Schizophrenia Research xxx (2017) xxx–xxx

Contents lists available at ScienceDirect

Schizophrenia Research

journal homepage: www.elsevier.com/locate/schres

# Motion energy analysis reveals altered body movement in youth at risk for psychosis

Derek J. Dean [a,b,*], Alayna T. Samson [c], Raeana Newberry [a], Vijay A. Mittal [d,e,f,g]

[a] University of Colorado Boulder, Department of Psychology and Neuroscience, Boulder, CO, USA
[b] University of Colorado Boulder, Center for Neuroscience, Boulder, CO, USA
[c] Children's Hospital Colorado, Denver, CO, USA
[d] Northwestern University, Department of Psychology, Evanston, IL, USA
[e] Northwestern University, Department of Psychiatry, Chicago, IL, USA
[f] Northwestern University, Institute for Policy Research, Evanston, IL, USA
[g] Northwestern University, Medical Social Sciences, Chicago, IL, USA

ARTICLE INFO

*Article history:*
Received 2 April 2017
Received in revised form 23 May 2017
Accepted 26 May 2017
Available online xxxx

*Keywords:*
Movement abnormalities
Motion energy analysis
Ultrahigh risk
Psychosis
Gross motor

ABSTRACT

*Background:* Growing evidence suggests that movement abnormalities occur prior to the onset of psychosis. Innovations in technology and software provide the opportunity for a fine-tuned and sensitive measurement of observable behavior that may be particularly useful to detecting the subtle movement aberrations present during the prodromal period.
*Methods:* In the present study, 54 youth at ultrahigh risk (UHR) for psychosis and 62 healthy controls participated in structured clinical interviews to assess for an UHR syndrome. The initial 15 min of the baseline clinical interview was assessed using Motion Energy Analysis (MEA) providing frame-by-frame measures of total movement, amplitude, speed, and variability of both head and body movement separately.
*Results:* Result showed region-specific group differences such that there were no differences in head movement but significant differences in body movement. Specifically, the UHR group showed greater total body movement and speed of body movements, and lower variation in body movement compared to healthy controls. However, there were no significant associations with positive, negative or disorganized symptom domains.
*Conclusion:* This study represents an innovative perspective on gross motor function in the UHR group. Importantly, the automated approach used in this study provides a sensitive and objective measure of body movement abnormalities, potentially guiding novel assessment and prevention of symptom development in those at risk for psychosis.

Published by Elsevier B.V.

## 1. Introduction

Signs of altered motor development are increasingly recognized as an important marker of risk for psychosis (Bernard and Mittal, 2015; Mittal, 2016). A growing body of literature suggests that movement abnormalities are present long before the first signs of thought disorder and prospective studies of youth at risk for psychosis show that movement abnormalities may predict eventual transition to psychosis (Callaway et al., 2014; Mittal et al., 2008; Mittal et al., 2010b).

Assessing youth during the ultrahigh risk (UHR) period immediately prior to psychosis is important as these individuals are experiencing moderate subthreshold psychotic symptoms and a decline in functioning (Cannon et al., 2008). Current research is focused on developing innovative calculators designed to organize or weight various risk markers for psychosis (Cannon et al., 2016). These efforts are important because 10–35% of UHR cases will go on to develop a psychotic disorder within 2–3 years (Fusar-Poli et al., 2012). In addition, with relatively little experience on neuroleptic medication or long term history of illicit drug abuse compared to patients with psychosis, research with UHR individuals is potentially valuable for understanding etiological factors and markers of increased risk for the disorder.

The assessment of movement abnormalities in individuals developing psychosis has gone through exciting developments in recent years (Hirjak et al., 2015; Mittal, 2016; Mittal and Wakschlag, 2016). However, much of this research has been based on observer ratings of movement abnormalities, which require a significant amount of training and time for reliability, are more subject to rater bias, and do not provide continuous data. Developing automated assessment strategies for motor performance has several benefits over traditional methods. First, automated and instrumental measures of movement are sensitive in identifying the same individuals as traditional observer-based

* Corresponding author at: University of Colorado at Boulder, Department of Psychology and Neuroscience, Center for Neuroscience, 345 UCB, Boulder, CO 80309-0345, United States.
*E-mail address:* derek.dean@colorado.edu (D.J. Dean).

http://dx.doi.org/10.1016/j.schres.2017.05.035
0920-9964/Published by Elsevier B.V.

methods while also capturing additional individuals showing more subtle aberrations (Mentzel et al., 2016a). Second, these measures are capable of detecting kinematic variables that not readily available with observation methods (e.g., amplitude, speed, variability). Finally, automated and instrumental measures are not subject to bias (Cortese et al., 2005). More recently, there has been a growing interest in using instrumental and automated measures to understand motor performance in UHR and in patients with psychosis (Caligiuri et al., 2009; Caligiuri et al., 2010; Cortese et al., 2005; Dean and Mittal, 2015; Dean et al., 2015b; Dean et al., 2013). Furthermore, instrumental and automated measures may detect a larger proportion of movement variation than traditional observer based measures (Pappa and Dazzan, 2009). Taken together, motor performance assessment may be helpful for early detection and intervention efforts in youth at risk for the disorder.

Novel developments in video technology and custom software may allow more fine-tuned measurement of stationary and seated gross motor performance in specific regions of interests. Ramseyer and colleagues have developed Motion Energy Analysis (MEA) to look at changes in grey scale pixel density in order to measure the amount of movement in user-defined regions of interest (Ramseyer and Tschacher, 2011, 2014; Tschacher et al., 2014). Moreover, this technology has been used to study impairment in nonverbal communication in schizophrenia patients, which may be impaired prior to the onset of psychosis (Kupper et al., 2010; Kupper et al., 2015; Walther and Mittal, 2016). In recent years, instrumental and automated procedures have elucidated motor abnormalities in these domains during the UHR period and in formal psychosis. However, our understanding of gross motor movement is more limited and this technology may allow objective quantification of multiple aspects of movement kinematics that are not ratable by an observing clinician including the size (amplitude) of movements, their speed and variability. Examining movement kinematics during seated communication may aid in symptom assessment and therapeutic efforts (Ramseyer and Tschacher, 2011) as well as treatment response (Caligiuri et al., 2009; Caligiuri et al., 2010; Caligiuri et al., 2006).

The current study seeks to examine gross motor behavior using an automated approach in a sample of UHR and healthy control participants. Each participant was recorded during a structured clinical interview. A 15-min segment of the clinical interview footage was subjected to MEA. Data was processed and target variables for total movement, amplitude of movements, speed of movement, and coefficient of variability of movement were extracted for both the head and body separately. Previous work with traditional observer-based scoring of head and body regions from video recordings has noted that at risk individuals and patients with schizophrenia show abnormal movements (Compton et al., 2015; Mentzel et al., 2017; Mittal et al., 2007b). We hypothesized that the UHR group would show more movement in general, greater movement amplitude and speed, and more variability of movement in both the head and body. Because this is the first study to examine gross motor behavior using MEA, exploratory analysis was conducted to examine relationships between movement kinematic variables and positive, negative and disorganized UHR symptoms.

## 2. Materials and methods

### 2.1. Participants

Adolescent and young adult UHR and healthy control participants between 12 and 21 years of age (mean age = 18.68) were recruited by Craigslist, email postings, newspaper ads, and community professional referrals. Exclusion criteria consisted of head injury, the presence of a neurological disorder, and lifetime substance dependence. The presence of an Axis I psychotic disorder (e.g., schizophrenia, schizoaffective disorder, schizophreniform) was an exclusion criterion for UHR participants. The presence of any category of Axis I disorder or a psychotic disorder in a 1st degree relative was an exclusion criterion for controls. The protocol and informed consent procedures were approved by the University Institutional Review Board. See Table 1 for the demographic characteristics of the sample.

### 2.2. Clinical interviews

The Structured Interview for Prodromal Syndromes (SIPS) (Miller et al., 1999) was administered to both UHR and control subjects to diagnose a UHR syndrome (the SIPS was used to rule out UHR symptoms in healthy controls). Participants in the present study met SIPS criteria for a prodromal or high-risk syndrome, defined by moderate to severe but not psychotic levels of positive symptoms (rated from 3 to 5 on a six-point scale) and/or a decline in global functioning accompanying the presence of schizotypal personality disorder and/or a family history of schizophrenia (Miller et al., 2002). The SIPS gages distinct categories of prodromal symptoms including positive and negative domains. A total sum score for each domain is used as an indicator of the respective dimensions of symptomatology.

The Structured Clinical Interview for Axis-I DSM-IV Disorders (SCID) (First et al., 1995) was administered to rule out a psychotic disorder diagnosis. Training of advanced doctoral student interviewers was conducted over a 2-month period, and inter-rater reliabilities exceeded the minimum study criterion of Kappa ≥ 0.80.

Antipsychotic prescription and dosage information was collected for each participant. The chlorpromazine equivalent (CPZ) dosage was calculated for each participant currently taking antipsychotic medication ($n = 7$) (Woods, 2003).

### 2.3. Motion energy analysis

Motion energy analysis (MEA) was completed using an automated software program specifically designed to measure movement in predefined regions of interest (ROI) in digital video recordings. This program provides frame-by-frame parameters of grey scale intensity during the video recording (Kupper et al., 2015; Ramseyer and Tschacher, 2011, 2014; Tschacher et al., 2014). Participants provided consent to be videotaped during the clinical interviews and were recorded using a high-resolution video camera (Sanyo VCC-HD4600P). The first 15 min of the SIPS clinical interview was trimmed and subjected to MEA based on similar duration of videos in past studies (Kupper et al., 2010; Ramseyer and Tschacher, 2014). This section of the video was chosen in order to maximize consistency of context for the video

**Table 1**
UHR and healthy controls did not differ in terms of age, education, gender, and parental education. UHR participants were rated significantly higher on positive, negative and disorganized symptom domains at baseline. NS indicates not significant.

| | UHR | Control | Statistic | p ≤ |
|---|---|---|---|---|
| Age | | | | |
| Mean (SD) | 18.78 (1.82) | 18.60 (2.35) | $t(114) = 0.46$ | NS |
| Gender | | | | |
| Male | 31 | 28 | | |
| Female | 23 | 34 | | |
| Total | 54 | 62 | $\chi^2(1, N = 116) = 1.28$ | NS |
| Education (years) | | | | |
| Mean (SD) | 12.46 (1.79) | 12.62 (2.43) | $t(113) = 0.40$ | NS |
| Parent Education | | | | |
| Mean (SD) | 15.57 (2.48) | 15.56 (2.56) | $t(114) = 0.04$ | NS |
| Symptoms | | | | |
| Positive: Mean (SD) | 12.30 (4.79) | 0.50 (1.22) | $t(59.03) = 17.59$ | 0.001 |
| Negative: Mean (SD) | 9.67 (7.1) | 0.47 (1.04) | $t(54.97) = 9.43$ | 0.001 |
| Disorganized: Mean (SD) | 5.77 (3.77) | 0.31 (0.71) | $t(56.32) = 10.36$ | 0.001 |

Please cite this article as: Dean, D.J., et al., Motion energy analysis reveals altered body movement in youth at risk for psychosis, Schizophr. Res. (2017), http://dx.doi.org/10.1016/j.schres.2017.05.035