# BIOLOGICAL MOTION PERCEPTION IN PERSONS WITH SCHIZOPHRENIA

# BIOLOGICAL MOTION PERCEPTION IN PERSONS WITH SCHIZOPHRENIA

JUSTINE M. Y. SPENCER, B.SC.

A Thesis Submitted to the School of Graduate Studies in Partial Fulfillment of the Requirements for the Degree of Doctor of Philosophy

McMaster University DOCTOR OF PHILOSOPHY (2015)

Hamilton, Ontario (Psychology)

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| TITLE: | Biological motion perception in persons with schizophrenia |
| AUTHOR: | Justine M. Y. Spencer, B.Sc. (University of Ottawa) |
| SUPERVISORS: | Bruce Christensen, Ph.D., C.Psych |
| | Allison B. Sekuler, Ph.D. |
| PAGES: | xvii, 236 |

## LAY ABSTRACT

As people navigate though day-to-day life, they encounter many objects in the world that move, such as other people. Research has shown that humans are adept at discriminating human movement and accurate in discerning the emotional states of other people based on this movement. These observations have lead researchers to speculate that, because biological motion is both easy to discriminate and emotionally informative, it plays an essential role in social processing among humans. Research has shown that individuals with Schizophrenia have difficulty understanding social environmental cues, such as the emotions of others. As such, this thesis aims to determine first, whether people with Schizophrenia have difficulty identifying human motion, and second, if they are able to identify emotions embedded within human motion. This thesis will help researchers understand and explain deficits in social perception among people with Schizophrenia.

## ABSTRACT

Schizophrenia (SCZ) is associated with robust social deficits, which have been shown to precede illness onset and predict functional outcome. As a result, social functioning is an important developmental domain affected by SCZ, which likely has a downstream negative impact on other functional abilities, such as interpersonal relationships and vocational capacity. Patients with SCZ also demonstrate significant visual perceptual deficits; however, a remaining question is whether basic impairment in visual processing gives rise to the deficits observed in social perception. In this context, previous research has shown that biological motion contains relevant social information, such as emotional states and intention, which is easily interpreted by healthy observers. Given that biological motion perception is an important source of social information, and that patients with SCZ have known visual perceptual impairment including motion processing deficits, it is possible that poor biological motion perception meaningfully impacts social perception among individuals with SCZ. While previous studies have documented preliminary evidence of biological motion processing deficits in this population, there is a current lack of understanding regarding the basic visual perceptual mechanisms that may underpin this impairment, including the importance of basic visual motion processing with respect to biological motion. Moreover, the ability of individuals with SCZ to extract relevant social information from biological motion, and its relationship with social perception more generally, have yet to be investigated. Thus, the specific aims guiding the current thesis were to examine whether basic visual motion processes may give rise to biological motion deficits and to examine the ability of individuals with SCZ to extract

social information, in the form of emotion, from biological motion. Several experimental tasks were used to examine these aims. Overall, the results from this thesis confirm that individuals with SCZ have difficulty perceiving biological motion; however, this deficit was not specific to biological motion, but instead reflected more widespread visual motion processing deficits, including impairment in global coherent motion perception. Additionally, results from this thesis suggest that individuals with SCZ demonstrated disproportionate difficulty extracting social cues, in the form of emotion, from biological motion, and that this deficit was related to perceiving unambiguous expressions of emotion. In contrast, the discrimination of more subtle or ambiguous emotion was relatively preserved. Moreover, impairment in biological motion processing was found to be unrelated to social perceptual abilities among individuals with SCZ. These experiments provide interesting suggestions regarding clinical approaches to treatment and remediation, although further research is needed to fully understand the brain-behaviour mechanisms underlying SCZ-related deficits in biological motion processing.

## ACKNOWLEDGEMENTS

There are many people who have provided a tremendous amount of guidance and support throughout this seven-year journey. First, I would like to thank my primary supervisor, Dr. Bruce Christensen, for his mentorship, guidance, and advocacy during my time at McMaster. I have learned so much from you, including, but not limited to psychopathology, statistics, and how to chose the best quality steak when grocery shopping. Your knowledge and advice have been invaluable and looking back, I could not have asked for a better advisor. I would also like to thank my co-supervisor, Dr. Allison Sekuler, who has been understanding and patient as I pursued this not-so-typical doctoral degree. You have been nothing but supportive in letting me pursue my goals and have provided me with every opportunity that I could have asked for as a graduate student. Thank you also to Dr. Patrick Bennett, who I have always regarded as an "unofficial" supervisor. Your knowledge and guidance have been so important during this process and I will always be appreciative of your willingness and availability to meet with me regardless of your busy schedule. Thank you also to Dr. Michael Kiang, who has always been encouraging and supportive in my research projects and ideas. A special thank you also goes to my colleague, Dr. Regan Patrick, who not only convinced me to pursue clinical psychology, but to a large extent, helped shape my graduate school experience. We've had to jump through a lot of hoops together and I know I would have missed a few if not for your friendship. I would also like to thank my VisLab family, including research assistant Donna Waxman, for your tremendous support and the thoughtful science-related discussions throughout the past few years. I have been fortunate to be surrounded by such

intelligent individuals and I will miss our VSS lab-bonding times. Thank you to my friends in Ottawa and Hamilton who have kept me sane along the way. Thank you also to my mother for providing me, throughout the years, any and every opportunity I could ever hope for and ensuring that I could be successful in any area that I wished. Finally, I would like to thank my husband, Jason Boulet, for your constant support and unwavering belief that I could accomplish anything I set out to do. Your positivity, pep talks, humour, understanding, and love have been paramount in getting me here and I don't have enough words to express how grateful I am to have you as my partner.

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| | |
|---|---|
| AC | Anterior cingulate |
| Alc | Alcohol problems |
| ANVOCA | Analysis of Covariance |
| ANOVA | Analysis of Variance |
| BOLD | Blood-oxygen-level dependent |
| CCTV | Closed-circuit television |
| CNTRICS | Cognitive Neuroscience Treatment to Improve Cognition in Schizophrenia |
| DA | Dopamine |
| Dep | Depression |
| DLPRC | Dorsolateral prefrontal cortex |
| Drg | Drug problems |
| DTI | Diffusion tensor imaging |
| EEG | Electroencephalography |
| ERP | Event-related potential |
| FA | Fractional anisotropy |
| fMRI | Functional magnetic resonance imaging |
| FSIQ | Full Scale Intelligence Quotient |
| GABA | Gamma-aminobutyric acid |
| HC | Healthy control |
| IQ | Intelligence quotient |
| ISI | Inter-stimulus interval |

| | |
|---|---|
| IPT-15 | Interpersonal Perception Task-15 |
| M | Magnocellular |
| MANOVA | Multivariate Analysis of Variance |
| MATRICS | Measurement and Treatment Research to Improve Cognition in Schizophrenia |
| MEG | Magnetoencephalography |
| M.I.N.I. | Mini International Neuropsychiatric Interview |
| MMN | Mismatch negativity |
| MRI | Magnetic resonance imaging |
| MT | Medial temporal |
| NDMA | N-methyl-D-aspartate |
| NIM | Negative Impression Management |
| NIMH | National Institute of Mental Health |
| P | Parvocellular |
| PAI | Personality Assessment Inventory |
| PANSS | Positive and Negative Syndrome Scale |
| PCP | Phencyclidine |
| PET | Positron emission tomography |
| PFC | Prefrontal cortex |
| PIM | Positive Impression Management |
| PL | Point-light |
| PLW | Point-light walker |

| | |
|---|---|
| PLWs | Point-light walkers |
| PT | Planum temporale |
| PSE | Point of subjective equality |
| RBANS | Repeatable Battery for the Assessment of Neuropsychological Status |
| SCIT | Social Cognition and Interactive Training |
| SCZ | Schizophrenia |
| SFS | Social Functioning Scale |
| SPD | Schizotypal Personality Disorder |
| STG | Superior temporal gyri |
| STS | Superior temporal sulcus |
| STSp | Posterior superior temporal sulcus |
| TMS | Transcranial magnetic stimulation |
| ToM | Theory of mind |
| V1 | Visual area 1 |
| V2 | Visual area 2 |
| V3 | Visual area 3 |
| V5 | Visual area 5 |
| WAIS-III | Wechsler Adult Intelligence Scale, 3rd Edition |

## DECLARATION OF ACHIEVEMENT AND ACADEMIC COPYRIGHT

**Chapter 2:** This chapter was a collaboration between myself, Dr. Bruce Christensen, Dr. Allison Sekuler, and Dr. Patrick Bennett. I was the lead on formulating and performing the experiments, analyzing the data, and preparing the manuscript. This chapter has been published in Frontiers in Psychology. The manuscript has been reformatted for consistency within the thesis. A full citation of the article is provided on the cover page of this chapter. No copyright has been assigned to this manuscript at the time of the final thesis submission.

**Chapter 3:** This chapter was a collaboration between myself, Dr. Bruce Christensen, Dr. Allison Sekuler, Dr. Patrick Bennett, Dr. Karin Pilz, and Dr. Martin Giese. I was the lead on formulating the experiments, analyzing the data, and preparing the manuscript. No copyright has been assigned to this manuscript at the time of the final thesis submission.

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## ORGANIZATION OF THESIS

This thesis has been compiled as a "sandwich" thesis. It contains three freestanding manuscripts that have been published (Chapter 2) or prepared for publication (Chapters 3 and 4). The manuscripts are preceded by a General Introduction (Chapter 1) and followed by a General Discussion (Chapter 5). Please note some redundancy between chapters due to the format of the thesis, such as between the General Introduction and the various introduction sections preceding each freestanding manuscript. Also please note that the References section that follows Chapter 5 provides references for the General Introduction and General Discussion chapters. References for the individual manuscripts (Chapters 2-4) are provided in self-contained Reference sections at the end of each manuscript.

# CHAPTER 1

## GENERAL INTRODUCTION

## 1.1 OVERVIEW OF THESIS

Schizophrenia (SCZ) is a psychiatric disorder that deleteriously affects many areas of functioning, including both vocational and interpersonal abilities. For example, approximately 80% of individuals with SCZ are unemployed and many experience homelessness throughout the course of their illness (Marwaha et al., 2007). Moreover, many individuals with SCZ do not form lasting romantic relationships and will experience limited social contact with friends and family (Pinkham & Penn, 2006). Research has suggested that such social deficits might, at least in part, explain poor outcomes more generally since social dysfunction often manifests in real world consequences, such as reduced occupational success and interpersonal fulfillment. For example, among persons with SCZ, variance in social functioning and social skills is mediated by deficits in social cognition (Addington, Girard, Christensen & Addington, 2010; Pinkham & Penn, 2006). Despite these findings, however, the mechanisms underlying SCZ-related social impairment still remain largely unknown. Although humans are exposed to many forms of social information across various distinct naturalistic environments, a consistently important source of non-verbal social information is the perception of others' movement and posture (Niedenthal, 2007; Sevdalis & Keller, 2011). To date, few studies have investigated whether persons with SCZ extract, process, and interpret the movement and posture of others in a normative fashion. Therefore, the purpose of this thesis was to examine the ability of individuals with SCZ to perceive complex visual information in the form of biological motion and to examine the relationship between this ability and more general deficits in social

cognition. The experiments presented here were motivated, in part, by inconsistencies and methodological problems inherent in previous studies, as well as more recent hypotheses proposing the importance of lower-level perceptual mechanisms (e.g., basic motion perception) to explain commonly observed clinical features and outcomes associated with SCZ. Individual chapters of this thesis include the relevant background information and rationale for each individual study. To establish a broader context, however, the current chapter provides an overview of SCZ and associated deficits in social and visual-perceptual processing, in addition to a review of the research literature on biological motion processing in both healthy observers and individuals with SCZ.

## 1.2 SCHIZOPHRENIA: A GENERAL REVIEW

Schizophrenia (SCZ) is a complex and heterogeneous psychiatric disorder that has been extensively studied. Given this large body of research, the purpose of this section (1.2.1 to 1.2.6) is to summarize findings regarding the clinical presentation, epidemiology, and etiology of SCZ, including its impact at both the individual and societal levels.

### 1.2.1 Clinical Features

Schizophrenia is characterized by a wide range of cognitive, behavioural, and emotional abnormalities, although no individual symptom has been shown to be pathognomonic of this disorder (American Psychiatric Association, 2013). Instead, the diagnosis is made based on a constellation of signs and symptoms, including impaired functional capacity (e.g., occupational and social functioning). Common features of SCZ-related psychosis, also referred to as *positive symptoms*, include the occurrence of delusions, hallucinations,

and disorganized thoughts and behaviours. *Delusions* are false beliefs that are firmly held even in the face of conflicting evidence. They can reflect a variety of themes but typically surround ideas of persecution (e.g., the belief that one is the target of harm by another individual, group, and/or organization), grandiosity (e.g., the belief that one possesses exceptional abilities or means), control (e.g., the belief that one's thoughts and actions are manipulated and initiated by an outside force), reference (e.g., belief that environmental cues, gestures, and comments are directed at an individual), and/or somatic concerns (e.g., preoccupation regarding health and bodily function). *Hallucinations* are abnormal, yet vivid, perceptions and interpretations of experiences in the absence of external stimuli (e.g., hearing voices of people who are not present). Although hallucinations occur in all sensory modalities, auditory hallucinations are the most common. *Disorganized thoughts* are typically observed via abnormal speech and language and frequently include loose associations (e.g., spontaneously changing of topics) and tangentiality (e.g., speech containing unrelated ideas and responses). Similarly, *disorganized behaviour* can manifest as agitation, reduced goal-directed activity, bizarre posturing, mutism, echolalia (i.e., repetition of vocalizations made by another individual), and catatonia. The *negative symptoms* of SCZ are often prominent, particularly those of reduced emotional expression and avolition. Reduced emotional expression (i.e., blunted affect) typically is characterized by diminished facial expression, eye contact, prosody, and gesturing. Avolition reflects an overall decrease in motivation and purposeful activities, which can manifest in reduced participation in vocational and social activities. Other negative symptoms include alogia (e.g., poverty of speech) and anhedonia (e.g., reduced ability to

experience pleasurable responses).

A diagnosis of SCZ requires the presence of at least two of these prototypical symptoms (e.g., delusions, hallucinations, disorganized thoughts, disorganized behaviour, negative symptoms) over the course of the past six months (American Psychiatric Association, 2013). Also, significant functional impairment (e.g., occupational, interpersonal, and/or self-care abilities) must be observed for diagnosis. Although not traditionally required for a diagnosis of SCZ, deficits in cognitive and sensory processing also are commonly observed (Tandon, Nasrallah & Keshavan, 2009; Javitt, 2009).

### 1.2.2 Cognitive Impairment in Schizophrenia

Although contemporary conceptions of SCZ focus on manifest positive and negative symptoms (Tandon et al., 2009), early descriptions of the disorder emphasized cognitive disruptions, also giving rise to its earlier name, *dementia praecox*, literally meaning "cognitive decline with [the] onset of youth" (Kraepelin, 1919). Research over the past three decades has increasingly demonstrated that cognitive symptoms are a hallmark of the disorder (Heinrichs & Zakzanis, 1998). Cognitive dysfunction is highly prevalent, with some studies suggesting that as many as 98% of patients with SCZ fail to meet the expected level of functioning predicted by estimates of premorbid intellectual ability (Keefe, Eesley & Poe, 2005). The observed cognitive impairment is also robust, with patients scoring, on average, 1-2 standard deviations below healthy control samples (Fioravanti, Bianchi & Cinti, 2012; Heinrichs & Zakzanis, 1998). Cognitive deficits have been found across a variety of domains, including memory (e.g., Achim & LePage, 2005; Ranganath, Minzenberg & Ragland, 2008), attention (e.g., Carter et al., 2010), processing

speed (e.g., Dickinson, Ramsey & Gold, 2007), verbal fluency (e.g., Henry & Crawford, 2005), working memory (e.g., Barch & Smith, 2008), and executive functioning (e.g., Laws, 1999). Consequently, SCZ-related cognitive deficits are purported to represent a generalized rather than specific deficit profile (Dickinson, Iannone, Wilk & Gold, 2004; Dickinson, Ragland, Gold & Gur, 2008). For instance, Dickinson and colleagues (2008) used structural equation modeling to demonstrate that SCZ-associated cognitive deficits across six neuropsychological domains were almost exclusively mediated through a general ability factor, which accounted for 63% of variance in overall cognitive functioning.

Importantly, cognitive impairment among individuals with SCZ is a strong determinant of both social and vocational outcomes (Green, Kern, Braff & Mintz, 2000; van Winkel et al., 2007; Bowie et al., 2008). For example, Bowie and colleagues (2008) demonstrated that neuropsychological functioning directly mediated real-world outcomes, including social skills, interpersonal functioning, and work skills. Moreover, research has also indicated that social cognition mediates the relationship between cognitive deficits and overall social functioning (Addington, Girard, Christensen & Addington, 2010). Given these relationships, initiatives have been implemented to study and develop treatments targeting cognitive impairment in this population. For example, the National Institute of Mental Health (NIMH) has established the Measurement and Treatment Research to Improve Cognition in Schizophrenia (MATRICS) initiative, specifically aimed at developing pharmacological treatments to enhance neurocognitive functioning among individuals with SCZ (Marder & Fenton, 2004). In addition, the more recent

Cognitive Neuroscience Treatment to Improve Cognition in Schizophrenia (CNTRICS; Carter and Barch, 2007) initiative has been established to develop clinical tools and measurement approaches to identify cognitive systems as targets of treatment.

### 1.2.3 Development and Course

The development of SCZ is viewed as phasic, although the precise demarcations between these phases are imprecise and often overlapping. Prior to the manifestation of a fully developed clinical disorder, a *premorbid phase*, characterized by subtle behavioural, cognitive, and emotional impairments, in addition to difficulties in academic and social functioning (Tandon et al., 2009) can be (usually retrospectively) identified. Early impairments may also include difficulties in motor development, attention, language, and social functioning (Schenkel & Silverstein, 2004).

Directly preceding the onset of clinical symptoms is the *prodromal phase*, which can last from months to years, but has been estimated to have a mean duration of approximately five years (Klosterkotter, Schultze-Lutter & Ruhrmann, 2008). The prodromal phase is characterized by both cognitive and negative symptoms, with attenuated positive symptoms (e.g., unusual ideas, ideas of reference that are not threatening, increased suspiciousness and/or paranoid thinking, beliefs of superiority, vague and unformed changes in sensory perception) emerging approximately one year prior to initial clinical contact (Tandon et al., 2009). Among individuals who demonstrate attenuated positive symptoms, one sixth to one half go on to develop SCZ (Yung et al., 2008). Although the mechanisms that lead to the development of SCZ are not fully understood, more severe positive symptoms and greater social impairment empirically

predict the progression to SCZ following the prodromal phase (Tandon et al., 2009).

The onset of overt psychotic symptoms typically marks the onset of SCZ (American Psychiatric Association, 2013). The first psychotic episode, similar to subsequent episodes, generally begins with increased negative symptoms, followed by a gradual increase in positive symptoms, and cumulating in a peak expression of positive symptoms (Tandon et al., 2009). This peak is followed by a gradual resolution of positive symptoms and a return to depressive and negative symptomatology and, finally, a resolution phase in which psychotic symptoms are absent or significantly attenuated (Tandon et al., 2009). Over the course of a patient's lifetime, they typically experience multiple psychotic episodes in a relapsing and remitting pattern, that are separated by periods of increased negative symptoms.

Following the psychotic phase, the course of SCZ plateaus and enters a stable phase, which is characterized by decreased positive symptoms, more prominent negative symptoms, and generally stable cognitive deficits. During this phase, individuals do not typically experience any further decline in functioning (Tadon et al., 2009).

### 1.2.4 Epidemiology and Impact

Schizophrenia has a lifetime prevalence ranging from 0.3 to 2.0%, with an average prevalence of approximately 0.7% (Saha, Chant, Welham & McGrath, 2005). Symptom onset is typically observed between the ages of 15 to 25 years, although it can appear before puberty or over the age of 50 (Castle, Wessely & Murray, 1993). Moreover, while the onset of symptoms in males typically occurs during late adolescence and early adulthood, the onset distribution for females is bimodal, with peaks between the ages of

18 to 30 and an additional peak later in life, after the age of 40 (American Psychological Association, 2013; Harris & Jeste, 1988). Although it was widely believed that the risk of developing SCZ was similar among males and females (Wyatt, Alexander, Egan & Kirch, 1988), more recent studies have indicated a higher lifetime disease risk among males compared to females, with a male-female risk ratio of approximately 1.4 (Aleman, Kahn & Selten, 2003; McGrath et al., 2004).

While relatively uncommon compared to other psychiatric disorders (e.g., 7% and 2.9% lifetime prevalence for Major Depressive Disorder and Generalized Anxiety Disorder, respectively), SCZ is considered to be one of the most debilitating mental illnesses due to its chronic nature and its significant impact on daily functioning (American Psychiatric Association, 2013). Moreover, individuals with SCZ have an increased risk of suicide attempt and a greater likelihood of death from suicide completion compared to the general population (Pompili, Lester, Innamorati, Tatarelli & Girardi, 2008), although it is important to note that this is generally true of many psychiatric disorders (i.e., mood disorders, anxiety disorder, substance use disorders; Harris & Barraclough, 1997). Specifically, approximately one third of individuals with a diagnosis of SCZ attempt suicide and 5% of these individuals die of suicide (Tandon, Keshavan & Nasrallah, 2008). SCZ is also strongly associated with substance use, most notably alcohol, nicotine, and cannabis abuse, all of which can lead to further impairment, worsening of psychosis, and reduced treatment efficacy (Green et al., 2004). Moreover, approximately two thirds of individuals with SCZ, compared to one half of the general population, die of coronary heart disease, which is predominantly attributed to cigarette

smoking, hypertension, obesity, diabetes, and antipsychotic medication (Hennekens, Hennekens, Hollar & Casey, 2005). As such, individuals with SCZ have, on average, a 12-15 year shorter life expectancy compared to the general population (Saha et al., 2005).

As noted previously, SCZ has also been shown to affect quality of life and many areas of functioning, including vocational and interpersonal functioning. Studies have indicated that the employment rate among people with SCZ is approximately 20% (Marwaha et al., 2007), while homelessness also is approximately 20% (Folsom et al., 2005). With respect to interpersonal relationships, approximately two-thirds of individuals with SCZ have never married and many experience reduced contact with family and friends (Tandon et al., 2008). Moreover, individuals with SCZ, as well as their families, experience reduced support from social networks and professionals when compared with other chronic illnesses (Magliano et al., 2005). Given its significant impact on functioning, in addition to high medical and substance use comorbidity, it is not surprising that the societal cost of SCZ is disproportionally high, with estimated annual healthcare costs amounting to $6.85 billion in Canada (Goeree et al., 2005). Together, these findings highlight the importance of continued research to increase our understanding of this disorder with the aim of creating treatment programs that will improve functional outcome and quality of life among these individuals.

### 1.2.5 Etiology

The importance of both genetic and environmental risk factors in the etiology of SCZ is well known. Although a genetic basis for SCZ has long been speculated (e.g., Kallman, 1946), family dynamics were the chief explanation for the familial pattern of the disorder

until the 1960s when a series of adoption studies showed that the risk of SCZ was associated with the presence of SCZ in biological parents but not in adoptive parents (Heston, 1966; Kety, Rosenthal, Wender & Schulsinger, 1968). Similarly, twin studies have shown a three-fold increase in SCZ among monozygotic (e.g., identical) twins compared to dizygotic twins (Gottesman, McGuffin & Farmer, 1987; Sullivan, Kendler & Neale, 2003). Specifically, should one dizygotic twin have SCZ, the risk of the other twin developing the illness is approximately 10-15%, but the risk of developing SCZ among monozygotic twins is 40-50%.

Despite the clear role of genetics in the etiology of SCZ, the precise mechanisms involved are less known. As such, much effort has been directed towards uncovering the chromosomal abnormalities and genetic associations related to the development of SCZ. Studies using linkage analysis (i.e., the use of familial genetic information to identify regions of the genome linked with SCZ), has implicated chromosomal regions 8p21-21 and 22q11-12 as having possible SCZ-risk genes (Badner & Gershon, 2002; Lewis et al., 2003), although numerous other regions have also been implicated (Lewis et al., 2003). However, linkage analysis studies do not identify specific genes linked to SCZ and approximately 4000 genes are in the chromosomal regions linked to SCZ, underscoring the lack of precision in this approach (Tandon et al., 2008). Given these results, coupled with the inherent difficulty of locating large families for analysis, linkage analysis has recently declined as a tool for identifying SCZ-risk genes.

In contrast, genetic association studies examine variations in gene sequences to identify genetic loci that vary between individuals with and without SCZ (Tandon et al.,

2008). Although numerous genes have been identified with respect to the development of SCZ, results across studies have been inconsistent. Hence, the current genetic view of SCZ suggests that multiple genetic polymorphisms, each possibly contributing to a small amount of disease susceptibility, underpin the heterogeneous and multifactorial nature of SCZ (Lichtermann, Karbe & Maier, 2000).

A number of environmental risk factors have also been implicated in the etiology of SCZ. Research has shown that maternal infection (e.g., influenza, rubella) and nutritional deficiency during the prenatal period, specifically during the first two trimesters, are associated with an increased risk for developing SCZ (Penner and Brown, 2007; Meyer, Yee & Feldon, 2007). Although the precise mechanisms leading to this increased risk are not fully understood, animals studies indicate that the effects of maternal infection are mediated by indirect actions, such as immune mediators (e.g., cytokines), that lead to abnormal fetal brain development during the prenatal period (Ashdown et al., 2006). Obstetric and perinatal complications, such as fetal hypoxia, also increase the risk of developing SCZ (Byrne, Agerbo, Bennedsen, Eaton & Mortensen, 2007). A range of childhood and adolescent environmental risk factors have also been linked to the development of SCZ, although a review of the literature suggests that these findings are similarly inconsistent. Such factors include childhood trauma, brain injury, parental separation and death, and stressful life events more generally (Tandon et al., 2007). Cannabis use has also been implicated in the development of SCZ (Moore et al., 2007), although others have argued that cannabis does not increase the risk of developing SCZ *per se*, but instead may lead to the development of SCZ in vulnerable individuals or

modify the expression of SCZ (Degenhardt and Hall, 2006; Barnes, Mutsatsa, Hutton, Watt & Joyce, 2006).

Many genetic and environmental factors have been implicated in the etiology of SCZ and modern theories of SCZ posit that both factors are important in the development of this disorder. How both genetic and environmental factors interact, and the neurobiological mechanisms involved to cause SCZ, is not understood at this time.

### 1.2.6 Pathophysiology

*1.2.6.1 Structural Brain Abnormalities.* In the past 30 years, advancements in neuroimaging techniques (e.g., magnetic resonance imaging (MRI), diffusion tensor imaging (DTI)) have led to the identification of structural brain abnormalities among individuals with SCZ. Studies have consistently found medication-independent increased ventricular volume, in addition to a reduction in whole brain and grey matter volume, specifically involving the temporal lobe structures (e.g., hippocampus and amygdala), superior temporal gyri (STG), prefrontal cortex (PFC), and anterior cingulate (AC; Keshavan, Tandon, Boutros & Nasrallah, 2008). Moreover, studies have also identified anomalies in cerebral asymmetry among individuals with SCZ. For example, studies have shown that the planum temporale (PT), a cortical area involved in language and typically more developed in the left hemisphere among healthy individuals, is more symmetrical in persons with SCZ, specifically due to relatively larger right PT compared to healthy controls (Shapleske, Rossell, Woodruff & David, 1999). Volumetric reductions in white matter areas, such as the corpus collosum, and associated fiber tracts have also been implicated (Arnone, McIntosh, Tan & Ebmeier, 2008). Additionally, DTI studies have

shown reduced fractional anisotropy (FA), a measure of structural integrity of white matter tracts, among several white matter regions in SCZ, including the corpus collosum, cingulum, and arcuate fasciculus (Kubicki et al., 2007).

*1.2.6.2 Functional Brain Abnormalities.* Functional neuroimaging techniques, such as positron emission tomography (PET) and functional magnetic resonance imaging (fMRI), have allowed research to explore *in vivo* changes in regional brain function. Among persons with SCZ, the most consistent finding using these techniques is attenuated activation of the dorsolateral prefrontal cortex (DLPFC), especially when completing cognitive tasks (e.g., hypofrontality; Keshavan et al., 2008). Moreover, this finding has been demonstrated for both activation and resting hypofrontality (Hill et al., 2004). However, it is important to note that findings across studies have been variable due to methodological discrepancies, such as the use of differing activation tasks (e.g., working memory, executive functioning, verbal fluency). Moreover, studies have also demonstrated that performance differences between healthy observers and people with SCZ may moderate DLPFC activity. In fact, some studies suggest that, when controlling for performance differences, patients with SCZ may show increased prefrontal activities, suggesting an inefficient frontal response (Van Snellenberg, Torres & Thornton, 2006). This is consistent with the suggestion that variability in performance (e.g., cognitive and perceptual abilities) observed among people with SCZ may reflect an increase in neural noise, which can lead to inefficient performance across multiple domains (Winterer et al., 2000; Rolls, Loh, Deco & Winterer, 2008; Christensen, Spencer, King, Sekuler & Bennett, 2013).

Studies using electroencephalography (EEG) have demonstrated neuro-electrical abnormalities among patients with SCZ. For example, mismatch negativity (MMN) amplitude, an event-related potential (ERP) that is elicited when uniform auditory stimuli are interrupted by deviant stimuli (e.g., an auditory oddball paradigm), are consistently reduced among people with SCZ (Keshavan et al., 2008). MMN is thought to represent a pre-attentive stage of auditory processing, and thus is suggestive of early-stage sensory processing abnormalities among persons with SCZ. Similarly, atypical P300 ERP responses have also been implicated in SCZ and are thought to represent a biological marker of this population. This ERP component, occurring 300 ms following the delivery of a relevant stimulus, is thought to reflect higher cognitive functioning and has been suggested to involve the STG, inferior parietal lobe, and frontal lobe, in addition to the hippocampus and thalamus (Smith et al., 1990). Studies have consistently demonstrated reduced amplitude of the P300 response among persons with SCZ, in addition to delayed latency (Jeon & Polich, 2003). Lastly, studies investigating the activation/priming of semantic long-term memory have also revealed specific neurophysiological abnormalities among individuals with SCZ. It has been posited that semantic memory functions as a type of neural network, in which semantic concepts are represented as network nodes (Collins & Loftus, 1975). As such, activation of one node (e.g., a word or visual stimulus) results in a subsequent spread of activation among related nodes. Increased activation of a node results in priming – that is, related concepts are processed more quickly. Neurophysiology studies have demonstrated that the N400, occurring 400 ms after a stimulus, is smaller (i.e., less negative) if preceded by a conceptually related prime (e.g.,

Holcomb & McPherson, 1994). As such, this N400 priming effect is thought to represent the ability of the brain to use contextual cues to predict forthcoming items (Kutas & Federmeier, 2000). Among individuals with SCZ, this priming effect has been reported to be abnormal, in that larger N400s are observed for targets that are preceded by both strong and weak primes, as such, resulting in smaller priming effects (e.g., Kiang, Christensen & Zipursky, 2011; Kiang, Christensen, Kutas & Zipursky, 2012). This result has proved to be quite robust and has been shown to be correlated with psychotic symptomatology (Kiang, Kutas, Light & Braff, 2008), suggesting that the abnormal N400 may be used as a biomarker for SCZ more generally (Kiang, Patriciu, Roy, Christensen & Zipursky, 2013).

*1.2.6.3 Neurotransmitter Abnormalities.* The dopamine (DA) hypothesis is the most venerable and influential theory of SCZ pathophysiology. The earliest evidence of the DA hypothesis stemmed from the work of Carlsson and Lindqvit, who observed that antipsychotic drugs increased DA metabolism when administered to animals (Carlsson & Lindqvit, 1963). Further studies also indicated that amphetamine, and other similar drugs, resulted in increased levels of DA and caused psychotic symptoms (Lieberman, Kane and Alvir, 1987). In the 1970s, the DA hypothesis was further refined by establishing that antipsychotic effects were achieved largely (or perhaps exclusively) through the blockage of DA $D_2$ receptors (Seeman, 1987; Creese, Burt and Snyder, 1976). Taken together, these findings suggested that hyperactivity within the mesolimbic dopaminergic system resulted in excess stimulation of $D_2$ receptors that caused the increase of positive symptomatology.

The most important limitation of the classical DA hypothesis has been its lack of explanatory power for the negative and cognitive symptoms of SCZ; this is also consistent with the observation that these symptoms are generally resistant to the effects of $D_2$ receptor antagonists. Further research has suggested that negative and cognitive symptoms instead may result from altered PFC functioning. In this context, studies have suggested that a prefrontal $D_1$ receptor deficit may manifest in these symptoms (Weinberger, 1987) given that increased $D_1$ receptor availability correlates with impaired working memory and negative symptoms in SCZ (Goldman-Rakic, Muly & Williams, 2000; Abi-Dargha et al., 2002). These findings have lead to a revised DA hypothesis, in which a hyperactive dopaminergic mesolimbic system results in positive symptoms of SCZ while a hypoactive mesocortical dopaminergic system underlies negative and cognitive symptoms (Weinberger, 1987).

More recent theories of SCZ pathophysiology have also implicated the role of glutamate and gamma-aminobutyric acid (GABA). The glutamate hypothesis posits that the function of N-methyl-D-aspartate (NDMA) receptors, an excitatory amino acid receptor, is compromised in SCZ (Olney & Farber, 1995; Olney, Newcomer & Farber, 1999). This finding stemmed from observations that drugs such as phencyclidine (PCP) and ketamine, both NDMA receptor antagonists, lead to psychotic symptoms and notably both positive and negative symptoms (Krystal et al., 1994). Moreover, post-mortem studies have also shown reduced expression of NMDA receptor subunits in varying brain regions among individuals with SCZ, including the PFC and hippocampus (Harrison, Law & Eastwood, 2003). Despite evidence regarding the glutamate hypothesis, it has

been noted that the effects of antipsychotic drugs result only from the blockage of $D_2$ receptors (Kapur & Mamo, 2003), suggesting that the glutamatergic system is modulated by the dopaminergic system, or conversely, leads to downstream effects at the dopaminergic system (Stone, Morrison & Pilowsky, 2007).

Studies have also suggested a role for GABA, the most abundant inhibitory neurotransmitter in the central nervous system. Evidence for GABAergic dysfunction in SCZ predominantly stems from post-mortem studies showing reduced levels of GABA expression in the PFC, anterior cingulate gyrus, and hippocampus, as measured by the major determinants and precursors of GABA synthesis (Lewis, Hashimoto & Volk, 2005). Importantly, GABA dysfunction in SCZ has been localized to areas implicated in thought disturbance and both declarative and working memory (Lewis & Gonzalez-Burgos, 2006). As a result, some researchers have speculated that reduced GABA expression in cortical areas may lead to cognitive symptoms observed in SCZ, while limbic GABA reductions instead may result in emotion processing deficits and blunted affect (Benes & Barretta, 2001).

## 1.3 SOCIAL PERCEPTUAL DEFICITS IN SCHIZOPHRENIA

One of the hallmarks of SCZ is marked dysfunction in the domain of social cognition, which can include a variety of components including emotion processing, social perception, theory of mind (ToM), and attributional style/bias (e.g., the biased interpretation of social events and its impact on subsequent behaviour; Pinkham, 2013). In general, studies have demonstrated impairment in all domains of social cognition in

this population. For example, individuals with SCZ show deficits in ToM, such as the ability to understand false beliefs, the intentions of others, and deception (Penn, Sanna & Roberts, 2008). Impairment in this area is also seen among first-degree relatives with a high number of schizotypy traits (Irani et al., 2006). Additionally, individuals with SCZ are less able to discriminate subtle gender differences, cues that signify a friendly or unfriendly social context, or the trustworthiness of faces (Bigelow et al., 2006; Baas, van't Wout, Aleman & Kahn, 2008; Hooker & Park, 2002). Moreover, social cognitive deficits among persons with SCZ are evident early in the course of the disorder and remain generally constant over time (Green et al., 2012; Pinkham, Gur & Gur, 2007). For example, a cross-sectional study investigating emotion processing, ToM, and social relationship perception across illness stages of SCZ (e.g., prodromal, first episode, chronic) found no evidence of progression or improvement over time, suggesting a stable pattern of social cognition (Green et al., 2012). Furthermore, studies have also found that social cognitive impairments are also present in individuals with a higher risk for developing SCZ (Addington, Penn, Woods, Addingon & Perkins, 2008; Chung, Kang, Shin, Yoo & Kwon, 2008).

Given the dual presence of impaired *general* and *social* cognition among individuals with SCZ, it is important to consider the impact of one on the other. Although there is overlap between social cognition and other cognitive abilities, specifically in the areas of memory, attention, and executive functioning, recent correlational (Ventura, Wood & Hellemann, 2013) and factor analytic studies (Allen, Strauss, Donohue & van Kammen, 2007) indicate that social cognition is largely independent from general

cognitive functioning (Pinkham, 2013).

Importantly, the social cognitive deficits observed in SCZ have real world consequences. A recent study found that nearly 80% of the variance in social functioning among persons with SCZ (e.g., number of friends, performance in social situations) is mediated by deficits in social cognition (Addington, Girard, Christensen, & Addington, 2010). Additionally, the impact of social cognitive deficits on social functioning has been found to be greater than that of overall neurocognitive abilities. For example, a study by Pinkham and Penn (2006) examining variance in social skills among individuals with SCZ found that cognitive factors, such as overall intellectual ability and executive functioning, predicted 15% of variance in social skills. Alternatively, social cognitive abilities, such as emotion recognition and ToM, resulted in an additional 26% of the variance. Given the impact of social functioning on real-world outcomes such as occupational success and interpersonal fulfillment, research is now seeking to uncover the underlying causes of these problems, and potential treatments to address social cognitive impairments. In this context, some treatment methodologies involving social cognitive remediation have been shown to improve social functioning (Lindenmayer et al., 2013), relationships (Sachs et al., 2012), and overall social skills (Roberts & Penn, 2009).

Among the components of social cognition, emotion perception has been the most widely studied in SCZ. Many studies have demonstrated impaired emotional functioning among persons with SCZ across a variety of domains. For example, studies have indicated that individuals with SCZ experience reduced emotional responses to external stimuli and are less expressive both facially and vocally compared to healthy controls

(HC; Kring & Moran, 2008). More recently, a large body of literature has examined perceptual emotion recognition and discrimination among patients with SCZ, motivated in large part by the social repercussions typically stemming from the erroneous interpretation of emotions. For example, individuals with SCZ who are less able to accurately recognize emotions have poorer social outcomes, in that they are less likely to sustain friendships and obtain competitive employment (Combs et al., 2007; Hooker & Park, 2002).

Many studies in this area have focused on the recognition of visual emotion cues. For example, the literature has consistently demonstrated that individuals with SCZ are less able to perceive emotions from faces (e.g., Kohler et al., 2003; Schneider et al., 2006; Kohler, Walker, Martin, Healey & Moberg, 2010). However, an important caveat to these findings is that patients are impaired in face perception tasks more generally (Chan, Li, Cheung, & Gong, 2010), which calls into question whether these deficits reflect impairment in emotion recognition *per se* or a generalized impairment in face processing. Although, at the current time, results in this regard are mixed, there is some evidence to suggest a specific emotion-processing deficit in this population. For example, Schneider and colleagues (2006) demonstrated that, although individuals with SCZ were impaired in facial judgments of identity and age, the largest discrepancy in performance was found in the emotion discrimination task compared to healthy controls. Moreover, emotion perception deficits have also been demonstrated in other visually oriented tasks. In this context, individuals with SCZ are less able to perceive emotions from static whole-body expressions that are presented with blurred faces compared to healthy observers (Van den

Stock, De Jong, Hodiamont & Gelder, 2011).

## 1.4 VISION AS A GATEWAY TO SOCIAL PERCEPTION

Given the complexity of social cues, how do humans successfully discriminate emotions and form social judgments? At the most basic level, the ability to judge and understand the social environment begins with the capacity to extract relevant cues from the external environment through sensory and perceptual systems. For example, the ability to identify and experience emotions begins with the perception of a sensory experience (e.g., contraction of specific facial muscles), which is then conceptualized according to prior knowledge and finally experienced as an internal state or affect (Barrett, 2006). In this context, sensory information, including audition, olfaction, and somatosensation have all been shown to be important in the interpretation of the social world; however, the most well studied domain in this regard is visual perception.

A large body of research has demonstrated that specific classes of visually perceived environmental stimuli contain a wealth of social cues and that the human visual system is well adapted for extracting this information. For example, humans are able to efficiently and accurately make social categorizations from faces, including judgments pertaining to sex, age, race, and emotional status (Bruce and Young, 1986). Moreover, this quick categorical processing differs from the ability to discriminate facial identity, which requires a finer-grained analysis of face information and is more susceptible to errors under challenging task conditions (e.g., degraded presentation; Rhodes, Tan, Brake & Taylor, 1989; Cloutier, Mason & Macrae, 2005). Eye gaze has also been implicated as

an important nonverbal social cue, as humans will look at aspects of the environment that are relevant to their behaviours (i.e., objects or people of interest). Moreover, the perception of another's eye gaze can provide important information about their emotional state (Adams & Kleck, 2005) and can influence our judgment regarding traits such as likability and attractiveness (Mason, Tatkow & Macrae, 2005). While much research has been devoted to understanding social cues embedded in facial expressions, the visual perception of dynamic bodies has, until very recently, received less attention. Similar to faces, the visual perception of body movement and posture has been shown to convey socially relevant information. For example, individuals are readily able to recognize and extract emotion cues of varying intensities from body stimuli, although dynamic cues, opposed to static cues, were found to be more informative overall (Atkinson, Dittrich, Gemmell & Young, 2004). Additionally, humans are able to accurately detect small differences in body language. A study by Sinke and colleagues (2010), using videos of actors with blurred faces displaying teasing and threatening social interactions, demonstrated that individuals were able to readily identify these social interactions in a forced-choice paradigm. Moreover, utilizing fMRI, these researchers also showed that individuals were able to recognize threatening behaviour when attention was deliberately directed away from the social interaction, suggesting that humans are able to process threatening stimuli from bodies even when not attending to relevant aspects of the social interaction. These studies collectively demonstrate the importance of the visual system in extracting socially relevant cues (e.g., from body posture and movement) to form judgments about and interpretations of the social environment.

As highlighted previously, individuals with SCZ have demonstrated significant difficulty in the domain of social perception. Given the importance of vision in the extraction and interpretation of social environments, recent attention has turned to understanding general visual perception deficits and their role underpinning social deficits in this population. For example, research has now demonstrated that individuals with SCZ demonstrate reduced ability to extract social information from visual stimuli, including deficits in discriminating emotions from faces (Kohler et al., 2003; Schneider et al., 2006; Kohler, Walker, Martin, Healey & Moberg, 2010) and whole-body expressions (Van den Stock, De Jong, Hodiamont & Gelder, 2011). Given that individuals with SCZ do not typically demonstrate obvious visual deficits (e.g., amblyopia, macular degeneration, visual field neglect), early research characterizing the disorder assumed visual processing to be intact. Despite this assumption, individuals with SCZ do in fact report visual perceptual distortions, even in the early stages of the disorder (McGhie & Chapman, 1961; Javitt, 2009). Moreover, it has been demonstrated that disturbances in visual perception (e.g., seeing objects as altered) can predict progression from the prodromal stage to SCZ more strongly than other clinical measures, such as ideas of reference and language difficulties (Klosterkotter et al., 2001). In this context, these findings suggest that the study of visual perception in SCZ is important, not only to elucidate and describe perceptual deficits, but also to understand how basic perceptual mechanisms can give rise to functional and clinical impairments in this population. As such, the field has witnessed a steady and robust 40-year increase in SCZ-related research in vision perception. This work has revealed many deficits, including impaired visual/backward masking (Green,

Lee, Wynn & Mathis, 2011), perceptual organization (Silverstein & Keane, 2011b), and altered visual surround suppression (Dakin, Carlin & Hemsley, 2005; Tadin et al., 2006). However, one of the most frequently studied and robust lines of SCZ-related research relates to deficits in motion processing, which is reviewed in the following section. In this context, impairments in visual motion processing have important implications in the interpretation of dynamic environmental cues, such as the ability to discriminate and infer emotional states and intentions from the body movements of other individuals in the social world.

## 1.5 VISUAL MOTION PERCEPTION IN SCHIZOPHRENIA

The study of visual motion processing in SCZ was initially used to elucidate perceptual mechanisms related to eye-tracking impairments typically observed in this population (e.g. Holzman, Proctor & Hughs, 1973). More recently, SCZ-focused motion perception research has shifted to understanding how dynamic visual information is processed in its own right. This research demonstrates that many aspects of visual motion processing are impaired among individuals with SCZ.

To support motion perception, the visual system has a specialized capacity for processing object speed, direction, and the integration of spatial and temporal signals. In general, visual motion is processed in the medial temporal (MT) cortical area, which is also known as V5 (visual area 5; Born & Bradley, 2005). Inputs to MT have been shown to originate from both cortical (e.g., V2, V3) and subcortical regions, although studies suggest that the most predominant inputs arise from V1 (visual area 1), also referred to as

the primary visual cortex (Born & Bradley, 2005). The input projections from V1 to MT originate in layer 4B of the primary visual cortex, which, in turn, receives strong inputs from the underlying 4Ca layer, consisting of magnocellular (M) cells. M cells are responsive to lower spatial frequencies and higher temporal frequencies while parvocellular (P) cells are responsive to higher spatial frequencies and lower temporal frequencies (Born & Bradley, 2005). As such, the M-pathway sensitivity to higher temporal frequencies results in better detection of visual motion.

One of the primary features of motion perception is the ability to accurately process speed. The perception of speed signals in the visual system can be measured via discrimination tasks, in which observers must judge the relative speed of two moving objects. A number of studies have demonstrated impaired speed discrimination among individuals with SCZ (Chen et al., 1999a; Chen et al., 1999b; Kim, Wylie, Pasternak, Butler & Javitt, 2006; Clementz, McDowell & Dobkins, 2007; Hong et al., 2009). Furthermore, results from these studies, and others, suggest that this deficit is related specifically to impaired motion processing and does not reflect a generalized visual deficit (Chen, 2001). In this context, the evidence supporting a specific motion processing deficit in SCZ is three-fold. First, speed discrimination deficits in SCZ are observed using varying visual stimuli (e.g., gratings, single dots, random dot patterns), indicating that the form of visual targets has minimal impact on the processing of speed signals (Chen et al., 1999a; Hong et al., 2009; Clementz et al., 2007; Kim et al., 2006). Second, deficits in speed discrimination have been shown to be more prominent at intermediate speeds (e.g.,

10 degrees/s[1]). This is notable, as slower stimulus speeds facilitate positional cues and fast speeds facilitate temporal frequency cues. In contrast, perceptual judgment of intermediate speeds are dominated by speed cues alone (McKee, Silverman, Nakayama, 1986; Chen, Bedell & Frishman, 1998), suggesting that impairments in speed discrimination are specific to motion processing. Third, speed discrimination deficits have also been observed among unaffected biological relatives of persons with SCZ, implying that this deficit is not attributable to other clinical features of this disorder (Chen, 1999b).

An important role of the visual motion processing system is the ability to accurately integrate information across space and time (e.g., spatiotemporal signals). In this context, conventional coherent motion tasks consist of two separate components: (a) a group of spatially distributed dots moving together in one direction (i.e., signal), and (b) a superimposed set of dots moving in random directions (i.e., noise). Studies have demonstrated that individuals with SCZ are impaired when asked to detect the coherent motion, or signal, of these stimuli (Stuve et al., 1997; Chen, Nakayama, Levy, Matthysse & Holzman, 2003; Slaghuis, Holthouse, Hawkes & Bruno, 2007). Specifically, patients are less accurate and require stronger signal strength for the detection of coherent motion. These findings indicate that the ability of individuals with SCZ to spatially integrate motion components is impaired. Moreover, Chen and colleagues (2005) have demonstrated that this ability is persevered in individuals with bipolar disorder, suggesting that deficits in motion integration may be specific to SCZ.

Various imaging and electrophysiological techniques have been used to illuminate

[1] Degrees per second is a unit of rotational speed, or angular velocity. The degree per second is the change in orientation of a stimulus, in degrees, for every one second.

the neural anomalies underlying motion processing impairment in SCZ. For example, individuals with SCZ demonstrated reduced blood-oxygen-level dependent (BOLD) signal in area MT and increased BOLD signal in PFC when detecting coherent motion (Chen et al., 2008). Notably, these effects were not observed when participants completed a non-motion contrast discrimination task. These results are interesting, as they not only suggest an impaired sensory system with respect to reduced activation of area MT in SCZ, but also an abnormally activated cognitive system with respect to increased activation in PFC. Therefore, it is likely that neural abnormalities underlying motion processing deficits in SCZ may include a network of cortical systems that are activated as a compensatory mechanism. Additionally, a study utilizing EEG to examine motion processing deficits in SCZ found enhanced early neural activity (e.g., 90 ms after stimulus onset) and reduced late neural activity over the parietal cortex (e.g. 400 ms after stimulus onset) in a direction detection task (Wang, Brown, Dobkin, McDowell & Clementz, 2011). Moreover, reduced late neural activity was associated with poorer behavioural performance. Together, these results suggest that deficits in motion perception may be related to the later-stages of motion processing, such as in area MT.

Finally, as discussed earlier in this section, the motion perception system receives inputs from early visual processing areas (e.g., V1) and therefore it is important to consider whether early visual system deficits may impact motion processing. Butler and colleagues (2001) examined M and P function in SCZ, using visual evoked potentials, and demonstrated that responses to M-biased stimuli (e.g., stimuli with low luminance contrast, low spatial frequency, and low colour contrast) were significantly lower among

individuals with SCZ compared to healthy controls. Moreover, responses to P-biased stimuli (e.g., high luminance contrast, high spatial frequency, and high colour contrast) were not significantly different between both groups, suggesting a greater dysfunction of the M-pathway opposed to the P-pathway. Additionally, abnormal motion processing deficits, specifically regarding impaired motion velocity discrimination, have also been shown to reflect deficits in the M visual system (Kim et al., 2006). In summary, research on visual perception among individuals with SCZ has demonstrated consistent impairment in visual motion processing, including speed discrimination and the ability to integrate spatiotemporal signals. In this context, biological motion processing is a special class visual motion perception that involves the complex integration of dynamic cues, allowing humans to interpret the social environment. This may be of particular relevance to the study of SCZ, given persistent social deficits observed in this population.

## 1.6 BIOLOGICAL MOTION PERCEPTION

### 1.6.1 Overview of biological motion perception

The ability of the visual motion system to process motion direction and speed can give rise to more complex interpretations of dynamic information, such as the perception of bodily form. Furthermore, as highlighted previously, the visual perception of dynamic bodies conveys socially relevant information, including the emotional states, actions, and intentions of actors. As such, the ability to perceive human motion, or biological motion, has particular relevance in everyday human social discourse, allowing humans to form judgments and, perhaps, adjust social behaviours accordingly. Given that people with

SCZ have deficits in both social perception and visual motion processing, these impairments may undermine their ability to accurately interpret social environments on the basis of visual motion cues alone. The following section aims to review the literature pertaining to biological motion processing and SCZ-related deficits in this domain.

Biological motion is the pattern of movement generated by a living form. Although biological motion has been attributed to the movement of animals and non-human forms (Pinto & Shiffrar, 2009, Pyles, Garcia, Hoffman, & Grossman, 2007), the most commonly studied form of biological motion is human gait. Seminal research in this area was conducted by Johansson (1973), who created stimuli known as point-light (PL) animations. To create these PL stimuli, researchers recorded videos of actors wearing a number of reflective markers that were positioned on the head and body joints. The final videos depicted only the motion of these markers, resulting in stimuli that could generate the perception of human motion with a relatively small number of visual stimuli. Computer algorithms (Cutting, 1978) and motion capture technology (Ma, Paterson & Pollick, 2006; Vanrie & Verfaillie, 2004) are now commonly used to refine PL stimuli. Interestingly, the static presentation of these stimuli is often interpreted as a meaningless array of dots; however, with the presentation of successive frames, observers are able to experience apparent motion depicting a dynamic human form (Blake & Shiffrar, 2007). To this end, the use of PL animations have provided vision scientists the ability to analyze the perception of human movement by examining motion cues (e.g., separate and integrated spatial and temporal parameters), in addition to studying the inherent ability of humans to extract a variety of social cues from such degraded displays of human

movement.

### 1.6.2 Visual analysis of biological motion

Multiple studies using PL stimuli have shown that the human visual system is well adapted for the perception of biological motion. Observers are able to identify actions in a given PL display (Dittrich, 1993) and can readily determine the actors' identity (Cutting & Kozlowski, 1977; Troje, Westhoff & Lavrov, 2005) and sex (Kozlowski & Cutting 1977; Mather & Murdoch, 1994; Sumi, 2000; Troje, 2002) from these displays. Moreover, the ability to discriminate biological motion from PL animations has also been shown to be quite robust, as observers can recognize human motion even under ambiguous and impoverished conditions. For example, PL animations can be detected when presented for very short durations (e.g., less than one-tenth of a second; Johansson, 1973), with scrambled stereoscopic depths of the dots (Lu, Tjan & Liu, 2006), and when animations are embedded in an array of dynamic noise dots (Bertenthal & Pinto 1994; Cutting, Moore & Morrison, 1988). Moreover, the ability to detect biological motion may exist during the early stages of development, as four-month-old infants have been shown to gaze at PL displays for longer durations compared to non-biological motion displays (Bertenthal, 1993).

The ability of observers to detect biological motion can be disrupted with the manipulation of specific PL display parameters. For example, the addition of spatiotemporal jitter of the dots forming PL animations disrupts the quality of motion and results in the decreased ability to detect these stimuli when embedded in noise (Grossman & Blake, 1999). However, one of the most consistent features of biological motion

perception is observers' reduced ability to perceive PL animations when they are inverted (e.g., Sumi, 1984). Moreover, prior knowledge of PL inversion presentation is not beneficial, as knowledgeable observers still demonstrate reduced accuracy detecting PL motion (Pavlova & Sokolov, 2000). Observers are able to learn to detect inverted biological motion with practice; however, the observers have been shown to rely on the detection of specific clusters of dots, and not the global form of the stimulus *per se* (Shiffrar & Pinto, 2002).

Given that point-light walkers (PLWs) contain relevant low-level (e.g., local motion processes) and high-level (e.g., global form) cues, several studies have investigated the contribution of these variables to overall biological motion perception. While this question remains a topic of debate, it is generally agreed that both low and high level mechanisms are involved in the perception of biological motion. In support of low level mechanisms, Mather and colleagues (1992) interspersed blank intervals between PL display frames to create varied inter-stimulus intervals; in this context, it was hypothesized that the perception of stimuli consisting of brief inter-stimulus intervals (ISIs) reflected low-level motion analysis, while the perception of stimuli consisting of longer ISIs reflected high-level motion processing. Results from this study showed that discrimination performance was best at brief ISIs, suggesting that the perception of biological motion relies more heavily on low-level visual mechanisms (Mather, Radford & West, 1992). More recently, Troje and Westhoff (2006) showed that observers were able to retrieve direction information from spatially scrambled PL displays, indicating that local motion signals, without configural or global information, are sufficient for the

processing of biological motion. Furthermore, Troje and Westhoff (2006) noted that direction information derived from biological motion is attributed to the local motion of the feet alone.

Several studies have also demonstrated the importance of high-level processing, such as visual form, in the perception of biological motion. Specifically, studies have shown that sequentially presenting two static frames of an individual performing an action is sufficient for the perception of human movement (Heptulla-Chatterjee, Freyd & Shiffrar, 1996). Moreover, observers easily perceive the direction of PLW animations that contain global form cues but lack local motion information (Beintema & Lappe, 2002). This is in contrast to studies utilizing spatially scrambled, or arbitrary motion sequences. Hiris and colleagues (2005) demonstrated that these scrambled sequences, in which the spatial location of dots is displaced while retaining the same local (e.g., dot motion) information as non-arbitrary PL stimuli, were more difficult to detect in a dynamic noise mask among observers. Collectively, these studies suggest that *both* motion and form information are important in the perception of biological motion.

### 1.6.3 Social perception and biological motion

In addition to motion and form information, biological motion is differentiated from other forms of apparent motion in that it conveys a wealth of social information. As mentioned previously, the motion of PL animations is sufficient to identify characteristics such as sex and identity. In addition, PL animations have been shown to convey interpersonal social information, such as the nature of interpersonal interactions including whether two people are dancing, boxing, greeting each other, or threatening each other

(Dittrich, 1993). Observers have also been shown to accurately perceive highly complex social characteristics and cues, such as openness (Brownlow, Dixon, Egbert & Radcliffe, 1997), social dominance (Montepare & Zebrowitz-McArther, 1988), vulnerability to attack (Gunns, Johnston & Hudson, 2002), and intent to deceive (Runeson & Frykholm, 1983) by viewing PL animations.

Perhaps one of the most important aspects of social perception is the ability to accurately process the emotional information conveyed by other individuals. In this context, studies show that PL animations convey affective cues. For example, Atkinson and colleagues (2004) found that observers were able to identify the emotions of anger, fear, sadness, disgust, and happiness from PL displays of human actions. Moreover, simple affective PL animations, such as an arm knocking on a door, are sufficient for observers to accurately discriminate the emotion information of the actor performing the arm movements (Pollick, Paterson, Bruderlin & Sanford, 2001). In fact, research has shown that specific affective information can facilitate the detection of biological motion. Chouchourelou and colleagues (2006) showed that observers were able to detect masked PLWs when they were conveying anger as opposed to happiness, sadness, or fear. Emotion interactions are also readily discriminated from PL animations. In a study where two PL animations were depicted in an emotional interaction, observers were better able to discriminate emotions with two PL actors as opposed to individual PL actors, suggesting that social context also facilitates the ability to perceive emotion (Clarke, Bradshaw, Field, Hampson & Rose, 2005). Finally, studies have also demonstrated that emotional cues are readily extracted from PLWs, and not expressive action or gestures,

alone (Roether, Omlor, Christensen & Giese, 2009; Ikeda & Watanabe, 2009). For example, Ikeda and Watanabe (2009) demonstrated that observers were able to detect emotions (e.g., anger and happiness compared to neutral stimuli) conveyed by coherent biological motion containing both low and high levels of noise. Interestingly, in this study, participants were more accurate detecting the expression of anger compared to happiness, suggesting that the expression of anger may contain more salient cues in the perception of biological motion stimuli. The results of these studies suggest that not only are observers unusually sensitive to biological motion, but that the visual system is also tuned to extract socially relevant information inherent within these stimuli.

### 1.6.4 Neural correlates of biological motion

Research has shown that a specialized, large-scale, neural network mediates the interpretation of human motion. The initial neurophysiological evidence for biological motion specific processing was demonstrated through single-cell recording responses in the superior temporal sulcus (STS) of macaque monkeys (Oram & Parrett, 1994). This finding was particularly interesting because the STS region is thought to represent a convergence point for the dorsal and ventral visual streams, and as such, plays a role in the integration of both form and motion information (Felleman & Van Essen, 1991; Oram & Perrett, 1996; Shiffrar, 1994). This work was further extended by Rizzolatti and colleagues (2001), who found visually-activated neurons in the ventral premotor and inferior parietal cortices of macaque monkeys: these so-called mirror neurons responded only to primate goal-directed action (e.g., grasping) as opposed to non-biological (e.g., a mechanical device) motion (Rizzolatti, Fogassi & Gallese, 2001; Rizzolatti & Craighero,

2004; Fogassi et al., 2005).

Using both PET (Bondra, Petridies, Ostray, & Evans, 1996) and fMRI (Grossman et al., 2000), studies have confirmed that regions along the posterior STS (STSp) are activated when participants view coherent, but not scrambled, PL animations. Both of these studies also found that coherent and scrambled PL animations activated area MT/V5 equally. Importantly, Grossman and Blake (2001) also found stronger STSp activation for upright compared to inverted biological motion, which, as previously discussed, is typically more difficult to detect. Similarly, PL animations that were occluded in a mask to reduce the detectability of human motion to chance levels yielded no STSp response. However, STSp activity response increased following extensive practice that resulted in better detection of PL animations (Grossman, Blake & Kim, 2004). Finally, the STSp is activated when observers view natural scenes and events involving human activity. For example, increased STSp activity has been demonstrated when observers view videos of another individual yawning, regardless of whether observers also felt compelled to yawn (Schürmann et al., 2005). Also, whole-brain fMRI activation during the viewing of an audiovisual movie also noted consistent STSp activity during movie sequences that depicted human activities compared to scenes lacking human activity (Hasson, Nir, Levy, Fuhrmann & Malach, 2004).

Additionally, studies have documented that individuals with parietal lobe lesions experience difficulty detecting a PLW in noise, but are able to discriminate the direction of non-biological coherent motion (Schenk & Zihl, 1997). Similarly, another case study of a patient with bilateral posterior visual pathway lesions showed impaired perception of

coherent non-biological motion, but intact recognition of human PL display actions (Vaina et al., 1990). Moreover, transcranial magnetic stimulation (TMS) applied to the STSp resulted in decreased ability to recognize upright PL displays in noise, while inverted displays were less affected (Grossman, Battelli & Pascual-Leone, 2005). Interestingly, Grossman et al. (2005) found that TMS applied to the MT/V5 area did not have any effect on the perception of PL displays.

Imaging studies have demonstrated that the STSp is involved in the perception of action intention (Zacks et al., 2001, Saxe et al., 2004). For example, in a study by Saxe and colleagues (2004), the identical human action was observed in differing context that subsequently changed the implied intention of the actor. fMRI results of this study revealed STSp activity was stronger in response to intentional action, suggesting that this brain region may be sensitive to intentional action and not human motion *per se*.

Various studies also suggest that the STS is important for social interpretations in the absence of motion. For example, the STS is activated when individuals infer the mental states of other individuals (Frith & Frith, 1999). Furthermore, this brain area is also activated when individuals make social judgments regarding others (Winston, Strange, O'Doherty & Dolan, 2002) and is more strongly activated to expressive gestures compared to instrumental gestures (Gallagher & Frith, 2004). In addition, the STS is also differentially activated in response to the emotional content of stimuli, which is expected given multiple interconnections between the amygdala and the STS (Adolphs, 1999). In this context, STS activity is increased during fear-inducing actions (Wheaton, Pipingas, Silberstein & Puce, 2001) and is also activated during dynamic expressions of facial

emotion (LaBar, Crupain, Voyvodic & McCarthy, 2003). These results converge to suggest that the STS plays an important role in the interpretation and analysis of social information (Iacoboni et al., 2004). As such, the perception of biological motion is especially relevant, given that human movement and action can be a strong indicator of social and emotional cues.

### 1.6.5 Schizophrenia and the perception of biological motion

As outlined above, individuals with SCZ are impaired in their ability to process visual motion and perceive/interpret social and emotional cues. As a result, the ability of patients with SCZ to accurately perceive and judge biological motion stimuli is an important target for investigation. The few studies conducted in this domain have demonstrated that individuals with SCZ are generally impaired on tasks of biological motion perception. The first study to investigate biological motion perception in this population was completed by Kim and colleagues (2005), who demonstrated that individuals with SCZ are less able to detect coherent PL actions compared to a static visual perceptual grouping task. Subsequent studies later confirmed these initial results, again demonstrating impaired detection and direction discrimination of PL animations, both in the presence and absence of an external noise mask, among individuals with SCZ (Kim, Norton, McBain, Ongur & Chen, 2013; Brittain, Ffytche, McKendrick & Surguladze, 2010).

Moreover, a more recent study completed by Kim, Park and Blake (2011) utilized fMRI to investigate activated brain areas among people with SCZ during the processing of biological motion. Contrary to HCs, who, as expected, showed increased STSp

activation in response to biological motion but not to non-biological motion, individuals with SCZ showed similar activation of the STSp for both types of motion. Moreover, area MT activation was not different between these groups and no correlations were found between MT and STSp activity for either group. Interestingly, the authors noted that false-alarm trials among healthy participants (e.g., error trials in which non-biological motion was judged as biological) also resulted in strong STSp activity. In this context, the authors suggest that the deficits observed in biological motion processing, and increased STSp activity in response to non-biological motion among patients with SCZ, may reflect an exaggeration of neural events associated with these false alarm errors seen in healthy observers.

Despite the promise of these early findings, several methodological shortcomings warrant further consideration. First, the impact of generalized visual motion processing deficits on biological motion processing has been largely ignored and raises the question of whether biological motion perception deficits are unique from or indicative of this general impairment. Although Kim and colleagues (2005) found SCZ-related biological motion impairment, their control task (i.e., *static* perceptual grouping) was not an appropriate control for examining general motion deficits. The few studies that have attempted to examine this confound have produced conflicting results. Kim and colleagues (2013) demonstrated impairments on tasks of biological motion detection and discrimination and coherent motion detection. However, correlational analysis between these three tasks revealed a significant relationship between coherent motion and biological motion detection only ($r$ = -0.623): there was no significant correlation

between coherent motion detection and masked biological motion direction discrimination. Another study, again using a non-biological coherent motion task, showed that impairment in biological motion perception among patients could be partly attributed to deficits in basic motion processing (Brittain et al., 2010), in that significant correlations were observed between masked biological motion perception (i.e., direction discrimination) and a coherent motion discrimination task among individuals with SCZ. It is important to note that the discrepancy between these two studies may reflect methodological differences, as each study utilized different masking characteristics and procedures to obstruct biological motion stimuli. Nevertheless, these results indicate a lack of consensus regarding the role of a generalized visual motion deficit with respect to biological motion perception among individuals with SCZ. Moreover, the above-noted studies investigated the relationship between these two domains using correlational analysis, which does not necessarily address the contribution of visual motion processing *per se* to biological motion processing more generally. As such, this small body of research raises the important question of whether SCZ-related biological motion processing deficits can be parsimoniously accounted for by a general impairment in motion processing.

Second, scant research has been directed towards understanding the mechanisms of biological motion processing deficits among people with SCZ. For example, as reviewed previously, research with healthy observers has suggested that both local and global visual cues contribute to the perception of biological motion. This dissociation is relevant to understanding SCZ-related biological motion deficits given related research

showing impaired global (e.g., coherent) motion processing, in the context of preserved local motion processing (Chen et al. 2003). These results raise the possibility that the SCZ-related impairment in biological motion processing reflects, primarily, dysfunction in the global motion processing system in the context of relatively intact local motion processing capabilities.

Third, while studies have demonstrated correlations between biological motion perception and social functioning (Kim et al., 2005), few studies have investigated its relationship to *social perception,* specifically. For example, Kim et al. (2005) utilized questionnaires that evaluated various aspects of social functioning (e.g., time spent alone, number of friendships, romantic relationships), but failed to include measures of social perception (e.g., interpreting cues, such as expressive gestures, through social contexts). Although a significant relationship between social functioning and social perception has been documented (Addington, Saeedi & Addington, 2006), social functioning is undoubtedly influenced by several additional external factors (e.g., socioeconomic status, education) and, as a result, does not reflect social perceptual abilities *per se*. Moreover, according to conceptual models of social cognition and functioning, social perception plays a crucial and preliminary role in achieving appropriate social functioning outcomes. For example, the ability to accurately perceive and extract social cues from the environment subsequently allows for other social cognitive processes to be executed (i.e., ToM and attributional style), which ultimately culminates in appropriate social behaviour and function (Couture, Penn & Roberts, 2006). That is, social perception forms the necessary building blocks for social functioning. Interestingly, studies investigating

biological motion perception and other constructs of social cognition, although not necessarily social perception, have failed to demonstrate significant relationships. For example, Kim and colleagues (2013) identified that ToM was more related to non-biological motion tasks compared to biological motion tasks among individuals with SCZ. They also failed to find a relationship between ToM and biological motion among healthy observers. Therefore, given conceptual models suggesting that social perception is necessary for other social cognitive constructs, such as ToM, it is plausible that the failure to find this relationship in fact stems from impaired social perception in SCZ and not necessarily ToM. As such, it is important that future research utilize specific measures of social perception, and not only social functioning, when examining the relationship between biological motion and social perception.

Given the variety of constructs (i.e., social functioning, ToM) utilized to investigate social cognition and biological motion perception among individuals with SCZ, this has resulted in the use of varied measures, including questionnaires (Kim et al., 2005, Peterman, Christensen, Giese & Park, 2013), static tasks involving only specific facial features (e.g., Kim et al., 2013), and brief (i.e., 2 seconds) dynamic video clips of a sole actor communicating facial expressions, voice intonations, and bodily gestures (e.g., Brittain et al., 2010), all of which are limited in their capacity to specifically investigate social perception in this population. Again, this highlights the importance of utilizing appropriate tasks of social perception that are both psychometrically and ecologically valid, specifically in relation to biological motion tasks. Due to these difficulties, the relationship between SCZ-related biological motion processing and social perception has

not yet been fully elucidated. An appropriate alternative to those measures described above would include a task of social perception with good ecological validity, such as the Interpersonal Perception Task-15 (IPT-15; Costanzo & Archer, 1993). The IPT-15, a dynamic (i.e., video) task measuring social perception, contains a number of positive psychometric characteristics: (1) The stimuli involve real individuals in real world setting, opposed to other tasks that utilize actors; (2) A variety of social cues encountered during interpersonal interactions (i.e., posture, gestures, prosody, facial expressions, etc.) are compared to other tasks with limited cues and brief exposures; and (3) The videos involve a high degree of diversity (i.e., age, race, and gender) while other tasks of social perception typically involve one to two Caucasian actors (Vaskinn, Sergi & Green, 2009). Therefore, the use of social perception measures such as the IPT-15 may help clarify the role of social perception among patients with SCZ more generally, in addition to examining the relationship between this domain and biological motion perception.

Fourth, despite the claim that individuals with SCZ are less able to perceive social information from environmental stimuli, the ability to extract relevant social cues from biological motion among this population has not been experimentally tested. As stated previously, the capacity to judge and understand the social environment starts with the ability to extract relevant cues through sensory and perceptual systems. In this context, limited studies have investigated the ability of patients with SCZ to extract socially relevant cues, such as emotion, from human movement and the potential mechanisms involved in this process. To this end, Peterman and colleagues (2013) used full-bodied dynamic volumetric avatars to demonstrate that patients with SCZ were less able to

recognize emotional information from these stimuli. Moreover, similar to healthy participants, patients with SCZ also demonstrated increased performance when discriminating high intensity stimuli compared to lower intensity stimuli. That is, stimuli presented with 100% intensity (e.g., prototypical happy or angry gait) and 150% intensity (e.g., exaggerated happy or angry gait) were more easily identified compared to those presented at 50% intensity (e.g., attenuated happy or angry gait). At present, this is the only study that has investigated the ability of individuals with SCZ to detect social cues from dynamic stimuli and, while important, it is unable to provide insight into potential mechanisms underlying this deficit. That is, the visual analysis of perceiving human movement, as discussed above, requires the complex integration of spatiotemporal cues in the form of both low-level (e.g., local motion) and high-level (e.g., global form) processes. As such, the use of PL animation stimuli, consisting of both global and local features, allows for the manipulations needed to investigate potential motion processing mechanisms contributing to emotion discrimination from biological motion, which cannot be readily achieved utilizing volumetric avatars. As a result, the use of PLWs, opposed to volumetric avatars used by Peterman et al., may help elucidate the mechanisms involved in discriminating social cues from human movement. Furthermore, at this time, it is unknown whether patients with SCZ can extract these social cues from PL animations at all compared to healthy individuals.

Lastly, the ability to evaluate social perceptual information occurring in naturalistic environments often requires the judgment of more subtle and ambiguous cues. That is, with respect to the perception of social cues, observers typically are not required

to form social judgments of emotions expressed at 150%, or even 100%, intensity, but must discriminate and detect subtle expressive features. This is highlighted by research indicating that automatic emotion responding, which is reactive, effortless, and involves the processing of emotions outside conscious awareness (McDonald, 2008), is utilized when individuals are confronted with subtle or ambiguous information, opposed to more effortful or analytic processing of emotion, which is typically conscious and controlled. For example, electromyography studies have demonstrated that individuals will automatically and spontaneously contract facial muscles when viewing positive and negative emotional stimuli (Sonnby-Borgström, Jönsson & Svensson, 2003). Moreover, with respect to human motion perception, research has suggested that humans are readily able to interpret social cues from highly ambiguous stimuli. For example, Troscianko et al. (2004) demonstrated that in naturalistic environments, such as when observing real closed-circuit television (CCTV) recordings, both naïve and expert individuals were able to successfully predict criminal or antisocial behaviour from body movements (i.e., gestures, gait, and body position) alone. That is, both naïve and expert observers were able to infer social information, such as emotion and intention, in others from subtle and ambiguous visual stimuli equally, suggesting that these cues are interpreted at an automatic, or low-level stage of processing, in the absence of experiential cues. Or, in other words, the ability to infer social information from subtle cues was not modified by experience (i.e., expert vs. naïve observers). This finding is particularly relevant with regard to individuals with SCZ as, despite impairment in emotion discrimination more generally, studies have also demonstrated areas of preserved emotional responding in this

population, particularly involving more automatic and/or reactive processing of emotional stimuli. This is in contrast to impaired effortful or controlled processing of emotions. For example, although individuals with SCZ demonstrate difficulty applying labels to emotional faces (e.g., Kohler, Walker, Martin, Healey & Moberg, 2010), they are able to accurately make rapid judgments regarding facial emotions (Gur et al., 2002, Gur et al., 2007). Moreover, individuals with SCZ have been shown to exhibit preserved emotional experience, such as experiencing similar levels of pleasure compared to healthy controls in response to emotional stimuli (Kring & Elis, 2013) and demonstrating similar levels of subjective reaction (e.g., intensity of perceived emotional valence and arousal) to emotionally evocative stimuli, using self-report rating scales (Herbener, Song, Khine & Sweeney, 2008). As such, it is plausible that the ability of individuals with SCZ to extract social information in the form of emotion from human movement may also vary when observing overt compared to more ambiguous or subtle displays of emotion.

## 1.7 SPECIFIC AIMS OF THE CURRENT THESIS

As reviewed above, there exists a relatively small body of literature investigating biological motion processing among individuals with SCZ and, furthermore, these studies have produced some inconsistent findings and are hampered by various methodological concerns. While existing studies have documented deficits in biological motion processing in SCZ, the importance of generalized visual motion processing deficits in this population has been largely ignored. Moreover, there is a current lack of understanding regarding the basic visual-perceptual mechanisms that might underpin this impairment,

such as the contributions of both global form and local motion to the perception of biological motion. Additionally, it is unknown whether individuals with SCZ are able to extract socially relevant cues, such as emotions, from biological motion, and if this ability relates directly to social perceptual deficits in this population. Finally, given that individuals with SCZ demonstrate relatively preserved automatic emotional responding, it is unknown whether individuals with SCZ are able to process more subtle or ambiguous social cues from biological motion, as this is particularly relevant in naturalistic environments.

As such, the current thesis aims to examine whether these basic visual motion processes may give rise to biological motion deficits observed among individuals with SCZ. In addition to these visual-perceptual mechanisms, and as reviewed above, PL animations have been shown to convey complex social information, which is noteworthy, given well-documented social cognition impairment among individuals with SCZ. Moreover, it is plausible that SCZ-related deficits in the perception of dynamic social information, such as biological motion, may not solely be accounted for by differences in motion processing and/or spatial-temporal integration of visual parameters, but instead may also reflect a deficit in extracting relevant social cues from these stimuli. Given the aforementioned inconsistencies and methodological limitations, the current thesis also aims to examine the ability of individuals with SCZ to extract social information, in the form of emotion, from biological motion, in addition to investigating the relationship between biological motion processing and social perceptual deficits in this population. Lastly, social judgments in naturalistic environments often require the discrimination of

subtle and ambiguous cues. This is of particular interest as the judgment of subtle emotional cues is related to automatic responding, which is generally preserved in patients with SCZ. As such, the final aim of this thesis is to examine whether individuals with SCZ are able to extract subtle and ambiguous social information from biological motion.

## 1.8 SUMMARY OF CHAPTERS

These aims were executed at a behavioural level of analysis using a variety of experimental paradigms. Chapter 2, consisting of three experiments, investigated several visual motion processing mechanisms that could potentially underlie SCZ-related impairments in the perception of biological motion. Experiments 1 and 2 investigated the contribution of coherent motion to biological motion perception, in which patients with SCZ and HCs discriminated the direction of motion of both PLWs and a non-biological motion stimulus. Given the findings of Experiments 1 and 2, suggesting that biological motion deficits could be accounted for by global coherent motion, Experiment 3 extended and confirmed these findings by isolating global form and local motion cues embedded within the point-light stimuli to examine more specific mechanisms involved in the perception of biological motion.

Chapter 3 consisted of three separate experiments examining the ability of patients with SCZ to extract relevant emotional cues from PLWs. Specifically, Experiment 1 examined the ability of patients with SCZ to discriminate emotions (e.g., happiness, anger, sadness) from PLWs. The stimuli were presented in four forms, including upright,

inverted, scrambled, and random-position displays, to elucidate the role of global and local mechanisms in the extraction of emotion information from the stimuli. Additionally, participants also completed the Interpersonal Perception Task-15, a social perception and nonverbal communication test, to determine the relationship between emotion discrimination and natural and unscripted social interactions. Experiment 2 extended the results of the previous experiments by examining the role of speed confounds with respect to emotion discrimination from biological motion. That is, the speed of PLWs varied due to the natural speed of these stimuli (e.g., angry PLWs were displayed at increased speed compared to sad PLWs). As such, the speed across all PLW displays was equated to remove cues provided by the velocity profiles of the stimuli. Finally, given findings from Experiments 1 and 2 regarding the use of local motion cues in emotion discrimination from PLWs, Experiment 3 investigated whether affective local motion cues augmented the processing of motion information from biological motion.

Chapter 4 consisted of a single experiment that examined the ability of individuals with SCZ to discriminate varying degrees of emotion intensity from PLWS, as in naturalistic environments, emotions are rarely presented at high intensities. As such, emotion judgments are often required from less intense and salient stimuli. In this context, Chapter 4 investigated the ability of participants to accurately discriminate emotions from three affective dimensions on a continuous axis: Happy-angry, happy-sad and angry-sad. The signal, or proportion of emotion within a given PLW, was altered to depict varying degrees of emotional intensity, ranging from extreme to more ambiguous displays of emotion.

Chapter 5 provides a general summary of the main findings from the individual studies. The implications for SCZ, including neurobiology, neural networks, psychopathology, and treatment are also discussed in the context of the main findings of this thesis. Finally, this chapter identifies limitations of the current thesis and potential future directions that may stem from the work presented in this thesis.

# CHAPTER 2

## CONTRIBUTION OF COHERENT MOTION TO THE PERCEPTION OF BIOLOGICAL MOTION AMONG PERSONS WITH SCHIZOPHRENIA*

Justine M. Y. Spencer[1], Allison B. Sekuler[1], Patrick J. Bennett[1] & Bruce K. Christensen[1,2]

[1] Department of Psychology, Neuroscience & Behaviour, McMaster University

[2] Department of Psychiatry and Behavioural Neurosciences, McMaster University

* Spencer, J. M. Y., Sekuler, A. B., Bennett, P. J., & Christensen, B. K. (2013). Contribution of coherent motion to the perception of biological motion among persons with Schizophrenia. *Frontiers in Psychology*, *4*, 507. doi:10.3389/fpsyg.2013.00507

## ABSTRACT

People with schizophrenia (SCZ) are impaired in several domains of visual processing, including the discrimination and detection of biological motion. However, the mechanisms underlying SCZ-related biological motion processing deficits are unknown. Moreover, whether these impairments are specific to biological motion or represent a more widespread visual motion processing deficit is unclear. In the current study, three experiments were conducted to investigate the contribution of global coherent motion processing to biological motion perception among patients with SCZ. In Experiments 1 and 2, participants with SCZ (n=33) and healthy controls (n=33) were asked to discriminate the direction of motion from upright and inverted point-light walkers in the presence and absence of a noise mask. Additionally, participants discriminated the direction of non-biological global coherent motion. In Experiment 3, participants discriminated the direction of motion from upright scrambled walkers (which contained only local motion information) and upright random-position walkers (which contained only global form information). Consistent with previous research, results from Experiments 1 and 2 showed that people with SCZ exhibited deficits in the direction discrimination of point-light walkers; however, this impairment was accounted for by decreased performance in the coherent motion control task. Furthermore, results from Experiment 3 demonstrated similar performance in the discrimination of scrambled and random position point-light walkers.

## 2.1 INTRODUCTION

Since Johansson (1973) first introduced point-light walkers as an experimental tool for examining the perception of human motion, many studies have demonstrated the sensitivity of the human visual system with respect to detecting and perceiving biological motion. For example, healthy individuals are able to recognize human actions from point-light stimuli following short presentation durations (e.g., 200 ms; Johansson, 1973), under conditions of additional dynamic noise (Bertenthal & Pinto, 1994), and when the number of illuminated joint markers has been substantially reduced (Johansson, 1973). Furthermore, infants as young as three months old are able to discriminate upright point-light walkers from inverted walkers (Bertenthal, Proffit, & Cutting, 1984). Dynamic biological motion has also been shown to convey relevant social information, such as cues regarding a person's affect (Atkinson, 2004), sex (Barclay, Cutting, & Kozlowski, 1978; Pollick, Kay, Heim, & Stringer, 2005), intention to deceive (Runeson & Frykholm, 1983), and identity (Cutting & Kozlowski, 1977; Loula, Prasad, Harber, & Shiffrar, 2005). As a result, biological motion can convey information not only about the perceptual characteristics (e.g., size and shape) of a walker, but also higher-order social information regarding a walker's intentions and emotional states.

Individuals with Schizophrenia (SCZ) exhibit deficits in several aspects of visual motion processing including speed discrimination (Chen et al., 1999; Clementz, McDonell, & Dobkins, 2007) and the perception of coherent global motion (Chen et al., 2003; Stuve et al., 1997). Furthermore, this population exhibits deficits in their ability to recognize and interpret social stimuli (Bigelow et al., 2006; Baas, van't Wout, Aleman, &

Khan, 2008) or detect emotions from affective facial expressions (Johnston, Devir, Karayanidis, 2006; Edwards, Pattison, & Jackson, 2001; Kohler et al., 2003; Monkel, 2007). Given known deficits in both motion processing and social cognition, it has been suggested that people with SCZ also may be impaired on tasks of biological motion processing, and that such deficits may contribute to the above-noted social deficits. Indeed, several studies that have examined biological motion perception in SCZ suggest that these patients are impaired on biological motion processing tasks. Kim, Doop, Blake, and Park (2005) demonstrated that people with SCZ show a deficit in recognizing biological motion activities compared to biological scrambled motion sequences. Moreover, people with SCZ performed similarly when completing a static global form detection task, suggesting that the observed group difference in the biological motion task was not due to a general performance deficit in SCZ patients. Additionally, Kim, Park, and Blake (2011) found that people with SCZ were less able to detect and discriminate biological motion on tasks that included a noise mask and the perturbation of kinematic information respectively.

Despite evidence suggesting that SCZ patients have greater difficulty detecting and discriminating biological motion, it is unclear whether these deficits are specific to biological motion *per se* or represent a more general deficit in perceiving global motion. Chen and colleagues (2003) measured direction discrimination thresholds using a sine wave grating, a task that requires only local motion processing, and random dot kinematograms, which require global motion processing. Chen et al. (2003) found that SCZ patients had elevated direction discrimination thresholds only in the task that used

random dot stimuli, which suggests that processing of global, but not local, motion is impaired in SCZ patients. Point light walker stimuli contain both local and global cues: the trajectory of each dot constituting a point-light walker conveys information about the motion of a particular part of the human figure (e.g., the feet, the elbows, etc.) and grouping these local elements creates a holistic perception of the walker's global form (e.g., a whole body). Moreover, previous research suggests that both local (Mathers, Radford & West, 1992; Troje & Westhoff, 2006) and global processes (Bertenthal & Pinto, 1994; Beintema & Lappe, 2002; Pilz, Bennett, & Sekuler, 2010) contribute to the perception of point light walkers. Hence, the results of Chen et al. raise the possibility that at least some of the SCZ-related deficit in biological motion tasks reflects a general deficit in global motion processing. According to this hypothesis, the effect of SCZ on the perception of biological motion should be diminished or eliminated once the general effect of SCZ on global motion processing is taken into account. The current experiments examine this hypothesis. To our knowledge, previous studies investigating biological motion processing in SCZ have not used control tasks that could estimate deficits in global, non-biological motion processing. For example, Kim et al (2005) used a control task that measured the ability of participants to group stationary lines into a larger global form. Although this task considered the grouping of visual elements into a Gestalt, the fact that it used static stimuli means that it does not provide an appropriate control for examining global motion deficits.

To investigate the contribution of global motion to biological motion perception, three experiments were completed in which participants were asked to discriminate the

direction of motion from point-light walkers. In Experiment 1, we measured direction discrimination thresholds for upright and inverted point-light walkers embedded in a dynamic noise mask. Importantly, direction discrimination thresholds also were measured for non-biological global motion, consisting of coherently translating dots, embedded in a dynamic noise mask. To determine if the results obtained in Experiment 1 generalize to supra-threshold conditions, Experiment 2 measured response accuracy in a direction discrimination task that used stimuli that were similar to those used in Experiment 1 but which did not contain dynamic noise. Finally, Experiment 3 investigated the contribution of local and global mechanisms to biological motion among participants with SCZ by using point-light walkers that contained only local motion information (scrambled point-light walkers) or global motion information (random position point-light walkers).

## 2.2 GENERAL METHODOLOGY

### 2.2.1 Participants

Thirty-three people with SCZ (5 female, 28 males) and 33 healthy controls (18 females, 15 males) participated in all experiments. All participants had normal or corrected-to-normal visual acuity, as ascertained using a standard Snellen chart, and reported an absence of lifetime neurological illness, brain injury, learning disability, current or past substance dependence, or medical conditions that could affect cognitive performance (e.g. coronary heart disease, type 1 diabetes).

All patients met criteria for SCZ (21 patients) or Schizoaffective Disorder (12 patients), as confirmed by the Mini International Neuropsychiatric Interview (M.I.N.I.)

(Sheehan et al., 1998), but did not meet criteria for any other Axis 1 disorder. Patients with SCZ were outpatients, medication-stable for at least the past six months, and were prescribed either typical (5 patients) or atypical antipsychotics (28 patients). Healthy control participants did not meet criteria for any Axis I disorder and were also excluded if they reported having a first-degree relative with a SCZ-spectrum illness. Estimates of Full Scale Intelligence Quotient (FSIQ) were obtained by prorating performance on the Matrix Reasoning and Information subtests from the Wechsler Adult Intelligence Scale, 3rd Edition (Wechsler, 1997). General cognitive functioning was assessed via the Repeatable Battery for the Assessment of Neuropsychological Status (Randolph, 1998). Patients with SCZ were also administered the Positive and Negative Syndrome Scale (PANSS; Kay, Fiszbein, & Opler, 1987) to assess current symptom status. In addition, both patients and controls were administered select scales from the Personality Assessment Inventory (PAI), including the Depression (Dep), Alcohol Problems (Alc), Drug Problems (Drg), Positive Impression Management (PIM), and Negative Impression Management (NIM) scales (Morey, 1991). Both groups were age-matched, but healthy controls had achieved significantly higher years of education. Regarding neuropsychological measures, significant differences were found across WAIS-III FSIQ and all RBANS indices. Although participants with SCZ also had significantly elevated scores on the PAI-Drg and PAI-Dep subscales compared to healthy controls, no single participant scored in a range suggesting significant clinical problems in these domains (i.e., T>70). Moreover, no participant evidenced deliberate distortion of their responses across both validity scales (i.e., PIM and NIM). Table 2.1 provides information characterizing the study participants.

Ethics approval for the study was obtained by the St. Joseph's Healthcare Hamilton Research Ethics Board. All participants provided written, voluntary consent to participate and received $10/hour for their participation. Each participant was tested in all three experiments. The order of the experiments was counterbalanced across participants.

**Table 2.1** Means (SD) for demographic, neuropsychological, and clinical characteristics of the sample.

| Variable | Healthy Controls n = 33 | SCZ n = 33 |
|---|---|---|
| Demographic | | |
| Age (years) | 38.76 (11.01) | 42.78 (8.11) |
| Education (years) | 15.24 (2.17) | 13.00 (2.02)* |
| Neuropsychological | | |
| Estimated FSIQ | 111.42 (13.72) | 97.44 (16.43)* |
| RBANS | 102.15 (16.14) | 78.69(13.55)* |
| Clinical | | |
| PAI - Alc | 46.36 (3.13) | 49.50 (12.10) |
| PAI - Drg | 50.18 (9.19) | 56.47 (14.22)* |
| PAI - Dep | 46.24 (7.24) | 58.84 (13.27)* |
| PAI - PIM | 53.76 (9.91) | 52.72 (11.69) |
| PAI - NIM | 45.58 (8.60) | 51.19 (16.16) |
| PANSS - Pos | - | 40.62 (4.23) |
| PANSS - Neg | - | 42.34 (10.12) |

* Indicates a significant difference between healthy controls and people with SCZ.
FSIQ = Full Scale Intelligence Quotient; RBANS = Repeatable Battery for the Assessment of Neuropsychological Status; PAI = Personality Assessment Inventory; PANSS = Positive and Negative Syndrome Scale.

### 2.2.2 Apparatus and Stimuli

All experimental tasks were programmed and presented using a Macbook Pro laptop computer with MATLAB and the Psychophysics and Video ToolBox extensions (Brainard, 1997, Pelli, 1997). Stimuli were presented on a 19-inch monitor with a resolution of 1024 x 864 pixels and a refresh rate of 60 Hz.

### 2.2.3 Procedure

In each experiment, participants were seated in a darkened room and viewed the stimuli at a distance of 60 cm with their heads stabilized by a chin rest. On each trial, the direction of motion was either towards the left or the right, and participants were asked to identify the direction of motion displayed by the stimulus by pressing a key on a standard QWERTY computer keyboard (i.e., “a” key (left) and “l” key (right)). Stimulus durations were intermixed randomly across trials. Prior to the experiments, participants performed 10 practice trials for each stimulus type to familiarize themselves with the stimuli.

## 2.3 EXPERIMENT 1

### 2.3.1 Methods

Experiment 1 used upright and inverted point-light walkers, in addition to the non-biological motion control task. The stimulus used in the control task consisted of 11 dots that moved coherently to the left or right at a speed of 7 deg/s. Point-light walker stimuli were generated using a modified version of Cutting's classic point-light walker algorithm (Cutting, 1978; Thornton, Pinto, & Shiffrar, 1998). The walkers consisted of 11 dots (2 x 2 pixels) that simulated points on the head, shoulder, elbows, wrists, hip, knees, and

ankles. The starting position of the stride cycle was chosen randomly on every trial, which prevented participants from recognizing the walker simply from the starting point or from a specific frame. The walker, which subtended 1.9 x 4.2 degrees did not move across the screen, but rather appeared to walk in place, as if on a treadmill. Inverted walkers were rotated by 180 deg so that they appeared to be walking on the ceiling. The walker stimuli consisted of 5, 15, 30, or 45 frames presented at 25 frames per second, resulting in total presentation times of 0.2, 0.6, 1.2, and 1.8 seconds respectively. These specific durations were chosen based on a previous research suggesting that durations shorter than 0.2 s are insufficient for direction discrimination whereas increasing duration beyond 1.8 s does not improve performance (Pilz et al., 2010). One complete gait cycle was achieved after 40 frames, or 1.6 seconds.

All stimuli were occluded with a dynamic noise mask composed of an array of dots whose positions varied randomly on each stimulus frame. The point-light walkers, the dynamic noise mask, and the control stimulus, were all constructed with dots that were identical in size and contrast. All stimuli were presented on a black background and were centered on the middle of the screen. Dot luminance was 67.4 $cd/m^2$ and the background luminance was less than $1cd/m^2$. Trials in the conditions using upright walkers, inverted walkers, and drifting dots were randomly intermixed.

Direction discrimination thresholds were estimated by varying the number of dots presented in the dynamic noise mask using a 3-up/1-down staircase procedure. Note that the staircase increased the number of mask dots (i.e., reduced the signal-to-noise ratio) after three consecutive correct responses, and decreased the number of mask dots (i.e.,

increased the signal-to-noise ratio) after one incorrect response. The staircase converged on the number of mask dots needed to produce 79% correct responses, which in this task corresponds to a $d'$ of 1.14. Thresholds for each stimulus duration were estimated by averaging the last 10 reversals.

### 2.3.2 Results and Discussion

Direction discrimination thresholds are shown in Figure 2.1. Because thresholds are expressed in terms of the number of mask dots that are required to produce 79% correct responses, higher values correspond to better performance.

An initial 2 (group) X 3 (stimulus type) x 4 (stimulus duration) Analysis of Variance (ANOVA) was conducted on resulting thresholds. The ANOVA revealed a significant main effect of group ($F(1, 64) = 4.89$, $p = 0.031$), where participants with SCZ required fewer noise dots to reach threshold compared to healthy controls across all walker types and stimulus durations. A significant main effect of stimulus type was also observed ($F(2, 128) = 34.85$, $p < 0.001$) where both groups of participants demonstrated better performance in the coherent motion task compared to the upright ($t(263) = 9.17$, $p < 0.001$) and inverted point-light walker ($t(263) = 11.42$, $p < 0.001$) conditions. Bonferroni adjusted paired t-tests also revealed that participants performed significantly more accurately in the upright condition compared to the inverted condition ($t(263) = 3.41$, $p < 0.001$). A significant main effect of stimulus duration was also revealed: Participants required fewer noise dots to reach threshold at 0.2 second duration, followed by 0.8, 1.2, and 1.6 second durations respectively. All Bonferroni adjusted t-tests were significant ($p < 0.05$). No significant interactions were observed.

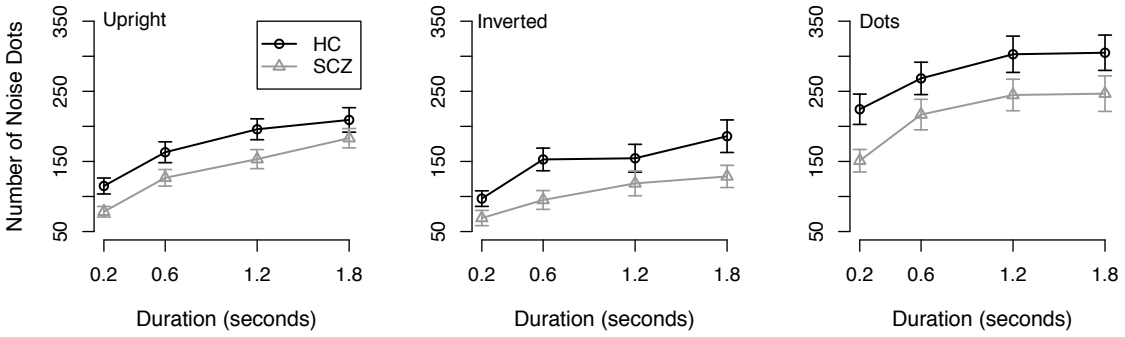


**Figure 2.1** Direction discrimination noise threshold for SCZ and healthy controls in the three conditions and across all durations. Threshold is expressed as the number of dots in a dynamic noise mask; the point light walker consisted of 11 dots. Both groups showed better performance in the dots condition compared to upright and inverted point-light walkers. Both groups also showed better performance in the upright condition compared to the inverted condition. No interactions were found.

Results from the initial analysis suggest that people with SCZ have deficits in discriminating the direction of both biological motion and coherent non-biological motion. Importantly, the group x stimulus type interaction was not significant ($F(2, 128) = 0.79$, $p = 0.45$), which suggests that the difference between groups did not depend on the type of stimulus. Hence, the SCZ-related deficit in discriminating the direction of biological motion (i.e., point light walkers) was no bigger than the deficit in discriminating non-biological motion (i.e., drifting dots). We therefore examined whether group differences in the upright and inverted walker conditions could be accounted for by performance in the control condition. First, we confirmed that the group difference in the upright and inverted walker conditions was significant: a 2 (group) x 2 (walker orientation) x 4 (stimulus duration) condition revealed significant main effects of group ($F(1, 64) = 5.42$, $p = 0.023$), walker orientation ($F(1, 64) = 26.17$, $p < 0.001$), and

duration ($F(3, 192) = 40.28$, $p < 0.001$). The group x walker orientation interaction ($F(1, 64) = 1.71$, $p = 0.19$) was not significant, nor were any of the other interactions (in each case, $F < 1.19$, $p > 0.31$). To investigate whether group differences in biological motion discrimination can be accounted for by differences in global coherent motion discrimination, thresholds in the upright and inverted walker conditions were submitted to a 2 (group) x 2 (walker orientation) x 2 (stimulus duration) Analysis of Covariance (ANCOVA), where discrimination threshold in the control condition served as the covariate. In this analysis, the covariate was calculated by averaging thresholds in the control condition across stimulus duration, because a preliminary ANOVA on thresholds in the control condition failed to reveal a reliable group x stimulus duration interaction ($F(3, 192) = 2.10$, $p = 0.100$), suggesting that group differences in the control condition did not vary as a function of stimulus duration. The ANCOVA revealed a significant effect of the covariate ($F(1,63) = 34.68$, $p < 0.001$), and significant main effects of walker orientation ($F(1, 63) = 25.91$, $p < 0.001$) and stimulus duration ($F(3, 192) = 23.41$, $p < 0.001$). Importantly, the main effect of group was not significant ($F(1, 63) = 1.92$, $p = 0.171$), nor were any of the interactions. These results suggest thresholds in the upright and inverted walker conditions do not differ between groups, once threshold in the control condition is taken into account.

## 2.4 EXPERIMENT 2

Consistent with previous reports (Kim et al., 2005; Kim et al., 2011), Experiment 1 found that people with SCZ exhibit deficits in the discrimination of the direction of

biological motion. However, Experiment 1 also found that the group difference was not significant once threshold in a control task, which used non-biological global motion, was taken into account. This result suggests that deficits observed in the direction discrimination of point-light walkers among SCZ participants were not specific to biological motion but instead may represent a more widespread processing deficit for global visual motion.

Experiment 1 measured direction discrimination thresholds, which means that our stimuli were presented at low signal-to-noise ratios. However, biological motion stimuli are presented at very high signal-to-noise ratios in many naturalistic contexts. Do SCZ patients exhibit biological motion processing deficits in such situations? Previous studies suggest that such deficits do exist: Kim et al. (2005), for example, used high signal-to-noise stimuli in a biological motion detection task and found that sensitivity in SCZ patients ($d' = 2.2$) was significantly lower than sensitivity in control participants ($d' = 2.8$). Also, Spencer et al. (2013) found that response accuracy in an emotion discrimination task using unmasked, high signal-to-noise ratio point light walkers was significantly lower in SCZ patients than control subjects. However, neither one of these studies examined whether the SCZ-related deficits could be accounted for by deficits in non-biological, global motion processing. Therefore, Experiment 2 examined this question by having participants perform the same tasks as Experiment 1, but without the dynamic noise mask.

### 2.4.1 Methods

Experiment 2 used identical stimuli to those presented in Experiment 1, but with the dynamic noise mask removed.

### 2.4.2 Results and Discussion

The dependent variable, proportion of correct responses, was not normally distributed; therefore, statistical analyses were performed on the arcsine-transformed data. First, transformed data were submitted to a 2 (group) x 3 (stimulus type) x 4 (stimulus duration) ANOVA. Results of this analysis revealed a significant main effect of group ($F(1, 65) = 4.47$, $p = 0.038$) where people with SCZ demonstrated reduced accuracy across all conditions and stimulus durations (Figure 2.2). A significant main effect of stimulus type was also observed ($F(2, 130) = 9.19$, $p < 0.001$) where both groups of participants performed more accurately in the coherent motion task compared to the inverted point-light walker condition ($t(267) = 2.23$, $p = 0.026$). Bonferroni corrected pairwise t-tests did not reveal significant differences between the other conditions. A main effect of stimulus duration was also revealed ($F(3, 195) = 5.88$, $p < 0.001$). Subsequent Bonferroni corrected t-tests revealed that significant differences were only found in the stimulus duration of 0.2 seconds ($p < 0.05$). Comparisons between 0.6, 1.2, and 1.8 seconds were not significantly different. The group x stimulus type interaction ($F(2, 130) = 0.8$, $p = 0.45$) was not significant, nor were any of the other interactions ($F < 1.54$, $p > 0.20$ in each case).

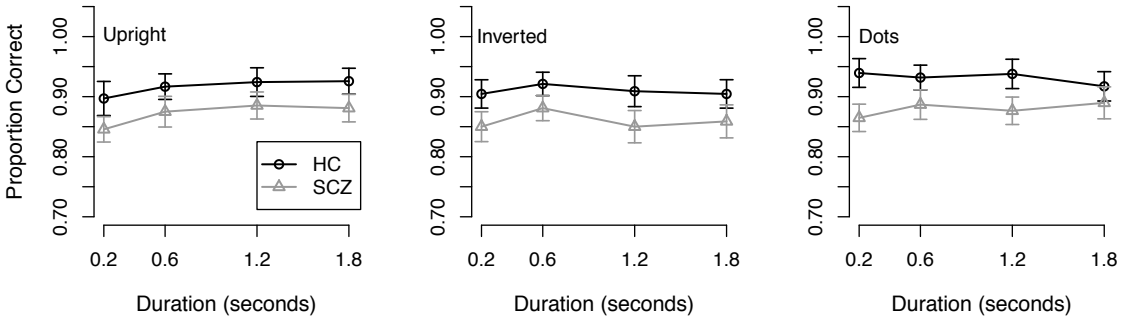


**Figure 2.2** Response accuracy from Experiment 2. Both groups showed better performance in the dots condition compared to upright and inverted point-light walkers. Both groups also showed better performance in the upright condition compared to the inverted condition. No interactions were found.

As in Experiment 1, we next conducted analyses to determine if the group differences in the upright and inverted walker conditions could be accounted for by differences in the control condition. First, we confirmed that the group difference was significant in the two walker conditions: a 2 (group) x 2 (walker orientation) x 4 (stimulus duration) ANOVA revealed significant main effects of walker orientation ($F(1, 65) = 4.51$, $p = 0.037$) and stimulus duration ($F(3, 195) = 3.93$, $p = 0.01$), and a significant walker orientation x stimulus duration interaction ($F(3, 195) = 2.72$, $p = 0.046$). The main effect of group approached significance ($F(1, 65) = 3.75$, $p = 0.057$), although a one-tailed test, which is appropriate for the prediction that accuracy is lower in the SCZ group, was significant ($t(65) = 1.94$, $p = 0.028$). Next, we analyzed the results in the control condition using a 2 (group) x 4 (stimulus duration) ANOVA: the main effect of group was significant ($F(1, 65) = 5.69$, $p = 0.02$) but the group x duration interaction was not ($F(3, 192) = 1.83$, $p = 0.143$), suggesting that the group difference did not vary as a function of stimulus duration. We therefore averaged performance across stimulus durations and used the

resulting value as a covariate in a 2 (group) x 2 (walker orientation) x 4 (stimulus duration) ANCOVA. The ANCOVA revealed a significant effect of the covariate ($F(1, 64) = 495.07$, $p < 0.001$), significant main effects of both walker orientation ($F(1, 64) = 4.47$, $p < 0.038$) and stimulus duration ($F(3, 192) = 3.99$, $p < 0.009$), and a significant walker orientation x stimulus duration interaction ($F(3, 189) = 2.70$, $p = 0.046$). However, the main effect of group ($F(1, 64) = 0.075$, $p = 0.389$) was not significant, nor were any of the remaining interactions ($F < 1.87$, $p > 0.13$ in all cases). These results suggest that healthy controls and patients with SCZ perform similarly in the direction discrimination of supra-threshold biological motion stimuli once differences in coherent global motion are taken into account.

## 2.5 EXPERIMENT 3

The results of Experiments 1 and 2 suggest that SCZ-related deficits in the discrimination of the direction of point-light walkers is not specific to biological motion, but instead can be accounted for by more general global coherent motion processing deficits. This result was the same across both experiments, indicating that SCZ-related deficits in discriminating biological motion can be accounted for by global coherent motion processing regardless of signal-to-noise conditions.

To further investigate the contribution of global motion processing to biological motion discrimination, Experiment 3 compared SCZ and control group direction discrimination of scrambled and random position point-light walkers. In the *scrambled* condition, the trajectory of each local dot was maintained, but the initial dot positions

were shifted randomly along the x and y-axes of the display, resulting in a point-light walker with intact local motion information but distorted global form (e.g., Troje & Westhoff, 2006; Thronton et al., 1998; Pilz et al., 2010). In the *random position* condition, each dot was shifted randomly between two adjacent joints across successive frames (e.g., Beintema and Lappe, 2002; Pilz et al., 2010), resulting in disrupted local trajectories of individual dots but preserved global form of a walker. A recent study by Pilz et al. (2010) using similar stimuli showed that among both younger and older adults, the removal of global elements from point-light walkers (i.e., scrambled point-light walkers) resulted in significantly reduced direction discrimination. Conversely, the removal of local motion information (i.e., random position point-light walkers) had little impact on performance. Given the results from Experiments 1 and 2 suggesting that SCZ-related deficits in biological motion discrimination can be accounted for by general deficits in global coherent motion processing, it was hypothesized that SCZ patients would be negatively impacted by the removal of global form information but undeterred by the removal of information regarding local position.

### 2.5.1 Methods

In Experiment 3, healthy controls and patients with SCZ discriminated the direction of upright, scrambled, and random position point-light walkers. As in the previous experiments, stimuli were presented in four durations (0.2, 0.8, 1.2, 1.6 seconds), which were randomized on every trial. Participants completed 20 trials for each type of walker at each stimulus duration, resulting in a total of 240 trials. The dependent variable was the proportion of correct responses.

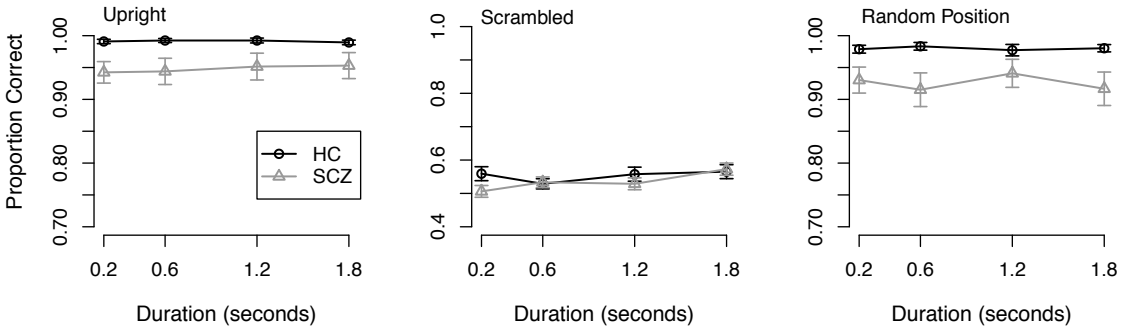


**Figure 2.3** Response accuracy from Experiment 3. Both groups of participants showed better performance in the upright and random position conditions compared to the scrambled condition. No interactions were found.

### 2.5.2 Results and Discussion

Response accuracy is plotted as a function of stimulus duration in Figure 2.3. A 2 (group) x 3 (stimulus type) x 4 (duration) ANOVA on arcsine-transformed data revealed a significant main effect of group ($F(1,64) = 7.17$, $p = 0.009$), where people with SCZ were less accurate overall compared to healthy controls. The ANOVA also found a significant main effect of stimulus type ($F(2, 128) = 1002.03$, $p < 0.001$), such that response accuracy in both groups was greater in the upright and random-position conditions compared to the scrambled condition. No other significant main effects or interactions were observed.

Because accuracy did not vary with stimulus duration, we averaged accuracy across stimulus duration for each participant. The mean of the averaged accuracy is plotted as a function of group and stimulus type in Figure 2.4, which illustrates that accuracy in both groups of participants was quite high in the upright and random walker conditions and near chance in the scrambled walker condition. Hence, manipulation of

local and global information had qualitatively similar effects in SCZ patients and healthy controls.

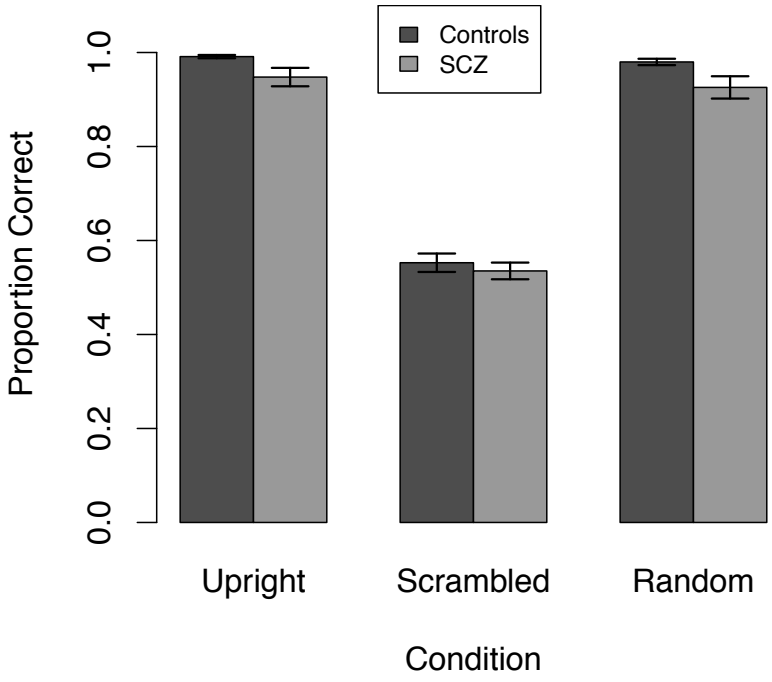


**Figure 2.4** Response accuracy averaged across stimulus durations in three conditions in Experiment 3. Both SCZ and healthy controls performed significantly worse in the scrambled condition compared to the upright and random position conditions. Results shown are collapsed across all stimulus durations.

However, Figure 2.4 also highlights the existence of ceiling effects in the upright and random walker conditions and a possible floor effect in the scrambled condition. These ceiling and floor effects would make it difficult for an ANOVA to find group differences in performance, and therefore we analyzed the data in another way. Following an approach previously suggested by Kim et al. (2011), first, we compared the proportion

of participants in each group whose accuracy in each of the upright and random conditions was less than 1.0, and whose accuracy in the scrambled condition was significantly greater than chance (i.e., accuracy $\geq 0.587$, $p < 0.05$, one-tailed). In each condition, the proportions of participants in the SCZ and control groups did not differ (see Table 2.2). Next, we used *t* tests to compare the mean response accuracy for participants in each group who had an accuracy less than 1.0 in the upright and random walker conditions and above chance in the scrambled condition: for these subsets of participants, accuracies in the SCZ group and the control group differed in the upright and random walker conditions, but not the scrambled walker condition (see Table 2.3).

Taken together, our analyses suggest that there was a small group difference in response accuracy in the upright and random conditions, but not in the scrambled condition. However, the primary finding was that manipulations of local motion information and global form had similar effects on direction discrimination in both groups.

**Table 2.2** Proportion of participants in Experiment 3 with response accuracies that were less than 1.0 in the upright and random walker conditions and greater than chance in the scrambled walker condition.

| | SCZ | Controls | Chi-Square | *p* |
|---|---|---|---|---|
| Upright | 17/33 = 0.51 | 16/33 = 0.49 | 0 | 0.99 |
| Scrambled | 6/33 = 0.18 | 13/33 = 0.39 | 2.66 | 0.10 |
| Random | 22/33 = 0.67 | 20/33 = 0.61 | 0.065 | 0.79 |

**Table 2.3** Mean response accuracy of participants who had an accuracy less than 1.0 in the upright and random conditions and greater than chance in the scrambled condition.

| | SCZ | Controls | *t* | *df* | *p* |
|---|---|---|---|---|---|
| Upright | 0.898 | 0.982 | 2.58 | 31 | 0.02 |
| Scrambled | 0.606 | 0.613 | 0.62 | 17 | 0.54 |
| Random | 0.888 | 0.966 | 2.39 | 40 | 0.02 |

## 2.6 DISCUSSION

The present study examined the effects of SCZ on the perception of biological motion. Consistent with previous reports (Kim et al., 2005; Kim et al., 2011), Experiments 1 and 2 found that SCZ patients were worse than healthy control participants at discriminating the direction of upright and inverted point-light walkers. However, Experiments 1 and 2 also found that SCZ patients were worse in a control task that required participants to discriminate the direction of non-biological global motion (i.e., coherently drifting dots). Furthermore, we found that group differences in conditions that used point-light walkers were eliminated once performance in the control task was taken into account. Taken together, the results of Experiments 1 and 2 suggest that although people with SCZ do exhibit deficits in the direction discrimination of point-light walkers, this impairment is not specific to biological motion *per se* but likely represents more general deficits in global motion processing.

Experiment 3 also found evidence that SCZ patients were slightly less accurate at discriminating the direction of standard upright point-light walkers as well as random walkers that contained the global form, but not the local motion cues. These results

suggest that patients with SCZ exhibit deficits utilizing global form compared to healthy controls. Although no significant group differences were found in the scrambled condition, it is more difficult to speculate regarding local motion mechanisms, as most participants in both groups were found to perform at chance level. Additionally, results of Experiment 3 demonstrate that manipulations of the global form and local motion information in point-light walkers had similar effects on direction discrimination in both patients with SCZ and control participants: in both groups, removing local motion cues (i.e., the random position condition) had small effects on performance, but removing global form cues (i.e., the scrambled condition) made discrimination much more difficult. This result suggests that the relative influence of global form and local motion cues on the perceived direction of point-light walkers is similar in people with SCZ and healthy controls. Despite these results, it is difficult to speak directly to the nature of local and global mechanisms in this experiment given the observed floor and ceiling effects (see Figure 4). The use of a noise mask to remove performance from the floor and ceiling would be helpful to examine specific contributions of local and global mechanisms to biological motion processing and represents an avenue of future study. Nevertheless, despite floor and ceiling effects, results from Experiment 3 demonstrate that people with SCZ performed similarly to that of healthy controls, in that form information is important for the direction discrimination of point-light walkers. Furthermore, these results are consistent with Pilz, Bennett, and Sekuler (2010), in which removing global form from point-light walkers was shown to reduce performance in both younger and older healthy adults. As a result, using the identical mechanism to alter the point-light walker stimuli

resulted in similar performances among healthy controls and people with SCZ, suggesting that the mechanisms used during this experiment were also likely similar.

It is also important to note that the stimuli used in the current study were generated using a modified version of Cutting's classic point-light walker algorithm. Although these stimuli have been used repeatedly in previous studies, more recent research by Saunders, Suchan, and Troje (2009) has suggested that the Cutting point-light walker algorithm lacks important visual information associated with the local motion of dots representing the feet compared to more naturalistic point-light walkers displays. Specifically, Saunders et al (2009) show that while detection performance of Cutting and naturalistic point-light walkers was unchanged, participants were better able to discriminate the direction of motion from scrambled naturalistic point-light walkers compared to Cutting point-light walkers. Given these results, future research should utilize naturalistic point-light walkers to further examine deficits in SCZ regarding biological motion perception.

Regarding additional limitations, all patients with SCZ who took part in the current study were medicated, and we are unable to comment as to whether the results observed in the study were confounded by medication status. Additionally, analysis of sample characteristics revealed that the patients in the study had a significantly lower education level, as well as estimated intelligence levels and general neuropsychological scores. The issue of how to approach confounding group differences, however, is a complicated one and a topic of active debate within SCZ research. On the one hand, several characteristics that reliably distinguish SCZ from healthy participants are indeed

correlated with outcomes of interest. In this situation, it is conventional to attempt to equate between-group differences on the confounding variable via linear covariate analyses. The popularity of these methods notwithstanding, they have been criticized on both statistical and conceptual grounds. In the case of the latter, Meehl (1970) has argued that if the confounding variable is a valid reflection of a pathological state (e.g., psychological symptoms), linear removal of the shared variance will necessarily attenuate the between-group variance of interest. Statistically, as Miller and Chapman (2001) and others discuss, the use of ANCOVA to correct for factors such as IQ is statistically dubious, as this analysis assumes that the covariate and independent variable, such as diagnostic group, are independent (Silverstein, 2008). As such, in psychopathological research, these variables are often not independent, and using ANCOVA to control for a covariate in psychopathology research removes meaningful variance from the independent variable of interest. Consequently, in the absence of random assignment, group membership is generally acknowledged to represent a broad collection of symptoms and problems that denote the entirety of a psychopathological category.

The perception of global coherent motion in random dot patterns requires the visual system to represent the speed and direction of individual dots and to integrate such information across space and time. Chen et al. (2003) presented evidence that processing of global, but not local, motion is impaired in SCZ, which suggests that spatiotemporal integration of local motion cues is deficient in SCZ patients. Given this apparent spatiotemporal motion integration deficit in patients with SCZ, and the fact that biological motion processing involves the integration of both local and global cues (Mathers,

Radford, and West, 1992), it is not surprising that SCZ-related deficits in biological motion processing have been observed in previous studies (Kim et al., 2005; Kim et al., 2011). Deficits in global motion processing also are consistent with an fMRI study by Chen et al. (2008) which found that SCZ patients had reduced activation in middle temporal area (MT), a cortical area that has been implicated in global motion processing (Maunsel & Newsome, 1987), during tasks of coherent motion and speed discrimination, but not during a task of contrast discrimination. Interestingly, Chen et al., (2008) also found greater activation in prefrontal cortex during motion tasks in SCZ patients than control participants, suggesting that higher-order cognitive processes may be used by SCZ patients as a compensatory mechanism for motion processing deficits.

However, not all studies have found differential activation of MT in SCZ patients. Recently, Kim et al (2011) reported that the overall pattern of brain activity associated with the processing of biological motion, but not activation in area MT, differs between healthy controls and patients with SCZ. Kim et al (2011) interpreted their results as showing that deficits observed in biological motion among patients with SCZ were not solely attributable to motion processing more generally. One explanation for the lack of differential MT activity observed by Kim et al (2011) is that behavioural differences in biological motion may instead involve mechanisms underlying the integration of spatial and temporal motion cues. People with SCZ exhibit deficits in spatial (Doniger et al., 2001; Doniger et al., 2002) and temporal (Schwartz, Winstead, & Addinoff, 1983; Izawa & Yamamoto 2002) integration. For example, compared to healthy controls, patients with SCZ are less able to spatially integrate fragmented images into coherent objects (Doniger

et al., 2001). Furthermore, using event-related potential recordings, the inability to integrate these fragments has been correlated positively with dorsal stream processing in people with SCZ (Doniger et al., 2002), which is consistent with a wealth of literature suggesting impaired dorsal stream function in this population (Gur et al., 2000; Selemon, Rajkowska, & Goldman-Rakic, 1995; King, Christensen, & Westwood, 2008).

Many studies have also implicated cortical area STSp, a component of the dorsal stream network, in the perception of biological motion (e.g., Bondra, Petridies, Ostray, & Evans, 1996; Grossman & Blake, 2002; Puce & Perrett, 2003; Grossman & Blake, 2011). However, there is some evidence that the activity of the STSp differs in SCZ patients. For example, Kim et al (2011) used fMRI to show that activation in STSp was higher when viewing biological motion than non-biological motion in healthy controls but not SCZ patients. Given that the STSp is a component of the dorsal stream network and also involved in the integration of other sensory information (Barraclough, Xiao, Baker, Oram & Parrett, 2005) the lack of STSp activity in response to biological motion among patients with SCZ may reflect a general integration deficit regarding visual elements. Furthermore, Giese and Poggio (2002) have argued that STS plays an important role in integrating information from the ventral and dorsal pathways into a single, coherent percept of biological motion. Given proposed integration deficits in people with SCZ, the differential activation of STSp reported by Kim et al (2011) may reflect a more general impairment in the integration of visual elements.

In summary, the current experiments suggest that differences between SCZ and healthy controls in the ability to discriminate the direction of point-light walkers can be

accounted for by SCZ-related deficits in the ability to perceive the direction of non-biological motion, which may be caused by deficits in spatial and/or temporal integration. However, in addition to having a perceived direction of motion, point-light walkers also can convey complex social information such as affect, intention, and identity. It is entirely possible that SCZ patients have deficits in perceiving this social information that cannot be accounted for by differences in spatial and temporal integration of non-biological motion. Given well-documented impaired social cognition among persons with SCZ (Bigelow et al., 2006; Monkul et al., 2007; Baas, van't Wout, Aleman & Kahn, 2008; Hooker & Park, 2002), it is important to examine the perception of biological motion in its relation to social cognition.

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# CHAPTER 3

## GLOBAL VERSUS LOCAL MOTION CUES AS MECHANISMS OF IMPAIRED EMOTION RECOGNITION OF AFFECTIVE POINT-LIGHT WALKERS IN PERSONS WITH SCHIZOPHRENIA

[1] Justine M. Y. Spencer[1], Allison B. Sekuler[1], Patrick J. Bennett[1], Martin A. Giese[2], Karin S. Pilz[3], Bruce K. Christensen[1,4,5]

[1]Department of Psychology, Neuroscience & Behaviour, McMaster University

[2]Computational Sensomotorics, Department of Cognitive Neurology, Hertie-Institute for Clinical Brain Research and Center for Integrative Neuroscience, University Clinic Tübingen, Germany

[3]School of Psychology, University of Aberdeen, Scotland, UK

[4]Department of Psychiatry and Behavioural Neurosciences, McMaster University

[5] Research School of Psychology, Australian National University, Canberra, ACT, Australia

## ABSTRACT

Accumulating evidence has suggested that individuals with Schizophrenia (SCZ) are impaired in the perception of biological motion. Moreover, studies have also indicated that these same individuals find it difficult to extract social information from visual stimuli, including human movement. These abilities are important as humans utilize both motion and emotion cues to understand aspects of their social environment. Furthermore, individuals with SCZ are well known to have deficits in social perception. Therefore, the current study investigated the ability of individuals with SCZ to discriminate emotions from four types of emotional point-light walkers: Upright, inverted, scrambled (containing only local motion information) and random position (containing only global form information). The point-light walkers were presented in three emotion conditions: angry, happy, and sad. Results showed that overall, individual with SCZ were less accurate in discriminating emotions from point-light walkers compared to healthy controls, where performance was stronger for upright walkers, worst with scrambled walkers, and intermediate with random position and inverted walkers. Furthermore, social perception performance was related to the ability to discriminate emotions from point-light walkers in healthy controls; however, this correlation was not found among individuals with SCZ. Lastly, results also suggest that local motion cues stemming from emotional stimuli not only contain sufficient information to make accurate judgments of emotion, but may also provide more salient cues for visual motion processing more generally.

## 3.1 INTRODUCTION

A large body of literature demonstrates that individuals with Schizophrenia (SCZ) exhibit deficits across several aspects of visual motion processing, including speed discrimination and the perception of coherent global motion (for a review, see Chen, 2011). More recently, studies have also demonstrated deficits in the discrimination and detection of biological motion from point-light walkers (Kim, Doop, Blake & Park, 2005; Kim, Park & Blake, 2011; Brittain, Ffytche, McKendrick, & Surguladze, 2010; Hastings, Brittain, & Ffytche, 2013; Spencer, Sekuler, Bennett & Christensen, 2013; Kim et al., 2013). In addition to conveying information about perceptual properties (e.g., size, shape, motion), dynamic biological motion also conveys higher-order social information, such as cues regarding a person's affect (Atkinson, 2004), sex (Barclay, Cutting, & Kozlowski, 1978; Pollick, Kay, Heim, & Stringer, 2005), intention to deceive (Runeson & Frykholm, 1983), and identity (Cutting & Kozlowski, 1977; Loula, Prasad, Harber, & Shiffrar, 2005). Given well-documented social cognition and social perception deficits in persons with SCZ (Bigelow et al., 2006; Monkul et al., 2007; Baas, van't Wout, Aleman & Kahn, 2008; Hooker & Park, 2002; Corrigan & Toomey, 1995; Penn et al., 1996), it has been hypothesized that impaired biological motion perception may underpin, at least in part, SCZ-related deficits in social perception.

Research also suggests that biological motion perception and social cognition/perception are mediated by overlapping neural systems (Iacoboni et al., 2004). Much of the evidence supporting this relationship stems from functional magnetic resonance imaging (fMRI) studies of the posterior superior temporal sulcus (STSp), a

brain structure typically activated during the performance of both social perception (e.g., theory of mind) and biological motion perception tasks (e.g., Bondra, Petridies, Ostray, & Evans, 1996; Grossman & Blake, 2002; Puce & Perrett, 2003; Grossman & Blake, 2001). For example, STS activation is significantly greater when participants make social judgments about others (e.g., evaluating their trustworthiness) compared to when they make non-social judgments (e.g., estimating their age; Winston et al., 2002). Moreover, STS activity is more sensitive to expressive hand gestures compared to instrumental hand gestures (Gallagher & Frith, 2004). Similarly, Kim, Park and Blake (2011) observed stronger STSp activation to biological motion stimuli compared to non-biological motion among healthy volunteers. In contrast, this study also found that STSp activation was not selective to biological motion discrimination in persons with SCZ, which suggests that STSp may be part of the neural substrate for deficits in biological motion perception, and perhaps social cognition, in this clinical population.

The perception of emotions conveyed by visual stimuli, which is a core component for interpreting social cues, has been well studied in SCZ. Overall, people with SCZ perform worse than healthy observers when asked to report or discriminate emotion from a variety of stimuli including static facial expressions (Cutting, 1981, Izard, 1959, Pollard et al., 1995) and dynamic (Archer et al., 1994; Hellewell et al., 1994) facial expressions. More recently, Peterman, Christensen, Giese, and Park (2013) also demonstrated impaired discrimination of emotions conveyed by gait using dynamic volumetric avatars. In this study, emotional gait was presented at various intensities. Although both groups responded predictably to the intensity manipulation, SCZ patients

were less sensitive overall at discriminating emotional differences in gait. Interestingly, emotion discrimination was not correlated with social functioning, as measured using the Social Functioning Scale (SFS; Birchwood et al., 1990), among either healthy controls or persons with SCZ, although response bias was found to correlate with specific SFS subscales (i.e., social engagement and interpersonal communication) among patients with SCZ. This result is unexpected given the documented relationship between social and biological motion perception in previous literature. One possible explanation for these results is that the SFS evaluates social functioning (e.g., social activity, social withdrawal, employment status) and not social perception (e.g., inferring mental states and expressive gestures) *per se*. In contrast, behavioural studies implicating the STSp in social perception/cognition have utilized tasks that measure social perception, not social functioning. Moreover, although a significant relationship between social perception and social functioning has been documented (Addington, Saeedi, Addington, 2006), social functioning is undoubtedly influenced by other external factors (e.g., socioeconomic status, education), and, as a result, may not represent social perception, more narrowly defined. Consequently, it is important to employ measures of social perception when examining the relationship between biological motion processing and social perception/cognition.

In addition, it is important to note that point-light walker stimuli comprise both local and global motion cues: the trajectory of each dot constituting a point-light walker conveys information about the motion of a particular part of the human figure (e.g., the feet, the elbows, etc.) and grouping these local elements creates a holistic perception of

the walker's global form (e.g., a whole body). Previous research suggests that both local (Mather, Radford & West, 1992; Troje & Westhoff, 2006) and global information (Bertenthal & Pinto, 1994; Beintema & Lappe, 2002; Pilz, Bennett, & Sekuler, 2010) contribute relevant and unique information to observers when making biological motion judgments. Chen and colleagues (2003) reported that the processing of global, but not local, motion is impaired in SCZ using non-biological motion direction discrimination tasks, but Spencer et al. (2013) found that the manipulation of both global form and local motion information have similar effects in the direction discrimination of point-light walkers among healthy controls and people with SCZ. Specifically, Spencer et al. measured direction discrimination accuracy with scrambled point-light walkers (i.e., walkers with preserved local motion information but disrupted global form; Troje and Westhoff, 2006) and random position walkers (i.e., walkers with preserved global form but disrupted local motion information; Beintema and Lappe, 2002) and found that, in both groups, accuracy declined substantially when global form cues, but not local cues, were removed. These results suggest that the relative influence of global form and local motion cues on direction discrimination was similar in both groups. However, it remains unclear whether global and local cues differentially impact the perception of emotional biological motion in persons with SCZ. A recent study (Spencer, Sekuler, Bennett, & Pilz, 2010) examining the influence of emotion cues on local and global processing in younger and older healthy adults demonstrated that the addition of affective information results in more salient local motion cues. That is, participants were able to more

efficiently discriminate both emotion and direction information when local cues contained affective content.

The goal of the current study was to investigate SCZ-related ability to discriminate emotional cues from biological motion. In addition, the impact of local versus global motion information on these judgments was considered and the relation between emotional biological motion discrimination and social perception was examined. To achieve these primary goals, an initial experiment was conducted where response accuracy was measured in an emotion discrimination task using point-light walkers across four walker-type conditions: upright, inverted, scrambled, or random position walkers. In addition, the correlation between emotional discrimination performance and performance on a social perception task was computed across groups. Given that emotional point-light walkers have inherently differing speeds as a function of specific emotions portrayed, Experiment 2 examined how differences in stimulus speed contributed to performance in Experiment 1 by measuring response accuracy in an emotion discrimination task using speed-matched point-light walkers. Lastly, previous studies have demonstrated that both healthy controls and individuals with SCZ are less able to extract information from local motion cues in the discrimination of non-emotion containing point-light walker stimuli (Spencer et al., 2013). As such, to determine whether affective information augmented the ability of participants to discriminate biological motion more generally, Experiment 3 measured response accuracy on direction discrimination tasks utilizing the same affective point-light walkers used in Experiments 1 and 2.

## 3.2 GENERAL METHODOLOGY

### 3.2.1 Participants

Participants in all experiments were either healthy volunteers or patients diagnosed with a SCZ-spectrum disorder. The number of participants varied across experiments. All participants had normal or corrected-to-normal visual acuity (as ascertained using a standard Snellen chart) and reported an absence of lifetime neurological illness, brain injury, learning disability, current or past substance dependence, or medical conditions that could affect cognitive performance (e.g. coronary heart disease, type 1 diabetes). All patients met criteria for SCZ or Schizoaffective Disorder, as confirmed by the Mini International Neuropsychiatric Interview (M.I.N.I.) (Sheehan et al., 1998), but did not meet criteria for any other Axis 1 disorder. Patients with SCZ were outpatients, without medication changes in the previous six months, and were prescribed either typical (5 patients) or atypical antipsychotics (28 patients), in addition to other medications to address individual health issues. Healthy control (HC) participants did not meet criteria for any Axis I disorder and were also excluded if they reported having a first-degree relative with a SCZ-spectrum illness.

Estimates of Full Scale Intelligence Quotient (FSIQ) were obtained by prorating performance on the Matrix Reasoning and Information subtests from the Wechsler Adult Intelligence Scale, 3rd Edition (Wechsler, 1997). General cognitive functioning was assessed via the Repeatable Battery for the Assessment of Neuropsychological Status (Randolph, 1998). Patients with SCZ were also administered the Positive and Negative Syndrome Scale (PANSS; Kay, Fiszbein, & Opler, 1987) to assess current symptom

status. In addition, both patients and HCs were administered select scales from the Personality Assessment Inventory (PAI), including the Depression (Dep), Alcohol Problems (Alc), Drug Problems (Drg), Positive Impression Management (PIM), and Negative Impression Management (NIM) scales (Morey, 1991). All groups were age-matched, but HCs had achieved significantly higher years of education. Regarding neuropsychological measures, significant differences were found across WAIS-III FSIQ and all RBANS indices. Although participants with SCZ also had significantly elevated scores on the PAI-Drg and PAI-Dep subscales compared to HCs, no single participant scored in a range (i.e., T>70) suggesting significant clinical problems in these domains. Moreover, no participant evidenced deliberate distortion of their responses across both validity scales (i.e., PIM and NIM). Table 3.1 provides information characterizing the study participants. Ethics approval for the study was obtained by the St. Joseph's Healthcare Hamilton Research Ethics Board. All participants provided written, voluntary consent to participate and received $10/hour for their participation.

**Table 3.1** Experiment 1 means (SD) for demographic, neuropsychological, and clinical characteristics of the sample.

| Variable | Healthy Controls n = 33 | SCZ n = 33 |
|---|---|---|
| Demographic | | |
| Age (years) | 38.76 (11.01) | 42.78 (8.11) |
| Education (years) | 15.24 (2.17) | 13.00 (2.02)* |
| Neuropsychological | | |
| Estimated FSIQ | 111.42 (13.72) | 97.44 (16.43)* |
| RBANS | 102.15 (16.14) | 78.69(13.55)* |
| Clinical | | |
| PAI - Alc | 46.36 (3.13) | 49.50 (12.10) |
| PAI - Drg | 50.18 (9.19) | 56.47 (14.22)* |
| PAI - Dep | 46.24 (7.24) | 58.84 (13.27)* |
| PAI - PIM | 53.76 (9.91) | 52.72 (11.69) |
| PAI - NIM | 45.58 (8.60) | 51.19 (16.16) |
| PANSS - Pos | - | 40.62 (4.23) |
| PANSS - Neg | - | 42.34 (10.12) |

* Indicates a significant difference between HCs and people with SCZ.
FSIQ = Full Scale Intelligence Quotient; RBANS = Repeatable Battery for the Assessment of Neuropsychological Status; PAI = Personality Assessment Inventory; PANSS = Positive and Negative Syndrome Scale.

### 3.2.2 Apparatus and Stimuli

*Biological Motion Task:* All experimental tasks were programmed and presented using a Macbook Pro laptop computer with MATLAB and the Psychophysics and Video ToolBox extensions (Brainard, 1997, Pelli, 1997). Stimuli were presented on a 19-inch monitor with a resolution of 1024 x 864 pixels and a refresh rate of 60 Hz. The emotional point-light walkers were recorded with a Vicon 612 motion capture system (Vicon, Oxford, UK) consisting of eight cameras. Actors were recorded walking in a straight line

with emotionally expressive gaits (happiness, sadness, anger) and were instructed not to use gestures, which could interrupt a normal walking pattern. See Roether et al. (2009) for more information regarding the construction of the stimuli. The resulting emotionally expressive point-light walkers consisted of eleven dots depicting the major joints of the body and the head. Walkers did not travel across the screen, but instead appeared to walk in place in a rightward (Experiments 1 and 2), or in both rightward and leftward (Experiment 3) directions. For the purpose of the current experiments, we used four different actors who produced three walking patterns for each emotion. Walker figures subtended 1.9 x 4.2 deg. The stimuli were also presented in four block-randomized conditions: upright, inverted, scrambled, and random position. Inverted walkers were rotated by 180 deg so that they appeared to be walking on the ceiling. In the scrambled condition, the initial dot positions for the point-light walkers were presented at the correct x-position in the display, but with a randomly selected position along the y-axis of the display. The result was a point-light walker with intact local dot motion, but a distorted global form (e.g., Troje & Westhoff, 2006; Thornton et al., 1998; Pilz et al., 2010). For random position walkers, the dots constituting the point-light walker on each frame were presented at random positions on the (invisible) skeleton of the walker between two adjacent joints (e.g., Beintema and Lappe, 2002; Pilz et al., 2010). In this condition, the global form of the walker was maintained, but the local dot motion was not visible.

*Social Perception Task:* Participants also completed the Interpersonal Perception Task-15 (IPT15; Costanzo & Archer, 1993) as a measure of social perception and nonverbal communication. The IPT-15 is a video consisting of fifteen short scenes that

involve actors engaged in spontaneous behaviour and unscripted conversations (between two to four individuals) depicting five common types of social interaction: intimacy, competition, deception, kinship, and status. Following each scene, participants were asked to conclude or "decode" information from the scene, in which there is one objectively correct answer. For example, participants viewed a scene in which two individuals discuss a game of basketball that has been played. Following the scene, participants decided which individual in the video won the basketball game. Participants may use multiple strategies to determine the correct solution, including utilizing facial expression, gesture, and tone of voice (Costanzo & Archer, 1993).

### 3.2.3 Procedure

Prior to completing the experiments, participants completed one session of baseline testing, including a structured diagnostic interview, symptom measures, and intellectual and cognitive measures, as described above. Within a week of ascertaining these measures, participants returned to complete the three experiments in addition to the IPT-15, which was completed prior to the experiments. With respect to the IPT-15, participants viewed the video on the MacBook Pro laptop computer and following each scene, indicated their answers on a response form.

For all experiments, participants were seated in a darkened room and viewed the stimuli at a distance of 60 cm with their heads stabilized by a chin rest. In Experiments 1 and 2, the point-light walker's direction of motion was towards the right of the screen and participants were asked to identify the emotion displayed by the walker by pressing a key on a standard QWERTY computer keyboard (i.e., space bar (happy), s key (sad) and l key

(angry)). Point-light walkers were also presented in four configurations: upright, inverted, scrambled, and random position. In Experiment 3, point-light walker stimuli were displayed in both leftward and rightward directions and presented in three emotion conditions (happy, angry, and sad). Similar to Experiments 1 and 2, point-light walkers were presented in four configurations: upright, inverted, scrambled, and random position. Participants were asked to discriminate the direction of motion by pressing keys on a computer keyboard to indicate perceived direction. Prior to the experiments, participants performed four blocks of practice trials classified by walker type, each with five stimulus presentations, so that they were able to familiarize themselves with the stimuli.

## 3.3 EXPERIMENT 1

### 3.3.1 Methods

Thirty-three people with SCZ (5 female, 28 males) and 33 HCs (18 females, 15 males) participated in Experiment 1. All patients met criteria for SCZ (21 patients) or Schizoaffective Disorder (12 patients). Participants performed four blocks of trials: one for each walker type. The order of blocks was randomized across subjects, and the presentation of the three emotions was randomized within each block. The task was to identify the emotion presented on each trial. Each participant performed 60 trials for each emotion condition and walker type, resulting in 180 trials per block and a total of 720 trials. Walkers were presented at a frame rate of 25 frames per second, and were each shown for one full walk cycle (i.e., two steps). As a result, the stimuli duration ranged from 0.2 to 2.0 seconds, depending on the emotional walker that was used.

### 3.3.2 Results and Discussion

The dependent variable, proportion of correct responses, was not normally distributed, and statistical analyses therefore were performed on the arcsine-transformed data. First, transformed data were submitted to a 2 (group) x 4 (walker type) x 3 (emotion) Analysis of Variance (ANOVA). Results of this analysis revealed a main effect of group ($F(1, 64) = 9.80$, $p = 0.003$, $\eta_p^2 = 0.985$), where people with SCZ demonstrated reduced accuracy overall across all walker types and emotion conditions. A main effect of condition was also revealed ($F(3, 192) = 122.9$, $p < 0.001$, $\eta_p^2 = 0.822$) and Bonferroni corrected pairwise t-tests revealed that all comparisons of walker type were significantly different ($p < 0.0125$, $d > 0.236$): performance was best for upright walkers and increasingly worse for random position, inverted, and scrambled walkers, respectively (Figure 3.1). A main effect of emotion also was revealed ($F(2, 128) = 35.1$, $p < 0.001$, $\eta_p^2 = 0.466$). Pairwise t-tests revealed that accuracy for angry walkers was significantly worse than for either happy or sad walkers ($p < 0.017$, $d > 0.139$). Additionally, an emotion x walker type interaction was observed ($F(6, 384) = 4.86$, $p < 0.001$, $\eta_p^2 = 0.295$). Simple main effects testing of this interaction revealed a significant effect of walker type in each emotion condition: Angry ($F(3, 195) = 18.06$, $p < 0.001$, $\eta_p^2 = 0.411$); Happy ($F(3, 195) = 53.58$, $p < 0.001$, $\eta_p^2 = 0.633$); Sad ($F(3, 195) = 74.02$, $p < 0.001$, $\eta_p^2 = 0.713$). Within the happy and sad emotions, Bonferroni corrected pairwise comparisons revealed significant differences between all walker types ($p < 0.008$, $d > 0.503$), with the exception of the upright and random position conditions, which were not significantly different ($p > 0.008$, $d < 0.247$; Figure 3.2). Further analysis revealed that within the angry point-light walkers,

accuracy was not significantly different between the inverted and scrambled, inverted and random position, scrambled and random position, and the upright and random position point-light walkers ($p > 0.008$, $d < 0.005$). All other pairwise comparisons with the angry condition were significantly different ($p < 0.008$, $d > 0.667$; Figure 3.2).

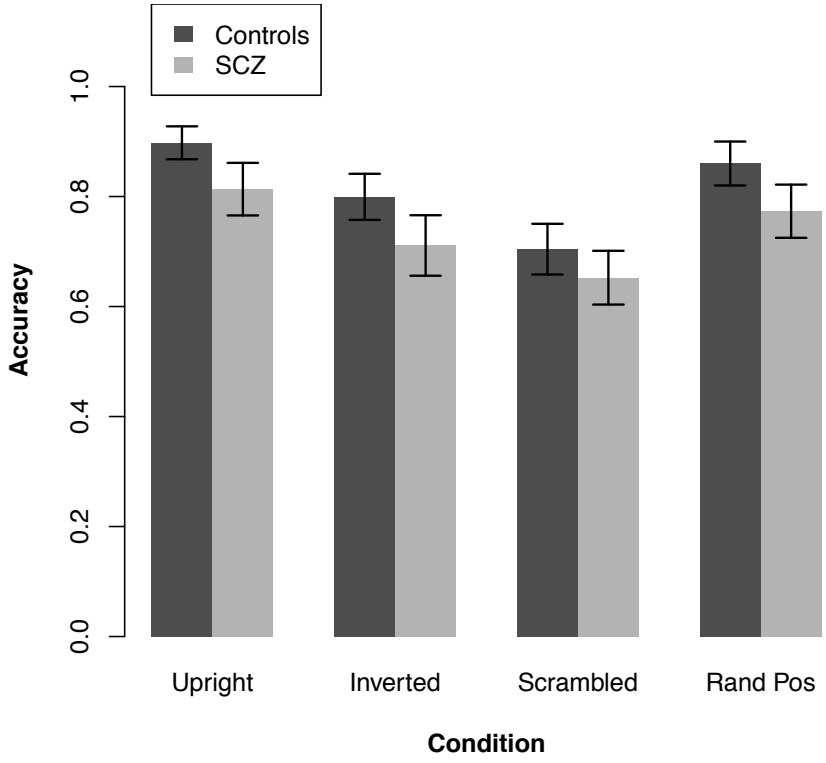


**Figure 3.1** Accuracy for SCZ and HCs in the four walker type conditions. Both groups of participants demonstrated more accurate performance in the upright walker type, followed by the random position, inverted, and scrambled walker types. No group x walker type interaction was observed.

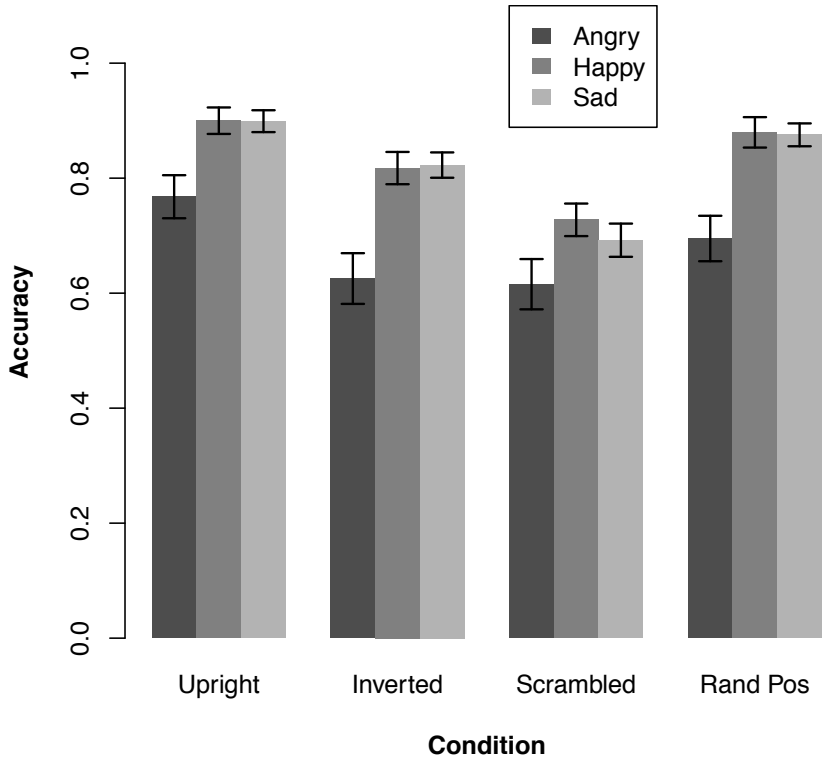


**Figure 3.2** Accuracy for SCZ and HCs in the four walker types and three emotion presentations. The walker type and emotion interaction was predominately driven by the angry condition, where significant differences were found between the upright and inverted walker types and between the upright and scrambled walker types.

To examine the relationship between social perception and emotion perception from biological motion, a correlation analysis between IPT-15 performance and overall discrimination accuracy, collapsed across all walker types and emotion conditions, was completed. When both groups were combined, discrimination accuracy and IPT-15 performance were positively correlated ($r(64) = 0.42$, $p < 0.001$; see Figure 3.3). When

the two groups were analyzed separately, the correlation was significant among HCs, ($r(31) = 0.46$, $p = 0.001$) but not the SCZ group ($r(31) = 0.19$, $p = 0.298$).

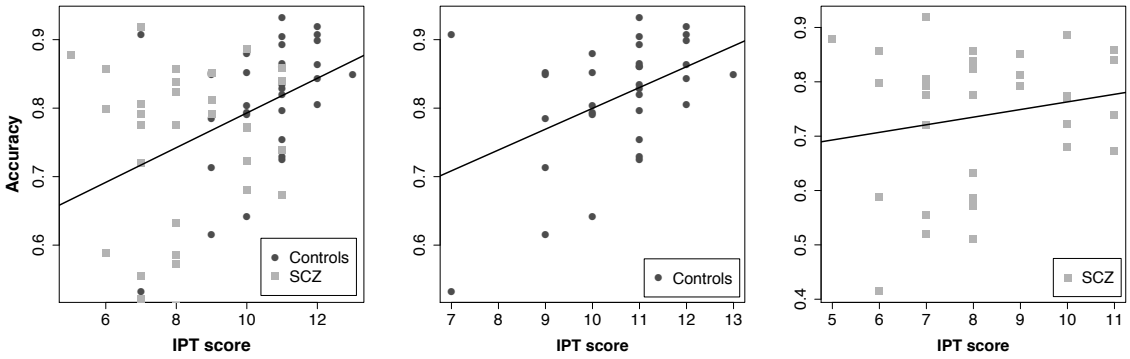


**Figure 3.3** Correlation between IPT score and accuracy collapsed across all conditions. Social perception and accuracy were found to be significantly correlated across all participants. In considering each participant group separately, the significant correlation was maintained in HCs; however, the correlation was not significant in patients with SCZ.

We also computed correlations between IPT-15 scores and discrimination accuracy for each walker type. When both groups were combined, IPT-15 scores were significantly and positively correlated with discrimination performance with upright, inverted, and random position walkers ($r > 0.403$, $p < 0.001$, in each case) but not in the scrambled walker condition ($r = 0.217$, $p = 0.080$). However, when analyzing HC and SCZ groups separately, significant correlations with upright, inverted, and random position walkers were observed among HCs ($r > 0.356$, $p < 0.042$, in each case), but not in patients with SCZ ($r > 0.116$, $p > 0.093$, in each case). The scrambled walker condition revealed that IPT-15 scores and discrimination accuracy were not significantly correlated in either HCs ($r(31) = 0.319$, $p = 0.070$) or patients with SCZ ($r(31) = -0.027$, $p = 0.882$; Figure 3.4). These results suggest that social perception and emotion discrimination were

correlated only among HCs, indicating that among patients with SCZ, social perception, as measured through the IPT-15 task, was not associated with the ability to detect emotions from point-light walkers. Furthermore, this correlation only occured with upright, inverted, and random position walkers, but not with scrambled walkers, suggesting that scrambled walkers are not perceived as containing biologically relevant characteristics.

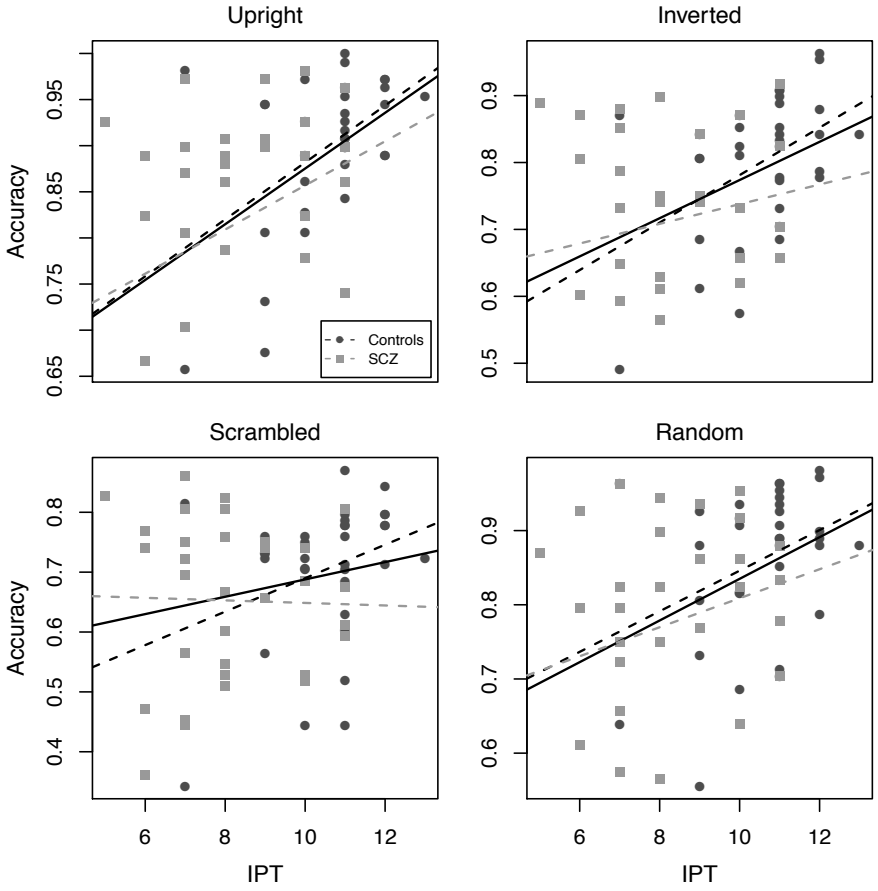


**Figure 3.4** Correlation between IPT score and accuracy within each walker type. Social perception and accuracy were found to be significantly correlated among HCs in the upright, inverted, and random position walker types. These correlations were not found in patients with SCZ. No significant correlations were found in the scrambled walker type condition in both groups of participants.

Consistent with previous reports, patients with SCZ demonstrated overall deficits in the ability to discriminate emotions from affective point-light walkers. Furthermore, both HCs and patients with SCZ were able to more accurately discriminate the emotions of happy and sad compared to angry as manifest by point-light walkers. Additionally, both groups of participants performed more accurately in the upright and random position conditions compared to the inverted and scrambled walker types. The scrambled walker stimuli are constructed in a way that minimizes global cues, and stimulus inversion is thought to disrupt the processes that encode global cues (Pavlova & Sokolov, 2000), and therefore our results suggest that participants in both groups relied more on global cues compared to local cues to discriminate emotions. However, it is important to note that accuracy in the scrambled condition was significantly above chance (i.e. above 33%; $p < 0.001$), which suggests that participants could use local information to perform the task. This result is interesting, as previous work examining direction discrimination with non-affective point-light walkers found that accuracy in the scrambled condition did not differ from chance in both patients with SCZ and HCs (Spencer et al., 2013); however, the task in the Spencer et al. (2013) study (left-right direction discrimination) is fundamentally different than the one employed here, and therefore one must be cautious when comparing the two studies. Nevertheless, the different results raise the possibility that affective cues embedded within local motion trajectories of point-light walkers may in fact provide more directional motion information compared to non-affective point-light walkers. Local motion and global form effects were also observed to be important within the context of emotion. Specifically, within the angry condition, both the removal of local

and global cues was shown to result in impaired performance among both groups. In contrast, only the removal of global cues (i.e., scrambled walker type) resulted in decreased performance of happy and sad point-light walker discrimination, while removal of local cues (i.e., random position walkers) did not affect performance. These results suggest that discriminating the angry emotion was more difficult for both groups, as performance was negatively affected by the removal of both local and global cues.

Overall, HC social perception ability was associated with their affective biological motion discrimination, where increased social perception was positively correlated with better discrimination performance in the upright, inverted, and random position conditions. However, patients with SCZ did not demonstrate this same association, suggesting that social perception from the IPT-15 task was not associated with the ability to detect emotions from point-light walkers. Although the reasons for this lack of correlation among patients with SCZ is unclear, it might reflect reduced activation of the STSp among individuals with SCZ, as discussed further in the General Discussion below.

In sum, results from Experiment 1 demonstrated that patients with SCZ were less able to discriminate emotion from point-light walkers compared to HCs and that their deficit was more pronounce when discriminating the angry emotion. Moreover, both groups of participants performed more accurately in the upright and random position conditions compared to the inverted and scrambled walker types. However, an important methodological confound should be considered. Specifically, the speed of the point-light walkers varied across affective conditions. For example, the happy point-light walkers typically were displayed at increased speed compared to the sad walkers, due to the

natural speed of these affective stimuli. Similar speed differences also existed between angry and sad walkers. Given these confounding differences between emotion conditions, it is possible that participants were using the speed of stimulus presentation, rather than emotional cues *per se*, to discriminate the point-light walkers. To control for this confound, the velocity profiles of the point-light walkers used in Experiment 2 were equated.

## 3.4 EXPERIMENT 2

### 3.4.1 Methods

Twenty persons with SCZ (6 female, 14 male) and twenty HCs (13 female, 7 male) took part in this experiment. Importantly, this experiment was conducted with a different sample compared to Experiment 1 (Table 3.2). Statistical analyses between Experiment 1 and Experiment 2 samples revealed no significant differences with respect to both demographic ($p > 0.566$) and neuropsychological ($p > 0.326$) characteristics. In contrast, these samples were noted to differ with respect to clinical scales. Specifically, significant differences between Experiment 1 and Experiment 2 samples were observed in overall positive (i.e., PANSS - Pos; $t(51) = 3.47$, $p = 0.001$) and negative (i.e., PANSS – Neg; $t(51) = 2.89$, $p = 0.006$) symptomatology. That is, both positive and negative symptoms were significantly increased in the Experiment 1 compared to the Experiment 2 samples.

The stimuli were similar to those used in Experiment 1. To control for stimulus speed, the average distance travelled by the point-light walkers was equated for all emotions. This was achieved as follows: We computed the average stimulus duration for 2 step cycles per walker across all walkers (1.93 seconds for sad walkers, 0.99 seconds

for angry walkers, and 1.21 seconds for happy walkers) and the average stimulus duration was calculated as 1.158 seconds. To equate the velocity profile across all walkers, dot speeds were adjusted so that all walkers completed two step-cycles in 1.158 seconds. As a result, angry and happy point-light walkers appeared to move slower than their original versions whereas the sad walkers appeared to move faster. During the experiment, participants were asked to identify the emotion displayed by the point-light walkers. Each participant completed 180 trials per block, resulting in a total of 720 trials. Prior to the start of the experiment, participants completed practice trials for each walker type, during which walkers were also shown for 1.158 seconds.

**Table 3.2** Experiment 1 means (SD) for demographic, neuropsychological, and clinical characteristics of the sample.

| Variable | Healthy Controls<br>n = 20 | SCZ<br>n = 20 |
|---|---|---|
| Demographic | | |
| Age (years) | 38.4 (15.1) | 42.1 (7.99) |
| Education (years) | 15.8 (3.94) | 12.9 (2.53)* |
| Neuropsychological | | |
| Estimated FSIQ | 111.2 (16.20) | 95.5 (15.26)* |
| RBANS | 97.9 (14.7) | 95.8 (18.7) |
| Clinical | | |
| PAI - Alc | 47.5 (5.50) | 50.9 (8.66) |
| PAI - Drg | 47.4 (5.64) | 52.8 (12.6) |
| PAI - Dep | 46.9 (8.79) | 59.4 (9.04)* |
| PAI - PIM | 53.55 (7.07) | 54.2 (8.57) |
| PAI - NIM | 46.6 (3.73) | 53.0 (14.9) |
| PANSS - Pos | - | 34.9 (4.82) |
| PANSS - Neg | - | 36.7 (5.92) |

* Indicates a significant difference between HCs and people with SCZ.
FSIQ = Full Scale Intelligence Quotient; RBANS = Repeatable Battery for the Assessment of Neuropsychological Status; PAI = Personality Assessment Inventory; PANSS = Positive and Negative Syndrome Scale.

### 3.4.2 Results and Discussion

The data were not normally distributed and statistical analyses therefore were performed on the arcsine-transformed data. First, transformed data were submitted to a 2 (group) x 4 (walker type) x 3 (emotion) ANOVA. A main effect of group was observed ($F(1, 38) = 8.56$, $p = 0.006$, $\eta_p^2 = 0.484$) where patients performed worse overall compared to HCs. A main effect of condition also was found ($F(3, 114) = 86.72$, $p < 0.001$, $\eta_p^2 = 0.695$). Subsequent Bonferroni corrected t-tests revealed that all comparisons between walker types were significant ($t > 2.70$, $p < 0.007$, $d > 0.348$ in each case) with the exception of the comparison between the upright and random position walkers ($t(237) = 0.815$, $p = 0.416$, $d = 0.105$; see Figure 3.5). A main effect of emotion was also observed ($F(2, 76) = 46.45$, $p < 0.001$, $\eta_p^2 = 0.550$), where all pairwise comparisons were significantly different ($p < 0.016$, $d > 0.500$). The walker type x emotion interaction was also significant ($F(6, 228) = 13.62$, $p < 0.001$, $\eta_p^2 = 0.264$). Simple main effects testing of this interaction revealed a significant effect of emotion in each walker type: Upright ($F(2, 78) = 62.94$, $p < 0.001$, $\eta_p^2 = 0.617$); Inverted ($F(2, 78) = 41.74$, $p < 0.001$, $\eta_p^2 = 0.517$); Scrambled ($F(2, 78) = 11.16$, $p < 0.001$, $\eta_p^2 = 0.222$); Random Position ($F(2, 78) = 48.38$, $p < 0.001$, $\eta_p^2 = 0.554$). Within the inverted walker type, Bonferroni corrected pairwise comparisons revealed that the emotions of happy and sad were not significantly different ($t(76) = 0.472$, $p = 0.638$, $d = 0.106$; Figure 3.6). Additionally, within the scrambled

walker type condition, pairwise comparisons showed that performance in the angry and sad conditions were not significantly different ($t(59) = 1.52$, $p = 0.134$, $d = 0.339$). All other comparisons were significant ($p < 0.016$, $d > 0.106$)

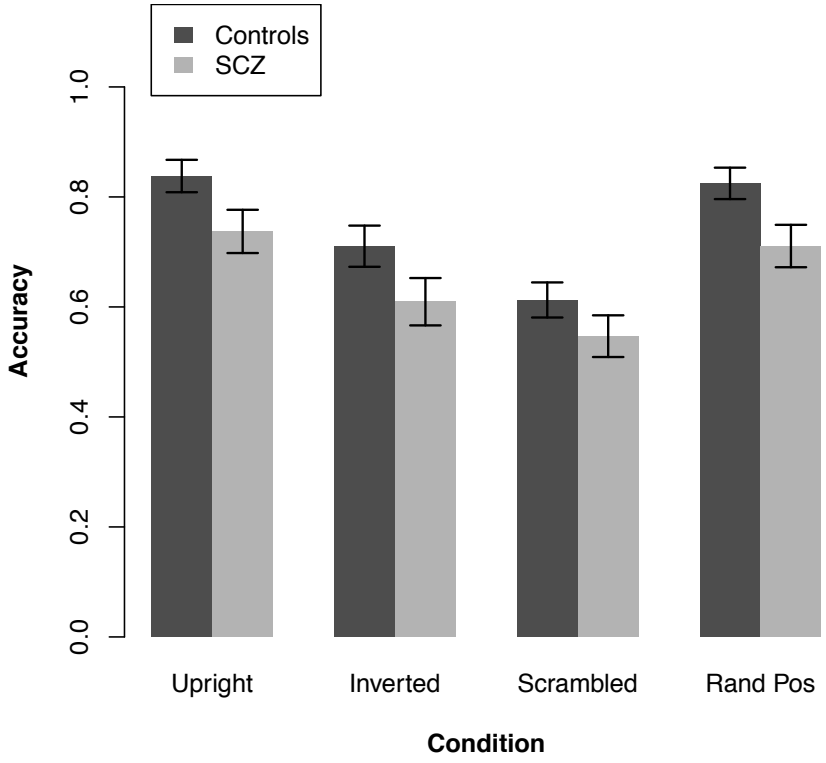


**Figure 3.5** Accuracy for SCZ and HCs in the four walker type conditions utilizing speed-matched point-light walkers. Both groups of participants demonstrated more accurate performance in the upright and random position walker types compared to the inverted and scrambled point-light walkers. No group x walker type interaction was observed.

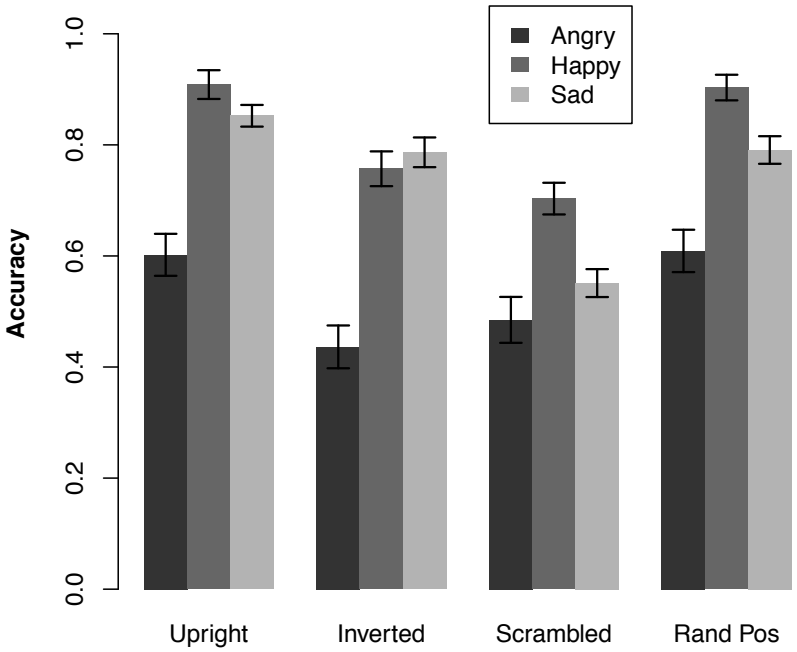


**Figure 3.6** Walker type and emotion accuracy for SCZ and HCs utilizing speed-matched point-light walkers. No difference in accuracy was observed between the emotions of happy and sad in the inverted walker type and between the angry and sad emotions within the scrambled point-light walkers.

Experiment 2 examined whether the removal of speed information from point-light walkers would alter the ability of participants to discriminate emotions from these stimuli. Accuracy in Experiment 2 was generally lower than in Experiment 1, which suggests that variations in stimulus speed, which were removed in Experiment 2, did aid performance in the first experiment. However, the effects of group and walker type were similar in the two experiments. For example, as was found in Experiment 1, patients with SCZ performed less accurately overall compared to HCs in the discrimination of emotions from point-light walkers. Furthermore, the effects of walker type suggest that participants in both groups relied more on global cues compared to local cues.

Again, similar to Experiment 1, results from Experiment 2 demonstrate that the ability of participants to discriminate emotions from scrambled point-light walkers was found to be above chance levels (i.e., 0.33; $p < 0.05$). This result differs from previous reports that direction discrimination accuracy is near chance with scrambled, non-affective walkers (Spencer et al., 2013), and suggests that local motion cues may be more informative about walker emotion than walker direction. To investigate whether affective local motion cues do in fact augment the processing of motion information, Experiment 3 was performed, in which participants discriminated the direction in which emotion containing point-light walkers were moving.

## 3.5 EXPERIMENT 3

### 3.5.1 Methods

Twenty people with SCZ (6 female, 14 male) and twenty HCs (13 female, 7 male) took part in Experiment 3 (Table 3.2). The stimuli were similar to those used in Experiment 1, with the exception that the point-lighter walkers were presented as travelling to the right or to the left. Participants performed four blocks of trials, one for each walker type, in which the order of blocks was randomized across all subjects. Within each block, the three emotions were also presented randomly. Twenty-four trials were completed per condition, resulting in 288 trials in total. Similar to Experiment 1, walkers were presented at a frame rate of 25 frames per second, and were shown for one full walk cycle (i.e., 2 steps). As a result, the stimuli duration ranged from 0.2 to 2.0 seconds depending on the

emotion condition. During the experiment, participants viewed the point-light walkers and judged the direction of motion of the stimuli (e.g., Right or Left).

### 3.5.2 Results and Discussion

The data were not normally distributed, and statistical analyses therefore were performed on the arcsine-transformed data. First, transformed data were submitted to a 2 (group) x 4 (walker type) x 3 (emotion) ANOVA. No significant main effects of group ($F(1, 38) = 1.34$, $p = 0.255$, $\eta_p^2 = 0.035$) and emotion ($F(2, 75) = 1.51$, $p = 0.227$, $\eta_p^2 = 0.0388$) were observed. A significant main effect of walker type ($F(3, 113) = 122.0$, $p < 0.001$, $\eta_p^2 = 0.824$) was revealed where performance in the scrambled condition was significantly decreased compared to the other three walker types ($p < 0.001$, $d > 1.636$). The group x walker type x emotion interaction was significant ($F(6, 227) = 2.99$, $p = 0.008$, $\eta_p^2 = 0.073$). To further investigate this three-way interaction, we conducted separate group x emotion ANOVAs within each walker type condition (Figure 3.7). In the upright, inverted, and random position conditions, the main effects of group and emotion were not significant ($p > 0.208$, $\eta_p^2 < 0.041$), nor was the group x emotion interaction ($p > 0.127$, $\eta_p^2 < 0.053$). In the scrambled walker condition, the main effects of group ($F(1, 38) = 0.515$, $p = 0.478$, $\eta_p^2 = 0.001$) and emotion ($F(2, 75) = 0.008$, $p = 0.992$, $\eta_p^2 = 0.006$) were not significant, but the group x emotion interaction was significant ($F(2, 76) = 4.24$, $p = 0.018$, $\eta_p^2 = 0.100$). Analyses of simple main effects revealed a significant simple main effect of group only in the angry condition ($F(1,38) = 4.82$, $p = 0.034$, $\eta_p^2 = 0.112$): response accuracy was *higher* in patients with SCZ compared to HCs. It is also important to note that, in both groups, accuracy in the scrambled condition was above chance levels

(i.e. 50%), as was found in Experiments 1 and 2. Experiment 3 examined the ability of participants to discriminate the direction of affective point-light walkers. The results show that both patients with SCZ and HC were able to discriminate the direction of motion at above chance levels in all conditions, although in both groups response accuracy was lowest in the scrambled condition. As such, results from Experiment 3 demonstrated that local motion cues help to augment the perception of motion information more generally.

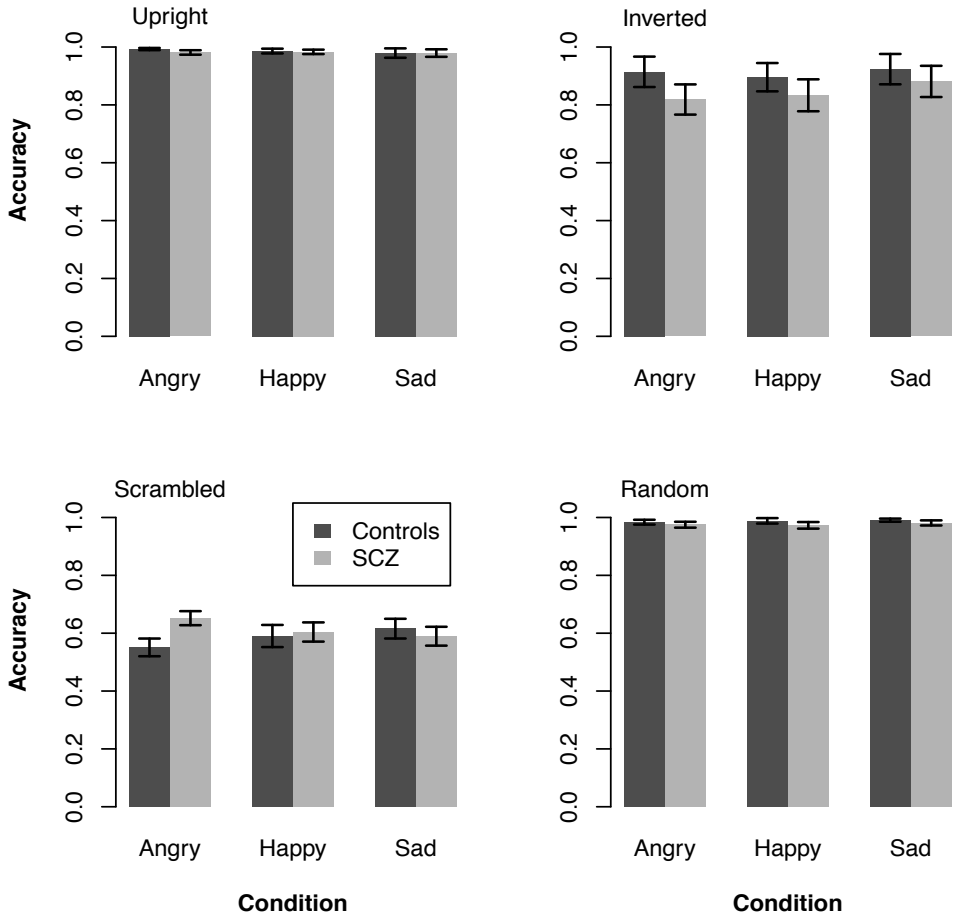


**Figure 3.7** Direction discrimination accuracy for SCZ and HCs across the four walker types. Within the scrambled walker type condition, patients with SCZ demonstrated more accurate performance within the angry emotion condition.

## 3.6 DISCUSSION

The present study examined the ability of persons with SCZ to discriminate emotions from dynamic point-light walkers. Moreover, in Experiments 1 and 3, the impact of both local motion and global form information, in addition to the relationship between emotional biological motion discrimination and social perception, was also investigated. Additionally, Experiment 2 examined the contribution of stimulus speed to emotion discrimination more generally.

Results of Experiment 1 demonstrated that patients with SCZ were less able to discriminate the emotions of happy, angry, and sad from point-light walkers, which is consistent with previous reports specifically demonstrating this deficit using affective motion stimuli (e.g., Peterman et al., 2013). Additionally, similar to a previous study (Spencer et al., 2013), both patients and HCs exhibited better performance when viewing random position walkers compared to the scrambled walkers, suggesting a greater impact of global form over local motion cues on the discrimination of emotion from point-light walkers more generally. Importantly, results from this experiment also demonstrated a significant correlation between emotion discrimination and social perceptual abilities among HCs; however, this correlation was not evident among patients with SCZ.

Experiment 2 replicated the main results of Experiment 1 with point light walkers that were equated for speed. That is, although accuracy was generally lower in Experiment 2 than Experiment 1, the effects of group and walker type were similar in the two experiments. From an emotion processing context, results from Experiment 2 also suggest that equalizing the speed of the stimuli also reduced participants' ability to

discriminate the emotion of sad among both HCs and people with SCZ. Finally, Experiment 3 found that direction discrimination accuracy for affective point-light walkers was similar in SCZ patients and HCs. Moreover, unlike the results of Spencer et al (2013), we found that accuracy in the scrambled walker condition was significantly above chance for both patients and HCs. This result suggests that the affective scrambled walkers contain more directional information than the non-affective scrambled walkers used by Spencer et al., and/or that observers can extract the available information more efficiently from affective walkers.

Consistent with Peterman et al. (2013), the current study demonstrated that patients with SCZ were less able to discriminate emotions from the gait of dynamic human figures compared to HCs. Moreover, in Experiment 1, both patients and HCs were less able to identify angry point-light walkers compared to both happy and sad stimuli. The reason for this is unclear, although a similar result was seen in a recent study examining emotion discrimination using point-light walkers among younger and older healthy participants (Spencer et al., 2010). Alternatively, these results may also reflect bias, as two studies have demonstrated increased response bias in the discrimination of happy emotions from point-light walkers in both individuals with SCZ and HC (Peterman et al., 2013; Spencer, Sekuler, Bennett, Giese & Christensen, 2013). Although results from Experiment 1 suggest that the shorter duration of the angry point-light walkers may have resulted in less accurate performance, results from Experiment 2 clearly demonstrate that the speed of the stimuli did not significantly alter the performance of both groups; that is, the main effects of both group (i.e., HC > SCZ) and emotion (i.e., Happy and Sad

> Angry) from Experiment 1 could not be accounted for by the confounding effect of walker speed. Nevertheless, discrimination accuracy was diminished for speed-matched sad walkers among both groups of participants. Within the upright, scrambled, and random position conditions, accuracy was significantly decreased in the sad emotion condition. Since performance in this condition was decreased in Experiment 2 compared to Experiment 1, this change in performance can likely be attributed to the increased discrimination difficulty in the sad walker condition in the speed-matched experiment. Since the sad stimuli were presented at slower speeds compared to the other stimuli, increasing the speed of these point-light walkers in Experiment 2 likely resulted in a more difficult task for participants, as they were unable to discriminate based only on speed information.

Overall, results from Experiments 1 and 2 show that both groups of participants were less accurate when discriminating emotion from scrambled point-light walkers compared to the other walker types. These results suggest that all participants utilized global form cues to a greater extent compared to local motion cues when making emotional discriminations. Interestingly, although performance in the scrambled walker type condition was found to be less accurate, performance was consistently above chance (i.e., < 33.3%). This result is surprising, given results from a previous study examining non-affective discrimination of biological motion in people with SCZ showing that both patients and HCs were unable to discriminate the direction of motion from scrambled point-light walkers above chance levels (Spencer et al, 2013). These results suggest that *local* motion cues containing affective information may be more informative with regards

to judging biological motion. This hypothesis was confirmed by the results from Experiment 3, showing that participants were able to discriminate direction from emotional point-light walkers above chance levels in the scrambled condition. Moreover, the lack of a group effect in Experiment 3 is likely related to this premise; that is, the emotion content contained in the stimuli likely helped individuals with SCZ better discriminate the direction of biological motion due to enhanced local motion cues.

The finding that local motion provides more informative cues for discrimination of affective stimuli is similar in some respects to some results obtained in studies of agency and animacy. Heider and Simmel (1944) showed that participants consistently imposed human qualities, such as emotion and intent, to moving geometric shapes including triangles and circles. The attribution of these properties to non-biological stimuli is a result of the qualities of motion, rather than the geometric characteristics of the stimuli (Szego and Rutherford 2007; Szego and Rutherford 2008, Gergely et al. 1995; Kuhlmeier et al. 2003, Zacks 2004). In the current experiment, it is plausible that, in a similar way, the local motion/motion trajectories of individual dots also conveyed information about emotional state even when global form information is disrupted, as is the case for scrambled walkers, even if global form information typically dominates.

In this context, results from Experiment 3 demonstrate that local motion cues from affective stimuli may also be informative in discriminating non-affective properties of visual motion, such as directional information. The above-chance performance observed in the discrimination of emotional scrambled point-light walkers may stem from the motion characteristics of specific elements of the point-light walker. Troje and Westhoff

(2006) have demonstrated that the discrimination of direction from point-light walkers may be directly related to the motion of the feet. In this study, the authors found that only inverting the feet of a point-light walker resulted in significantly decreased direction discrimination performance compared to viewing upright feet. As a result, in the current study, it is possible that participants were able to discriminate both emotion and direction information from the movement of the feet. To test this idea, we conducted a follow-up pilot experiment in which a single practiced observer (JMYS) discriminated the direction of emotional point-light walkers with the feet present (i.e., similar to Experiment 3) and without the feet dots present. Results of this experiment show that the practiced observer was able to accurately discriminate direction of the scrambled point-light walkers when feet were present in the angry (96%), happy (100%), and sad (100%) conditions. However, when the feet dots were removed, the participant's accuracy was decreased in each of angry (54%), happy (42%), and sad (74%) conditions. Although this experiment requires replication using a larger and more varied sample of participants, it does provide some confirmation of the importance of specific aspects of the point-light walker stimuli with regards to direction and emotion discrimination.

Results of the current study also suggest that among healthy observers, there is a positive relationship between social perception and emotion discrimination from biological motion. However, this pattern of results was not observed in patients with SCZ; that is, no relationship was seen in their ability to discriminate emotion from point-light walkers and their social perceptual abilities. The reasons for this lack of relationship are not clear. It may, however, support results from a fMRI study completed by Kim et al

(2011), in which the STSp, an area known to be involved in biological motion processing and social perception more generally, was not selectively activated when patients with SCZ viewed biological motion stimuli compared to scrambled, or non-biological motion. Given the many studies suggesting the importance of the STS in social perception, such as in the interpretation of intention (Saxe et al., 2004), social judgments (Winston et al., 2002), and expressive gestures (Ghallager and Frith, 2004), in addition to well documented activation of this area during the perception of biological motion, it is possible that healthy participants who were able to better discriminate biological motion were also able to accurately perceive social perceptual tasks. That is, STS activation is crucial in perceiving tasks of social perception, in addition to biological motion. In contrast, patients with SCZ are well documented to have social perceptual deficits. Since Kim et al. (2011) have demonstrated that patients with SCZ do not show differential activation of the STSp in biological motion discrimination, it is logical to speculate that this lack of differentiation may also occur with respect to social perception. As a result, the lack of correlation between these two measures, as seen in the current study, may be indicative of a lack of activation of brain areas associated with these two tasks. That is, it is plausible that people with SCZ employ differing neural networks and pathways when perceiving biological motion and social information, while similar networks are likely utilized among HCs. While numerous imaging studies investigating the role of the STS in social judgment and perception have been completed, these studies have not been conducted, to the authors' best knowledge, in a SCZ population. This represents an

interesting avenue of study and represents a possible future avenue of research in this domain, particularly regarding the perception and discrimination of biological motion.

Regarding limitations, all patients with SCZ who took part in the current study were medicated, and, therefore, we are unable to comment as to whether the results observed in the study were confounded by medication status. Additionally, analysis of sample characteristics revealed that the patients in the study had a significantly lower education level, lower estimated intelligence levels and decreased neuropsychological performance more generally. The issue of how to approach confounding group differences, however, is complex and a topic of active debate within the SCZ research field. As noted previously (Meehl, 1970; Miller and Chapman 2001), several characteristics that reliably distinguish SCZ from healthy participants are indeed correlated with outcomes of interest. In this situation, it is conventional to attempt to equate between-group differences on confounding variables via linear covariate analyses. However, this method has been criticized on both statistical and conceptual grounds. Meehl (1970) has argued that if the confounding variable is a valid reflection of a pathological state (e.g., psychological symptoms), linear removal of the shared variance will necessarily attenuate the between-group variance of interest. Statistically, as Miller and Chapman (2001) and others discuss, the use of ANCOVA to correct for factors such as IQ is statistically dubious, as this analysis assumes that the covariate and independent variable, such as diagnostic group, are independent (Silverstein, 2008). As such, in psychopathological research, these variables are often not independent, and using ANCOVA to control for a covariate in psychopathology research removes meaningful

variance from the independent variable of interest.

In summary, the current experiments suggest that people with SCZ are less able to discriminate emotions from point-light walkers. Furthermore, the ability to accurately perceive social information is related to the ability to discriminate emotions from point-light walkers in healthy observers, but this relationship is not found in people with SCZ. Results of the experiments also suggest that local motion cues stemming from affective stimuli not only contain sufficient information to make accurate judgments of emotion, but may also provide more salient cues for visual motion processing more generally.

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# CHAPTER 4

## DISCRIMINATING EMOTIONAL SALIENCE FROM BIOLOGICAL MOTION IN SCHIZOPHRENIA

Justine M. Y. Spencer[1], Allison B. Sekuler[1], Patrick J. Bennett[1], Martin A. Giese[2], Bruce K. Christensen[1,3,4]

[1]Department of Psychology, Neuroscience & Behaviour, McMaster University

[2]Computational Sensomotorics, Department of Cognitive Neurology, Hertie-Institute for Clinical Brain Research and Center for Integrative Neuroscience, University Clinic Tübingen, Germany

[3]Department of Psychiatry and Behavioural Neurosciences, McMaster University

[4]Research School of Psychology, Australian National University, Canberra, ACT, Australia

## ABSTRACT

Individuals with Schizophrenia (SCZ) consistently demonstrate deficits in the perception of emotion from visual stimuli, including stimuli depicting human movement. However, whether this population can discriminate more subtle or ambiguous emotional cues has yet to be investigated. This ability is relevant because emotional stimuli from naturalistic environments are frequently subtle and/or ambiguous, causing observers to process such stimuli intuitively. Moreover, previous research has shown that individuals with SCZ perform better when making intuitive judgments, suggesting that their discrimination of subtle/ambiguous emotions may be superior to their discrimination of more obvious emotions, relative to healthy controls. The current study investigated the ability of people with SCZ to discriminate emotions exhibited by point-light walkers morphed along emotion continua (e.g., happy-angry, happy-sad, angry-sad). The morphed stimuli provided emotional cues that were both more subtle/ambiguous (e.g., stimuli with input from the two polar emotions) and more obvious (e.g., stimuli with input largely from one of the two polar emotions). Results showed that individuals with SCZ are similarly able to discriminate emotions from emotionally subtle/ambiguous point-light walkers compared to healthy controls; however, they exhibited reduced ability to discriminate emotions from more obvious emotion stimuli. These results lend support to the body of literature suggesting preserved automatic, reactive, or intuitive processing of emotions among individuals with SCZ.

## 4.1 INTRODUCTION

Several studies suggest that persons with schizophrenia (SCZ) process emotional stimuli differently than healthy observers. For example, they are impaired in their identification (e.g., Addington & Addington, 2008; Penn, Combs & Ritchie, 2000; Whittaker, Deakin & Tomenson, 2011) and discrimination (e.g., Martin, Baudouin, Tiberghien et al., 2005; Sachs, Steger-Wuchse, Kryspin-Exner et al., 2004; Weniger, Lange, Ruther et al., 2004) of static emotional facial expressions, dynamic emotional facial expressions (Archer, Hay, & Young, 1994; Hellewell, Connell & Deakin, 1994), and vocal prosody (Murphy and Cutting, 1990). These deficits are thought to be important because the inability to accurately discriminate emotions may result in decreased social perception skills and, in turn, greater social dysfunction (Phillips, Drevets, Rauch & Lane, 2003). Furthermore, emotional processing deficits are thought to negatively affect other functional capabilities, such as vocational and daily living skills (Kee, Green, Mintz, Brekke, 2003).

Among theoretical accounts of emotional processing, researchers have posited the existence of two separate streams of emotional responding (e.g., MacDonald, 2008). The automatic processing of emotional information is reactive and effortless and involves responses to emotional stimuli outside of conscious awareness (McDonald, 2008). For example, studies have demonstrated, using backward masking, that skin conductance responses conditioned to rapidly presented fear relevant stimuli, such as angry facial expressions and pictures of snakes, could be elicited from these masked stimuli (Esteves, Dimbery, & Öhman, 1994; Öhman & Soares, 1993). That is, automatic responses to fear-relevant stimuli were evoked in the absence of awareness. In contrast, effortful processing

of emotional information is conscious and controlled, and involves the analytical and explicit processing of emotion stimuli, which typically necessitates increased cognitive control (McDonald, 2008). In this model, effortful processing of emotions also allows individuals to evaluate and reframe emotional information in order to change an existing emotional response if relevant and advantageous. For example, studies have demonstrated that emotional appraisal of stimuli can be modulated by learning new emotional associations and by altering expectations and beliefs regarding such stimuli (Ocshner & Gross, 2005).

Importantly, research has also demonstrated that automatic processes typically are utilized when individuals are confronted with information that is subtle and/or ambiguous or presented outside of conscious awareness. For example, within the domain of facial mimicry, studies have demonstrated through the use of electromyography, that individuals automatically and spontaneously contract facial muscles when viewing positive and negative emotional stimuli presented at very short duration times (Sonnby-Borgström, Jönsson & Svensson, 2003). Moreover, research in facial mimicry feedback, such as the ability of humans to evaluate or experience emotion by simulating expressions through their own facial musculature, has also implicated the role of automatic processing with respect to ambiguous facial expressions. For example, temporarily paralyzing facial muscles used in the expression of emotion results in a decreased self-report of emotional responses to only weaker, or more ambiguous, emotion stimuli compared to more obvious emotion stimuli (Davis, Senghas, Brandt & Ochsner, 2010). Furthermore, temporarily paralyzing facial muscles can impair the perception of subtle emotions (Neal &

Chartrand, 2011). Neuroimaging studies have also shown increased amygdala response to fearful faces that were processed outside of conscious awareness. That is, using backwards masking, studies have also demonstrated that fearful faces, masked by a neutral face, resulted in stronger amygdala activation compared to masked happy faces. Additionally, participants in this study did not report explicitly seeing any emotional faces (Whalen et al., 1998). Interestingly, the ability to discriminate emotions has also been shown by an individual with right hemianopia, caused by left occipital lobe damage, when presented in this patient's blind hemifield (de Gelder, Vroomen, Pourtois & Weiskrantz, 1999). Furthermore, this patient demonstrated increased amygdala activation in response to fearful faces presented in his blind hemifield (Morris, de Gelder, Weisfrantz, & Dolan, 2001), suggesting that subcortical pathways may also be important in the detection of emotion perception outside conscious awareness (Pessoa, 2005). Evidence of automatic processing to ambiguous stimuli has also been observed in other domains of social perception. For instance, racially ambiguous faces (e.g., subtle variations in facial features) have been shown to evoke automatic evaluations with respect to racial categorizations (Ito, Willadsen-Jensen, Kaye & Park, 2011).

Despite the multiple reports of impaired emotion discrimination and identification, individuals with SCZ also manifest preserved emotional responding, particularly when it involves automatic or reactive processing of emotional stimuli. For example, although individuals with SCZ have difficulty with correctly categorizing emotional faces (e.g., Kohler, Walker, Martin, Healey & Moberg, 2010), they can make simple emotional facial judgments such as identifying emotional valance (e.g., negative/positive), or

discriminating a target emotion (e.g., fear) from other emotions (e.g., happiness, sadness, and anger; Gur et al., 2002, Gur et al., 2007). Additionally, although individuals with SCZ have been shown to be less emotionally expressive (Kring & Moran, 2008), they do demonstrate accurate facial displays consistent with emotional stimuli. For example, individuals with SCZ appropriately display more zygomatic muscle activity in response to positive pictures and film clips compared to negative stimuli (Kring, Kerr, & Earnst, 1999; Varcin, Bailey, & Henry, 2010; Wolf, Mass, Kiefer, Wiedemann, & Naber, 2006). People with SCZ have also been shown to experience similar levels of pleasure compared to healthy controls in response to emotional stimuli (Kring & Elis, 2013) and demonstrate similar levels of subjective reaction (e.g., intensity of perceived emotional valence and arousal) to emotionally evocative stimuli, using a self-report rating scales (Herbener, Song, Khine & Sweeney, 2008). Neurophysiological studies have revealed that early stage event-related potentials are similar to those observed in healthy controls in response to emotional stimuli. For example, both healthy controls and individuals with SCZ demonstrated similar event-related potentials, termed the early posterior negativity (200 to 300 ms) and late positive potential (400 to 1000 ms), for both pleasant and unpleasant, compared to neutral, pictures, indicating increased attention to these relevant stimuli (Horan, Wynn, Kring, Simons & Green, 2010). Similar results were also observed between both healthy and SCZ participants when emotional stimuli were task-irrelevant (e.g., counting non-emotional targets), again suggesting preserved motivated attention to emotional stimuli (Horan, Foti, Hajcak, Wynn & Green, 2012).

In addition to facial expression, humans are adept at extracting emotional information from others' physical movements, including their actions and gait. For example, point-light (PL) animations, consisting of human movement reduced to the motion of the actors' joints (i.e., biological motion), accurately convey highly complex social characteristics and cues such as openness (Brownlow, Dixon, Egbert & Radcliffe, 1997), social dominance (Montepare & Zebrowitz-McArther, 1988), vulnerability to attack (Gunn, Johnston & Hudson, 2002), and the intent to deceive (Runeson & Frykholm, 1983). Importantly, studies have also shown that point-light animations convey affective cues. For example, Atkinson and colleagues (2004) found that observers were accurately able to discriminate the emotions of anger, fear, sadness, disgust, and happiness from PL displays of human movement. Moreover, simple affective point-light animations, such as an arm knocking on a door, are sufficient for observers to accurately discriminate the emotion of the actor (Pollick, Paterson, Bruderlin & Sanford, 2001).

There is some evidence that individuals are able to perceive subtle cues from human movement. For example, Camurri, Lagerlöft & Volpe (2003) examined emotion perception through nonpropositional dance movement, which involved natural expressions of emotion based on parameters such as tempo and force, opposed to propositional movement, such as overt and distinct actions (e.g., raising a hand to indicate "stop"). Participants observing nonpropositional movement were accurate in discriminating intended emotions depicted through these motions, suggesting that individuals were able to identify these subtle displays of emotions (Camurri et al., 2003). Humans also can make complex judgments of emotion and intention based on subtle

movements that are seemingly processed outside of conscious awareness: Troscianko et al. (2003) demonstrated that in naturalistic environments, such as when observing real closed-circuit television (CCTV) recordings, naïve observers successfully predicted criminal or antisocial behaviour from subtle body movements (i.e. gestures, gait, and body position) alone. Moreover, among trials where unlawful behaviour was predicted, participants were asked to identify specific time-points during the videos in which they perceived that a criminal event would occur. Interestingly, these identified time points were generally consistent among all participants and typically coincided with a specified dynamic behaviour (e.g., a person on the recording walking with a distinct gait and pointing). Additionally, novice observers made these judgments as accurately as observers who had previous surveillance experience. These results suggest that healthy adults can infer emotion and social intention from subtle and ambiguous visual stimuli. Moreover, the comparable performance between expert and novice observers suggests that these cues are interpreted at an automatic level of processing and in the absence of salient and experiential cues. The ability to make these judgments is important as it allows observers to interpret social aspects of their environment accurately and quickly. Although much research has focused on the ability to discriminate emotions from static facial expressions among patients with SCZ, less attention has been given to their ability to extract emotions from dynamic stimuli, such as human movement. Moreover, given the high exposure to human movement in naturalistic environments, in addition to general visual motion processing (e.g., Chen, 2011) and social perception deficits (e.g., Pinkham,

2013) in this population, the ability of patients to judge emotions from biological motion may have particular relevance in everyday human social discourse.

Limited studies have investigated the ability of individuals with SCZ to accurately judge subtle and ambiguous expressions of emotion, despite their importance in naturalistic environments and social perception more generally. Furthermore, the few existing studies have yielded inconsistent results. For example, Kohler et al. (2003) demonstrated that the effect of SCZ on performance in an emotion discrimination task did not depend on the intensity of the affective face stimuli, suggesting a similar ability to process both emotionally ambiguous and unambiguous stimuli. Bigelow et al. (2006) also reported that patients with SCZ did not differ in their ability to discriminate emotions from ambiguous morphed faces compared to healthy controls; however, they were less able to discriminate emotions during other unambiguous tasks, such as movie stills containing emotional facial expression and body posture stimuli, suggesting an attenuated deficit in processing ambiguous expressions of emotion. In contrast, Huang et al. (2011) have shown, using morphed facial expressions with varying intensities between 0% and 100%, that people with SCZ demonstrated decreased sensitivity to morphed facial expressions compared to healthy observers. Similarly, Kee and colleagues (2006), also using morphed facial expressions, showed that patients with SCZ demonstrated shallow response curves compared to healthy observers, when categorizing ambiguous displays of emotion. Additionally, Peterman et al. (2013) used dynamic volumetric avatars to demonstrate that patients were less sensitive to differences in affective gaits (e.g., happy versus angry gaits) and improved their performance when discriminating high intensity

stimuli compared to lower intensity stimuli; that is, stimuli presented with 100% intensity (e.g., prototypical happy or angry gait) and 150% intensity (e.g., exaggerated happy or angry gait) were more easily identified compared to those presented at 50% intensity (e.g., attenuated happy or angry gait). As such, although the processing of obvious/unambiguous emotion information among individuals with SCZ has been well documented, the ability of patients to discriminate more subtle expressions of emotions is unclear. However, given previous results suggesting preserved automatic and reactive processing of emotional stimuli among patients with SCZ, it is plausible that these individuals may be able to accurately judge subtle and ambiguous, compared to more obvious expressions of emotion.

Although preliminary studies suggest that SCZ participants have difficulty discriminating high-intensity emotions conveyed by dynamic biological stimuli (Peterman, Christensen, Giese & Park; 2013; Spencer et al., in prep), research has yet to study the ability of patients to discriminate more ambiguous and subtle expression of emotions from dynamic (e.g., biological motion) stimuli. The use of human movement in the current study (e.g., point-light walkers) is especially relevant to the study emotion perception, given the highly developed ability of healthy observers to extract relevant social information from these stimuli. Therefore, the current study was designed to assess the ability of both patients with SCZ and healthy observers to accurately discriminate emotions from three affective dimensions presented across continuous axes: Happy-angry, happy-sad, angry-sad. That is, three emotional PLWs (i.e., representing three canonical emotions: happy, angry, and sad) were morphed across all pairings, giving rise

to the three emotional axes ranging from 100% of each emotion at the poles of a given axis and graded representations in between the poles reflecting varying proportions of each emotion. The signal, or proportion of emotion, for a given point-light walker was altered via a morphing algorithm. Given previous research suggesting relatively preserved automatic or intuitive emotional processing among persons with SCZ, it was hypothesized that when confronted with emotionally subtle/ambiguous stimuli (e.g., reduced emotional signal from stimuli situated at mid-ranges between the emotional poles), patients would not differ from healthy participants in their ability to discriminate emotions. In contrast, it was hypothesized that individuals with SCZ would demonstrate reduced performance when discriminating emotion from salient or obvious stimuli, reflecting impairments in effortful processing or analytic processing of emotion.

## 4.2 GENERAL METHODOLOGY

### 4.2.1 Participants

Thirty-three people with SCZ (5 female, 28 males) and 33 healthy controls (18 females, 15 males) participated in the experiment. All patients met criteria for SCZ (21 patients) or Schizoaffective Disorder (12 patients), as confirmed by the Mini International Neuropsychiatric Interview (M.I.N.I.; Sheehan et al., 1998), but did not meet criteria for any other Axis 1 disorder. All participants had normal or corrected-to-normal visual acuity, as ascertained by a standard Snellen chart, and reported an absence of lifetime neurological illness, brain injury, learning disability, current or past substance dependence, or medical conditions that could affect cognitive performance (e.g. coronary heart disease, type 1 diabetes). Patients with SCZ were outpatients, medication-stable for

at least the past six months, and were prescribed either typical (2 patients) or atypical antipsychotic medication (28 patients). Healthy control participants did not meet criteria for any Axis I disorder and were also excluded if they reported a history of brain injury and/or neurological conditions, a diagnosis of substance abuse with the past six months or a lifetime diagnosis of substance dependence, the use of psychotropic drugs during the previous 14 days, and/or having a first-degree relative with a SCZ-spectrum illness.

Estimates of Full Scale Intelligence Quotient (FSIQ) were obtained by prorating performance on the Matrix Reasoning and Information subtests from the Wechsler Adult Intelligence Scale, 3rd Edition (Wechsler, 1997). General cognitive functioning was assessed via the Repeatable Battery for the Assessment of Neuropsychological Status (Randolph, 1998). Patients were also administered the Positive and Negative Syndrome Scale (PANSS; Kay, Fiszbein, & Opler, 1987) to assess current symptom status. In addition, both patients and controls were administered select scales from the Personality Assessment Inventory (PAI), including the Depression (Dep), Alcohol Problems (Alc), Drug Problems (Drg), Positive Impression Management (PIM), and Negative Impression Management (NIM) scales (Morey, 1991). Both groups were age-matched, but healthy controls had achieved significantly higher years of education. Regarding neuropsychological measures, significant differences were found across WAIS-III FSIQ and all RBANS indices. Although participants with SCZ also had significantly elevated scores on the PAI-Drg and PAI-Dep subscales compared to healthy controls, no single participant scored in a range suggesting significant clinical problems in these domains (i.e., T>70). Moreover, no participant evidenced deliberate distortion of their responses

across both validity scales (i.e., PIM and NIM). Table 4.1 provides information characterizing the study participants. Ethics approval for the study was obtained by the St. Joseph's Healthcare Hamilton Research Ethics Board. All participants provided written, voluntary consent to participate and received $10/hour for their participation.

**Table 4.1** Means (SD) for demographic, neuropsychological, and clinical characteristics of the sample.

| Variable | Healthy Controls n = 33 | SCZ n = 33 |
|---|---|---|
| Demographic | | |
| Age (years) | 38.76 (11.01) | 42.78 (8.11) |
| Education (years) | 15.24 (2.17) | 13.00 (2.02)* |
| Neuropsychological | | |
| Estimated FSIQ | 111.42 (13.72) | 97.44 (16.43)* |
| RBANS | 102.15 (16.14) | 78.69(13.55)* |
| Clinical | | |
| PAI - Alc | 46.36 (3.13) | 49.50 (12.10) |
| PAI - Drg | 50.18 (9.19) | 56.47 (14.22)* |
| PAI - Dep | 46.24 (7.24) | 58.84 (13.27)* |
| PAI - PIM | 53.76 (9.91) | 52.72 (11.69) |
| PAI - NIM | 45.58 (8.60) | 51.19 (16.16) |
| PANSS - Pos | - | 40.62 (4.23) |
| PANSS - Neg | - | 42.34 (10.12) |

* Indicates a significant difference between HCs and people with SCZ.
FSIQ = Full Scale Intelligence Quotient; RBANS = Repeatable Battery for the Assessment of Neuropsychological Status; PAI = Personality Assessment Inventory; PANSS = Positive and Negative Syndrome Scale.

### 4.2.2 Apparatus and Stimuli

All experimental tasks were programmed and presented using a Macbook Pro laptop computer with MATLAB and the Psychophysics and Video ToolBox extensions (Brainard, 1997, Pelli, 1997). Stimuli were presented on a 19-inch monitor with a resolution of 1024 x 864 pixels and a refresh rate of 60 Hz. The emotional point-light walkers were recorded with a Vicon 612 motion capture system (Vicon, Oxford, UK) consisting of eight cameras. Actors were recorded walking in a straight line with emotionally expressive gaits (happiness, sadness, anger) and were instructed not to use gestures, which could interrupt a normal walking pattern. (See Roether et al. (2009) for more information regarding the construction of the stimuli.) The resulting emotionally expressive point-light walkers consisted of eleven dots depicting the major joints of the body and the head. Walkers did not travel across the screen, but instead appeared to walk in place in a rightward direction. For the purpose of the current experiment, 12 different actors/walkers were used. Each walker utilized was previously rated in a pilot experiment as being highly expressive and produced rates of emotion discrimination accuracy over 95%. Walker figures subtended 1.9 x 4.2 deg. The emotional point-light walkers were morphed along three affective dimensions -- angry-happy, happy-sad, sad-angry -- by creating weighted averages consisting of 0, 20, 40, 60, 80, or 100% of the trajectory and speed of the individual dots from angry, happy, and sad point-light walkers. As such, the signal, or proportion of emotion within a given point-light walker, was adjusted to create new stimuli depicting varying degrees of emotion expression. We expected that the emotions conveyed by stimuli consisting of morphs of 40% and 60% would be difficult to

discriminate, whereas emotions conveyed by morphs of 0% and 100% would be easy to discriminate (Peterman et al., 2013).

### 4.2.3 Procedure

Participants were seated in a darkened room and viewed the stimuli at a distance of 60 cm with their heads stabilized by a chin rest. The experiment was presented in three blocks (i.e., angry-happy, happy-sad, sad-angry) and the order of the blocks was counterbalanced across all participants. On each trial, participants were asked to identify the emotion displayed by the point-light walker (e.g., angry or happy) by pressing a key on a standard QWERTY computer keyboard. Each stimulus was displayed for 1.2 seconds, given previous research demonstrating that this duration allows sufficient time to identify the emotional characteristics of the stimuli (Spencer et al., 2013; Pilz et al., 2010). Prior to the experiments, participants performed 10 practice trials within each block to familiarize themselves with the stimuli. During each experimental block, participants performed 48 trials for each level of emotion intensity, resulting in 288 trials per block and a total of 864 trials over the entire experiment.

### 4.2.4 Data Analysis

For each affective dimension, the proportion of responses was determined and a logistic function was used to fit to the data, resulting in three psychometric functions for each participant. In the angry-happy condition, the psychometric function describes how the probability of responding "angry" varied as a function of the emotional signal in the morphed stimuli. Likewise, the happy-sad and sad-angry continuums represents the proportion of trials identified as happy and sad, respectively. The resulting fits provided

an estimation of the point of subjective equality (PSE), or the shift point, which indicates the level of signal (i.e., morph level) required to shift emotion classification from one emotional pole to the other. The resulting fits also provide an estimation of the slope of the psychometric, which indicates how much performance changes with changes in the emotional signal. Higher value slopes (i.e., steeper slopes) reflect greater sensitivity to variations in the emotional signal, whereas lower values (i.e., shallower slopes) indicate lower sensitivity. Importantly, our fitting procedure allowed the upper and lower asymptotes to vary, and therefore those parameters are a measure of a participant's ability to accurately identify emotional movement at the extreme ends of emotional intensity (i.e., when the emotional information embedded within stimuli were more salient).

## 4.3 RESULTS

Figure 4.1 shows the resulting mean psychometric functions for each emotion dimension and for both healthy observers and patients with SCZ. The functions displayed in the left, middle, and right panels indicate the probability that participants classified a given morph as being angry, happy, or sad, respectively.


**Figure 4.1** Mean psychometric functions across all affective morphs for healthy controls and people with SCZ. The x axes represent the proportion of angry (left panel), happy (middle panel), and sad (right panel) motion information contained in the morphed stimuli. The y axes represent the proportion of trials that participants responded angry (left panel), happy (middle panel), and sad (right panel).

A multivariate analysis of variance (MANOVA) was conducted with two independent variables (participant group; morph conditions) and the four psychometric function parameters (slope, PSE, upper asymptote, and lower asymptote) as repeated measures factors. This initial analysis revealed a significant main effect of group ($F(1, 189) = 4.31$, $p = 0.002$, $\eta_p^2 = 0.184$), indicating that patients with SCZ differed from healthy controls across the linear combination of psychometric function parameters. A significant main effect for morph condition ($F(2, 380) = 12.60$, $p < 0.001$, $\eta_p^2 = 0.210$) was also found, suggesting that the four parameters differed across the three affective morph conditions. The group x morph condition interaction was not significant ($F(2, 380) = 1.07$, $p = 0.380$, $\eta_p^2 = 0.022$), indicating that both individuals with SCZ and healthy controls did not exhibit differential performance across each emotion continuum.

Next, univariate analyses of variance (ANOVA) were used to examine the contribution of individual dependent variables to the group and morph condition differences. With regard to the estimated slope parameter, these analyses revealed no significant differences between healthy controls and patients with SCZ ($F(1, 192) = 0.826$, $p = 0.364$, $\eta_p^2 = 0.004$) and no significant effect of morph condition ($F(2, 192) = 2.04$, $p = 0.133$; $\eta_p^2 = 0.021$; Figure 4.2).

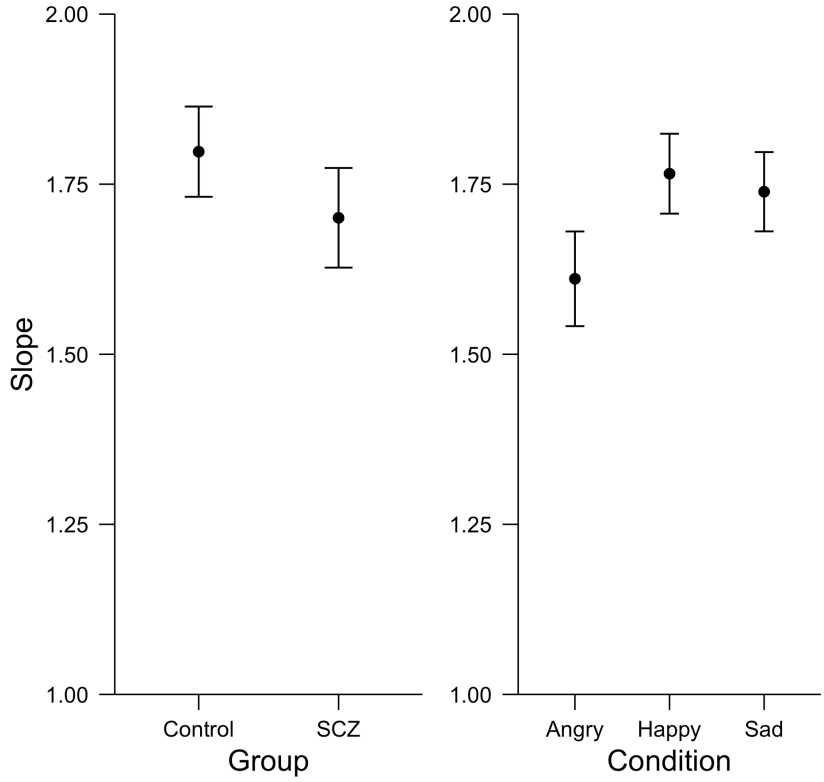


**Figure 4.2** Slopes of the resulting psychometric functions. No significant differences in slope were found between healthy controls and patients with SCZ. Similarly, no significant differences were observed between the three morph conditions.

Furthermore, no significant differences in estimated PSE were observed between the two groups ($F(1, 192) = 1.66$, $p = 0.199$, $\eta_p^2 = 0.009$) or between morph condition

($F(2, 192) = 1.66$, $p = 0.193$, $\eta_p^2 = 0.017$; Figure 4.3). These results suggest that healthy controls and patients with SCZ did not exhibit significant differences in emotion classification sensitivity when discriminating emotions from the morphed, affective PLW stimuli. Similarly, the results also indicate that the morph conditions did not differ with respect to the PSE (i.e., the level of signal required to shift emotion classification from one emotional pole to the other).

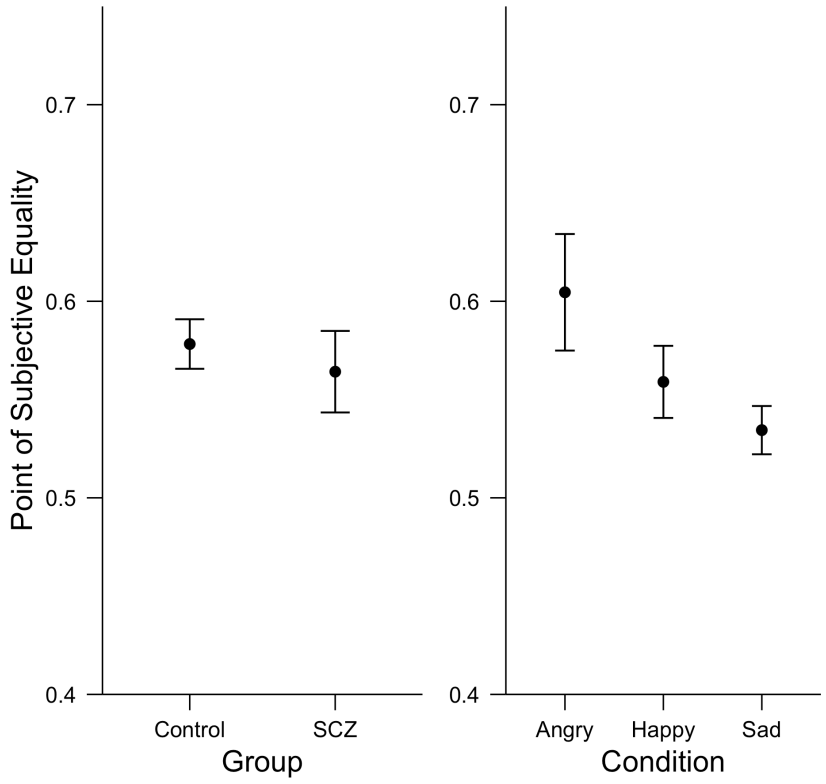


**Figure 4.3.** Point of subjective equality (PSE) from the resulting psychometric functions. No significant differences in PSE were found between healthy controls and people with SCZ, nor where significant difference observed between the morph conditions.

In contrast, univariate analyses did reveal significant effects of group and condition on the estimates of the upper and lower asymptotes. With regard to the upper

asymptote parameter, a significant effect of group ($F(1, 192) = 3.86$, $p = 0.050$, $\eta_p^2 = 0.020$) was observed, where healthy controls were found to have a higher upper asymptote (i.e., closer to the value of 1) compared to patients with SCZ, suggesting that patients with SCZ had more difficulty discriminating emotions at higher intensity levels. Additionally, a main effect of morph condition ($F(2, 192) = 14.44$, $p < 0.001$, $\eta_p^2 = 0.130$) was observed. Bonferroni adjusted t-tests revealed significant differences between the happy morph and the angry morph conditions ($t(65) = 4.87$, $p < 0.001$, $d = 0.700$), as well as between the happy morph and the sad morph conditions ($t(65) = 6.30$, $p < 0.001$, $d = 1.08$), where the upper asymptote for the happy morph was greater compared to the angry and sad morph conditions. These results suggest that participants were more accurate when identifying a happy gait at higher intensity levels compared to both sad and angry gaits. No significant difference was observed between the angry and sad morph conditions (Figure 4.4). Additionally, the group x morph condition interaction was not significant ($F(2, 96) = 0.716$, $p = 0.491$, $\eta_p^2 = 0.007$).

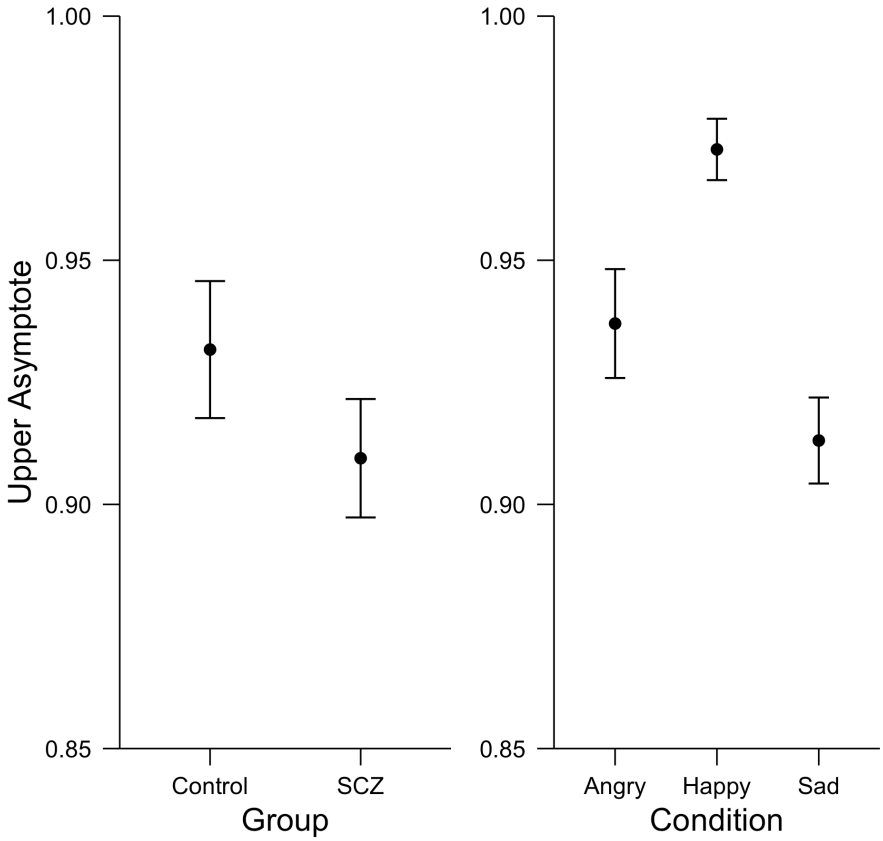


**Figure 4.4** Estimated upper asymptotes of the psychometric functions. Healthy controls were found to have a significantly greater (i.e., closer to 1) upper asymptote compared to patients with SCZ, indicated that the patient group demonstrated reduced ability to discriminate high intensity emotions. Both groups of participants had more difficulty discriminating high intensity angry and sad emotions compared to the happy morph condition.

Similarly, with regard to the estimated lower asymptote parameter, a significant group difference was also found ($F(1, 192) = 14.54$, $p < 0.001$, $\eta_p^2 = 0.170$), whereby healthy controls had a lower asymptote (i.e., close to the value of 0) compared to patients with SCZ, suggesting again that patients with SCZ were less accurate in identifying emotions at higher intensity levels. A significant omnibus difference also was found across the morph conditions ($F(2, 192) = 30.25$, $p < 0.001$, $\eta_p^2 = 0.240$). Bonferroni adjusted t-tests

revealed significant differences between all morph conditions ($p < 0.001$, $d > 0.582$), such that the sad condition was found to have the lowest asymptote, followed by the angry and happy conditions (Figure 4.5). The group x morph condition interaction was not significant ($F(2, 96) = 0.548$, $p = 0.580$, $\eta_p^2 = 0.005$).

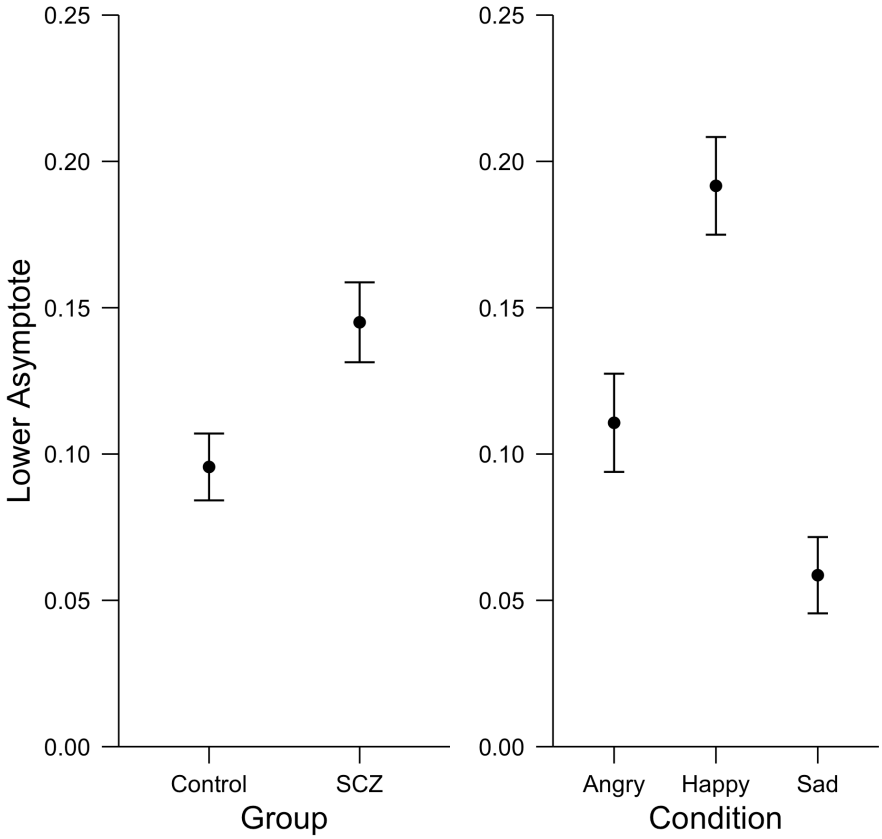


**Figure 4.5** Estimated lower asymptotes of psychometric functions. Healthy controls demonstrated reduced lower asymptotes compared to people with SCZ, indicating that the patient population had more difficulty discriminating high intensity emotions. Both groups of participants were more accurate in identifying the emotions of sad and angry compared to the happy morph condition.

It is important to note that in both individuals with SCZ and HC, the upper asymptotes were high (i.e., >90%) while lower asymptotes were generally low (i.e., <15%). As such, these results do suggest that both groups of participants were able to

attend appropriately to during the experiment. Additionally, it is also plausible that differences in upper and lower asymptotes may have been attributable to response bias, or the tendency to consistently select a particular response during the experiment. To examine the potential for response bias, discrimination sensitivity (d') was calculated for each morph condition by pairing the six signal strengths used in the experiment (e.g., [100, 0] and [0, 100]; [80, 20] and [20, 80]; [60,40] and [40, 60]) with each morph condition. Discrimination sensitivity was submitted to a repeated-measures ANOVA with group (e.g., HCs and SCZ) as a between-group factor and both morph condition and signal strength as within-group factors. Results of this analysis revealed significant main effects of group ($F(1, 64) = 15.29$, $p < 0.001$, $\eta_p^2 = 0.193$), morph condition ($F(2,128) = 62.31$, $p < 0.001$, $\eta_p^2 = 0.493$), and signal strength ($F(2, 128) = 530.38$, $p < 0.001$, $\eta_p^2 = 0.892$; Figure 4.6). Furthermore, a group x morph condition interaction was observed ($F(2, 128) = 7.05$, $p = 0.001$, $\eta_p^2 = 0.099$) and post-hoc analysis revealed that individuals with SCZ demonstrated reduced discrimination sensitivity in the angry-happy condition compared to both happy-sad ($p < 0.001$, $d = 0.609$) and sad-angry conditions ($p < 0.001$, $d = 0.576$). No significant differences were observed between the happy-sad and sad-angry morph condition among individuals with SCZ and all morph conditions were significantly different among healthy controls ($p < 0.001$, $d > 0.217$). A morph condition x signal strength interaction was also revealed ($F(4, 256) = 8.229$, $p < 0.001$, $\eta_p^2 = 0.114$). Post-hoc analysis indicated that within the 80%-20% signal strength condition, reduced discrimination sensitivity was found in the angry-happy condition compared to both the happy-sad ($p < 0.001$, $d = 0.711$) and sad-angry conditions ($p < 0.001$, $d = 0.815$) while

no significant differences were observed between the happy-sad and sad-angry conditions. Similar results were found with in the 60%-40% signal strength condition, where lower discrimination sensitivity was found in the angry-happy condition compared to the other morph conditions ($p < 0.001$, $d > 0.721$) and no differences were seen between the happy-sad and sad-angry condition. No other interactions were significant.

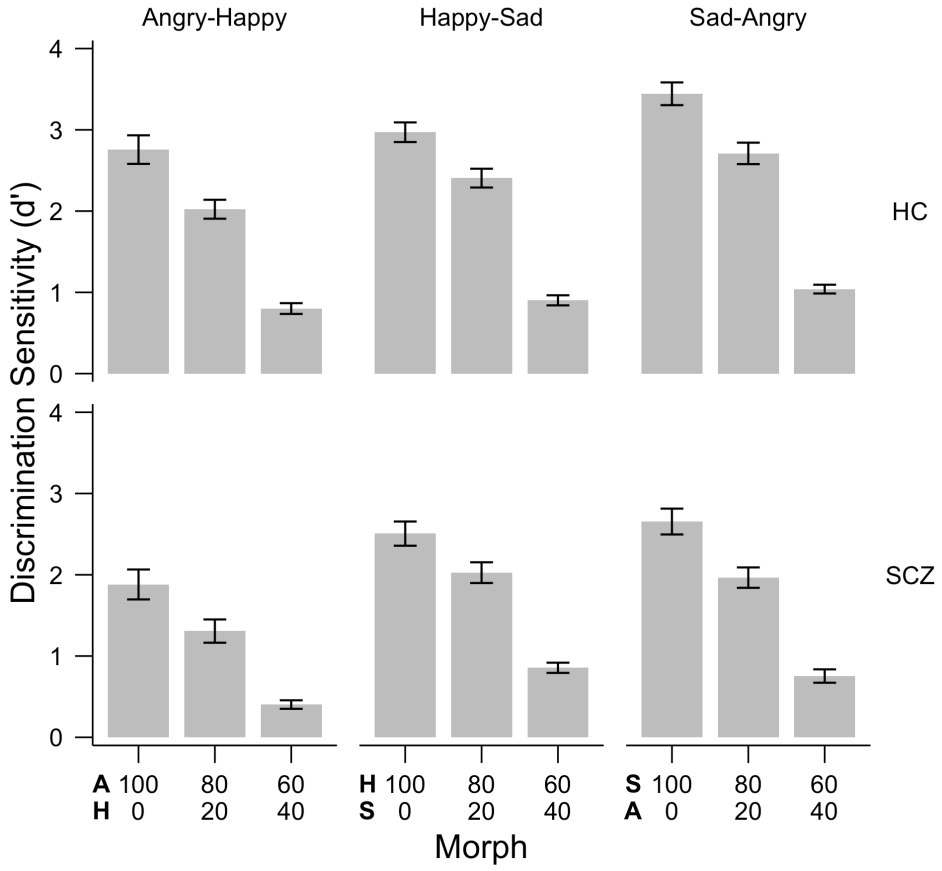


**Figure 4.6** Discrimination sensitivity (d') across signal strength, emotion morphs, and group. Individuals with SCZ demonstrated reduced d' in the angry-happy condition compared to both the happy-sad and sad-angry conditions. Within the 80%-20% and 60%-40% signal strength conditions, reduced d' was found in the angry-happy condition compared to both happy-sad and sad-angry conditions.

Response bias (i.e., criterion C) was calculated to examine the tendency to engage in a particular response (e.g., happy, angry, sad). Differences in response bias were tested using a repeated-measures ANOVA with group as the between-group factor and both morph condition and signal strength as within-group factors. Results of this analysis revealed significant main effects of morph condition ($F(2, 128) = 50.871$, $p < 0.001$, $\eta_p^2 = 0.443$) and signal strength ($F(2, 128) = 5.783$, $p = 0.004$. $\eta_p^2 = 0.083$). Notably, no main effect of group was observed ($F(1, 64) = 0.372$, $p = 0.544$, $\eta_p^2 = 0.006$). Furthermore, a group x morph condition x signal strength interactions was revealed ($F(4, 256) = 3.134$, $p = 0.015$, $\eta_p^2 = 0.047$). This three-way interaction was analyzed by conducting separate group x signal strength ANOVAs within each morph condition. Results of this analysis revealed a significant group x signal strength interaction only in the happy-sad morph condition ($F(2, 128) = 3.917$, $p = 0.022$, $\eta_p^2 = 0056$), in which group differences were observed in the 80%-20% ($F(1,64) = 4.765$, $p = 0.033$, $\eta_p^2 = 0.069$) and 60%-40% ($F(1,64) = 6.391$, $p = 0.014$, $\eta_p^2 = 0.091$) signal strength conditions. Within these signal strengths, HCs were found to exhibit increase response bias for happy compared to patients with SCZ (Figure 4.7). Importantly, no group differences in response bias were observed in the 100%-0% signal strength conditions among the differing morphs, suggesting that group asymptote differences were not influenced by response bias.

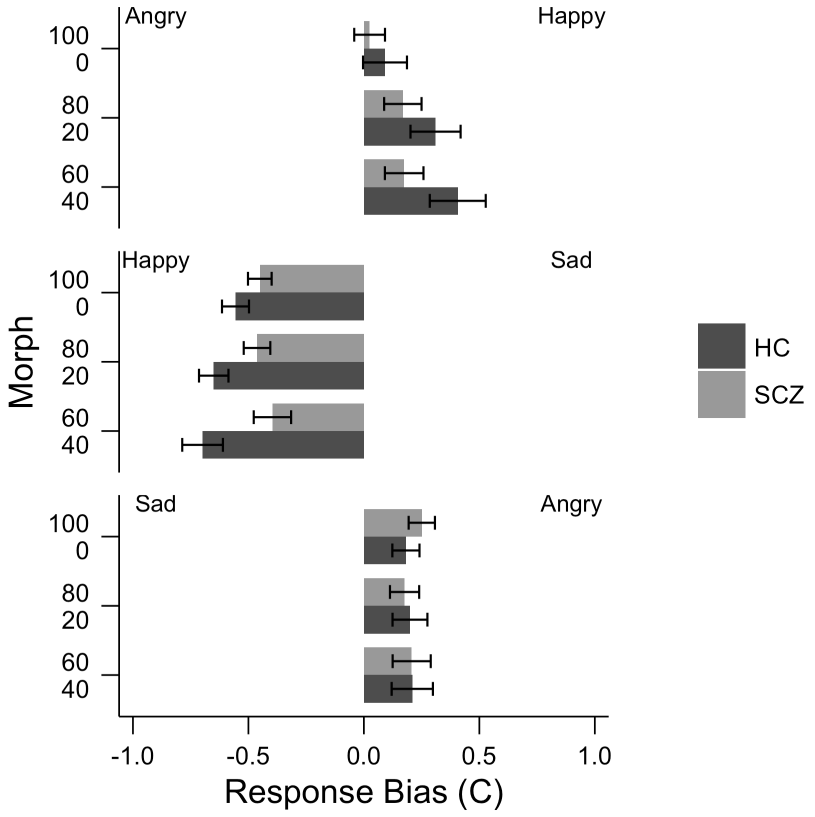


**Figure 4.7** Response bias (C) across signal strength, emotion morphs, and group. Group differences were observed with in the happy-sad condition, where HCs demonstrated increase response bias for happy in the 80%-20% and 60%-20% signal strength conditions.

## 4.4 DISCUSSION

The present study examined the ability of persons with SCZ to discriminate emotions that varied in terms of salience and were conveyed by PLWs. We found that the slopes and PSEs estimated from psychometric functions in three discrimination conditions -- angry-happy, happy-sad, and sad-angry --- did not differ significantly between groups. The similarity of psychometric function slopes and PSEs suggests that healthy observers and people with SCZ were equally sensitive to dynamic emotion information in conditions

where the emotion signal was relatively weak (i.e., more subtle/ambiguous). However, the upper and lower asymptotes of the psychometric functions did differ between groups, indicating that individuals with SCZ were less accurate when discriminating emotions from salient, unambiguous and higher intensity stimuli compared to healthy controls. Also, both groups more readily identified the happy compared to angry and sad walkers.

With respect to methodological limitations, the sample of emotions utilized in the current study was small and was not equally distributed with respect to negative (e.g., angry and sad) and positive (happy) emotions. This is in contrast to many studies utilizing face stimuli, which typically use a much wider range of emotions. Although some emotions are less easily discriminated among point-light walkers (e.g., disgust and fear), it would be beneficial in the future to consider a wider range of affective presentations.

Additionally, all patients with SCZ who took part in the current study were medicated, and we are unable to comment as to whether the results observed in the study were confounded by medication status. Additionally, analysis of sample characteristics revealed that the patients in the study had a significantly lower education level, lower estimated intelligence levels and decreased neuropsychological scores more generally. As noted in previous studies (Meehl, 1970; Miller and Chapman 2001), several characteristics that reliably distinguish SCZ from healthy participants are indeed correlated with outcomes of interest. In this situation, it is conventional to attempt to equate between-group differences on the confounding variable via linear covariate analyses. However, this method has been criticized on both statistical and conceptual grounds (Meehl, 1970; Miller & Chapman, 2001; Silverstein, 2008) and, therefore, was

not applied in the current study. To the extent possible, the field will benefit from future research that is able to exclude confounding factors (e.g., medication) from their study sample.

The current results are consistent with previous studies suggesting that patients with SCZ demonstrate difficulty classifying more obvious emotions (i.e., those with greater signal strength), while their ability to discriminate more subtle/ambiguous emotions (e.g., those with decreased signal strength) are relatively preserved (Kohler et al., 2003; Bigelow et al., 2006). The current findings lend support to the body of literature suggesting intact automatic or reactive emotion processing compared to more controlled emotional processing, among individuals with SCZ. From a social cognitive perspective, this finding may be considered surprising. That is, as outlined above, previous studies have indicated that many aspects of social perception and cognition, which include the ability to accurately infer the emotional states and intentions of others, are impaired in persons with SCZ. Given these deficits, why might the ability of people with SCZ to discriminate low intensity emotion stimuli be relatively preserved? Possible explanations for this result can be found in neurobiological models of emotion processing.

The amygdala has consistently been well known as a mediator of emotion processing (Adolphs, 2002; LeDoux, 2007). Moreover, amygdala response to emotional stimuli is automatic (Morris, Ohman, & Dolan, 1998; Winston, Strange, O'Doherty & Dolan, 2002) and is more strongly activated in presentations of high-intensity emotion compared to low-intensity emotions (Winston, O'Doherty, & Dolan, 2003; Winston, Strange, O'Doherty & Dolan, 2002). In addition, many studies have shown that the

amygdala response to high intensity affective faces is attenuated in individuals with SCZ (Pinkham, Gur & Gur; 2007; Brunet-Gouet & Decety, 2006; Schneider et al., 1998; Gur et al., 2002). Hence, emotion discrimination deficits that are found with high intensity affective faces, as well as from the point-light walkers used in the current study, may be linked to insufficient amygdala activation. However, it is important to note that several studies have found normal and even supra-normal amygdala responding among persons with SCZ when processing emotions. (Kosaka et al., 2002; Fernandez-Egea et al., 2010; Salgado-Pineda, Fakra, Delaveau, Hariri, Blin, 2010). To our knowledge, no previous imaging studies have investigated how amygdala activation varies as a function of emotional stimulus signal in people with SCZ. As such, further research is needed in this area to give more consistency with respect to amygdala activation in response to low and high intensity emotions among people with SCZ.

Similarly, research has also shown that intensity of emotion is related to activation of the medial prefrontal cortex during explicit emotion discrimination tasks. That is, increased activation of the medial prefrontal cortex is observed when an affective stimulus is perceived to be more arousing or intense (Winston, Strange, O'Doherty & Dolan, 2002). As a result, it is plausible that, during the current task, patients with SCZ perceived the higher intensity affective stimuli as less salient, which may have been associated with reduced medial prefrontal cortex activation and decreased accuracy overall. This is bolstered by evidence demonstrating abnormal structural and functional changes in the medial prefrontal cortex among individuals with SCZ, including reduced volume (i.e., grey matter deficits; Nenadic et al., 2015) and reduced activation of this area

in response to consummatory pleasure (i.e., the emotional state while experiencing pleasurable events; Yan et al., 2015). Additionally, recent research using dopamine transporter knockout mice that show numerous phenotypes relevant to SCZ (e.g., cognitive deficits, impairment of prepulse inhibition), revealed decreased spine density of pyramidal neurons in the medial prefrontal cortex, suggesting that this may be related to behavioural abnormalities observed in these mice (Kasahara, Arime, Hall & Uhl, 2015). Importantly, reduced activation of the medial prefrontal cortex among individuals with SCZ has also been observed in visually dynamic and socially relevant tasks. Mothersill et al. (2014) demonstrated that patients with SCZ demonstrated reduced activation of the medial frontal cortex during the passive viewing dynamic facial expression, where faces with neutral expressions dynamically changed to facial expressions of anger. Finally, a recent study has also demonstrated reduced activation of the medial prefrontal cortex among patients with SCZ when viewing non-emotional biological motion compared to HCs (Hashimoto et al., 2014).

Interestingly, results from the current study are also consistent with theories suggesting impaired dorsal stream functioning, and spared ventral stream functioning, among individuals with SCZ. For example, within the visual system, there is currently much evidence to suggest that sensory processing deficits are more pronounced in the magnocellular (M) pathway, which projects predominately to the dorsal visual stream, among individuals with SCZ. For example, SCZ-related M-pathway impairment has been documented in a variety of paradigms, including backwards visual masking (Schechter, Butler, Silipo, Zemon & Javitt, 2003), motion perception (Kim, Wylie, Pasternak, Butler

& Javitt, 2006), and contrast sensitivity (Butler et al., 2001). Additionally, much research has demonstrated that SCZ-related functional deficits are mediated by dorsal brain regions, including visually-guided grasping behaviour (King, Christensen & Westwood, 2008), working memory (Lee & Park, 2005), and conflict monitoring (Kerns et al., 2005). A more recent theory has also suggested that social cognition stems from a duel-process model, in which controlled (e.g., effortful, intentional and conscious) and automatic (e.g., implicit and non-conscious) social cognition is processed relatively independently (Lieberman, 2008). These two processing streams, termed the reflexive (X) and the reflective (C) systems, notably correspond with automatic and controlled processing of social cognition respectively. Specifically, the X-system is involved in tasks requiring automatic categorization, including learning patterns outside of conscious awareness (Aizenstein et al., 2000) and the processing of implicit threatening images and negative stereotypes (e.g., Whalen et al., 1998; Lieberman, Hariri, Jarcho, Eisenberger, & Bookheimer, 2005). Conversely, the C-system has been implicated in explicit learning and categorization (Aizenstein et al., 2000) and evaluating emotions and social stimuli (e.g., race) using specific verbal labels (e.g., Liebermann et al., 2005). Moreover, this duel-process model of social cognition is related, both functionally and anatomically, to dorsal and ventral stream processing, in which the X and C-systems correspond to ventral and dorsal streams respectively (Lieberman, Gaunt, Gilbert & Trope 2002). As such, this model is consistent with results from the current study, in that SCZ-related difficulty discriminating unambiguous emotion from biological motion may reflect generally reduced dorsal stream functioning. Conversely, relatively preserved discrimination of

subtle expressions of emotion may reflect relatively intact ability to process information through the ventral stream.

Results of the current study also indicated that the emotion of happy was the most easily discriminated and that this preference for detecting the emotion of happy stems from increased response bias. Specifically, increased response bias for happy was observed among both groups of participants, although significant groups differences were only shown when discriminating between happy and sad emotions in more ambiguous signal strength conditions (i.e., 80%-20%; 60%-40%). Additionally, no differences in response bias were observed in the 100%-0% condition, suggesting that differences in unambiguous emotion discrimination (i.e., upper and lower asymptotes) were not observed due to changes in response bias. Moreover, these results are generally consistent with Peterman et al (2013) who also demonstrated increased response bias for happy among both individuals with SCZ and HCs with more ambiguous emotion discrimination. This apparent preference for the happy affective condition is not surprising, as much work involving emotion discrimination from faces has shown increased accuracy and reduced reaction time in discriminating happy emotions compared to other emotions, although these studies, notably did not account for response bias (Calvo, Nummenaa & Avero, 2010; Calvo & Lundqvist, 2008). Moreover, another study has also shown that healthy observers more accurately identify the emotion of happy from dynamic point-light walkers (Spencer et al., in prep). Individuals with SCZ have relatively preserved ability to discriminate happy from other emotions (Kohler et al., 2003; Linden et al., 2010). Interestingly, many studies have also noted deficits in the ability to discriminate negative

emotions, particularly the emotion of angry, among individuals with SCZ (Mandal, Pandey & Prasad, 1998; Kohler et al., 2003; Spencer et al., in prep). While results from the current study do not show a specific deficit for the emotion of angry, the two negative emotions were more difficult to identify among both healthy observers and patients with SCZ.

The current study utilized estimates of asymptote parameters to examine the ability of participants to discriminate high intensity emotions. In this context, it is important to discuss whether the difference in asymptotes between healthy observers and individuals with SCZ represents performance inaccuracies or whether the asymptotic differences reflect another process. In this context, it is generally thought that asymptote parameters reflect the "lapse rate" or "error rate", in that inaccuracies, given high intensity signal and decreased task demands, are attributable to stimulus-independent errors such inattention (Pestilli, Viera & Carrasco, 2007; Wichmann & Hill, 2001; Klein, 2001). Given that individuals with SCZ have typically been shown to have reduced attentional abilities (Fioravanti, Carlone, Vitale, Cinti & Clare, 2005; Neuchterlein, Dawson, Ventura, Miklowitz & Konishi, 1991; Carter et al., 2010), it is plausible that differences in asymptote parameters were instead indicative of lapses in attention among the patient group. However, while it has been demonstrated that attention can affect estimated asymptote parameters, research indicates that inattention also reduces the slope of the psychometric function (Pestilli, Viera & Carrasco, 2007). Consequently, had deficits in attention among individuals with SCZ influenced asymptote parameters, we should also have found a group difference in the slope of the psychometric function. The

fact that slope did not differ between groups suggests that group differences in the upper and lower asymptotes cannot be due solely to differences in attention, but rather reflect (at least in part) a reduced ability to discriminate high intensity emotions in persons with SCZ. Additionally, as discussed previously, differences in asymptotes may also have been attributable to response bias; however, analysis of response bias did not reveal group differences in 100%-0% signal strength conditions across the three emotion morphs, suggesting that response bias did not contribute to group asymptote differences.

Finally, the findings from the current study support the notion that automatic/reactive emotion processing is relatively intact among individuals with SCZ compared to more controlled emotional processing. Moreover, these results are generally inline with the hypothesis that the perception of emotional experience, including response/reaction to emotionally evocative stimuli, is also relatively preserved in this population (e.g., Kring & Elis, 2013). These results may also lend support to more theoretical models of emotion processing. For example, Barrett (2006) has suggested that the perception of emotion involves two district features: The *core affect system*, a neurophysiological state that is experienced as feelings of pleasure or displeasure, and a *conceptual knowledge system*, a database of emotions gained through learned experiences. As such, in this model of emotion processing, individuals utilize the conceptual knowledge system to categorize affect (e.g., happiness, anger, sadness, etc.) in order to interpret emotional states and subsequently take appropriate action (e.g., communication). In this context, findings from this study, in addition to previous research, suggests that individuals with SCZ, while possessing an intact core affective

system, resulting in preserved emotional experience, may have difficulty categorizing these experiences according to their conceptual knowledge system, resulting in impaired discrimination of more obvious expressions of emotions. This is consistent with other studies suggesting that individuals with SCZ have difficulty in cognitive control associated with emotion, including the ability to draw upon and access their own representations and beliefs of emotion (for a review, see Kring and Elis, 2013). These represent intriguing future avenues of research that may shed light on emotion processing in SCZ more generally.

In summary, the current study suggests that people with SCZ are less able to discriminate high intensity emotions compared to low intensity emotions from point-light walkers. Furthermore, results from this study confirm the both patients with SCZ and HCs have minimal difficulty discriminating the emotion of happy, while angry and sad affective presentations were overall more difficult to identify.

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# CHAPTER 5

## GENERAL DISCUSSION

## 5.1 SUMMARY OF RATIONALE, OBJECTIVES AND RESULTS

Previous studies exploring the ability of individuals with SCZ to perceive social cues have largely focused on the extraction of social information from static emotional stimuli, such as faces. Less attention has been paid to the perception of social cues from dynamic stimuli, such as human movement, which is particularly relevant given well-documented deficits in visual motion processing among individuals with SCZ. Moreover, because biological motion also contains rich social and interpersonal information, it is plausible that SCZ-related social deficits could also be underpinned, at least in part, by deficits in biological motion processing impairment. However, the extant literature investigating biological motion processing among people with SCZ is both limited and hampered by inconsistencies and methodological shortcomings. These concerns highlight the need for further research to understand SCZ-related impairment in the perception of human movement, the mechanisms underlying this impairment, and the broader implications of this deficit. Accordingly, the primary goal of this thesis was to further characterize and understand human movement processing *per se*, and, additionally, the processing of social/emotional cues arising from human movement among persons with SCZ.

Previous, although limited, research has shown that persons with SCZ do not detect and discriminate biological motion from PL animations as well as healthy individuals. Notwithstanding these documented results, the importance of generalized visual motion processing deficits has been largely ignored, despite consistent and robust SCZ-related impairments in this general domain. Moreover, the specific mechanism(s) underlying the observed biological motion impairment is unknown. In this regard,

biological motion processing is somewhat unique in that it relies strongly on both local and global motion cues. Given related research demonstrating that SCZ participants may have disproportionate deficits in global motion processing, the contribution of either global or local motion information to the manifest deficits in SCZ was a target of the current thesis. Thus, the experiments presented in this thesis aimed to examine whether individuals with SCZ have disproportionate difficulty perceiving biological motion and if basic visual motion processes, such as global and local motion cues, may account for this deficit.

In addition to visual perceptual mechanisms, biological motion stimuli convey complex social information, which is relevant given well-documented SCZ-related social cognitive impairments. As such, SCZ-related deficits in biological motion may not solely be accounted for by visual perceptual mechanisms, but may also reflect reduced ability to extract relevant social cues from these stimuli. In this context, the relationship between biological motion and social perception among individuals with SCZ has been vague. Moreover, it is unclear whether individuals with SCZ are able to extract socially relevant cues from biological motion and if this ability relates directly to social perceptual deficits in this population. As such, the current thesis also aimed to examine the ability of individuals with SCZ to extract social cues, in the form of emotion, from biological motion, in addition to investigating the relationship between biological motion processing and social perception deficits in this population.

Finally, within naturalistic environments, social judgments often require the ability to discriminate more subtle and ambiguous cues. Moreover, the ability to judge

subtle emotional cues has been linked to automatic responding, which has been shown to be relatively preserved among individuals with SCZ. As such, it is also unknown whether individuals with SCZ are able to extract relevant social information from more ambiguous and subtle cues, as typically observed in real-world social environments. In this context, the final aim of this thesis was to examine the ability of patients with SCZ to extract subtle and ambiguous social information from biological motion. The current data resulting from these experiments (as reviewed below) give insight into mechanisms and parameters involved in perceiving and understanding these complex social stimuli.

The experiments in Chapter 2 (Contribution of coherent motion to the perception of biological motion) investigated visual motion processing mechanisms contributing to SCZ-related impairments in the perception of biological motion. Specifically, Experiments 1 and 2 investigated the contribution of coherent motion to biological motion perception, in which patients with SCZ and HCs discriminated the direction of motion of both PLWs and a non-biological motion stimulus. Similar to previous studies, results from these first two experiments confirmed that individuals with SCZ demonstrated disproportionate difficulties discriminating biological motion compared to non-biological motion. However, these experiments also found that group differences were not significant once coherent global motion was taken into account, suggesting that the SCZ-related deficits observed in these experiments were not specific to biological motion, but instead reflected a more widespread processing deficit for global visual motion. Given these results, Experiment 3 further investigated the contribution of global motion to biological motion discrimination by isolating global form (i.e., random position

PLWs) and local motion cues (i.e., scrambled PLWs) embedded within the point-light stimuli. Results from Experiment 3 revealed reduced accuracy in the ability of individuals with SCZ to discriminate random position and upright, but not scrambled, PLWs, again suggesting that SCZ-related impairments reflected global motion deficits more generally. These data, therefore, offer support to the hypothesis that individuals with SCZ demonstrated difficulty discriminating biological motion; however, these data also provide further insight into mechanisms contributing to this deficit with respect to deficits in overall visual motion processing and the utilization of global form cues.

The experiments presented in Chapter 3 (Global versus local motion cues as mechanisms of impaired emotion recognition of affective point-light walkers in persons with Schizophrenia) utilized biological motion containing emotion cues to examine the ability of individuals with SCZ to extract relevant social cues, in the form of emotion, from PL animations. Moreover, this chapter also examined (1) the relationship between extracting emotion information from these stimuli and social-perceptual abilities more generally, and (2) the visual perceptual mechanisms, including global form (i.e., random position PLWs) and local motion (i.e., scrambled and inverted PLWs), contributing to the ability to discriminate emotions from PL animations. Results showed that individuals with SCZ were less able to discriminate emotions from PL animations, including conditions in which speed confounds were removed. However, while a significant relationship between emotion discrimination and social perceptual abilities was found among HCs, this relationship was not evident among patients with SCZ. To this end, the findings from Chapter 3 again support the hypothesis that individuals with SCZ have a

disproportionate difficulty extracting socially relevant cues from biological motion; however, the results from this chapter also indicate that this impairment is not directly related social perceptual abilities more generally. Additionally, similar to results from Chapter 2, findings from Chapter 3 confirmed that the manipulation of global form and local motion had similar effects on emotion discrimination in both patients with SCZ and HCs, in that disrupted global form more significantly impacted the ability of participants to discriminate emotions from PLWs compared to disrupted local motion cues. However, results from Chapter 3 also revealed that local motion cues were found to be relatively more informative in the perception of emotion from biological motion (Experiments 1 and 2). Moreover, in Experiment 3, which investigated the ability of participants to discriminate the direction of emotional PLWs, no group differences were noted, in that the emotion content in the stimuli likely helped individuals with SCZ better discriminate the direction of biological motion due to enhanced local motion cues. As such, these data suggest that local motion cues embedded in the emotion stimuli contain informative information to make accurate evaluations of emotion judgment, in addition to providing more salient cues with respect to visual motion processing more generally.

The experiment presented in Chapter 4 examined the ability of individuals with SCZ to accurately judge subtle or ambiguous expressions of emotion from biological motion, such as those found in naturalistic environments, using morphed PLW stimuli depicting varying degrees of emotional salience. This experiment was conceptualized based on previous work suggesting that individuals with SCZ have demonstrated areas of persevered emotion responding, particularly involving automatic and reactive processing

opposed to effortful and controlled processing of emotion. Results showed that, when discriminating emotions that were presented with reduced signal (e.g., more subtle/ambiguous emotion presentation), patients with SCZ and HCs demonstrated similar ability to discriminate emotions. In contrast, individuals with SCZ were less accurate when discriminating emotions from unambiguous stimuli compared to HCs, lending support to previous work suggesting preserved automatic or reactive processing of emotions compared to more controlled processes in this population. As such, these data support the hypothesis that individuals with SCZ have a disproportionate difficulty extracting socially relevant cues from biological motion; however, these data also suggest that this impairment is evident only when discriminating emotions from high signal-to-noise ratio stimuli, or in other words, unambiguous emotional emotion presentations.

Taken together, the results from this thesis support the assertion that patients with SCZ demonstrate a disproportionate difficulty not only perceiving biological motion, but also interpreting relevant social information, in the form of emotional cues, from these dynamic stimuli. Indeed, all of the studies presented clearly show that individuals with SCZ had difficulty discriminating various parameters from biological motion stimuli. However, the findings from this thesis also demonstrate that SCZ-related deficits in biological motion processing were eliminated once non-biological coherent motion was taken into account, suggesting that these deficits were not specific to biological motion, but instead reflected a more widespread visual motion processing deficit. Moreover, with respect to mechanisms underlying this deficit, SCZ-related impairment in the discrimination of biological motion also reflected poorer global, opposed to local, motion

perceptual deficits more generally. Additionally, although results from the thesis indicate that patients with SCZ have disproportionate difficulty extracting social cues from biological motion and perceiving social stimuli more generally (i.e., through the IPT-15), this impairment was found to be unrelated to their social perceptual abilities. Moreover, local motion cues containing emotion information were also found to relatively enhance the ability of patients with SCZ in discriminating biological motion. Finally, while findings from the thesis support the hypothesis that individual with SCZ demonstrate reduced ability to extract social cues in the form of emotion from biological motion, results also indicate that this was isolated to only salient and unambiguous expressions of emotion, while the discrimination of subtle and ambiguous emotion presentation was relatively persevered in this population.

## 5.2 VISUAL ANALYSIS OF BIOLOGICAL MOTION PROCESSING IN SCHIZOPHRENIA

As noted above, results from this thesis suggest reduced ability to perceive biological motion among individuals with SCZ. As such, it is worthwhile to consider these findings collectively and to explore potential mechanisms that may underlie this deficit more generally. That is, given our current knowledge with respect to the brain's ability to visually decipher and analyze biological motion, what do these results suggest about SCZ-related biological motion deficits? Or, in other words, where might things have gone awry in the SCZ perceptual system?

### 5.2.1 Dorsal and ventral stream processing in Schizophrenia

Within the visual system, there is currently much evidence to suggest that sensory processing deficits are more pronounced in the magnocellular (M) pathway, which projects predominately to the dorsal visual stream, among individuals with SCZ. For example, SCZ-related M-pathway impairment has been documented in a variety of paradigms, including backwards visual masking (Schechter, Butler, Silipo, Zemon & Javitt, 2003), motion perception (Kim, Wylie, Pasternak, Butler & Javitt, 2006), and contrast sensitivity (Butler et al., 2001). Additionally, deficits have also been noted in processes thought to be related to intact dorsal visual stream functioning, such as reading ability (Martinez et al., 2013) and facial emotion discrimination, in which impaired emotion identification was correlated with M-pathway visual deficits (Butler et al., 2009).

These documented deficits in M-pathway processes are consistent with theories suggesting impaired dorsal stream functioning, and spared ventral stream functioning, among individuals with SCZ. For example, research has posited, using evolutionary cytoarchitectonic theory, that dorsal stream impairment may underlie many SCZ-related deficits (Christensen & Builder, 2000). Specifically, the duel cytoarchitectonic trends theory (DTT; Sanides, 1969) suggests that neural architecture evolved along two separate pathways, namely the dorsal (i.e., archicortical) and ventral (paleocortical) trends. The dorsal trend proceeds along the dorsal-medial aspects of the cerebrum and functionally is utilized in the planning and organization of actions and executing internally-generated controls based on contextual factors. Conversely, the ventral trend proceeds along the ventral-lateral aspects of the cerebrum and is responsible for identifying and assigning

meaning to stimuli and in arousal-based, or reactive, behaviour to emotionally salient stimuli in the external environment (Giaccio, 2006). In this context, much research has demonstrated SCZ-related deficits in functioning that is mediated by dorsal trend brain regions, including visually-guided grasping behaviour (King, Christensen & Westwood, 2008), working memory (Lee & Park, 2005), conflict monitoring (Kerns et al., 2005), and the detection of peripheral targets (Elahipanah, Christensen & Reingold, 2010).

To this end, findings from this thesis, demonstrating that biological motion discrimination deficits among individuals with SCZ was attributable to impaired coherent visual motion processing more generally, contribute to theories of SCZ-related dorsal stream functioning impairment. First, M-pathways have been shown to be integral for intact coherent motion detection, in that disruption to this pathway, using flicker adaptation, has resulted in reduced global motion processing (Chapman, Hoag & Giaschi, 2004). As such, reduced global motion processing, and its contribution to biological motion perception, may be the result of impaired M-pathway processes among individuals with SCZ. Second, many studies have implicated cortical area STSp, a component of the dorsal stream network, in the perception of biological motion (e.g., Grossman & Blake, 2001). Given that STSp abnormalities have been observed among patients with SCZ when viewing biological motion (Kim et al., 2011), this also supports the notion of reduced dorsal stream functioning in this population.

Interestingly, dorsal and ventral stream functioning has more recently been implicated in the realm of social cognition. One of the more influential theories of social cognition stems from a duel-process model, which posits that controlled (e.g., effortful,

intentional and conscious) and automatic (e.g., implicit and non-conscious) social cognition are processed relatively independently. Lieberman and colleagues (Lieberman, Gaunt, Gilbert & Trope, 2002; Lieberman, 2008) have defined these two processes as the reflexive (X) and the reflective (C) systems corresponding with automatic and controlled processing of social cognition respectively. The X-system, as defined by Lieberman (2008), promotes the automatic and non-consciousness processing of social information and involves older brain structures, including the amygdala, basal ganglia, and the lateral temporal cortex. In this context, the X-system has been implicated in tasks requiring automatic categorization, including learning patterns outside of conscious awareness (Aizenstein et al., 2000) and the processing of implicit threatening images and negative stereotypes (e.g., Whalen et al., 1998; Lieberman et al., 2005). Moreover, the X-system is thought to be involved in social intuition, such as nonverbal cues utilized to gauge emotion, intentions, and attitudes of others (Lieberman, 2000). For example, intuitive social information processing has been implicated in the ability to identify facial expressions following short presentation times (Rosenthal et al., 1979) and to form accurate impressions of others with minimal visual information (Ambady and Rosenthal, 1993). For example, Ambady and Rosenthal (1993) demonstrated that students were able to form impressions of teachers following the viewing of a 6-second video clip and that these judgments were very consistent with students who had been taught by the same instructor over the course of a full semester. In contrast, the C-system, consisting of the anterior cingulate cortex, posterior parietal cortex, and lateral prefrontal cortex, is involved in the controlled and effortful processing of social information and can override

X-system processes (Lieberman, 2008). For example, the C-system has been implicated in explicit learning and categorization (Aizenstein et al., 2000), evaluating emotions and social stimuli (e.g., race) using specific verbal labels (e.g., Liebermann et al., 2005), and reappraising negative images so that they no longer resulted in negative responses (Ocshner, Bunge, Gross & Gabrieli, 2002). Most importantly, this duel-process model of social cognitive has been proposed to related, both functionally and anatomically, to dorsal and ventral stream processing, in addition to cytoarchitectonic theory, in which the X and C-systems correspond to ventral and dorsal streams respectively (Lieberman et al., 2002). This is especially relevant in considering results from the current thesis, in that SCZ-related impairment in coherent motion processing and discrimination of unambiguous displays of emotion (e.g., controlled and effortful processing) both reflect more dorsal stream processing deficits, which, as described above, has been shown to be impaired among individuals with SCZ. Moreover, results from the thesis indicate that individuals with SCZ did not have difficulty discriminating emotion from more subtle expressions of emotion, which may reflect the relatively intact ability to process information through the ventral stream.

Another interesting finding from the current thesis is that while persons with SCZ demonstrated impairment discriminating emotion from subtle/ambiguous stimuli, their ability to discriminate salient expression of emotion was preserved. As discussed in Chapter 4, these results are generally inline with the hypothesis that the perception of emotional experience, including response/reaction to emotionally evocative stimuli, is also relatively preserved in this population (e.g., Kring & Elis, 2013). Moreover, these

results lend support to more theoretical models of emotion processing. As noted previously, Barrett (2006) has suggested that the perception of emotion involves two district features: The *core affect system*, a neurophysiological state that is experienced as feelings of pleasure or displeasure, and a *conceptual knowledge system*, a database of emotions gained through learned experiences. As such, in this model of emotion processing, individuals utilize the conceptual knowledge system to categorize affect (e.g., happiness, anger, sadness, etc.) in order to interpret emotional states and subsequently take appropriate action (e.g., communication). As such, results from the thesis suggest that while persons with SCZ possess an intact core affective system, they may have difficulty with respect to their conceptual knowledge system, which is consistent with studies suggesting that individuals with SCZ have difficulty in cognitive control associated with emotion, including the ability to draw upon and access their own representations and beliefs of emotion (Kring and Elis, 2013). As such, the idea of this dual-process system in emotion perception also coincides with Lieberman's duel-system approach to social cognition and SCZ-related cytoarchitectonic theory. Specifically, the core affective system and conceptual knowledge system are consistent in function to X and C-systems respectively, which as discussed above, is likely related to ventral and dorsal stream functioning. As such, the results from Chapters 2, 3, and 4 converge and are consistent with SCZ-related dorsal stream impairment.

### 5.2.2 Visual integration in Schizophrenia

The ability to utilize global cues, with respect to biological motion, is dependent on the capacity to combine and integrate local information (e.g., individual dots) to create

the coherent percept of a PL animation. As such, is it plausible that the inability of individuals with SCZ to utilize global motion cues stems from a more general visual perception integration deficit? In this context, it is worthwhile to consider whether individuals with SCZ exhibit visual integration difficulties outside the realm of biological motion. Indeed, findings from various lines of research support this notion. First, as reviewed previously, individuals with SCZ demonstrate difficulty detecting and discriminating coherent motion signals, which requires the ability to accurately integrate information across space and time (Stuve, Friedman, Jesberger et al., 1997; Chen, Nakayama, Levy, Matthysse & Holzman, 2003; Slaghuis, Holthouse, Hawkes & Bruno, 2007). Second, findings from the perceptional organization literature, including the processes by which visual information is coherently structured into groups, contours, and perceptual wholes, have also implicated integration difficulties among individuals with SCZ. In particular, patients with SCZ have demonstrated difficulty with contour integration (e.g., Uhlhaas, Phillips, Schenkel & Silverstein, 2006; Kozma-Weibe et al., 2006; Uhlhaas, Phillips, Mitchell & Silverstein, 2006), integrating fragmented drawings into a perceptual whole (Sehatpour, Dias, Butler et al., 2010), and grouping dot patterns by similarities (Kurylo, Pasternak, Silipo, Javitt & Butler, 2007). Moreover, perceptual closure, such as the ability of the visual system to integrate or "fill in" missing information, is not only impaired in SCZ but also has been shown using electrophysiology, to be related to dorsal, but not ventral, stream processing (Doniger et al., 2002). Additionally, literature examining the brain regions involved in SCZ-related visual integration deficits has implicated predominantly reduced activation of extrastriate

visual cortex regions, including more anterior areas such as the temporoparietal junction (Silverstein et al., 2009; Sehatpour et al., 2010), which notably consists of two anatomical regions: the STSp and the inferior parietal lobe (Abu-Akel & Shamay-Tsoory, 2011), both of which have been shown to activate in response to biological motion perception (e.g., Bonda et al., 1996). To this end, it is plausible that the inability of individuals with SCZ to utilize global form cues from biological motion arises from a more general visual perception integration deficit. Consequently, these findings regarding visual integration deficits are particularly relevant to the use of global motion cues in the perception of biological motion, specifically pertaining to the STSp region. It is well documented that the perception of biological motion is associated with increased activity in this area among HCs (e.g., Bondra et al., 1996). Furthermore, when point-lights that define a moving person are scrambled, STSp activity is significantly reduced (Grossman & Blake, 2002), suggesting that efficient processing of biological motion depends highly on the global relationships between each point-light, or in other words, coherent global form. As such, the STSp plays an important role in integrating local motion signals to create the percept of a holistic PL animation.

As such, given the importance of the STSp in both human movement and global motion perception, we would therefore expect differential activity with respect to this area in patients with SCZ when perceiving biological motion. Although quite limited, preliminary evidence in the literature supports this notion. That is, Kim and colleagues (2011) observed that patients with SCZ showed similar STSp activation for both coherent and scrambled biological motion compared to HCs, suggesting that this region was not

selective for coherent human motion in this population. Moreover, HCs and individuals with SCZ did not show differential activation of area MT nor were any correlations observed between MT and STSp. These findings suggest, with respect to biological motion perception, that deficits in this domain are not wholly attributable to gross motion perception abilities, but rather involve neural mechanisms specific to the *integration* of dynamic point-lights into a coherent global form. As such, it is plausible that SCZ-related biological motion deficits may at least partly be explained by functional changes to the STSp with respect to this region's role in the visual integration of motion cues.

In contrast, it is important to note that the neural processes necessary for static and dynamic visual integration may not be the same, especially given that the perception of dynamic information requires integration of both spatial and temporal cues, while static visual integration requires only integration spatial information. Therefore, an area of future study, may involve studying correlations between static and dynamic visual integration among patients with SCZ to examine the relationship between static and dynamic integration.

### 5.2.3 Local cues in biological motion perception

It is also worthwhile to discuss some seemingly inconsistent results found between Chapters 2 and 3 in the context of visual motion processing. That is, findings from Chapter 2 demonstrated that individuals with SCZ were less able to discriminate direction from PL animations in the absence of a visual noise mask. In contrast, results from Chapter 3 show that both patients with SCZ and HCs had similar ability to discriminate the direction of emotion containing biological motion, again in the absence

of noise. These results suggest that the presence of emotional cues contained in PL animations improved the ability to discriminate direction from these stimuli among patients with SCZ, and as such facilitated the detection of motion direction.

Previous studies have indeed suggested that emotional cues can shape, or modify, visual sensitivity to biological motion, which is consistent with the extensive neural connections between the STSp and the amygdala (Amaral, 2003). For example, Chouchourelou and colleagues (2006), utilizing masked coherent and scrambled PL depictions of gait expressing differing emotional states, demonstrated that individuals were more successful in detecting the presence of human movement from angry gaits compared to neutral gaits, suggesting that emotional local cues may contribute to the detection of biological motion (Chouchourelou, Matsuka, Harber & Shiffrar, 2006). Moreover, results from this same study also demonstrated that individuals were able to accurately discriminate emotions from scrambled PL sequences that did not contain a coherent human form. As such, given that participants were relying solely on local cues, rather than coherent global form, this study suggests that emotion information can be carried by local velocity signals. Additionally, findings from agency and animacy studies have also shown that individuals are able to impose human qualities, such as emotion, to moving non-biological geometric shapes (e.g., Heider and Simmerl, 1944). The attribution of these properties is generally thought to stem from the quality of motion contained in these figures opposed to the global, or geometric characteristics of the stimuli (Szego and Rutherford 2007; Szego and Rutherford 2008, Zacks 2004). As such, emotion cues do, to some extent, facilitate the perception of visual motion.

Given the possibility that emotion information can be carried by local signals, it is also plausible that individuals with SCZ may be better able to utilize these cues, resulting improved ability to process biological motion stimuli. As discussed previously, although patients with SCZ demonstrate difficulty integrating local information to create a coherent percept, evidence also suggests that their ability to process local information in isolation is relatively preserved. For example, individuals with SCZ, as reported earlier, have difficulty processing coherent motion, yet demonstrate similar ability to HCs in discriminating local motion (Chen et al., 2003). Similarly, individuals with SCZ demonstrate difficulty discriminating global motion but are equally able to discriminate static global form (e.g., discriminating radial and concentric patterns), using Glass patterns, compared to controls, indicating SCZ-related deficits in global motion, but not global form (Brittain, Surguladze, McKendrick & Ffytche, 2010). As such, it is possible that, given more robust local information as provided by emotion cues, individuals with SCZ were better able to utilize local parameters in making judgments with respect to biological motion. As a result, group differences as seen in Chapter 2 were not found in Chapter 3 with respect to direction discrimination, due to this facilitation of local cue processing among the patient group. Importantly, it is also crucial to note that these experiments were conducted with different samples, and as such, a more direct study would be needed to fully evaluate this postulation.

## 5.3 SOCIAL PERCEPTION IN SCHIZOPHRENIA

Results from this thesis raise questions concerning the relationship between biological motion processing and social perception among individuals with SCZ. To this end, findings from Chapter 3 indicate that while patients demonstrated reduced social perceptual abilities, as measured through a dynamic visual task involving the interpretation of various social interactions, this ability was not correlated with biological motion perception. Moreover, results from Chapter 4 indicate that individuals with SCZ were able to discriminate less salient emotional cues from PL animations, an ability that is seemingly important in the interpretation of social environmental information. Collectively, although these results do not unequivocally indicate a lack of relationship between biological motion and social perception, the findings from this thesis do suggest that this relationship is not as clear as initially proposed.

With respect to findings from this thesis, it is plausible that the social perception task utilized (i.e., IPT-15) was not sensitive enough to capture social perceptual difficulties among individuals with SCZ. In this context, results from Chapter 4 demonstrated that patients, while unable to utilize cognitive and effortful processes, were more able to discriminate emotions from automatic responding. As such, in considering the IPT-15, it is possible that this task relied more heavily on effortful cognitive processing and responding rather than social perception *per se*. As a result, overall cognitive impairment among individuals with SCZ may have served as a confound in discriminating social behaviour as presented in the task. Additionally, given that the IPT-15 utilizes a variety of information to infer social behaviour, it is also possible that these

extraneous sources of information impacted the observed relationship between biological motion and social perception. That is, the IPT-15 contained short videos that adequately captured dynamic information (e.g., posture and gestures) as contained in social stimuli; however, these videos also contained information not strictly relevant to the perception of human movement, including facial expression and prosody (Costanzo & Archer, 1993). While healthy individuals were likely able to integrate these multiple sources of information, it is possible that patients, due potentially to cognitive and integrative impairments as outlined previously, were less able to interpret cues embedded in this task. Lastly, with respect to ecological validity, while the IPT-15 has been shown to exhibit strong verisimilitude (i.e., the extent to which a measure appears to be similar to everyday situations), research has shown that its veridicality (i.e., statistical relationship between a measure and real world performance) is weak among with respect to persons with SCZ (Vaskinn, Sergi & Green, 2009). That is, although the IPT-15 discriminated well the performance between SCZ and HCs, it was not correlated with functional status in individuals with SCZ. Moreover, Vaskinn and colleagues (2009) also noted that the internal consistency (i.e., the extent to which items measuring identical constructs are correlated) of the IPT-15 was low in both groups of participants, suggesting that this task may not measure only one domain of social perception, but instead may reflect multiple facets of social perceptual abilities. As such, it is possible that the lack of relationship between biological motion processing and social perception found in the thesis may reflect the multifaceted nature of the IPT-15, and as a result, were not directed related to the ability to perceive human movement *per se*. As such, future studies may aim to

utilize social perception tasks, which 1) are less confounded by overall cognitive demands, and 2) isolate social perception to solely movement based parameters, in investigating the relationship between social and biological motion processing.

Despite the lack of relationship between biological motion processing and social perception, results from this thesis clearly indicate that individuals with SCZ demonstrate difficulty in their ability to interpret social cues. This stems from both Chapters 3 and 4, in that individuals with SCZ were 1) less able to extract emotion information from biological motion, and 2) demonstrated overall reduced IPT-15 scores. An interesting avenue with respect to social and human movement perception in SCZ is in the area of action and perception research. The ability to perceive the actions of others and, in turn, imitate these actions, has been suggested to facilitate social perception, such as understanding others' emotional states through the subtle imitation of postures, mannerisms, and facial expressions (e.g., Chartrand & Bargh, 1999). In other words, the ability to understand the intentions and emotional states of others may arise from the ability to, outside of awareness, mimic, or imitate, another person's actions, thus allowing for social learning and perception. This theory has been bolstered by the discovery of mirror neurons in primates, which have been shown to fire when both executing and observing actions, thus mirroring the behaviour of the other animal (Rizzolatti & Craighero, 2004). In humans, this ability has been postulated to involve an analogous mirror neuron system, which consists of a network of regions, including the inferior frontal cortex gyrus and inferior parietal lobe (Iacoboni et al., 1999). Interesting, although not traditionally regarded as comprising the mirror neuron system, the STS has been

shown to respond to action imitation compared to passive observation, suggesting that this regions may be crucially involved in the linking of the actions of others and the self (Molenberghs, Brander, Mattingly & Cunnington, 2010). As such, an impaired or inefficient mirror neuron system would potentially result in decreased ability to learn social behaviours, and as such, may lead to decreased ability to understand social cues.

Interestingly, with respect to individuals with SCZ, a recent imaging study has demonstrated abnormal neural activity during action and imitation in this population (Thakkar, Peterman & Park, 2014). In this study, both patients and healthy controls observed and imitated both biological dynamic (e.g., fingers pressing buttons) and non-dynamic stimuli (e.g., still images of fingers pressing button), in addition to a non-biological static stimulus (e.g., symbols representing button presses). Patients with SCZ demonstrated attenuated responses of the inferior parietal lobe and STSp during action imitation, compared to healthy controls. Furthermore, patients were shown to have increased activation of these areas during non-imitative action. The authors suggest that, together, these findings demonstrated a less differentiated, or less fine-tuned, mirror neuron system among individuals with SCZ. In some respect, these results are similar to those discussed previously; namely, that STSp activation is seemingly non-differentiated among individuals with SCZ when observing biological motion (Kim et al., 2011). These results also may help elucidate mechanisms contributing to SCZ-related impairment in biological motion discrimination. That is, given of the importance of the mirror neuron system in learning and understanding human action, including social cues, a deficient system among individual with SCZ may play a partial role in their reduced ability to

accurately perceive and extract relevant social information from human movement as observed in the context of the thesis. More generally, this may play an important role in understanding impairments in social functioning, which is typically observed in this population.

## 5.4 IMPLICATIONS FOR TREATMENT

Results from this thesis, support the notion that marked social dysfunction is a hallmark of SCZ, in that patients were less able to extract relevant social cues from human movement and demonstrated impairment with respect to social perception as measured through the IPT-15. As such, with the growing body of literature examining social perceptual deficits in this population, in addition to its clear relationship with functional outcomes more generally, research has examined whether social cognition can be improved. Notably, there has been little support for pharmacological treatments, specifically atypical antipsychotics, pertaining to improved social cognitive in SCZ. For example, a large study demonstrated that both quetiapine and risperidone did not result in improved emotion perception among individuals with SCZ (Harvey, Patterson, Potter, Zhone & Brecher, 2006). As a result, much research as increasingly focused on cognitive and psychosocial treatments to improve social cognition in this population. In this context, interventions have generally fallen into two approaches: Social skills training and social cognitive based therapies.

Social skills training is predominantly a behavioural-based therapeutic approach, developed in the 1970s, in which individuals are taught communication techniques that

facilitate social functioning, such as relationships, vocational pursuits, and greater overall independence (Bellack & Mueser, 1993). Traditional techniques in this treatment involve instruction, modeling, rehearsal, feedback and homework to target interpersonal skills. Additionally, much focus is placed on retraining behaviour, such as eye contract, body postures, and speech (Halford & Hayes, 1991). Moreover, increased social competence resulting from social skills training is thought to improve mood, self-esteem, and self-confidence (Kopelowicz, Liberman & Zarate, 2006). Overall, social skills training consists of a large number of target behaviours, including social perception, responding skills (e.g., verbal and non-verbal communication), instrumental role skills (e.g., functional social skills, such as purchasing food, renting an apartment, etc.), interactional skills (e.g., starting and maintaining conversations), and behaviours governed by social norms (e.g., speaking politely to a police officer; Kopelowicz et al., 2006). As such, amelioration, or training of these specific target behaviours, are thought to, in the context of SCZ, improve interpersonal supports and quality of life. However, studies investigating the effectiveness of social skills training in SCZ has been mixed. While some studies have shown some positive outcomes of social skills training with respect to learning these target behaviours, overall, these learned skills have not been shown to be generalizable to realistic environments (Kopelowicz et al., 2006; Pilling et al., 2002) or transfer to overall social functioning (Huxley, Rendall, & Sederer, 2000). That is, patients are less able to transfer the behaviours learned through social skills training to their respective natural environments.

The current thesis may provide some insight into why social skills training may not be more beneficial for individuals with SCZ, as well as possible modifications that could enhance its effectiveness. As noted above, social skills training involves a variety of targeted behavioural interventions, including social perception and responding, in addition to both functional and interactional skills. An examination of these target behaviours reveals that these skills are not simplistic in nature, but rather represent a series of complex procedures – i.e., interactional skills requires a multi-faceted and fine tuned perception of others, including the interpretation of another individuals facial expressions, posture, and verbal communication. As such, these complex procedures must be combined to form a holistic perception of the social environment. Or, in other words, these independent social cues must be integrated to form an interpretation of another individual's affective state and intent. In this context, results from the current thesis suggest that not only may individuals with SCZ have difficulty integrating information, but also that the ability to actively interpret these complex social perceptual cues may also carry a larger cognitive load. That is, the ability to integrate the various social cues may require more effortful cognitive processes. To this end, results from the current thesis, specifically pertaining to Chapter 4, indicate that individuals with SCZ demonstrate reduced ability to discriminate emotions using these more cognitive and controlled processes compared to a more automatic processing of this information. As such, the controlled processes seemingly required by social skills training may place individuals with SCZ at a disadvantage given this observed deficit. Given results from the current thesis, improvement in social functioning through social skills training may be

ameliorated by placing fewer demands on controlled cognitive processes and simplifying the many complex processes involved in social perception. Additionally, training emphasized on using more automatic judgments may also prove to be beneficial, given the results of this thesis. Moreover, given poor results regarding generalizability, it may be prudent that social skills training involve a more individualized approach that takes into account the social environment specific to the patient.

More recently, there has been growing interest in devising interventions aimed at improving functional outcomes among individuals with SCZ through the targeting of social cognitive deficits in this population. Multiple approaches have been utilized with respect to social cognitive training, although most protocols are typically divided into two areas: targeted and broad-based interventions (Kurtz & Richardson, 2012). Targeted interventions, as the name implies, focuses on a specific social cognitive ability, such as facial affect recognition and ToM. Some of these interventions have produced positive results although the long-term effects of these treatments have not been conclusive. For example, Penn and Combs (2002) demonstrated that a single session of facial mimicry training, monetary reinforcement, or a combination of both, led to improvement in facial emotion perception. Interestingly, this protocol seemingly targets training of automatic processing of social information, which according to results from this thesis is an area of relative strength with respect to SCZ-related emotion perception. However, although these results appeared to be fairly stable over, time, there was limited evidence that the intervention effects generalized to facial affect discrimination. Similarly, other studies have also shown that emotion perception can be improved among individuals with SCZ

(e.g., Choi & Kwon, 2006; Wölwer et al., 2005), although the generalizability and maintenance of these improvements have been less conclusive (Combs et al, 2007). It is also important to note that these interventions did not take into account other well-known deficits previously identified in this population, such overall face perception impairment among patients with SCZ. Alternatively, broad-based social cognitive training aims to improve social functioning skills using techniques incorporating multiple domains. One example of broad-based social cognitive training that has reported positive results is social cognition and interactive training (SCIT; Roberts, Penn & Combs, 2006). This treatment paradigm is a 20-week group intervention that targets emotion perception, ToM, and attributional bias (Roberts & Penn, 2009). Generally, this treatment comprises of three phases, which target emotion perception dysfunction, interpreting situations (i.e., attributional biases and ToM), and integration (e.g., applying learned skills to interpersonal difficulties; Roberts et al., 2009). This intervention specifically has shown improved social skills following SCIT with respect to social functioning in both outpatient and inpatient samples (Roberts et al., 2009; Combs et al., 2007), although these results were noted to be preliminary.

In consideration of social cognitive training techniques, a recent meta-analysis investigated the efficacy of these training programs in improving social cognitive function. Results of this study demonstrated that social cognitive training programs improved facial affect recognition in the moderate to large range, while smaller effects were observed regarding improved ToM (Kurtz & Richardson, 2012), suggesting that these complex social functions can be improved with structured training. Moreover,

moderate to large effects were found on measures of community functioning, suggesting that social cognitive training was associated with improvements in everyday environments; that is, a generalization of training effects was revealed (Kurtz & Richardson, 2012). Interestingly, and of most importance with respect to the current thesis, findings from this study revealed that social cognitive training did not result in significant changes regarding *social perception*, defined as the ability to interpret and respond to social cues, including body language and voice intonation. Again, this SCZ-related difficulty with respect to social perception is not surprising given results from this thesis; that is, that individuals with SCZ were less able to interpret social cues from biological motion and did they perform well on a specific task of social perception (i.e., IPT-15). Moreover, as stated above, social perception not only involves the extraction of these cues, but also the ability to integrate this information holistically to interpret the states of other individuals. As such, results from this thesis suggest that deficits with respect to social perception may arise from difficulty integrating various forms of perceptual information, which may be a target of future research and study in clinical settings.

At the current time, treatment with respect to social cognitive among individuals with SCZ is relatively new form of intervention. Although many of these studies reviewed have elicited positive results, there are several avenues for future studies, including the investigation of other social cognitive domains and varying treatment settings. However, treatments targeting social cognitive in SCZ will be immensely helped

by further understanding of brain-behaviour mechanisms, which underlie this deficit in this population.

## 5.5 LIMITATIONS AND FUTURE DIRECTIONS

There are several limitations to the current thesis that can be applied to each study and that will be important to consider in future research. First, a primary limitation of all studies pertaining to the current thesis concerns the effects of antipsychotic medication. In all experiments, participating individual with SCZ were prescribed a variety of both typical and atypical antipsychotics, and as a result, it was not possible to conduct well powered statistical analysis to examine medication-related effects. As such, it is unknown to what extent the results from the thesis were influenced by potential medication effects. Moreover, it is important to note that medication-related limitations are not specific to the current thesis, but also represent a similar challenge with respect to psychopathology research more generally.

Relatively few studies have investigated the effect of medication with respect to visual perception among individuals with SCZ. Chen and colleagues (2003) showed, using a visual contrast detection task, that individuals with SCZ had higher contrast detection thresholds compared to healthy controls, which indicated poorer contrast sensitivity among the patient population. However, when classified according to medication use, SCZ patients using typical antipsychotic medication demonstrated significantly higher contrast detection thresholds compared to healthy controls and patients receiving atypical antipsychotics (Chen et al., 2003). Additionally, the

performance of patients utilizing atypical antipsychotic medication was not significantly different when compared to healthy observers. Importantly, results from this study also showed that individuals with SCZ not receiving any antipsychotic medications demonstrated significantly lower contrast sensitivity compared to healthy controls, indicating better contrast sensitivity among the non-medicated patient group, although the sample size of this group was noted to be small (n = 6). As such, these results may have important implications regarding our understanding of underlying pathophysiology of visual deficits among individuals with SCZ.

One such neurotransmitter that may be related to these results is DA. For example, DA has been shown to increase the inhibitory effect with respect to the surrounding areas of a neural receptive field (i.e., heightened surround suppression), leading to enhanced visual contrast detection (Djamgoz, Hankins, Hirano & Archer, 1997; Tagliati, Bodis-Wollner, Kovanecz & Stanzione, 1994). Interestingly, in a study completed in Parkinson's Disease, a hypo-dopaminergic disorder, patients demonstrated high visual contrast detection thresholds (Bodis-Wollner, 1990). As such, increased levels of DA could lead to enhancement of contrast sensitivity, which was observed in the context of the Chen et al (2003) study, in which the non-medication patient groups showed better contrast sensitivity compared to healthy controls. Furthermore, atypical antipsychotics transiently bind to $D_2$ receptors, which allows for endogenous DA to reoccupy these receptors. This is in contrast to typical antipsychotics, in which $D_2$ receptors are occupied for longer periods of time, and as such, prevent reoccupancy of endogenous DA (Seeman, 2002). As such, the use of atypical antipsychotic medication, as opposed to typical

antipsychotics, allows for greater amounts of available endogenous DA, which in turn may enhance visual contrast sensitivity, which is notably similar to the results reported by Chen and colleagues (2003).

It is important to note that visual motion related medication effects have not been thoroughly investigated. In fact, only one such study has been published, in which antipsychotic medications were found to have no effect on the ability to detect coherent motion among individuals (Kelemen, Benedek & Keri, 2013). Despite the limited nature of this research, this result is interesting as it suggests that higher-level visual processes (e.g., motion perception) may have differing medication-related mechanisms compared to early-stage visual processing (e.g., contrast detection). Given the limited nature of this research, the effects of medication-related visual perceptual processing in the current thesis is unknown.

It is also important to consider medication effects related to overall emotion processing abilities among individuals with SCZ. In this context, studies have indicated that antipsychotics are related to reduced emotional responding, including decreased facial expressiveness (Schneider et al., 1992), especially for typical, rather than atypical antipsychotics (Fakra et al., 2008), in addition to patient self-reports of emotional numbing, social withdrawal, and feelings of emotional indifference (Moritz, Andreou, Klingberg, Theoring & Peters, 2013). As such, these results collectively suggest that antipsychotic medications may be related to reduced emotional responding and functioning more generally. As a result, given that all studies in the current thesis involved the participation of individuals with SCZ taking at least one antipsychotic

medication, it is possible that their ability to discriminate emotions was reduced, thereby weakening the effects as seen specifically in Chapters 3 and 4.

Confounds introduced by the effects of antipsychotics can be addressed in a variety of ways, including altering patient samples and methodological designs. Of course, medications effects could be eliminated by conducting experiments with a non-medicated patient sample, including early first-episode patients who have not been exposed to antipsychotic medication or individuals who have chosen, for various reasons, not to take medication. While the use of a non-medicated SCZ sample is ideal, this is typical not feasible in psychopathology research due to challenges associated with both recruiting and conducting experiments with medication naïve patients. A second approach may involving conducting experiments with individuals with schizotypal personality disorder (SPD) or alternatively, with individuals scoring in the high range on schizotypal personality traits. Studies have shown that individuals with SPD share multiple traits similar to individuals with SCZ (Nelson, Seal, Pantelis & Phillips, 2013), while eliminating potential medication effects. As such, experiments involving individuals with SPD may help clarify the role of antipsychotic use pertaining to both visual and emotion perception more generally.

Pertaining to sample characteristics, a second limitation of the current thesis concerns the somewhat unbalanced sex ratio within SCZ groups. Specifically, experiments conducted in Chapters 2, 3, and 4 all had a high male to female sex ratio. It is important to note that this unequal sex ratio was not completed intentionally, but rather occurred due to the availability to patients completing the experiments at the time. With

respect to biological motion perceptions, the unequal sex ratio in the current thesis may be of concern, as studies have recently emerged citing sex difference in the ability to perceive human movement. In this context, research has demonstrated that females are able to more accurately perceive biological motion action recognition and more efficient (e.g., significantly reduced reaction time) in discriminating human movement and emotions from point-light actions, compared to males (Alaerts, Nackaerts, Meyns, Swinnen & Wenderoth, 2011). Moreover, in a recent fMRI study, female adults were shown to exhibit increased activation in brain areas involved in social cognition (e.g., temporal pole, medical temporal gyrus, amygdala) when viewing biological motion animations compared to scrambled displays, compared to males (Anderson et al., 2013). Similarly, Pavlova, Sokolow & Bidet-Ildei (2014) also showed sex-related changes in cortical megnetoencephalographic (MEG) response when viewing coherent point-light animations. Specifically, they demonstrated that female observers showed greater cortical MEG response to biological motion mostly over the right hemisphere and that females showed an earlier cortical response to biological motion, specifically in the right parietal, left temporal, and right temporal cortices, areas that known to be engaged in the visual processing of social signals (Pavlova et al., 2014). Notably, these results are also commiserate with previous studies showing that females demonstrate significantly better performance recognizing emotions (e.g., Hall, Carter & Horgan, 2000) and in social perception tasks more generally (Baron-Cohen, Wheelwright, Hill, Raste, Plumb, 2001). As such, given sex differences pertaining to biological motion perception, it is plausible that the results of the current thesis may underrepresent the ability of individuals with

SCZ to discriminate biological motion, given the high male to female sex ratio.

Finally, a third limitation with respect to the current thesis involves the issue of interpersonal context relating to tasks of social perception. As discussed previously, results from the current thesis demonstrate that the relationship between biological motion and social perception is unclear. Specifically, findings from Chapter 3 indicated that no relationship was found between these two parameters. As discussed earlier, the task of social perception used in the current thesis (i.e., IPT-15) contained many sources of information to infer social behaviour that was not limited to human movement, but also facial expression and prosody. In a similar context, many tasks items from the IPT-15 also contained unscripted conversations and spontaneous behaviour between two to four individuals, in which participants were then asked to judge, or decode, the social interaction (Costanzo & Archer, 1993). For example, participants viewed a scene in which two individuals discuss a game of basketball that has been played. Following the scene, participants decided which individual in the video won the basketball game. The social interactions between multiple individuals presented in the IPT-15 differed from tasks of biological motion perception conducted in the current thesis, in that the PL animations consisted of single actors. As such, it is plausible that a relationship between IPT-15 performance and the biological motion tasks was not observed due to the difference pertaining to social interactions within the two tasks.

In this context, research has demonstrated that, unsurprisingly, interactions between two individuals contain a wealth of social information that is easily identified by healthy observers. For example, Dittrich (1993) showed that PL animations of

interpersonal behaviours, such as dancing, sparring, and shaking hands, is readily identified by observers. Additionally, humans are able to accurately recognize and discriminate emotions when presented with two PL individuals engaging in emotionally charged conversations (Clarke, Bradshaw & Field, 2005). Interestingly, results from this same study also demonstrated that social interactions facilitate the ability to extract social information from PL displays. For example, Carke et al (2005) demonstrated that participants were more accurately able to identified emotions from the interaction of two PL actors opposed to displays containing only one actor. As such, increased context, such as emotions displayed by two individuals rather than one, helps facilitate the ability to extract social cues from dynamic displays. Similarly, body expressions have also been shown to be more accurately recognized when the emotional content of a social scene is congruent with a bodily expression, suggesting that social context influences the ability to recognize and interpret expressions of bodily emotion (Kret & de Gelder, 2010).

As such, the lack of social interactions displayed by the PL animations in the current thesis may have resulted in the lack of significant relationship observed between biological motion and social perception. Moreover, the ability of individuals with SCZ to interpret social cues in the presence and absence of context is particularly interesting as difficulty processing contextual information as been proposed to explain social deficits among this population (e.g., Cohen & Servan-Schreiber, 1992). This is especially relevant, as treatment targeting social deficits in SCZ have been shown to not generalize to the individual environments of patients. As such, the ability of individual with SCZ to

interpret and extract social information in the presence of social, or interpersonal, context is an interesting and important avenue of future research.

## 5.6 CONCLUSIONS

What can be concluded regarding biological motion processing in SCZ? It is clear that the ability to process biological motion involves an intricate network, from basic visual perceptual mechanisms to higher-order interpretations, which collectively interact to allow humans to make complex judgments from a seemingly simple array of dots. Results from this thesis suggest that SCZ-related deficits in biological motion may stem from a combination of factors, from impaired coherent motion and integrative processing to the inability to extract meaningful information, notably in processes requiring more effortful or controlled responding. Moreover, evidence from previous literature, in addition to this thesis, strongly implicate the role of the STSp in SCZ-related biological motion deficits with respect to motion integration and emotion discrimination, although future research is needed to extend and confirm these results. As such, the current thesis is viewed as a first-phase in elucidating the psychological, brain-behaviour processes, and associated mechanisms regarding SCZ-related deficits in biological motion perception.

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