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Aberrant patterns of neural activity when perceiving emotion from biological motion in schizophrenia

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A B S T R A C T

Social perceptual deficits in schizophrenia are well established. Recent work suggests that the ability to extract social information from bodily cues is reduced in patients. However, little is known about the neurobiological mechanisms underlying this deficit. In the current study, 20 schizophrenia patients and 16 controls completed two tasks using point-light animations during fMRI: a basic biological motion task and an emotion in biological motion task. The basic biological motion task was used to localize activity in posterior superior temporal sulcus (pSTS), a critical region for biological motion perception. During the emotion in biological motion task, participants viewed brief videos depicting happiness, fear, anger, or neutral emotions and were asked to decide which emotion was portrayed. Activity in pSTS and amygdala was interrogated during this task. Results indicated that patients showed overall reduced activation compared to controls in pSTS and at a trend level in amygdala across emotions, despite similar task performance. Further, a functional connectivity analysis revealed that controls, but not patients, showed significant positive connectivity between pSTS and left frontal regions as well as bilateral angular gyrus during the emotion in biological motion task. These findings indicate that schizophrenia patients show aberrant neural activity and functional connectivity when extracting complex social information from simple motion stimuli, which may contribute to social perception deficits in this disorder.

1. Introduction

We live in a dynamic visual world. The detection of motion and the ability to obtain information from motion is an important visual perception ability (Blakemore and Decety, 2001; Knoblich and Flach, 2001). Reflecting that importance, humans are remarkably adept at recognizing coherent motion (Mingolla et al., 1992; Williams and Sekuler, 1984), and distinguishing actions performed by other humans from non-human movement (Ahlström et al., 1997). Human movement is considered to be a type of biological motion. Humans can recognize biological motion even when the patterns of movements are portrayed by nothing more than a handful of light points attached to the head and major joints of the body, as in point-light animations (e.g., (Blake and Shiffrar, 2007; Grossman et al., 2000; Johansson, 1973).

Thus, biological motion is an important aspect of social cue perception. From observing biological motion (e.g., gestures and gait) we gather socially relevant information and make inferences about the intentions and motivations of others. We can also infer emotion based on particular patterns of human movement displayed by point-light animations (e.g., (Atkinson et al., 2004; Heberlein et al., 2004).

In healthy controls, there is robust evidence that activity in the posterior portion of the superior temporal sulcus (pSTS) is critical for biological motion perception (Allison et al., 2000). Activity in pSTS is associated with perception of static images of the face and body as well as movements of the eyes, mouth, hands, and body (Beauchamp et al., 2003; Puce and Perrett, 2003). More broadly, the pSTS is part of a large neural circuit involved in the perception of intention from action and response to objects and events of social and emotional relevance (Blake and Shiffrar, 2007; Zacks et al., 2001). Primate studies, as well as more recent neuroimaging studies in humans, have identified other key regions within this circuit, including amygdala and orbitofrontal cortex, which receive projections from pSTS (Aggleton et al., 1980; Bonda et al., 1996; de Gelder, 2006; Ethofer et al., 2011). The amygdala, in particular, is responsive to emotional facial expressions and complex body movements (e.g., (Adolphs et al., 1999; Conty et al., 2012; Wang et al., 2014) and has been shown to modulate activity in STS neurons (Aggleton et al., 1980; Blake and Shiffrar, 2007). That modulation has been shown to vary as a function of the emotional content of an action (e.g., (Labar et al., 2003; Wheaton et al., 2001).

In schizophrenia, the ability to extract social information, including emotion, from bodily cues is reduced (e.g., (Kern et al., 2013; Kim et al., 2005; Okruszek et al., 2015; Peterman et al., 2014; Strauss et al., 2015; Vaskinn et al., 2016). A recent meta-analysis of 6 published studies found an mean effect size for reduced detection of emotion in biological

Abbreviations: pSTS, posterior superior temporal sulcus

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motion of −0.61 (Okruszek and Pilecka, 2017). However, little is known about the neurobiological mechanisms underlying deficits in biological motion detection or the ability to extract more complex information such as emotion from biological motion in schizophrenia.

There have been only a few studies to examine the structural or functional neuroanatomy of impaired basic biological motion perception using point-light animations in schizophrenia. Kim et al. (Kim et al., 2011), in a series of experiments, used two sets of basic biological motion fMRI tasks – localizer tasks and the primary experimental paradigm. The pSTS localizer task was a simple block-design with alternating blocks of biological and scrambled motion designed to identify BOLD activity in pSTS. The experimental paradigm was a more complex event-related task which required participants to judge whether a given motion stimulus (biological, scrambled, and 37% scrambled) depicted a human activity or not. For the pSTS localizer task, patients activated pSTS to the same extent as controls. This finding was replicated by Hashimoto et al. (Hashimoto et al., 2014) in a separate study using a similar task. However, during the more complex discrimination task, Kim et al. found that patients with schizophrenia showed an abnormal pattern of pSTS activity compared to controls. Specifically, pSTS activation was selective to biological versus non-biological (i.e., scrambled) motion in controls, but not in patients. Finally, Matsumoto et al. (Matsumoto et al., 2017) examined the relationship between behavioral performance on a basic biological motion perception task and regional gray matter volume. They found that task accuracy was positively correlated with gray matter reductions in the middle and anterior portion of right STS in schizophrenia. No studies to date have examined the neural basis of detection of emotion in biological motion.

To address this gap in this literature, the current study utilized two fMRI tasks using point-light animations in controls and patients with schizophrenia. First, a basic biological motion task was used as a localizer task to activate pSTS. This task has reliably activated pSTS (Hashimoto et al., 2014) and has been used previously as a pSTS localizer (Kim et al., 2011). We hypothesized that patients would activate pSTS to the same extent as controls during this task. Second, an emotion in biological motion task was used to examine neural activation associated with emotion judgments from biological motion in two ROIs: pSTS and amygdala. We also examined functional connectivity between pSTS and amygdala, as well as between pSTS and the rest of the brain, during emotion judgments. We chose the pSTS as the seed region for the connectivity analyses given its central role in the neural network associated with perception of human biological motion (e.g., (Kim et al., 2011)). We hypothesized that during the emotion in biological motion task patients would show reduced activation in pSTS and amygdala, and that functional connectivity associated with the task would be reduced in patients.

2. Methods

2.1. Participants

Twenty patients with schizophrenia (7 female) and 16 healthy controls (5 female) completed the study. Patients were recruited from community outpatient treatment clinics and met diagnostic criteria for schizophrenia based on the Structured Clinical Interview for DSM-IV Axis I Disorders (SCID) (First et al., 1997b). Controls were recruited through internet postings and interviewed with the SCID-I and portions of the Structured Clinical Interview for DSM-IV Axis II Disorders (SCID-II) (First et al., 1997a).

All participants were between 18 and 65 years of age, and were excluded from participation if they had: an identifiable neurological disorder, history of loss of consciousness for more than 1 h, or were not sufficiently fluent in English to consent and understand procedures. Additional exclusion criteria for patients was self-reported substance abuse in the past month or dependence in the last six months, and indication of IQ < 70 based on chart review. Additional exclusion criteria for controls was a first-degree relative with schizophrenia or another psychotic disorder, a personal history of schizophrenia or other psychotic disorder, bipolar disorder, or recurrent depression, a lifetime history of substance dependence or any substance abuse in the last 6 months, and any of the following Axis II disorders: avoidant, paranoid, schizoid, or schizotypal.

2.2. Clinical measures

Psychiatric symptoms in patients were evaluated using the 24-item version of the Brief Psychiatric Rating Scale (BPRS) (Ventura et al., 1995) and Scale for the Assessment of Negative Symptoms (SANS) (Andreasen, 1982). For the BPRS we report the total score and the mean for the positive symptom factor (Kopelowicz et al., 2008). For the SANS we report the sum of four global scales: Affective Flattening, Alogia, Avolition-Apathy, and Anhedonia-Asociality. Functional outcome was assessed with the Role Functioning Scale (RFS) (Goodman et al., 1993; McPheeters, 1984).

All clinical assessments were conducted by interviewers trained to reliability through the Treatment Unit of the Department of Veterans Affairs VISN 22 Mental Illness Research, Education, and Clinical Center (MIRECC) based on established procedures (Ventura et al., 1998). The study protocol was reviewed and approved by the Institutional Review Board of the University of California, Los Angeles. All participants provided written informed consent after procedures were fully explained.

2.3. Procedures

2.3.1. Activation paradigms

Participants completed two tasks involving point-light animations during fMRI (Fig. 1). The first was the Basic Biological Motion Task (Jahshan et al., 2014; Kim et al., 2011). The second task was the Emotion in Biological Motion Task (Heberlein et al., 2004; Kern et al., 2013). The tasks were generated using *E*-Prime version 2.0 professional (Psychology Software Tools, USA). Prior to the scan session, participants completed practice trials to become familiar with each task.

Basic biological motion task (localizer): Stimuli consisted of 1 s animations of point-light walkers; each animation video was comprised of 12 black dots presented on a white background at central fixation. The dots were arranged and animated in a manner that corresponded to human (e.g., walking, jumping) or random movement (Fig. 1A). Participants viewed 12 alternating blocks of human (0% scrambled) and random (100% scrambled) movement. Each block included 7 animations with an inter-stimulus interval (ISI) of 1 s. A 1 s fixation cross was presented during each ISI. A 4 s fixation cross was presented between each block. To maintain the participant's attention, each block required performance of a 1-back task in which they were required to press a button whenever the current animation was identical to the one appearing immediately before it. Participants had 2 s to make their response; they could respond at any time after stimulus onset and prior to the onset of the next video.

Emotion in biological motion task (Emo Bio): Stimuli consisted of 20 animations of point-light walkers (average duration: 8.05 s, standard deviation: 6.7 s); videos were comprised of 12 white dots presented on a black background at central fixation. The dots were arranged and animated in a manner that depicted happiness, fear, anger, or neutral human emotion (Heberlein et al., 2004; Kern et al., 2013). A 1 s fixation cross was presented prior to each animation. After stimulus offset, the screen prompted the participant to make their response. Participants were asked to decide which emotion was being portrayed by pressing a corresponding button on a 4-button response box. Participants had 4 s to make their response. Responses triggered progression to a blank screen for the remainder of the 4 s response period. Each animation was followed by a “null” trial consisting of a fixation cross (mean duration: 4.25 s, range: 2.5–7.5 s).