and adolescent social perception measure. *Journal of Nonverbal Behavior, 19*, 151-169. doi: 10.1007/BF02175502

Maimburg, R. D., & Væth, M. (2006). Perinatal risk factors and infantile autism. *Acta Psychiatrica Scandinavica*, *114*, 257-264. doi: 10.1111/j.1600-0447.2006.00805.x

Majnemer, A. (1998, March). Benefits of early intervention for children with developmental disabilities. *Seminars in Pediatric Neurology*, *5*, 62-69. doi: 10.1016/S1071-9091(98)80020-X

Marlow, N., Wolke, D., Bracewell, M. A., & Samara, M. (2005). Neurologic and developmental disability at six years of age after extremely preterm birth. *New England Journal of Medicine, 352*, 9-19. doi: 10.1056/NEJMoa041367

Mather, G., & West, S. (1993). Recognition of animal locomotion form dynamic point-light displays. *Perception, 22*, 759-766.

Matsuishi, T., Yamashita, Y., Ohtani, Y., Ornitz, E., Kuriya, N., Murakami, Y., ... & Yamashita, F. (1999). Brief report: Incidence of and risk factors for autistic disorder in neonatal intensive care unit survivors. *Journal of Autism and Developmental Disorders*, *29*, 161-166. doi: 10.1023/A:1023048812202

McCormick, M. C., Brooks-Gunn, J., Buka, S. L., Goldman, J., Yu, J., Salganik, M., ... & Casey, P. H. (2006). Early intervention in low birth weight premature infants: Results at 18 years of age for the Infant Health and Development Program. *Pediatrics*, *117*, 771-780. doi: 10.1542/peds.2005-1316

McDonald, S., Bornhofen, C., Shum, D., Long, E., Saunders, C., & Neulinger, K. (2006). Reliability and validity of The Awareness of Social Inference Test (TASIT): A clinical test of social perception. *Disability & Rehabilitation*, *28*, 1529-1542. doi: 10.1080/09638280600646185

Milligan, K., Astington, J. W., & Dack, L. A. (2007). Language and theory of mind: Meta-analysis of the relation between language ability and false-belief understanding. *Child Development*, *78*, 622-646. doi: 10.1111/j.1467-8624.2007.01018.x

Montague, D. P., & Walker-Andrews, A. S. (2001). Peekaboo: A new look at infants' perception of emotion expressions. *Developmental Psychology*, *37*, 826-838. doi: 10.1037/0012-1649.37.6.826

Moore, D. G., Goodwin, J. E., George, R., Axelsson, E. L., & Braddick, F. M. B. (2007). Infants perceive human point-light displays as solid forms. *Cognition, 104*, 377-396. doi: 10.1016/j.cognition.2006.07.007

Moore, T., Johnson, S., Hennessy, E., & Marlow, N. (2012). Screening for autism in extremely preterm infants: problems in interpretation. *Developmental Medicine & Child Neurology*, *54*, 514-520. doi: 10.1111/j.1469-8749.2012.04265.x

Moriguchi, Y., Ohnishi, T., Lane, R.D., Maeda, M., Takeyuki, M., Nemoto, K., … Komaki, G. (2006). Impaired self-awareness and theory of mind: An fMRI study of mentalizing in alexithymia. *NeuroImage, 32*, 1472-1482. doi: 10.1016/j.neuroimage.2006.04.186

Moriguchi, Y., Ohnishi, T., Mori, T., Matsuda, H., & Komaki, G. (2007). Changes of brain activity in the neural substrates for theory of mind during childhood and adolescence. *Psychiatry and Clinical Neurosciences, 61*, 355-363. doi: 10.1111/j.1440-1819.2007.01687.x

Mosconi, M. W., Mack, P. B., McCarthy, G., & Pelphrey, K. A. (2005). Taking an “intentional stance” on eye-gaze shifts: A functional neuroimaging study of social perception in children. *Neuroimage*, *27*, 247-252. doi: 10.1016/j.neuroimage.2005.03.027

Moster, D., Lie, R. T., & Markestad, T. (2008). Long-term medical and social consequences of preterm birth. *The New England Journal of Medicine, 359*, 262-273. doi: 10.1056/NEJMoa0706475

Movsas, T. Z., Pinto-Martin, J. A., Whitaker, A. H., Feldman, J. F., Lorenz, J. M., Korzeniewski, S. J., ... & Paneth, N. (2013). Autism Spectrum Disorder Is Associated with Ventricular Enlargement in a Low Birth Weight Population. *The Journal of Pediatrics*, *163*, 73-78. doi: 10.1016/j.jpeds.2012.12.084

Msall, M. E., & Tremont, M. R. (2002). Measuring functional outcomes after prematurity: Developmental impact of very low birth weight and extremely low birth weight status on childhood disability. *Mental Retardation and Developmental Disabilities Research Reviews, 8*, 258-272. doi: 10.1002/mrdd.10046

Mundy, P., & Gomes, A. (1998). Individual differences in joint attention skill development in the second year. *Infant Behavior and Development, 21*, 469-482. doi: 10.1016/S0163-6383(98)90020-0

Nackaerts, E., Wagemans, J., Helsen, W., Swinnen, S. P., Wenderoth, N., & Alaerts, K. (2012). Recognizing biological motion and emotions from point-light displays in autism spectrum disorders. *PloS one*, *7*, e44473. doi: 10.1371/journal.pone.004473

Nadeau, L., Boivin, M., Tessier, R., Lefebvre, F., & Robaey, P. (2001). Mediators of behavioral problems in 7-year-old children born after 24 to 28 weeks of gestation. *Journal of Developmental & Behavioral Pediatrics*, *22*, 1-10.

Neil, J., Miller, J., Mukherjee, P., & Hüppi, P. S. (2002). Diffusion tensor imaging of normal and injured developing human brain−a technical review. *NMR in Biomedicine*, *15*, 543-552. doi: 10.1002/nbm.784

Nelson, K. B. (1991). Prenatal and perinatal factors in the etiology of autism. *Pediatrics*, *87*, 761-766.

Norman, J. F., Payton, S. M., Long, J. R., & Hawkes, L. M. (2004). Aging and the perception of biological motion. *Psychology and Aging*, *19*, 219-225. doi: 10.1037/0882-7974.19.1.219

Nosarti, C., Reichenberg, A., Murray, R. M., Cnattingius, S., Lambe, M. P., Yin, L., … Hultman, C. M. (2012). Preterm birth and psychiatric disorders in young adult life. *Archives of General Psychiatry*, *69*, 610-617. doi: 10.1001/archgenpsychiatry.2011.1374

Nowicki Jr., S., & Duke, M. P. (1994). Individual differences in the nonverbal communication of affect: The Diagnostic Analysis of Nonverbal Accuracy Scale. *Journal of Nonverbal Behavior*, *18*, 9-35. doi: 10.1007/BF02169077

Olivieri, I., Bova, S. M., Urgesi, C., Ariaudo, G., Perotto, E., Fazzi, E., ... & Orcesi, S. (2012). Outcome of extremely low birth weight infants: What's new in the third millennium? Neuropsychological profiles at four years. *Early Human Development*, *88*, 241-250. doi: 10.1016/j.earlhumdev.2011.08.012

Orton, J., Spittle, A., Doyle, L., Anderson, P., & Boyd, R. (2009). Do early intervention programmes improve cognitive and motor outcomes for preterm infants after discharge? A systematic review. *Developmental Medicine & Child Neurology*, *51*, 851-859. doi: 10.1111/j.1469-8749.2009.03414.x

Ozonoff, S., Pennington, B. F., & Rogers, S. J. (1991). Executive function deficits in high-functioning autistic individuals: Relationship to theory of mind. *Journal of Child Psychology and Psychiatry*, *32*, 1081-1105. doi: 10.1111/j.1469-7610.1991.tb00351.x

Parron, C., Da Fonseca, D., Santos, A., Moore, D. G., Monfardini, E., & Deruelle C. (2008). Recognition of biological motion in children with autistic spectrum disorders. *Autism, 12*, 261-274. doi: 10.1177/1362361307089520

Pavlova, M. A. (2012). Biological motion processing as a hallmark of social cognition. *Cerebral Cortex*, *22*, 981-995. doi: 10.1093/cercor/bhr156

Pavlova, M., Bidet-Ildei, C., Sokolov, A. N., Braun, C., & Krageloh-Mann, I. (2008a). Neuromagnetic response to body motion and brain connectivity. *Journal of Cognitive Neuroscience, 21*, 837-846. doi: 10.1162/jocn.2009.21050

Pavlova, M., Krageloh-Mann, I., Sokolov, A., & Birbaumer, N. (2001). Recognition of point-light biological motion displays by young children. *Perception, 30*, 925-933.

Pavlova, M., Marconato, F., Sokolov, A., Braun, C., Birbaumer, N., & Krageloh-Mann, I. (2006a). Periventricular leukomalacia specifically affects cortical MEG response to biological motion. *American Neurological Association, 59*, 415-419. doi: 10.1002/ana.20762

Pavlova, M., Sokolov, A. N., Birbaumer, N., & Krageloh-Mann, I. (2008b). Perception and understanding of others' actions and brain connectivity. *Journal of Cognitive Neuroscience, 20*, 494-504. doi: 10.1162/jocn.2008.20034

Pavlova, M., Sokolov, A., Birbaumer, N., & Krageloh-Mann, I. (2006b). Biological motion processing in adolescents with early periventricular brain damage. *Neuropsychologia, 44*, 586-593. doi: 10.1016/j.neuropsychologia.2005.06.016

Pavlova, M., Sokolov, A., Staudt, M., Marconato, F., Birbaumer, N., & Krageloh-Mann, I. (2005). Recruitment of periventricular parietal regions in processing cluttered point-light biological motion. *Cerebral Cortex, 15,* 594-601. doi: 10.1093/cercor/bhh162

Pavlova, M., Staudt, M., Sokolov, A., Birbaumer, N., & Krageloh-Mann, I. (2003). Perception and production of biological movement in patients with early periventricular brain lesions. *Brain, 126*, 692-701. doi: 10.1093/brain/awg062

Pears, K. C., & Moses, L. J. (2003). Demographics, parenting, and theory of mind in preschool children. *Social Development*, *12*, 1-20. doi: 10.1111/1467-9507.00219

Pellegrini, D. S. (1985). Social cognition and competence in middle childhood. *Child Development, 56*, 253-264. http://www.jstor.org/stable/1130192

Pelphrey, K. A., & Carter, E. J. (2008). Brain mechanisms for social perception: Lessons from autism and typical development. *Annals of the New York Academy of Science, 1145*, 283-299. doi: 10.1196/annals.1416.007

Perner, J., Frith, U., Leslie, A. M., & Leekam, S. (1989). Exploration of the autistic child's theory of mind: Knowledge, belief, and communication. *Child Development, 60*, 689-700. http://www.jstor.org/stable/1130734

Perner, J., & Lang, B. (1999). Development of theory of mind and executive control. *Trends in cognitive sciences*, *3*, 337-344. doi: 10.1016/S1364-6613(99)01362-5

Perner, J., & Wimmer, H. (1985). "John thinks that Mary thinks that...": Attribution of second-order beliefs by 5-to10-year old children. *Journal of Experimental Child Psychology, 39*, 437-471.

Perrin, E. C., Stein, R. E., & Drotar, D. (1991). Cautions in using the children behavior checklist: Observations based on research about children with a chronic illness. *Journal of Pediatric Psychology, 16*, 411-421. doi: 10.1093/jpepsy/16.4.411

Pinto-Martin, J. A., Levy, S. E., Feldman, J. F., Lorenz, J. M., Paneth, N., & Whitaker, A. H. (2011). Prevalence of autism spectrum disorder in adolescents born weighing< 2000 grams. *Pediatrics*, *128*, 883-891. doi: 10.1542/peds.2010-2846

Pollick, F. E., Paterson, H. M., Bruderlin, A., & Sanford, A. J. (2001). Perceiving affect from arm movement. *Cognition, 82*, B51-61. doi: 10.1016/S0010-0277(01)00147-0

Potharst, E. S., Van Wassenaer‐Leemhuis, A. G., Houtzager, B. A., Livesey, D., Kok, J. H., Last, B. F., & Oosterlaan, J. (2013). Perinatal risk factors for neurocognitive impairments in preschool children born very preterm. *Developmental Medicine & Child Neurology*, *55*, 178-184.

Premack, D. G., & Woodruff, G. (1978). Does the chimpanzee have a theory of mind? *Behavioral and Brain Sciences, 1,* 515-526.

Ramenghi, L. A., Ricci, D., Mercuri, E., Groppo, M., De Carli, A., Ometto, A., ... & Mosca, F. (2010). Visual performance and brain structures in the developing brain of pre-term infants. *Early Human Development*, *86*, 73-75. doi: 10.1016/j.earlhumdev.2010.01.010

Reed, T., & Peterson, C. (1990). A comparative study of autistic subjects' performance at two levels of visual and cognitive perspective taking. *Journal of Autism and Developmental Disorders, 20*, 555-568. doi: 10.1007/BF02216060

Reijneveld, S. A., de Klein, M. J. K., van Baar, A. L., Kollee, L. A. A., Verhaak, C. M.,Verhulst, F. C., & Verloove-Vanhorick, S. P. (2006). Behavioral and emotional problems in very preterm and very low birthweight infants at age 5 years. *Archives of Disease in Childhood Fetal Neonatal Edition, 91*, F423-F428. doi: 10.1136/adc.2006.093674

Reynolds, C. R., & Kamphaus, R. W. (2004). *Behavior Assessment System for Children Manual - Second Edition.* Circle Pines, MN: American Guidance Service.

Reynolds, C. R., & Kamphaus, R. W. (1998). *Behavior Assessment System for Children Manual.* Circle Pines, MN: American Guidance Service.

Rickards, A. L., Kelly, E. A., Doyle, L. W., & Callanan, C. (2001). Cognition, academic progress, behavior and self-concept at 14 years of very low birth weight children. *Journal of Developmental & Behavioral Pediatrics*, *22*, 11-18.

Rickards, A. L., Kitchen, W. H., Doyle, L. W., Ford, G. W., Kelly, E. A., & Callanan, C. (1993). Cognition, school performance, and behavior in very low birth weight and normal birth weight children at 8 years of age: A longitudinal study. *Journal of Developmental and Behavioral Pediatrics, 14,* 363-368.

Rosch, E. (1988). Principles of categorization. In A. Collins & E. E. Smith (Eds.), *Readings in cognitive science* (pp. 312-322). San Mateo, CA: Morgenkaufmann.

Rose-Krasnor, L. (1997). The nature of social competence: A theoretical review. *Social Development, 6*, 111-135. doi: 10.1111/j.1467-9507.1997.tb00097.x

Rosenblum, L. D., Johnson, J. A., & Saldana, H. M. (1996). Point-light facial displays enhance comprehension of speech in noise. *Journal of Speech, Language and Hearing Research*, *39*, 1159-1170.

Russel, T. A., Reynaud, E., Herba, C., Morris, R., & Corcoran, R. (2006). Do you see what I see? Interpretations of intentional movement in schizophrenia. *Schizophrenia Research, 81*, 101-111. doi: 10.1016/j.schres.2005.10.002

Saigal, S., den Ouden, L., Wolke, D., Hoult, L., Paneth, N., Streiner, D. L., ... & Pinto-Martin, J. (2003a). School-age outcomes in children who were extremely low birth weight from four international population-based cohorts. *Pediatrics*, *112*, 943-950. doi: 10.1542/peds.112.4.943

Saigal, S., Pinelli, J., Hoult, L., Kim, M., & Boyle, M. (2003b). Psychopathology and social competencies of adolescents who were extremely low birth weight. *Pediatrics, 111*, 969-975.

Saigal, S., Stoskopf, B. L., Streiner, D. L., & Burrows, E. (2001). Physical growth and current health status of infants who were of extremely low birth weight and controls at adolescence. *Pediatrics, 108*, 407-415. doi: 10.1542/peds.108.2.407

Salter, G., Seigal, A., Claxton, M., Lawrence, K., & Skuse, D. (2008). Can autistic children read the mind of an animated triangles? *Autism, 12*, 349-371. doi: 10.1177/1362361308091654

Sanefuji, W., Ohgami, H., & Hashiya, K. (2008). Detection of the relevant type of locomotion in infancy: Crawlers versus walkers. *Infant Behavior & Development, 31*, 624-628. doi: 10.1016/j.infbeh.2008.07.003

Sattler, J. M., & Hoge, R. D. (2006). *Assessment of children: Behavioral, social and* *clinical foundations* (5th ed.). San Diego, CA: Jerome M. Sattler Publisher Inc.

Saunders, D. (2011). *Components of biological motion perception* (unpublished dissertation). Queen's University, Kingston ON.

Saunders, D., Suchan, J., & Troje, N. F. (2009). Off on the wrong foot: Local features in biological motion. *Perception, 38*, 522-532. doi: 10.1068/p6140

Sauter, D. A., Panattoni, C., & Happé, F. (2013). Children's recognition of emotions from vocal cues. *British Journal of Developmental Psychology*, *31*, 97-113. doi: 10.1111/j.2044-835X.2012.02081.x

Schwartz, R. M., Luby, A. M., Scanlon, J. W., & Kellogg R. J. (1994). Effect of surfactant on morbidity, mortality, and resource use in newborn infants weighing 500 to 1500 grams. *New England Journal of Medicine, 30*, 1476-1480. doi: 10.1056/NEJM199405263302102

Segal, L. B., Oster, H., Cohen, M., Caspi, B., Myers, M., & Brown, D. (1995). Smiling and fussing in seven-month-old preterm and full-term black infants in the still-face situation. *Child Development*, *66*, 1829-1843. doi: 10.1111/j.1467-8624.1995.tb00968.x

Semrud-Clikeman, M. (2007). *Social competence in children.* New York, NY: Springer.

Sharkey, M. A., Palitz, M. E., Reece, L. F., Rutherford, B. L., Akers, J. P., Alvin, B. L., & Budenholzer, B. R. (1990). The effect of early referral and intervention on the developmentally disabled infant: Evaluation at 18 months of age. *The Journal of the American Board of Family Practice/American Board of Family Practice*, *3*, 163-170.

Shonkoff, J. P., & Hauser-Cram, P. (1987). Early intervention for disabled infants and their families: A quantitative analysis. *Pediatrics, 80*, 650-658

Silins, J., Semenciw, R. M., Morrison, H. I., Lindsay, J., Sherman, G. J., Mao, Y., & Wigle, D. T. (1985). Risk factors for perinatal mortality in Canada. *Canadian Medical Association Journal*, *133*, 1214.

Simion, F., Regolin, L., & Bulf, H., (2008). A predisposition for biological motion in the newborn baby. *Proceedings of the National Academy of Science, 105*, 809-813. www.pnas.orgcgidoi10.1073pnas.0707021105

Smith, H. J., Archer, D., & Costanzo, M. (1991). "Just a hunch": Accuracy and awareness in person perception. *Journal of Nonverbal Behavior*, *15*, 3-18. doi: 10.1007/BF00997764

Soken, N. H., & Pick, A. D. (1992). Intermodal perception of happy and angry expressive behaviors by seven-month-old infants. *Child Development, 63*, 787-795. doi: 10.1111/j.1467-8624.1992.tb01661.x

Sommerfelt, K., Ellertsen, B., & Markestad, T. (1995). Parental factors in cognitive outcome of non-handicapped low birthweight infants. *Archives of Diseases in Childhood: Fetal and Neonatal Edition, 73,* F135-F142. doi: 10.1136/fn.73.3.F135

Spencer, J., O'Brien, J., Johnston, A., & Hill, H. (2006). Infants' discrimination of faces by using biological motion cues. *Perception, 35*, 79-89. doi: 10.1068/p5379

Spittle, A. J., Ferretti, C., Anderson, P. J., Orton, J., Eeles, A., Bates, L., ... & Doyle, L. W. (2009). Improving the outcome of infants born at< 30 weeks' gestation-a randomized controlled trial of preventative care at home. *BMC Pediatrics*, *9*, 73. doi: 10.1186/1471-2431-9-73

Spitzberg, B. H. (2003). Methods of interpersonal skill assessment. In J. O. Greene & B. R. Burleson (Eds.), *Handbook of communication and social interaction skills* (pp. 93-134). Mahwah, NJ: Lawrence Erlbaum Associates, Inc.

Stephens, B. E., Bann, C. M., Watson, V. E., Sheinkopf, S. J., Peralta-Carcelen, M., Bodnar, A., … Vohr, B. R. (2012). Screening for autism spectrum disorders in extremely preterm infants. *Journal of Developmental & Behavioral Pediatrics*, *33*, 535-541. doi: 10.1097/DBP.0b013e31825fd0af

Stevenson, D. K., Wright, L. L., Lemons, J. A., Oh, W., Korones, S. B., ... & Verter, J. (1998). Very low birth weight outcomes of the national institute of child health and human development neonatal research network, January 1993 through December 1994. *American Journal of Obstetrics and Gynecology*, *179*, 1632-1639. doi: 10.1016/S0002-9378(98)70037-7

Symons, L. A., Hains, S. M., & Muir, D. W. (1998). Look at me: Five-month-old infants' sensitivity to very small deviations in eye-gaze during social interactions. *Infant Behavior and Development*, *21*, 531-536. doi: 10.1016/S0163-6383(98)90026

Swettenham, J. (1996). Can children with autism be taught to understand false belief using computers? *Journal of Child Psychology and Psychiatry, 37*, 157-165. doi: 10.1111/j.1469-7610.1996.tb01387.x

Tager-Flusberg, H. (1992). Autistic children's talk about psychological states: Deficits in the early acquisition of a theory of mind. *Child Development, 63*, 161-172. doi: 10.1111/j.1467-8624.1992.tb03604.x

Tanaka, J. W., Wolf, J. M., Klaiman, C., Koenig, K., Cockburn, J., Herlihy, L., ... & Schultz, R. T. (2010). Using computerized games to teach face recognition skills to children with autism spectrum disorder: The Let's Face It! program. *Journal of Child Psychology and Psychiatry*, *51*, 944-952. doi: 10.1111/j.1469-7610.2010.02258.x

Taylor, N. M. (2008). *Cortical visual processing in children born preterm and at term* (unpublished dissertation). University of Manitoba, Winnipeg MB.

Taylor, N. M., & Jakobson, L. S. (2013). Persisting deficits in mirror-normal discrimination among preterm youth. Presented at the 2013 meeting of the International Neuropsychological Society, Waikoloa, Hawaii.

Taylor, N. M., & Jakobson, L. S. (2010). Representational momentum in children born preterm and at term. *Brain and Cognition*, *72*, 464-471. doi: 10.1016/j.bandc.2010.01.003

Taylor, N. M., & Jakobson, L. S. (2009). Mental rotation in preterm children. *Journal of Vision, 9*, 1061; doi: 10.1167/9.8.1061

Taylor, N. M., Jakobson, L. S., Lewis, D., & Maurer, T. L. (2009). Differential vulnerability of global motion, global form, and biological motion processing in full-term and preterm children. *Neuropsychologia, 47*, 2766-2778. doi: 10.1016/j.neuropsychologia.2009.06.001

Thompson, B., Hansen, B. C., Hess, R. F., & Troje, N. F. (2007). Peripheral vision: Good for biological motion, bad for signal noise segregation? *Journal of Vision 7*, 12. doi: 10.1167/7.10.12

Trimboli, A., & Walker, M. (1993). The CAST test of nonverbal sensitivity. *Journal of Language and Social Psychology*, *12*, 49-65. doi: 10.1177/0261927X93121004

Troje, N. F. (2008). Retrieving information from human movement patterns. In T. F. Shipley & J. M. Zacks (Eds.), *Understanding events: From perception to action. Oxford series in visual cognition*. (pp. 308-334). New York: Oxford University Press.

Troje, N. F. (2002a). Decomposing biological motion: A framework for analysis and synthesis of human gait patterns. *Journal of Vision, 2*, 371-387. doi: 10:1167/2.5.2

Troje, N. F. (2002b). The little difference: Fourier based synthesis of gender-specific biological motion. In R. Würtz & M. Lappe (Eds.), *Dynamic perception* (pp. 115-120). Berlin: Aka Press.

Troje, N. F. (2013). What is biological motion? Definition, stimuli and paradigms. In M. D. Rutherford & V A. Kuhlmeier (Eds.), *Social perception: Detection and interpretation of animacy, agency, and intention* (pp. 13-37). Cambridge: MIT Press.

Troje, N. F. & Chang, D. H. F. (2013). Shape-independent processes in biological motion perception. In K. L. Johnson & M. Shiffrar (Eds.), *People watching: Social, perceptual, and neurophysiological studies of body perception*. (pp. 82-100). Oxford: University Press.

Troje, N. F., Sadr, J., Geyer, H., & Nakayama, K. (2006). Adaptation aftereffects in the perception of gender from biological motion. *Journal of Vision, 6*, 850-857. doi: 10.1167/6.8.7

Troje, N. F., & Westhoff, C. (2006). The inversion effect in biological motion perception: Evidence for a “Life Detector”? *Current Biology, 16*, 821-824. doi: 10.1016/j.cub.2006.03.022

Troje, N. F., Westhoff, C., & Lavrov, M. (2005). Person identification from biological motion: Effects of structural and kinematic cues. *Perception & Psychophysics, 67*, 667-675. doi: 10.3758/BF03193523

Ungerer, J., & Sigman, M. (1981). Symbolic play and language comprehension in autistic children. *Journal of the American Academy of Child Psychiatry, 20*, 318-337.

Vallortigara, G., Regolin, L., & Marconato, F. (2005). Visually inexperienced chicks exhibit spontaneous preference for biological motion patterns. *Plos Biology, 3*, 1312-1316. doi: 10.1371/journal.pbio.0030208

Vanderveen, J. A., Bassler, D., Robertson, C. M. T., & Kirpalani, H. (2009). Early interventions involving parents to improve neurodevelopmental outcomes of premature infants: A meta-analysis. *Journal of Perinatology*, *29*, 343-351. doi: 10.1038/jp.2008.229

Virués-Ortega, J. (2010). Applied behavior analytic intervention for autism in early childhood: Meta-analysis, meta-regression and dose-response meta-analysis of multiple outcomes. *Clinical Psychology Review*, *30*, 387-399. doi: 10.1016/j.cpr.2010.01.008

Volpe, J. J. (2001). Neurobiology of periventricular leukomalacia in the premature infant. *Pediatric Research*, *50*, 553-562.

Volpe, J. J. (2003). Cerebral white matter injury of the premature infant-more common than you think. *Pediatrics, 112,* 176-180.

Voss, W., Jungmann, T., Wachtendorf, M., & Neubauer A. (2012). Long-term cognitive outcomes of extremely low-birth-weight infants: The influence of the maternal educational background. *Acta Paediatrica, 101*, 569-573. doi: 10.1111/j.1651-2227.2012.02601.x

Walper, S., & Valtin, R. (1992). Children's understanding of white lies. In R. J. Watts, S. Ide, & K. Ehlich (Eds.), *Politeness in language* (pp. 231-251). Berlin/New York: Mouton de Gruyter.

Waters, E., & Sroufe, L. A. (1983). Social competence as a developmental construct. *Developmental Review, 3*, 79-97. doi: 10.1016/0273-2297(83)90010-2

Watson, A. B., & Fitzhugh, A. (1990). The method of constant stimuli is inefficient. *Perception & Psychophysics, 47*, 87-91.

Watson, A. B., & Pelli, D. G. (1983). QUEST - A bayesian adaptive psychometric method. *Perception & Psychophysics, 33*, 113-120.

Wechsler, D., (1991). *Wechsler Intelligence Scale for Children – Third Edition*. San Antonio, TX: The Psychological Corporation.

Weed, E., McGregor, W., Nielsen, J. F., Roepstorff, A., & Frith, U. (2010). Theory of mind in adults with right hemisphere damage: What's the story? *Brain and Language, 113*, 65-72. doi: 10.1016/j.bandl.2010.01.009

Westhoff, C., & Troje, N. F. (2007). Kinematic cues for person identification from biological motion. *Perception & Psychophysics, 69*, 241-253. doi: 10.3758/BF03193746

White, S. J., Coniston, D., Rogers, R., & Frith, U. (2011). Developing the Frith-Happé animations: A quick and objective test of Theory of Mind for adults with autism. *Autism Research, 3*, 1-6. doi: 10.1002/aur.174

Williams, K. T. (2007). Expressive Vocabulary Test, Second Edition, Circle Pines, MN: AGS Publishing.

Williamson, K. E. & Jakobson, L. S. (in press). Social Perception in Children Born at Very Low Birth Weight and its Relationship to Social/Behavioural Outcomes. *Journal of Child Psychology and Psychiatry*.

Williamson, K. E. & Jakobson, L. S. (in press). Social Attribution Skills of Children Born Preterm at Very Low Birth Weight. *Development and Psychopathology.*

Wing, L., Gould, J., Yeates, S. R., & Brierley, L. M. (1977). Symbolic play in severely mentally retarded and in autistic children. *Journal of Child Psychology and Psychiatry, 18*, 167-178. doi: 10.1111/j.1469-7610.1977.tb00426.x

Wocadlo, C., & Rieger, I. (2006). Social skills and nonverbal decoding of emotions in very preterm children at early school age. *European Journal of Developmental Psychology*, *3*, 48-70. doi: 10.1080/17405620500361893

Wood, N. S., Marlow, N., Costeloe, K., Gibson, A. T., & Wilkinson, A. R. (2000). Neurologic and developmental disability after extremely preterm birth. *New England Journal of Medicine*, *343*, 378-384. doi: 10.1056/NEJM200008103430601

Woodward, L. J., Anderson, P. J., Austin, N. C., Howard, K., & Inder, T. E. (2006). Neonatal MRI to predict neurodevelopmental outcomes in preterm infants. *New England Journal of Medicine*, *355*(7), 685-694

Woodward, L. J., Edgin, J. O., Thompson, D., & Inder, T. E. (2005). Object working memory deficits predicted by early brain injury and development in the preterm infant. *Brain, 128,* 2578-2587. doi: 10.1093/brain/awh618

World Health Organization. (2012). Born too soon: The global action report on preterm birth. Retrieved from http://www.who.int/pmnch/media/news/2012/201204_borntoosoon-report.pdf

Wright, T. M., Pelphery, K. A., Allison, T., McKeown, M. J., & McCarthy, G. (2003). Polysensory interactions along lateral temporal regions evoked by audiovisual speech. *Cerebral Cortex, 13*, 1034-1043. doi: 10.1093/cercor/13.10.1034

Yeates, K. O., & Selman, R. L. (1989). Social competence in the schools: Toward an integrative developmental model for intervention. *Developmental Review, 9*, 64-100. doi: 10.1016/0273-2298(89)90024-5

Zilbovicius, M., Meresse, I., Chabane, N., Brunelle, F., Samson, Y., & Boddaert, N. (2006). Autism, the superior temporal sulcus and social perception. *Trends in Neurosciences, 29*, 359-366. doi: 10.1016/j.tins.2006.06.004

Zubiaurre-Elorza, L., Soria-Pastor, S., Junque, C., Vendrell, P., Padilla, N., Rametti, G., … Botet, F. (2009). Magnetic resonance imaging study of cerebral sulci in low-risk preterm children. *International Journal of Developmental Neuroscience, 27*, 559-565. doi: 10.1016/j.ijdevneu.2009.06.006

Zwickel, J., White, S. J., Coniston, D., Senju, A., & Frith U. (2011). Exploring the building blocks of social cognition: Spontaneous agency perception and visual perspective taking in autism. *Social Cognitive and Affective Neuroscience, 6*, 564-571. doi: 10.1093/scan/nsq088

Appendices

Appendix A

Recruitment Letter - Preterm children

From: Dr. Diane Moddemann
Director, Newborn High Risk Follow-Up Program
Health Sciences Centre and St. Boniface Hospital

Dear parents/guardians,

I am writing to you on behalf of Kate Williamson, a Ph.D. student in the Department of Psychology at the University of Manitoba working under the supervision of Dr. Lorna Jakobson. I would like to ask for you and your child's help in completing an important research project that will form part of Ms. Williamson's Ph.D. thesis. While not directly involved in the research, the Newborn High Risk Follow-up Program supports this project and is assisting with participant recruitment.

<u>WHAT IS THE STUDY ABOUT?</u>

The study involves children who are now eight to eleven years of age who were born before 32 weeks gestation. It explores two skills that help us to understand other people and the world around us. The first is the ability to see and interpret human motion. The second involves our ability to use visual cues, like facial expressions or body language, to guess what a person is thinking or feeling. Past research in Dr. Jakobson's laboratory has shown that children who were born too soon and very small sometimes have more trouble with certain aspects of their vision than children who were born at the right time. In conducting her Ph.D. research, Ms. Williamson is trying to learn more about this, and to think of ways to help these children develop their visual skills.

<u>WHAT WILL MY CHILD HAVE TO DO?</u>

Your child will be asked to complete a series of tasks. These will include several tests assessing your child's vision and vocabulary, followed by several computerized tests assessing his/her ability to see and interpret the movements of human figures or shapes, or different social scenes. Your child will also be asked to complete a brief questionnaire concerning their behaviours and emotions. Most children find most of these activities quite fun, and none of them take very long. The researchers will provide your child with breaks when necessary throughout the testing, so that he/she doesn't become too tired.

<u>WHAT DO I HAVE TO DO?</u>

You will need to bring your child to the Psychology Department at the University of Manitoba and complete several short questionnaires while your child is being tested. This will take you no longer than 30-40 minutes. Specifically, you will be asked to complete several short questionnaires about your family demographics and your child's development, behaviours, emotions, social skills and personality traits. Testing will be carried out at a time that is convenient for you. We will provide parking, and families will be reimbursed for travel expenses if they are coming from out of town. We will provide you with an information sheet outlining some of what is known about the visual problems experienced by many premature children. Your child will receive a Certificate of Appreciation, and your family will receive an honorarium of $40 in appreciation of your time and research contribution.

IS THERE ANYTHING ELSE?

To complete this study the researchers will need your permission to access pertinent information about your child's birth and early medical history from his/her follow-up records. Your family's confidentiality will be respected at all times, and all information regarding your child's identity and performance will remain completely confidential. If you choose on behalf of your child to participate in this study, you can withdraw your child from the study at any time without any negative consequences.

Please indicate on the attached sheet whether it would be acceptable for Ms. Williamson to contact you regarding further information and participation in this study.

Yours truly,

Dr. Diane Moddemann
Director, Newborn High Risk Follow-Up Program
Health Sciences Centre and St. Boniface Hospital

Appendix B

Recruitment Letter - Full-term children

Dear Parents,

This letter is going home to parents of children in grades 3-6.

My name is Kate Williamson and I am a Ph.D. student in the Psychology Department at the University of Manitoba. I am carrying out a research project for my Ph.D. thesis looking at two skills that help us to understand other people and the world around us. The first is the ability to see and interpret human motion. The second involves our ability to use visual cues, like facial expressions or body language, to guess what a person is thinking or feeling. Past research has shown that children who were born too soon and very small sometimes have more trouble with certain aspects of their vision than children who were born at the right time. We are trying to learn more about this so that we can help them to develop their visual skills.

To determine which tests are most difficult for the premature children, we will be comparing their performance on a set of tests to that of a comparison group. **If your child is 8 to 11 years old, was born within 2 weeks of his/her expected due date, weighed more than 2.5kg (5.5 lbs) at birth and whose first language is English**, we would like to invite your child to participate in our project as part of the comparison group of children.

If you and your child agree to take part in my study, the testing would take place in the Psychology Department at the University of Manitoba. Your child will be asked to complete a series of tasks including several tests assessing vision and vocabulary, followed by several computerized tests assessing the ability to see and interpret the movements of human figures or shapes, or different social scenes. Your child will also be asked to complete a brief questionnaire concerning their behaviours and emotions. All tests will be administered to your child in a one-to-one testing situation by a trained examiner. While your child is being tested, you will be asked to complete several short questionnaires relating to your family demographics and your child's development, behaviours, emotions, social skills and personality traits. This will take no longer than 30-40 minutes.

Appointments can be arranged at your convenience, during the day, in the evenings, or on the weekends. We will cover your parking costs at the University. We will provide you with an information sheet outlining some of what is known about the visual problems experienced by many premature children. Your child will receive a Certificate of Appreciation, and your family will receive an honorarium of $40 in appreciation of your time and research contribution. Please note that participation in this research is entirely voluntary. You may choose not to participate. If you choose on behalf of your child to participate in this study you can withdraw your child from the study at any time without any negative consequences.

If you are interested in participating in this research study, or have any questions, please leave a message for Kate Williamson, at (**204)-474-8354**. Those with Internet access may also e-mail Kate Williamson at **umwill37@cc.umanitoba.ca**. Please include your telephone number in your message. Thank you.

Sincerely,

Kate Williamson, M.A.
Principle Investigator, Ph.D. Candidate

Dr. Lorna S. Jakobson, Ph.D.
Supervisor, Professor of Psychology

Appendix C

Recruitment Poster - Full-term children

Developmental Neuropsychology Laboratory

The Manitoba Institute of Child Health

Full-term 8-11 year old Children Needed for Research Study

RESEARCH STUDY DESCRIPTION: Children ages 8 to 11, born within 2 weeks of their expected due date and weighing more than 2.5 kg (5.5 lbs) are needed for a research study. The focus of the research project is on social perception (our ability to understand others and the world around us).

WHAT IS REQUIRED? Participating children will complete tasks assessing vocabulary and their ability to see and interpret the movements of objects and people. Children and their parents will be also be asked to complete some short questionnaires.

WHERE? Testing will take place at the University of Manitoba. Participants will receive an honorarium of $40.

For more information please contact Kate Williamson, Department of Psychology, University of Manitoba

Research Study for 8-11 year olds
Kate Williamson (204)-474-8354
Email: umwill37@cc.umanitoba.ca

Research Study for 8-11 year olds
Kate Williamson (204)-474-8354
Email: umwill37@cc.umanitoba.ca

Research Study for 8-11 year olds
Kate Williamson (204)-474-8354
Email: umwill37@cc.umanitoba.ca

Research Study for 8-11 year olds
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Research Study for 8-11 year olds
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Research Study for 8-11 year olds
Kate Williamson (204)-474-8354
Email: umwill37@cc.umanitoba.ca

Research Study for 8-11 year olds
Kate Williamson (204)-474-8354
Email: umwill37@cc.umanitoba.ca

Appendix D

Information and Consent Form - Preterm children

This consent form, a copy of which will be left with you for your records and reference, is only part of the process of informed consent. It should give you the basic idea of what the research is about and what your participation will involve. If you would like more detail about something mentioned here, or information not included here, you should feel free to ask. Please take the time to read this carefully and to understand any accompanying information.

Research Project Title: Biological Motion Perception and Theory of Mind Abilities in Preemies: Implications for Social Cognition

Principle Researcher: Kate Williamson, MA (204) 474-8354
Supervisor: Dr. Lorna Jakobson, Ph.D (204) 474-6980

This research will form part of Kate Williamson's PhD thesis in Psychology.

Purpose of the Research:
This research project concerns two skills that help us to understand other people and the world around us. The first is the ability to see and interpret human motion. The second involves our ability to use visual cues, like facial expressions or body language, to guess what a person is thinking or feeling. Past research has shown that children who were born too soon and very small sometimes have more trouble with certain aspects of their vision than children who were born at or near their due date. We are trying to learn more about this so that we can help them to develop their visual skills.

Description of the Research:
In this research study, information will be collected from both the parent or legal guardian, and the child. While your child is being tested, you will be asked to complete several short questionnaires relating to your family demographics and your child's development, behaviors, emotions, social skills and personality traits. This will take no longer than 30-40 minutes. We will also need your consent to obtain specific information about your child's birth and early medical history from his/her follow-up records. Your child will be asked to complete a series of tasks. These will include several tests assessing your child's vision and vocabulary, followed by several computerized tests assessing his/her ability to see and interpret the movements of human figures or shapes, or different social scenes. Your child will also be asked to complete a brief questionnaire concerning their behaviors and emotions. Although all of the testing will take about 2.5 hours, your child may find most of these activities quite fun, and none of them take very long. We will provide your child with breaks when necessary throughout the testing, so that he/she doesn't become too tired.

Risk and Benefits:
Taking part in this study will help you and your child to learn about the kind of research that psychologists do. The results will help us learn more about how our vision develops, and how vision helps us to understand social situations. If we can figure out why many premature children have difficulty with their vision, we may be able to think of better ways to help them develop their visual skills.

There are no known risks to people who take part in this research project. However, some of the children may find some of the tests boring or a little bit hard to do.

Confidentiality:
Confidentiality will be respected and no information about individuals will be released or published without consent unless required by law. The results of the tests described above will be used for research purposes only in the context of the study. The only people who will have access to this information are Dr. Jakobson and her students. All information will be stored in a secure place (locked filing cabinet and password protected electronic database). The electronic database will not contain any information that could be used to identify your child; these data will be kept for a minimum of 5 years, in accordance with the guidelines of the Human Ethics Review Board.

Our normal procedure is to destroy identifying information (information that could be used to link your child to the electronic database) as soon as it is no longer needed. If you would be interested in hearing about future opportunities to participate in research in our laboratory, however, we will ask for your permission to maintain your name and contact information in a secure place for up to 5 years. If you agree to this, you should know that you would be able to withdraw your consent at any point during this time, at which point we would destroy any records containing identifying information and remove your name from our contact list.

Reimbursement:
Parking will be covered. In addition, your family will be given a $40 honorarium in appreciation for your time and research contribution.

Participation:
Your signature on this form indicates that you have understood, to your satisfaction, the information regarding participation in the research project and agree to participate. In no way does this waive your legal rights nor release the researchers, sponsors, or involved institution from their legal and professional responsibilities. Participation in this study is voluntary. You are free to withdraw from the study at any time, and/or refrain from answering any questions you prefer to omit, without prejudice or negative consequences. Your continued participation should be as informed as your initial consent, so you should feel free to ask for clarification or new information throughout your participation. Upon completion of your part in this study, a detailed description about the purpose and expected findings of the experiment will be provided.

The Psychology/Sociology Research Ethics Board at the University of Manitoba has approved this research. If you have any concerns or complaints about this project you may contact any of the above-named persons or the Human Ethics Secretariat at 474-7122, e-mail margaret_bowman@umanitoba.ca. A copy of this consent form has been given to you to keep for your records and reference.

Consent:
In signing this form, I acknowledge that I have read and understood the research procedures described above and that any questions I may have had have been answered to my satisfaction. I also acknowledge that I have the right to not participate and the right to withdraw at any time. In addition, I have been informed of the potential harms and discomforts and understand the benefits of participating in this research. Finally, I have been assured that any information collected in this research project will be kept confidential and will not be released or printed without expressed written consent or required by law.

____
Child's Name (PLEASE PRINT)

______________________________________	____________________________
Parent/Guardian's Name (PLEASE PRINT)	Legal relationship to child
______________________________________	____________________________
Parent/Guardian's Signature	Date
______________________________________	____________________________
Researcher and/or Delegate's Signature	Date

Would you like to receive a summary of results at the completion of this study?
[Please note that only group results, and not individual findings from your child, will be released. A summary will be provided by September 2012.]

☐ Yes ☐ No

If you answered yes to the above, please print your surface or email address below.

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____

Would you be interested to hear about future opportunities to participate in research in our laboratory?

If so, please complete this form. By signing your name below, you agree to allow us to maintain contact information for your family in a secure place for up to 5 years, so that we may contact you with information about future studies. You may withdraw this consent at any point during this time, at which point we will destroy any records containing identifying information and remove you from our contact list.

I, _______________________________________, give my permission for Dr. Lorna Jakobson to keep a record of my contact information, as outlined above.

____
Child's Name (PLEASE PRINT)

____________________________ Parent/Guardian's Name (PLEASE PRINT)	________________________ Legal relationship to child
____________________________ Parent/Guardian's Signature	________________________ Date
____________________________ Researcher and/or Delegate's Signature	________________________ Date

Appendix E

Information and Consent Form - Full-term children

This consent form, a copy of which will be left with you for your records and reference, is only part of the process of informed consent. It should give you the basic idea of what the research is about and what your participation will involve. If you would like more detail about something mentioned here, or information not included here, you should feel free to ask. Please take the time to read this carefully and to understand any accompanying information.

Research Project Title: Biological Motion Perception and Theory of Mind Abilities in Preemies: Implications for Social Cognition

Principle Researcher: Kate Williamson, MA (204) 474-8354
Supervisor: Dr. Lorna Jakobson, Ph.D. (204) 474-6980

This research will form part of Kate Williamson's PhD thesis in Psychology.

Purpose of the Research:
This research project concerns two skills that help us to understand other people and the world around us. The first is the ability to see and interpret human motion. The second involves our ability to use visual cues, like facial expressions or body language, to guess what a person is thinking or feeling. Past research has shown that children who were born too soon and very small sometimes have mor e trouble with certain aspects of their vision than children who were born at or near their due date. We are trying to learn more about this so that we can help them to develop their visual skills. To do this, we need to compare their test results to those of a group of children who were born at the expected time (within two weeks of their due date) and weighing more than 5.5 pounds, to determine which tests are more difficult for the premature children. Your child has been invited to be part of this comparison group.

Description of the Research:
In this research study, information will be collected from both the parent or legal guardian, and the child. While your child is being tested, you will be asked to complete several short questionnaires relating to your family demographics and your child's development, behaviors, emotions, social skills and personality traits. This will take no longer than 30-40 minutes. Your child will be asked to complete a series of tasks. These will include several tests assessing your child's vision and vocabulary, followed by several computerized tests assessing his/her ability to see and interpret the movements of human figures or shapes, or different social scenes. Your child will also be asked to complete a brief questionnaire concerning their behaviors and emotions. Although all of the testing will take about 2.5 hours, your child may find most of these activities quite fun, and none of them take very long. We will provide your child with breaks when necessary throughout the testing, so that he/she doesn't become too tired.

Risk and Benefits:
Taking part in this study will help you and your child to learn about the kind of research that psychologists do. The results will help us learn more about how our vision develops, and how vision helps us to understand social situations. If we can figure out why many premature children have difficulty with their vision, we may be able to think of better ways to help them develop their visual skills.

There are no known risks to people who take part in this research project. However, some of the children may find some of the tests boring or a little bit hard to do.

Confidentiality:
Confidentiality will be respected
and no information about individuals will be released or published without consent unless required by law. The results of the tests described above will be used for research purposes only in the context of the study. The only people who will have access to this information are Dr. Jakobson and her students. All information will be stored in a secure place (locked filing cabinet and password protected electronic database). The electronic database will not contain any information that could be used to identify your child; these data will be kept for a minimum of 5 years, in accordance with the guidelines of the Human Ethics Review Board.

Our normal procedure is to destroy identifying information (information that could be used to link your child to the electronic database) as soon as it is no longer needed. If you would be interested in hearing about future opportunities to participate in research in our laboratory, however, we will ask for your permission to maintain your name and contact information in a secure place for up to 5 years. If you agree to this, you should know that you would be able to withdraw your consent at any point during this time, at which point we would destroy any records containing identifying information and remove your name from our contact list.

Reimbursement:
Parking will be covered. In addition, your family will be given a $40 honorarium in appreciation for your time and research contribution.

Participation:
Your signature on this form indicates that you have understood, to your satisfaction, the information regarding participation in the research project and agree to participate. In no way does this waive your legal rights nor release the researchers, sponsors, or involved institution from their legal and professional responsibilities. Participation in this study is voluntary. You are free to withdraw from the study at any time, and/or refrain from answering any questions you prefer to omit, without prejudice or negative consequences. Your continued participation should be as informed as your initial consent, so you should feel free to ask for clarification or new information throughout your participation. Upon completion of your part in this study, a detailed description about the purpose and expected findings of the experiment will be provided.

The Psychology/Sociology Research Ethics Board at the University of Manitoba has approved this research. If you have any concerns or complaints about this project you may contact any of the above-named persons or the Human Ethics Secretariat at 474-7122, e-mail margaret_bowman@umanitoba.ca. A copy of this consent form has been given to you to keep for your records and reference.

Consent:
In signing this form, I acknowledge that I have read and understood the research procedures described above and that any questions I may have had have been answered to my satisfaction. I also acknowledge that I have the right to not participate and the right to withdraw at any time. In addition, I have been informed of the potential harms and discomforts and understand the benefits of participating in this research. Finally, I have been assured that any information collected in this research project will be kept confidential and will not be released or printed without expressed written consent or required by law.

____
Child's Name (PLEASE PRINT)

______________________________	__________________________
Parent/Guardian's Name (PLEASE PRINT)	Legal relationship to child
______________________________	__________________________
Parent/Guardian's Signature	Date
______________________________	__________________________
Researcher and/or Delegate's Signature	Date

Would you like to receive a summary of results at the completion of this study?
[Please note that only group results, and not individual findings from your child, will be released. A summary will be provided by September 2012.]

☐ Yes ☐ No

If you answered yes to the above, please print your surface or email address below.

____

____

____

____

____

Would you be interested to hear about future opportunities to participate in research in our laboratory?

If so, please complete this form. By signing your name below, you agree to allow us to maintain contact information for your family in a secure place for up to 5 years, so that we may contact you with information about future studies. You may withdraw this consent at any point during this time, at which point we will destroy any records containing identifying information and remove you from our contact list.

I, ______________________________________, give my permission for Dr. Lorna Jakobson to keep a record of my contact information, as outlined above.

____
Child's Name (PLEASE PRINT)

______________________________________ ______________________________
Parent/Guardian's Name (PLEASE PRINT) Legal relationship to child

____ ______________________________
Parent/Guardian's Signature Date

____ ______________________________
Researcher and/or Delegate's Signature Date

Appendix F

GENERAL INFORMATION QUESTIONNAIRE

NOTE: This information will be kept strictly confidential and will be used for research purposes only. If you wish to decline to answer any of the following questions, please feel free to do so.

Participant ID #: ____________

MOTHER

Please indicate the highest level of education that you have completed:

_____ Less than seventh grade
_____ Seventh through ninth grade
_____ Tenth through eleventh grade
_____ Completed high school
_____ Partial college/university (at least one year) or specialized training
_____ Completed college or university degree
_____ Completed graduate degree

Please indicate which diploma(s), degree(s), or certificate(s) you have received:

_____ None
_____ HS diploma/GED
_____ Associate degree
_____ BA or BSc
_____ MA or MSc
_____ MD, DDS, JD, LLB, or LLD
_____ PhD or EdD
_____ Certificate (specify): ___________________

Present Occupation:
____

FATHER

Please indicate the highest level of education that you have completed:

_____ Less than seventh grade
_____ Seventh through ninth grade
_____ Tenth through eleventh grade
_____ Completed high school
_____ Partial college/university (at least one year) or specialized training
_____ Completed college or university degree
_____ Completed graduate degree

Please indicate which diploma(s), degree(s), or certificate(s) you have received:

_____ None
_____ HS diploma/GED
_____ Associate degree
_____ BA or BSc
_____ MA or MSc
_____ MD, DDS, JD, LLB, or LLD
_____ PhD or EdD
_____ Certificate (specify): ___________________

Present Occupation:
____

FAMILY

Please indicate who your child lives with:

______ Mother ______ Both Parents

______ Father ______ Other (please specify):

Please indicate your annual household income:

______ Under $11,000
______ $11,000-$20,999
______ $21,000-$30,999
______ $31,000-$40,999
______ $41,000-$50,999
______ $51,000-$75,000
______Over $75,000

How many individuals are living in the household?
____

What language(s) are spoken in the home?
____

What language(s) do you speak with your child?
____

Have either parent ever had any academic problems? If yes, whom and what type?
____
____
____

CHILD

Child's date of birth: ___________________ Age: ____________

Gender: M / F

Birth Weight: ____________ Current Height: ___________ Current Weight: ___________

Racial/Cultural Background: ____

Were there any problems during pregnancy or delivery (including perinatal complications in the mother, such as diabetes, pregnancy-induced hypertension or preeclampsia)? If yes, please describe:

____

____

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____

Has your child ever sustained a head injury? If yes, please describe:

____

____

____

____

____

If yes, how long was he/she unconscious for?

____

Has your child had any other major health problems that required medical attention? If yes, please describe:

____

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____

____

____

Please indicate the following services that your child has used and for what reason: Occupational Therapist, Physical Therapist, Speech Therapist, Dietician, Psychiatrist, Social Worker, Infant Development Worker/Infant Stimulation Worker, or any other special services:

Has your child taken part in any organized early intervention program (not mentioned above) to support their development?

Have any of your children been identified as having academic problems? If yes, whom and what type?

Have any of your children been identified as having behavioral difficulties? If yes, whom and what type?

In the past year, has your child participated in any of the following activities, such as organized sports, clubs, social networking (i.e. msn, facebook or email), computer or video games? If yes, please provide details about what activities, and the frequency of the activities?

____

____

____

____

Appendix G

CASP OBJECT MEMORY SCORING SHEET:

Instructions: Score one point for the correct identification of the number of characters and location, as well as one point of the following visual details. See below for acceptable answers and alternative names.

☐ **Scene 1 (max. score 5)**
__ Number of characters: 3
__ Location: room in house/school/restaurant
Features:
- __ table
- __ salt and pepper shakers
- __ seat/chair

☐ **Scene 2 (max. score 7)**
__ Number of characters: 2
__ Location: room in house
Features:
- __ couch
- __ magazine
- __ box or present
- __ sweater in box
- __ white shirt

☐ **Scene 3 (max. score 10)**
__ Number of characters: 2
__ Location: room in house
Features:
- __ pony tail
- __ couch
- __ TV screen/videogame
- __ video game hand controller
- __ pillow
- __ videogame plug (outlet)
- __ cabinet
- __ glasses

☐ **Scene 4 (max. score 6)**
__ Number of characters: 3
__ Location: at school
Features:
- __ water fountain
- __ 3 backpacks
- __ garbage can
- __ guy with the glasses

☐ **Scene 5 (max. score 9)**
__ Number of characters: 2
__ Location: room in house or kitchen
Features:
- __ pots
- __ spoon
- __ kitchen supplies
- __ tissue
- __ coffee cup
- __ tea pot
- __ food or supper

☐ **Scene 6 (max. score 7)**
__ Number of characters: 4 kids or 4 kids & teacher
__ Location: in a classroom
Features:
- __ student's desks
- __ papers on teacher's desk
- __ teacher's desk
- __ pencils
- __ test/papers

☐ **Scene 7 (max. score 10)**
__ Number of characters: 2
__ Location: cafeteria
Features:
- __ table
- __ flowers on table
- __ salt and pepper on table
- __ canned drink
- __ tray
- __ food/lunch/apple/sandwich
- __ spoon
- __ napkin

☐ **Scene 8 (max. score 5)**
__ Number of characters: 3
__ Location: behind house/school or outside
Features:
- __ can of beer/drink/pop can
- __ door/wall
- __ pocket

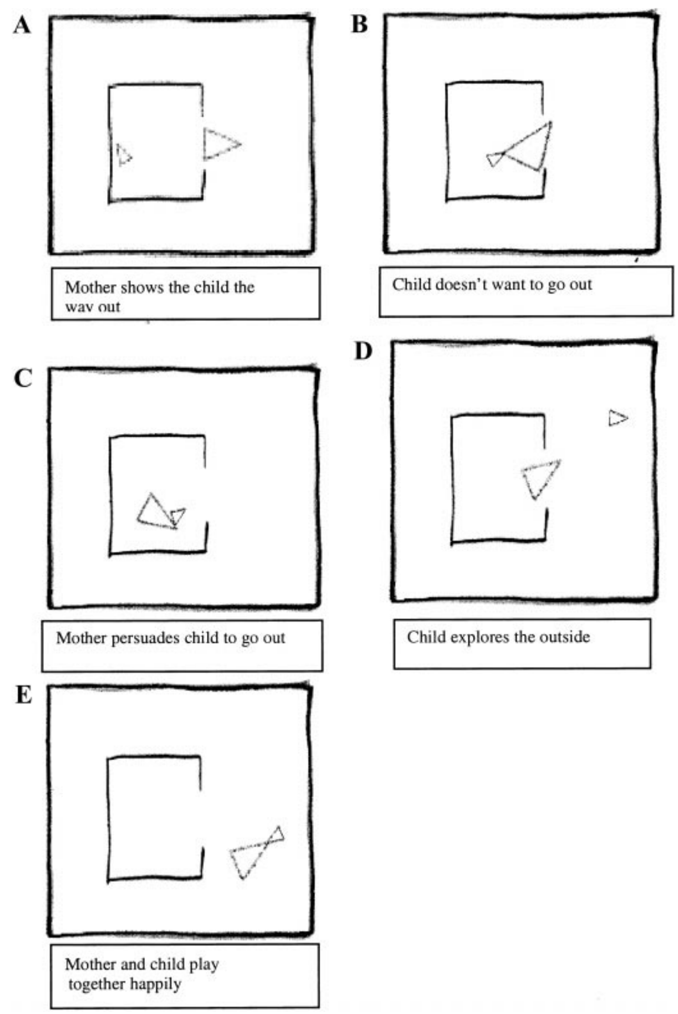
☐ **Scene 9 (max. score 8)**
__ Number of characters: 2
__ Location: classroom
Features:
- __ pony tail
- __ desks
- __ books on desk
- __ bag (girl sitting)
- __ backpack (girl kneeling)
- __ papers/binder/homework given

☐ **Scene 10 (max. score 9)**
__ Number of characters: 3
__ Location: room in house or kitchen
Features:
- __ papers/bills/homework
- __ coffee cup
- __ calculator
- __ paper rolls
- __ table
- __ pencil
- __ chair

Appendix H

Five stills taken from Animated Triangles Task - Theory of Mind "Coaxing" condition

(Reprinted from NeuroImage, 12, Castelli, Happé, Frith, & Frith, (2000). Movement and mind: A functional imaging study of perception and interpretation of complex intentional movement patterns, 323, Copyright (2013), with permission from Elsevier**)**



Appendix I

Scoring Criteria and Examples for Verbal Descriptions of Animations

(Reprinted from NeuroImage, 12, Castelli, Happe, Frith, & Frith, (2000). Movement and mind: A functional imaging study of perception and interpretation of complex intentional movement patterns, 323, Copyright (2013), with permission from Elsevier**)**

Score (0-5) for Intentionality:
0 = action, nondeliberate
(e.g., "Bouncing," "Moving around," "Rotating")
1 = deliberate action with no other
(e.g., "Ice-skating")
2 = deliberate action with another
(e.g., "Blue and red are fighting," "Parent is followed by child")
3 = deliberate action in response to other's action
(e.g., "Big is chasing little," "Red is allowing the Blue to get close to him," "Big is guarding little who was trying to escape")
4 = deliberate action in response to other's mental state
(e.g., "The little one is mocking the big one," "Two people are arguing," "A parent is encouraging a child to go outside")
5 = deliberate action with goal of affecting other's mental state
(e.g., "The blue triangle wanted to surprise the red one," "Child pretending not to be doing any- thing")

Score (0-3) for Appropriateness:
0 = no answer, "I don't know"
1 = inappropriate answer: reference to the wrong type of interaction between triangles
2 = partially correct answer: reference to correct type of interaction but confused overall description
3 = appropriate, clear answer

Score (0-3) for Certainty (based on voice tone):
0 = long hesitation or silence
1 = hesitation, few words, sentences unfinished, need to be prompted to say more
2 = hesitation between words, alternative answers
3 = no hesitation at all, quick answer, description correctly reflects the script underlying the animation