



Contents lists available at ScienceDirect

Schizophrenia Research

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

Beat gestures and postural control in youth at ultrahigh risk for psychosis

K. Juston Osborne^{a,*}, Jessica A. Bernard^{d,e}, Tina Gupta^a, Derek J. Dean^{b,c}, Zachary Millman^f, Teresa Vargas^a, Ivanka Ristanovic^a, Jason Schiffman^f, Vijay A. Mittal^g

^a Northwestern University, Department of Psychology, Evanston, Chicago, IL, USA

^b University of Colorado Boulder, Department of Psychology, Boulder, CO, USA

^c University of Colorado Boulder, Center for Neuroscience, Boulder, CO, USA

^d Texas A&M University, Department of Psychology, College Station, TX, USA

^e Texas A&M Institute for Neuroscience, College Station, TX, USA

^f University of Maryland Baltimore, Department of Psychology, Baltimore, MD, USA

^g Northwestern University, Department of Psychology, Department of Psychiatry, Institute for Policy Research, Department of Medical Social Sciences, Evanston, Chicago, IL, USA

ARTICLE INFO

Article history:

Received 13 October 2016

Received in revised form 15 November 2016

Accepted 18 November 2016

Available online xxxx

Keywords:

Gesture

Postural sway

Cerebellum

Prodrome

Psychosis

ABSTRACT

Beat gestures, rhythmic hand movements that co-occur with speech, appear to be uniquely associated with the cerebellum in healthy individuals. This behavior may also have relevance for psychosis-risk youth, a group characterized by cerebellar dysfunction. This study examined beat gesture frequency and postural sway (a sensitive index of cerebellar functioning) in youth at ultrahigh risk (UHR) for psychosis. Results indicated that decreased beat gesture frequency, but not self-regulatory movement, is associated with elevated postural sway, suggesting that beat gestures may be an important biomarker in this critical population.

© 2016 Published by Elsevier B.V.

1. Introduction

Longitudinal research indicates that gesture perception and performance deficits are associated with negative symptom severity and declines in functional outcome in patients with schizophrenia (Walther et al., 2016), suggesting that gestures may be useful markers of illness progression. Although the neural substrates of gesture behavior have been examined in schizophrenia patients (Straube et al., 2013a; Straube et al., 2013b), it is not well understood how gesture subtypes are related to the pathophysiology in youth with prodromal syndromes.

Recent research from our group focusing on gesture behavior in healthy individuals has indicated that beat gestures (i.e., rhythmic finger/hand movements that co-occur with speech to emphasize a word or phrase) are uniquely linked to cerebellar volume in functionally distinct subregions implicated in the timing of discrete movements (Bernard et al., 2015). Consistent with a cognitive dysmetria theory of psychosis (Andreasen et al., 1998), we believe that beat gesture abnormalities may reflect dysfunctional cerebellar integration of gesture timing and speech production. This suggests that beat gestures may be

a useful marker of cerebellar vulnerability in those with prodromal syndromes.

To test this hypothesis, we investigated the relationship between beat gesture use and postural sway, a sensitive index of cerebellar functioning (Bernard et al., 2014). Previous research indicates that when compared to healthy controls, sway area is significantly increased and closely linked with aberrant cerebello-thalamo-cortico-cerebellar circuit connectivity in UHR youth (Bernard et al., 2014). We hypothesized that increased postural sway area would be related to fewer beat gestures but not a control motor behavior (self-regulatory movements). Based on work indicating that cerebellar deficits and postural sway elevation in UHR youth are linked to negative symptoms specifically (Bernard et al., 2014; Dean et al., 2015), we predicted that beat gestures would also be correlated with this symptom domain alone.

2. Materials and methods

2.1. Participants

The present study utilized data obtained from 39 UHR adolescents (ages 13–21; see Table 1). A prodromal syndrome was defined as moderate levels of attenuated positive psychotic symptoms and/or a decline in functioning accompanying schizotypal personality disorder and/or a family history of schizophrenia (Miller et al., 1999). Exclusion criteria

* Corresponding author at: Department of Psychology, Northwestern University, 2029 Sheridan Road, Evanston, IL 60208, USA.

E-mail address: juston.osborne@u.northwestern.edu (K.J. Osborne).

Table 1

Demographic characteristics and descriptive statistics for beat gesture and self-regulatory behavior frequency and postural sway in youth with a prodromal syndrome.

Age	
Mean (SD)	18.43 (2.08)
Gender	
Male	16
Female	14
Total	30
Positive symptoms	
Mean (SD)	11.73 (5.01)
Negative symptoms	
Mean (SD)	10.21 (7.29)
Postural sway	
EOOB	38.77 (48.2)
EOCB	95.28 (80.23)
ECOB	59.29 (101.79)
ECCB	127.63 (134.28)
Beat gesture frequency	
Mean (SD)	8.4 (7.2)
Self-regulatory behavior	
Mean (SD)	75.2 (30.32)
Total speech time	
Mean (SD)	7.38 min (2.86 min)

Note: eyes open-open base (EOOB); eyes open-closed base (EOCB); eyes closed-open base (ECOB); eyes closed-closed base (ECCB).

consisted of any life-time history of head injury, substance dependence, a psychotic disorder, or the presence of a neurological disorder. In order to control for effects of alcohol consumption on postural sway (Deshmukh et al., 2002), nine participants that reported regular alcohol use (3 or more days of alcohol consumption per week) were excluded. Thus, the final sample consisted of 30 UHR individuals. All participants provided informed consent in accordance with the protocol approved by the Institutional Review Board. Other investigations have used subsets of this sample to examine associations between cerebellar connectivity, postural control, and symptom severity in UHR youth (Bernard et al., 2014; Dean et al., 2015). The current study is the first to use this sample to investigate the relationship between beat gesture frequency and postural sway.

2.2. Clinical interviews

The Structured Interview for Prodromal Syndromes (SIPS; Miller et al., 1999) was administered to diagnose a prodromal syndrome. Sum scores for each symptom domain were used to measure severity of positive and negative symptoms. To rule out the presence of a psychotic disorder, each participant was administered the Structured Clinical Interview for Axis-I DSM IV Disorders (First et al., 1995). Inter-rater reliabilities of the interviewers exceeded the minimum study criterion of Kappa ≥ 80 . Alcohol use frequency was assessed with the Alcohol Use Scale (AUS; Drake et al., 1996).

2.3. Beat gesture coding

For each participant, 15 min of a structured clinical interview was video recorded and used to code beat gesture frequency. The total speech time was recorded, and gesture frequency for each participant was divided by this number to control for variability in speech rate; this is an important correction as beat gestures are dependent on language, and participants vary on the length of answers during the structured interview. As in our prior work, a beat gesture was considered to have occurred if a participant used consecutive hand(s) strokes in at least two directions (e.g., down-up) to underscore a verbal expression; each stroke was counted as a single beat. Self-regulatory movements (i.e., readjusting clothing, twirling hair) are voluntary motor behaviors unrelated to speech that can be conscious or unconscious (Mittal et

al., 2006); they were coded as a control metric to determine whether associations between beat gestures and sway reflect more general differences in motor behavior. Highly trained raters (Cronbach's alpha's > 0.80) were blind to the hypotheses of the study.

2.4. Postural sway assessment

An Advanced Mechanical Technology Incorporated (AMTI) Accusway force platform (Watertown, MA) was used to measure postural sway. Participants were instructed to stand still in the middle of the force platform with their hands resting at their sides and their eyes focused on a fixation point. Conditions were administered in the following order: (1) eyes open, open base (EOOB), (2) eyes closed, open base (ECOB), (3) eyes open, closed base (EOCB), and (4) eyes closed, closed base (ECCB). The sway conditions are designed to provide increased challenge to cerebellar function by decreasing balance stability (i.e., feet close together) and sensory information (i.e., eyes closed). The center of pressure (COP) was recorded at a 50 Hz sampling rate during each condition for 2 min. We applied a 9th order Butterworth filter with a 20 Hz cutoff frequency to isolate the low-frequency postural sway process in the recorded data. COP and the 95% confidence interval of COP area were measured using principle component analysis (Oliveira et al., 1996).

2.5. Data analysis

Due to potential age related confounds associated with adolescent cerebellar development (Sowell et al., 2002), we controlled for age with partial correlations to investigate predicted associations between beat gesture frequency, sway area, and symptomatology within the UHR group. A one-way repeated measures ANOVA was used to examine the effects of sway condition on sway area. Postural sway data was unavailable for one UHR participant due to data corruption. Two-tailed tests were employed for each analysis.

3. Results

Participants used beat gestures frequently ($M = 8.4$), and showed variability in this behavior ranging from 0.75–26.60 gestures in the coding period. Self-regulatory movements ranged from 30 to 164 and also occurred frequently ($M = 75.2$). The results from a one-way repeated measures ANOVA indicated that participants varied significantly in sway area across condition ($F(3,84) = 10.75$; $p = 0.001$; $\eta_p^2 = 0.28$). The linear contrast was also significant ($p = 0.001$), demonstrating that sway area was largest in the limited stability and sensory condition (ECCB; $M = 127.64$) and smallest in the least challenging condition (EOOB; $M = 38.77$).

3.1. Relationship between beat gestures, postural sway, and symptoms

Partial correlations revealed that decreased beat gesture frequency was associated with elevated sway area in the EOCB condition, $r = -0.40$, $p = 0.04$. There was also a significant negative relationship between beat gesture frequency and sway area in the EOOB condition, $r = -0.43$, $p = 0.04$. However, there were no significant relationships between beat gesture frequency and sway area in either of the limited sensory input conditions: ECOB ($r = -0.25$, $p = 0.20$) and ECCB ($r = -0.27$, $p = 0.20$). Associations between self-regulatory movements and sway area in any condition did not approach significance. Contrary to our prediction, beat gesture frequency was not related to negative symptoms ($r = -0.17$, $p = 0.40$). Associations with positive symptoms were also not significant ($r = -0.10$, $p = 0.60$).

4. Discussion

The present findings indicate that decreased beat gesture use is related to elevated postural sway in individuals at UHR for psychosis. Self-regulatory movements were not associated with postural sway, suggesting that beat gestures may specifically tap into cerebellar dysfunction in high-risk individuals. In line with other efforts to identify biological markers that reflect cerebellar dysfunction (Bernard et al., 2014; Dean et al., 2013; Forsyth et al., 2012; Mittal et al., 2013), these findings are particularly interesting as they indicate that beat gestures are promising candidates for future neuroimaging studies investigating markers of cerebellar functioning in people with prodromal syndromes.

Previous work suggests there are functionally distinct areas of the cerebellum (Stoodley and Schmahmann, 2009); the observed associations between decreased beat gesture use and increased postural sway in the eyes open conditions may reflect deficits in cerebellar subdivisions related to motor timing (e.g., vermis, anterior regions). However, null findings in the more challenging eyes closed conditions suggest that potential cerebellar deficits in sensory integration may mask cerebellar motor timing deficits related to gesture. Contrary to our predicted association, beat gesture use was not linked to negative symptoms. This finding was unsurprising given that previous research in schizophrenia has demonstrated weak (Matthews et al., 2013, working memory condition) or null relationships (Walther et al., 2013; Walther et al., 2015) between gesture performance and negative symptoms.

Future work may benefit from more sensitive measures of motor behavior linked to negative symptoms, such as experience sampling or actigraphy. Similarly, gesture assessment may profit from more direct measures of gesture behavior. Indeed, it has been recently demonstrated that a data glove combined with hand and arm sensors can provide quantitative assessments of gesture behavior in patients (Matthews et al., 2013). Furthermore, longitudinal research investigating beat gestures related to symptom progression will help determine the utility of beat gestures as practical indices of the pathophysiology of prodromal syndromes.

Role of funding source

This work was supported by National Institutes of Health grant nos. R01MH094650 and R21/R33MH103231 to V.A.M.

Contributors

Dr. Mittal attained funding and oversaw data collection. Dr. Mittal and Mr. Osborne conceptualized the study, conducted analyses, interpreted data and drafted the manuscript. Dr. Bernard, Mrs. Gupta, Mr. Dean, Mr. Millman, Ms. Vargas, Ms. Ristanovic, and Dr. Schiffman helped to interpret data and to draft the manuscript.

Conflicts of interest

Dr. Mittal is a consultant to Takeda Pharmaceuticals. No other authors have any disclosures.

Acknowledgments

There are no acknowledgments.

References

- Andreasen, N.C., Paradiso, S., O'leary, D.S., 1998. "Cognitive dysmetria" as an integrative theory of schizophrenia: a dysfunction in cortical-subcortical-cerebellar circuitry? *Schizophr. Bull.* 24 (2), 203–218.
- Bernard, J.A., Dean, D.J., Kent, J.S., Orr, J.M., Pelletier-Baldelli, A., Lunsford-Avery, J.R., Gupta, T., Mittal, V.A., 2014. Cerebellar networks in individuals at ultra high-risk of psychosis: impact on postural sway and symptom severity. *Hum. Brain Mapp.* 35 (8), 4064–4078.
- Bernard, J.A., B. Millman, Z., Mittal, V.A., 2015. Beat and metaphoric gestures are differentially associated with regional cerebellar and cortical volumes. *Hum. Brain Mapp.* 36 (10), 4016–4030.
- Dean, D.J., Bernard, J.A., Orr, J.M., Pelletier-Baldelli, A., Gupta, T., Carol, E.E., Mittal, V.A., 2013. Cerebellar morphology and procedural learning impairment in neuroleptic-naïve youth at ultrahigh risk of psychosis. *Clin. Psychol. Sci.* 2 (2), 152–164.
- Dean, D.J., Kent, J.S., Bernard, J.A., Orr, J.M., Gupta, T., Pelletier-Baldelli, A., Carol, E.E., Mittal, V.A., 2015. Increased postural sway predicts negative symptom progression in youth at ultrahigh risk for psychosis. *Schizophr. Res.* 162 (1), 86–89.
- Deshmukh, A., Rosenbloom, M.J., Pfefferbaum, A., Sullivan, E.V., 2002. Clinical signs of cerebellar dysfunction in schizophrenia, alcoholism, and their comorbidity. *Schizophr. Res.* 57 (2), 281–291.
- Drake, R., Mueser, K.T., McHuge, G.J., 1996. Clinical rating scales: Alcohol Use Scale (AUS), Drug Use Scale (DUS), and Substance Abuse Treatment Scale (SATS). In: Dickey, B., Sederer, L.I. (Eds.), *Outcomes Assessment in Clinical Practice*. Williams and Wilkins, Baltimore, pp. 113–116.
- First, M.B., Spitzer, R.L., Gibbon, M., Williams, J.B., 1995. Structured Clinical Interview for DSM-IV Axis I Disorders, Patient Edition, January 1995 FINAL. SCID I/P Version 2.0. Biometrics Research Department, New York State Psychiatric Institute, New York, NY.
- Forsyth, J.K., Bolbecker, A.R., Mehta, C.S., Klaunig, M.J., Steinmetz, J.E., O'Donnell, B.F., Hetrick, W.P., 2012. Cerebellar-dependent eyeblink conditioning deficits in schizophrenia spectrum disorders. *Schizophr. Bull.* 38 (4), 751–759.
- Matthews, N., Gold, B.J., Sekuler, R., Park, S., 2013. Gesture imitation in schizophrenia. *Schizophr. Bull.* 39 (1), 94–101.
- Miller, T.J., McGlashan, T.H., Woods, S.W., Stein, K., Driesen, N., Corcoran, C.M., Hoffman, R., Davidson, L., 1999. Symptom assessment in schizophrenic prodromal states. *Psychiatr. Q.* 70 (4), 273–287.
- Mittal, V.A., Tessner, K.D., McMillan, A.L., Delawalla, Z., Trotman, H.D., Walker, E.F., 2006. Gesture behavior in unmedicated schizotypal adolescents. *J. Abnorm. Psychol.* 115 (2), 351–358.
- Mittal, V.A., Dean, D.J., Bernard, J.A., Orr, J.M., Pelletier-Baldelli, A., Carol, E.E., Gupta, T., Turner, J., Leopold, D.R., Robustelli, B.L., 2013. Neurological soft signs predict abnormal cerebellar-thalamic tract development and negative symptoms in adolescents at high risk for psychosis: a longitudinal perspective. *Schizophr. Bull.* 40 (6), 1204–1215.
- Oliveira, L.F., Simpson, D.M., Nadal, J., 1996. Calculation of area of stabilometric signals using principal component analysis. *Physiol. Meas.* 17 (4), 305–312.
- Sowell, E.R., Trauner, D.A., Gamst, A., Jernigan, T.L., 2002. Development of cortical and subcortical brain structures in childhood and adolescence: a structural MRI study. *Dev. Med. Child Neurol.* 44 (01), 4–16.
- Stoodley, C.J., Schmahmann, J.D., 2009. Functional topography in the human cerebellum: a meta-analysis of neuroimaging studies. *NeuroImage* 44 (2), 489–501.
- Straube, B., Green, A., Sass, K., Kircher, T., 2013a. Superior temporal sulcus connectivity during processing of metaphoric gestures in schizophrenia. *Schizophr. Bull.* 40, 936–944.
- Straube, B., Green, A., Sass, K., Kirner-Veselinovic, A., Kircher, T., 2013b. Neural integration of speech and gesture in schizophrenia: evidence for differential processing of metaphoric gestures. *Hum. Brain Mapp.* 34 (7), 1696–1712.
- Walther, S., Vanbellingen, T., Müri, R., Strik, W., Bohlhalter, S., 2013. Impaired gesture performance in schizophrenia: particular vulnerability of meaningless pantomimes. *Neuropsychology* 51 (13), 2674–2678.
- Walther, S., Stegmayer, K., Sulzbacher, J., Vanbellingen, T., Müri, R., Strik, W., Bohlhalter, S., 2015. Nonverbal social communication and gesture control in schizophrenia. *Schizophr. Bull.*, sbu222.
- Walther, S., Eisenhardt, S., Bohlhalter, S., Vanbellingen, T., Müri, R., Strik, W., Stegmayer, K., 2016. Gesture performance in schizophrenia predicts functional outcome after 6 months. *Schizophr. Bull.*, sbw124.