Schizophrenia Bulletin vol. 49 no. 3 pp. 746–755, 2023
https://doi.org/10.1093/schbul/sbac197
Advance Access publication 20 March 2023

Self-reported Gesture Interpretation and Performance Deficits in Individuals at Clinical High Risk for Psychosis

Erica L. Karp[*,1], Trevor F. Williams[1], Lauren M. Ellman[2], Gregory P. Strauss[3], Elaine F. Walker[4], , Philip R. Corlett[5], Scott W. Woods[5], Albert R. Powers[5], James M. Gold[6], Jason E. Schiffman[7], James A. Waltz[6], Steven M. Silverstein[8], and Vijay A. Mittal[9]

[1]Department of Psychology, Northwestern University, Evanston, IL 60208, USA; [2]Department of Psychology, Temple University, Philadelphia, PA 19122, USA; [3]Departments of Psychology and Neuroscience, University of Georgia, Athens, GA 30602, USA; [4]Department of Psychology and Program in Neuroscience, Emory University, Atlanta, GA 30322, USA; [5]Department of Psychiatry, Yale University, New Haven, CT 06519, USA; [6]Maryland Psychiatric Research Center, Department of Psychiatry, University of Maryland School of Medicine, Baltimore, MD 21228, USA; [7]Department of Psychological Science, University of California, 4201 Social and Behavioral Sciences Gateway, Irvine, CA 92697, USA; [8]Departments of Psychiatry, Neuroscience and Ophthalmology, University of Rochester Medical Center, Rochester, NY 14642, USA; [9]Institutes for Policy Research (IPR) and Innovations in Developmental Sciences (DevSci), Departments of Psychology, Psychiatry, Medical Social Sciences, Northwestern University, Evanston, IL 60208, USA

[*]To whom correspondence should be addressed; Department of Psychology, Northwestern University, 2029 Sheridan Road, Evanston, IL 60208, USA; tel: 847-467-5907, fax: 847-467-5707, e-mail: erica.karp@northwestern.edu

***Background and hypothesis*: Deficits in performing and interpreting communicative nonverbal behaviors, such as gesture, have been linked to varied psychopathology and dysfunction. Some evidence suggests that individuals at risk for psychosis have deficits in gesture interpretation and performance; however, individuals with internalizing disorders (eg, depression) may have similar deficits. No previous studies have examined whether gesture deficits in performance and interpretation are specific to those at risk for psychosis. Additionally, the underlying mechanisms (eg, cognition) and consequences (eg, functioning) of these deficits are poorly understood. *Study design*: This study examined self-reported gesture interpretation (SRGI) and performance (SRGP) in those at clinical high risk for psychosis (CHR; N = 88), those with internalizing disorders (INT; N = 51), and healthy controls (HC; N = 53). Participants completed questionnaires, clinical interviews, and neurocognitive tasks. *Study results*: *Results* indicated that the CHR group was characterized by significantly lower SRGI scores than the HC or INT groups (d = 0.41); there were no differences among groups in SRGP. Within CHR participants, greater deficits in SRGP were associated with lower verbal learning and memory (r = −.33), but not general intelligence or processing speed. Furthermore, gesture deficits were associated with higher cross-sectional risk for conversion to a full psychotic disorder in the CHR group. *Conclusions*: Overall, these findings suggest that specific subdomains of gesture may reflect unique vulnerability for psychosis, self-report may be a viable assessment tool in understanding these phenomena, and gesture dysfunction may signal risk for transition to psychosis.**

Key words: CHR/prodrome/gesture/cognition/working memory

Introduction

Gesture abnormalities (eg, decreased hand movements while speaking) are found across the psychosis spectrum, with some evidence suggesting they are also found among individuals at clinical high risk (CHR) for psychosis.. CHR individuals are generally defined by the presence of attenuated positive symptoms (eg, perceptual abnormalities, unusual thought content) and a substantial risk of developing full psychosis.[1] Notably, previous research has shown that CHR individuals have gesture abnormalities,[2–5] though no studies have examined whether the interpretation of gestures is also impacted in this critical group. Despite the importance of gesture to broader social and cognitive function,[6] much remains unknown about gesture performance and interpretation abnormalities in CHR individuals. In particular, it is currently unclear whether these deficits are specific to psychosis risk or indicate liability for serious mental illnesses more broadly; if cognitive deficits, also characteristic of this population[7,8] may be linked to gesture performance and interpretation; and if gesture impairments are associated with increased risk for conversion to full psychosis. The present study aims to advance our understanding of CHR gesture abnormalities by examining both performance and interpretation, including comparisons to a group with internalizing disorders, considering potential cognitive mechanisms, and examining relationships to risk for conversion to psychotic disorders.

Walther and Mittal[9] identified partially distinct gesture processes, among which are performance and interpretation. Gesture performance involves movements accompanying speech, while interpretation involves assigning appropriate meaning to perceived gestures. In schizophrenia, reduced use of gestures is related to both positive and negative symptoms, and predictive of functional outcomes, executive functioning, and working memory impairments.[10–12] Findings from the psychosis literature indicate that patients with schizophrenia have gesture performance deficits and also tend to misinterpret hand gestures, with these two deficits being correlated.[13] While there is a smaller body of research on gesture performance and perception in the CHR group, abnormalities have been reported.[2,5] Osborne and colleagues[5] found reduced use of gestures and an association with elevated postural sway in a CHR group, suggesting associations between cerebellar dysfunction and gesture performance. Millman and colleagues[3] also reported a link between gesture performance and clinical measures of both positive and negative symptoms, as well as visual information processing deficits.

Despite initial advances in understanding gesture abnormalities in CHR individuals, important limitations to this literature exist. First, aside from the limited number of studies, most previous work in CHR individuals has focused on gesture performance, and although a body of work suggests that deficits in processing social information (eg, facial expressions) can contribute to significant dysfunction in psychosis,[14,15] at the present it is unclear whether interpretation of gestures is impacted in high-risk individuals. Second, these processes have been examined separately as opposed to jointly, so it is hard to gauge the specificity and interrelations of gesture processes within CHR individuals. Third, and potentially explaining the prior two limitations, the CHR gesture abnormality literature is mainly based on time-consuming methodologies such as behavioral coding of gesture performance. Although there is a clear benefit to observer-based and instrumental motor assessments,[16] given that other papers examining self-report motor abnormalities in psychosis-continuum populations have shown good prognostic value,[17,18] assessing gesture via self-report may be a viable alternative. Additionally self-report may offer a briefer method of assessing gesture that could allow for larger samples, measuring multiple gesture processes simultaneously, and provide additional insights. Addressing these limitations to the literature may also advance our understanding of gesture abnormality mechanisms.

Gesture processes and cognitive functioning are inextricably linked; gesture drives cognitive functioning and cognitive functioning drives gesture.[6,19,20] Structural abnormalities and aberrant functional activation have been previously linked with gesture deficits in patients with schizophrenia. Previous studies have found direct links between poor gesture performance and working memory deficits as well as reduced structural connectivity and reduced cortical thickness in patients with schizophrenia.[10,11,21–23] Previous work has also found relationships between cognitive deficits and both gesture performance and gesture perception in CHR individuals.[2,3] Nonetheless, as noted above, these studies have not simultaneously examined both gesture performance and interpretation. Furthermore, only visual information processing and verbal production have been considered as possible perceptual and cognitive impairments associated with gesture-related abnormalities. Other cognitive functions such as verbal learning and working memory have been previously linked to gesture performance in healthy populations,[23] but have yet to be studied in CHR individuals. Using self-reports of multiple gesture processes may provide an efficient approach to expanding the existing literature on CHR gesture mechanisms to include a more diverse array of cognitive processes.

An additional question is whether reported gesture abnormalities in CHR individuals are specific to this population, relative to other common psychiatric disorders. Similar gesture abnormalities are observed in individuals with depression and anxiety, which are both highly comorbid in CHR samples.[24–26] For instance, a meta-analysis of social skills deficits in depression identified that gesture performance was aberrant relative to healthy controls (HC)[26] and a recent study found that such deficits may be driven by difficulties executing gestures that are complex and convey meaning.[27] Additionally, previous studies have found that during social interactions individuals with anxiety had a high frequency of irregular and fidgety hand movements.[28,29] While previous research has examined gesture processes in schizophrenia, depression, and anxiety, comparisons between clinical groups are limited. Such comparisons could inform a better understanding of which processes are specific to psychosis risk vs which are transdiagnostic.

In the present study, gesture performance and interpretation were assessed in a sample of individuals meeting the criteria for CHR syndrome, HC, and individuals with internalizing disorders (depression, anxiety, etc.). Given that abnormalities in gesture performance and interpretation have been documented in studies with schizophrenia and gesture performance deficits have been identified within the CHR group,[2–5] we predicted that the CHR group would report less gesture performance and poorer gesture interpretation than HC. Since gesture abnormalities are present in both the CHR group[2,3,5] and individuals with internalizing disorders,[26–29] but have yet to be compared between the groups, we compared these groups on an exploratory basis. Furthermore, since gesture performance and interpretation have yet to be investigated jointly in the CHR group, we examined relationships between gesture performance, gesture interpretation and symptoms (positive, negative, etc.), and scores on measures of cognitive functioning and overall psychosis risk. Based on research linking gesture domains, such as performance and cognition,[6,19,20] we predicted gesture abnormalities would be significantly related to lower cognitive functioning, in particular impaired verbal processing and working memory. In line with research showing other domains of motor function[30–32] as well as deficits in perceiving other forms of social information can predict disease progression and ultimate conversion,[14] we predicted both gesture interpretation and gesture performance deficits would relate to symptoms and elevated conversion risk.

Methods

Participants

A total of 192 participants were recruited across 6 study sites for the Computerized Assessment of Psychosis Risk (CAPR) study; 88 in the CHR group, 51 in the internalizing disorders (INT) group, and 53 in the HC group. All participants consented and the research was approved by Northwestern University's Institutional Review Board. See table 1 for demographic information and see Mittal et al.[33] for detailed information on the CAPR study. Exclusion criteria for all participants consisted of severe head injury, the presence of a neurological disorder, lifetime alcohol or substance dependence, and lifetime history of an Axis-I psychotic disorder. In addition, for HC, the presence of a psychotic disorder in a 1st-degree relative, past/current serious psychopathology, and use of psychotropic medication were exclusion factors. The internalizing disorders group consisted of participants who have an internalizing or mood disorder (eg, anxiety disorder, depression) and do not have a CHR diagnosis; 61% had a depressive disorder, 53% had an anxiety disorder, and 53% had other internalizing disorders (eg, obsessive-compulsive disorder, post-traumatic stress disorder) and because of comorbidity there is an overlap in diagnoses. Those in the CHR group were classified as having a progressive or persistent psychosis-risk syndrome based on ratings from the *Structured Interview for Psychosis-Risk Symptoms (SIPS)*[34] and/or APS criteria on the basis of DSM-5.

Measures

Clinical Interviews and Cognitive Assessments. Interviews and assessments were conducted by trained advanced

Table 1. Demographics and Clinical Characteristics

	Clinical High Risk (CHR)	Internalizing Disorders (INT)	Healthy Controls (HC)
N	88	51	53
Age *M*(*SD*)	23.22(4.28)	23.27(4.48)	23.35(3.74)
Female	69%	78%	66%
Race			
Asian	17%	22%	24%
Black	14%	20%	15%
White	57%	49%	51%
Multiracial	12%	9%	10%
Antipsychotics	6%	2%	0%
Parental education *M*(*SD*)	15.03(2.74)	14.91(2.91)	15.29(2.55)
WRAT-4 *M*(*SD*)	109.40(14.15)	110.62(9.88)	111.95(12.97)
CES-D *M*(*SD*)	18.01(8.77)	15.16(8.55)	8.87(5.58)
SIPS positive total *M*(*SD*)	10.87(3.56)	4.22(2.74)	3.18(2.94)
Gesture interpretation			
0 (Never)	76%	96%	94%
1 (Sometimes)	21%	0%	4%
2 (Always)	3%	4%	2%
Gesture performance 1			
0 (Never)	56%	46%	47%
1 (Sometimes)	40%	40%	42%
2 (Always)	4%	14%	11%
Gesture performance 2			
0 (Never)	89%	96%	90%
1 (Sometimes)	10%	4%	8%
2 (Always)	1%	0%	2%

Note: SIPS, Structured Interview for Psychosis-risk Symptoms; CES-D, Center for Epidemiologic Studies-Depression Scale; WRAT-4, Wide Range Achievement Test; Antipsychotics refers to current usage of antipsychotic medications.

doctoral students and postdoctoral professionals, and inter-rater reliabilities exceeded the minimum study criterion of Kappa ≥0.80. The SIPS[34] version 5.6.1 was administered by raters who passed official SIPS training certified by the creators of the scale and used to detect the presence of a psychosis-risk syndrome and to determine CHR status. Total scores for positive, negative, disorganized, and general symptom domains in the SIPS were used as indicators of the respective dimensions of symptomatology. We focused on the positive and negative symptom domains in the CHR participants. The *Structured Clinical Interview for DSM-5, Research Version (SCID)*[35] was used to determine the presence of other mental disorders. The screener and then, if necessary, the modules for psychotic, bipolar, depressive, anxiety, obsessive-compulsive, trauma-related, eating, and substance use disorders were administered to all participants. In the present study, the SCID-5 was used only to determine participant inclusion status. The *Center for Epidemiologic Studies-Depression Scale (CES-D)*[36] was used to assess the presence and severity of depressive symptoms in participants.

Cognitive functioning and intelligence were assessed in all 3 groups with the Word Reading section of the *Wide Range Achievement Test-4 (WRAT-4)*,[37] the *Brief Assessment of Cognition in Schizophrenia-Symbol Coding (BACS)*,[38] and the *Hopkins Verbal Learning Test-Revised (HVLT-R)*.[39] The WRAT-4 provides a reliable estimate of premorbid intellectual functioning and is used for descriptive purposes in the present study. The BACS, a symbol coding task that assesses processing speed, is sensitive to cognitive impairments and predictive of outcomes in patients with schizophrenia. The HVLT-R assesses verbal learning and memory, and a total of the 3 immediate recall trials was used in the present study.

The overall risk for developing a psychosis spectrum disorder was assessed in the CHR group with the ShangHai At Risk for Psychosis (SHARP) program's risk calculator (RC).[40] This calculator is used to estimate an individual's probabilistic risk for developing a psychosis spectrum disorder over a 2-year span. The SHARP-RC is based on a range of SIPS variables and the *Global Assessment of Functioning (GAF)*.

Gesture Self-report. Gesture interpretation and gesture performance were assessed via the *Motor and Activity Psychosis-Risk Scale (MAP-RS),* a motor scale designed and validated for use in CHR individuals.[41] The scale includes 3 self-report items that assess gesture abnormalities. One item measures gesture interpretation (ie, "Do you have difficulty interpreting hand gestures when someone is speaking?") and 2 items measure gesture performance (ie, Gesture Performance 1: "Do you gesture when you speak?", Gesture Performance 2: "Has anyone ever told you that you do not use gesture very often when you speak?"). The first gesture performance item was reverse scored so a higher score indicated a greater deficit. The 2 gesture performance items were collapsed, and the mean was used to create a composite gesture performance variable to better reflect dysfunction. Participants rated these questions on a scale of 0 (never) to 2 (often).

Statistical Analysis

ANOVA and chi-square tests were used to compare demographics among groups. One-way ANOVA was used to assess group differences in gesture interpretation and gesture performance, with significant results followed up via Tukey HSD post hoc tests. In addition, a series of Pearson correlation analyses, and post hoc tests using the Holm correction to adjust P, were conducted within the CHR group to test the hypothesis that increased gesture deficits would significantly relate to functioning, cognition, and risk calculator scores.[1]

Results

Groups did not significantly differ in age ($F[2, 189] = 0.35$, $P = .71$), sex assigned at birth ($\chi^2[2] = 1.89$, $P = .39$), race ($\chi^2[6] = 3.75$, $P = .71$), parental education ($F[2, 180] = 0.01$, $P = .99$), current antipsychotic medications ($\chi^2[2] = 4.94$, $P = .08$), or general intelligence ($F[2, 177] = 0.58$, $P = .56$). As expected, the CHR group displayed elevated positive symptoms ($F[2, 184] = 133.2$, $P < .001$). Additionally, the CHR group and HSC group displayed elevated depressive scores as expected ($F[2, 188] = 21.87$, $P < .001$).

Group Differences in Self-reported Gesture Interpretation and Self-reported Gesture Performance

Groups significantly differed on self-reported gesture interpretation (SRGI; $F[2, 189] = 4.69$, $P = .01$). Post hoc tests showed that the CHR and INT groups ($d = 0.41$), as well as the CHR and HC groups ($d = 0.43$), differed significantly ($P < .05$); the INT and HC groups were not significantly different from each other (see figure 1). These results indicated that the CHR group was significantly more impaired in SRGI than the INT and HC groups. The ANOVA indicated no significant difference among groups for self-reported gesture performance (SRGP; $F[2, 185] = 0.65$, $P = .53$).

Gesture Associations With Cognition

Correlations with cognition scores are presented in table 2 for the CHR group. There was a significant association of HVLT-R with SRGP ($r = -.33$, $P < .01$). Post hoc tests, using the Holm correction to adjust P, also indicated a significant association of HVLT-R with SRGP

[1]Spearman correlation analyses were also conducted and produced similar results, as such the results of the more familiar Pearson correlation analyses were presented.

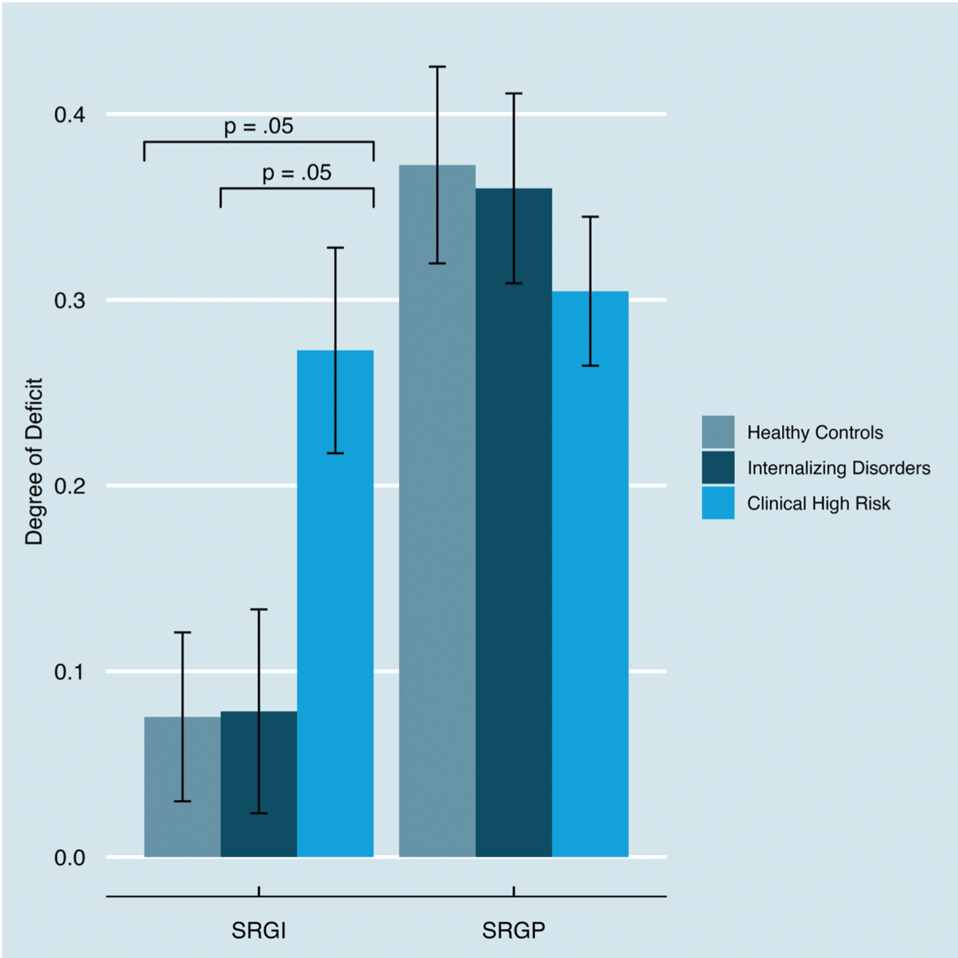

Fig. 1. Differences in self-reported gesture interpretation and self-reported gesture performance between healthy control, internalizing disorders, and clinical high-risk groups.

Table 2. Clinical High Risk Group Associations Between Self-reported Gesture Interpretation/Performance and Cognitive/Clinical Variables

	SRGI		SRGP	
	r	Adjusted *C.I.*	*r*	Adjusted *C.I.*
BACS	.06	−0.168 to 0.284	−.18	−0.436 to 0.101
HVLT-R	−.11	−0.347 to 0.133	−.33**	−0.559 to −0.045
SHARP-RC	.19	−0.082 to 0.438	.28*	0.001 to 0.517

Note: SRGI, Self-Reported Gesture Interpretation; SRGP, Self-Reported Gesture Performance; BACS, Brief Assessment of Cognition in Schizophrenia-Symbol Coding; HVLT-R, Hopkins Verbal Learning Test-Revised; SHARP, ShangHai At Risk for Psychosis Risk Calculator.
* $P < .05$, ** $P < .01$.

($P = .02$). Figure 2 illustrates the negative relationship between HVLT-R and SRGP, with greater SRGP deficits relating to lower HVLT-R scores. Neither SRGI nor SRGP were significantly associated with BACS scores or WRAT-4 scores. It is worth noting however that 15% of participants were missing BACS scores which may have contributed to not finding a significant correlation with either SRGI or SRGP.

Gesture Associations With Symptoms and Risk Scores

SRGP was not significantly correlated with positive, negative, or disorganized symptoms. However, there was a significant association with general symptoms ($r = -.24$, $P < .05$). General symptoms refer to the items assessing symptoms involving mood, anxiety, motor function, and sleep and this domain is not used to inform diagnosis but to inform the overall clinical picture. There was a significant association with the SHARP-RC and SRGP ($r = .28$, $P < .05$). Post hoc tests, using the Holm correction to adjust P, also indicated a significant association of SHARP-RC with SRGP ($P = .05$). Although positive, the association between SRGI and the SHARP-RC was nonsignificant ($r = .19$, $P = .08$). Figure 3 illustrates the positive association

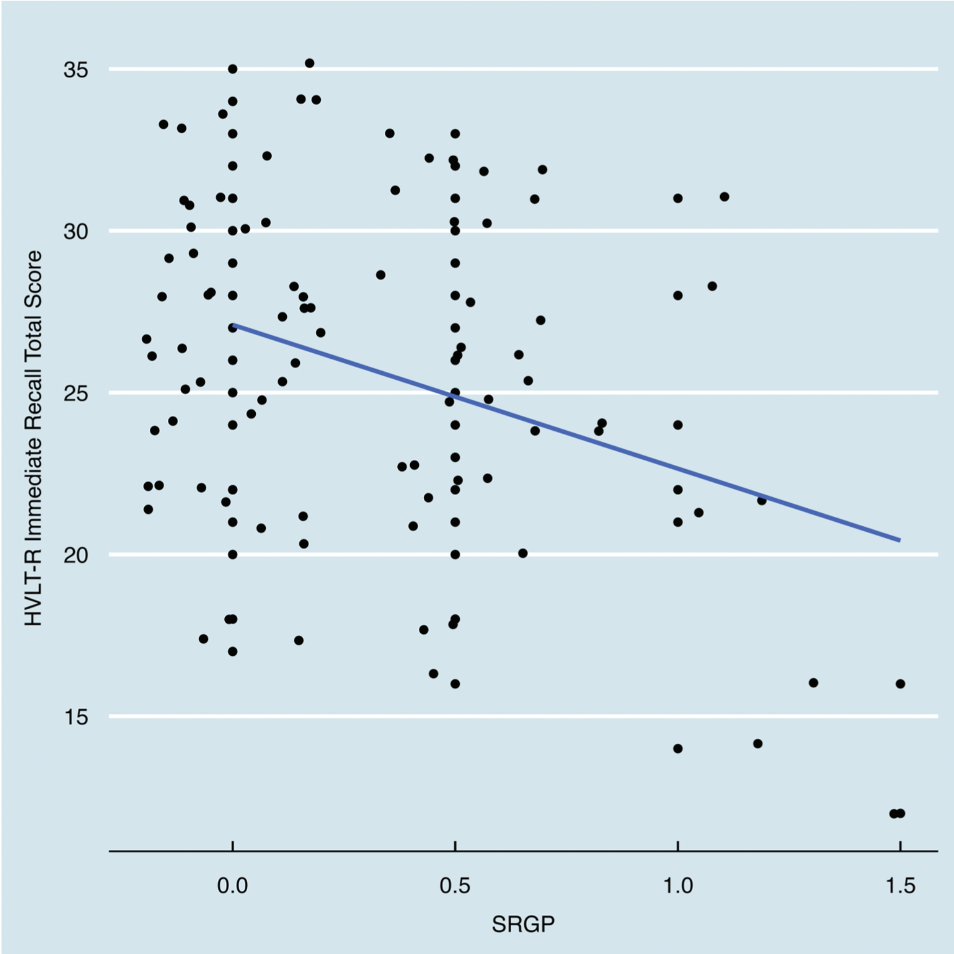

Fig. 2. Correlation between Hopkins Verbal Learning Test-Revised (HVLT-R) and self-reported gesture performance within the clinical high-risk group.

between SHARP-RC and SRGP, with greater SRGP deficits relating to higher risk rate calculations.

Correlations Between Gesture Items

Although positive, the association between SRGI and SRGP was nonsignificant (r = .16, P = .14). Since SRGP is a composite of 2 items from the gestures self-report, additional Pearson correlations were conducted with SRGI and each SRGP item. SRGI was not significantly correlated with Gesture Performance 1 (ie, "Do you gesture when you speak?"). However, there was a significant association with SRGI and Gesture Performance 2 (ie, "Has anyone ever told you that you do not use gesture very often when you speak?") (r = .24, P < .05).

Exploratory Follow-up Analyses: Depression Within CHR Group

Although there were differences between CHR individuals and individuals with an internalizing disorder in SRGI, since 32% of CHR individuals had SCID depression diagnoses, a closer examination of comorbidity within the CHR group was conducted. Exploratory follow up t-tests were conducted on CHR individuals that had comorbid depression (N = 28) and those that did not (N = 60). These 2 subgroups were compared on SRGI, SRGP, BACS, HVLT-R, and SHARP-RC. There were no significant differences between those with depression and those without on any of the aforementioned measures.

Discussion

Taken together, findings indicate that gesture impairments in those at CHR for psychosis are an important target for identifying and understanding this critical population. First, results indicated that the CHR individuals report gesture interpretation deficits when compared with both HC and INT groups, indicating that more severe gesture impairments may be a characteristic of psychosis risk syndromes. Second, for CHR individuals, lower

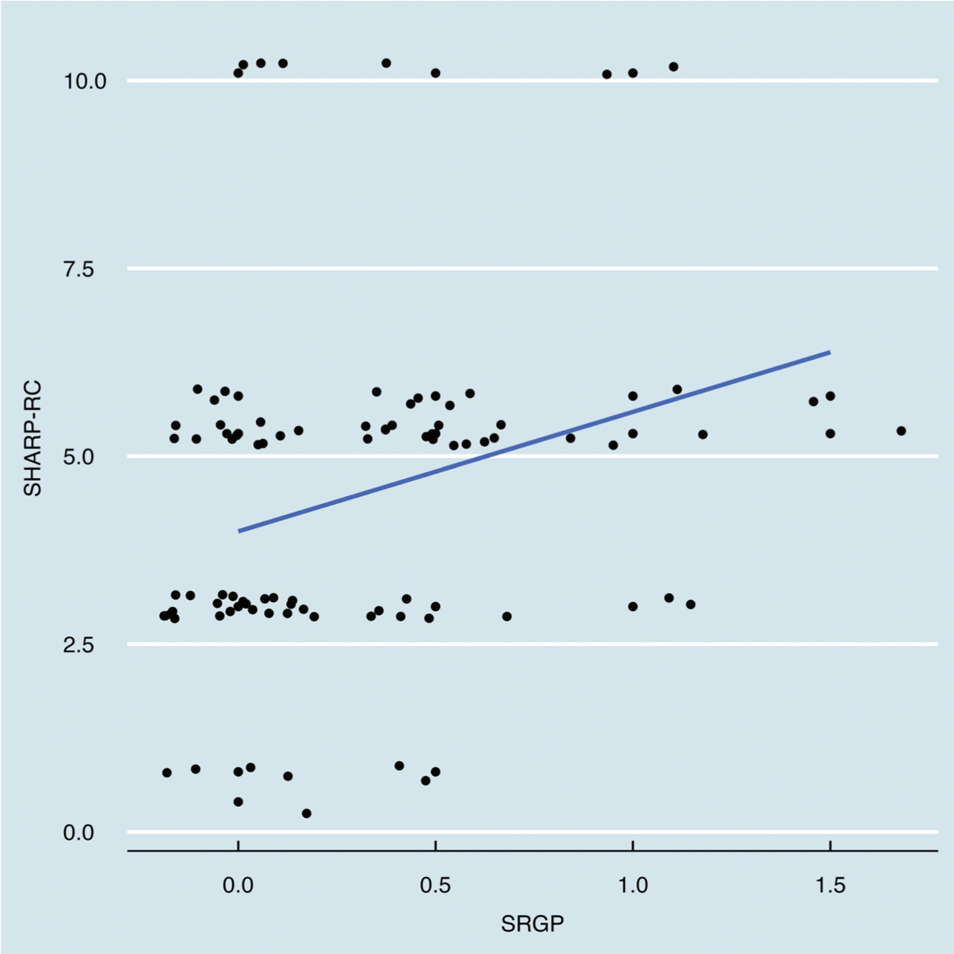

Fig. 3. Correlation between ShangHai At Risk for Psychosis (SHARP) program's risk calculator (RC) (SHARP-RC) and self-reported gesture performance within the clinical high-risk group. *Note.* SHARP-RC represents risk for conversion within a 2-year period.

SRGP was related to worse verbal learning, providing further evidence for a link between cognitive impairment and gesture abnormalities. Further, links between SRGP and a higher risk for conversion to psychosis point to the potential value of including the assessment of gesture deficits in predictive algorithms that inform clinical decision making. Finally, these findings indicate the promise of self-report methods for assessing gesture behavior.

The present study is the first to find that the gesture interpretation impairments found in patients with schizophrenia[13,42] also present in those at risk for psychosis. Although no previous study had examined gesture interpretation in CHR individuals, Gupta and colleagues[2] examined a related process—gesture perception which encompasses attention and capture of information from others' gestures—and found impairments in CHR individuals. Using an eye-tracking paradigm, Gupta and colleagues[2] found that CHR individuals attended to gestures significantly less than the control group, particularly when the gestures' meanings were more abstract. These findings were attributed in part to deficits in visual processing. Gesture perception and interpretation may be linked, in that visual attention-related impairments may limit or bias the information available to interpretation.[2] Consistent with this potential connection, previous research has linked similar brain regions (eg, inferior frontal gyrus) to both gesture perception and interpretation in schizophrenia, suggesting shared neurobiological mechanisms.[42] Future research should examine the neurobiology of gesture perception and interpretation in CHR individuals, as well as explore the relation of visual processing speed to gesture interpretation.

Additionally, the present study also showed that this gesture interpretation deficit is specific to CHR individuals, relative to individuals with internalizing disorders (depression, anxiety, etc.). Previous research had found that gesture deficits correlate with depression,[2] raising the question of whether gesture deficits are specific to CHR individuals. In the current study, gesture activity did not differentiate between groups, suggesting this effect may be specific to interpretation. Although gesture interpretation was unrelated to cognition or specific symptoms, it may be related to other processes relevant to psychosis risk, such as social cognition or functioning.[14]

Although SRGP did not differentiate groups, variable behavior within the CHR group may provide important clues. As noted, those CHR individuals reporting exhibiting fewer gestures also performed more poorly on a verbal learning and memory test (ie, HVLT-R). Given the bidirectional relationship between gesture performance and cognitive processing,[6,19,20] this result indicates gesture performance may reflect an important cognitive-motor symptom. This is particularly relevant given the overlap between language and motor networks and that the same neural systems are conceptually relevant to the pathogenesis of psychosis. Indeed, the left hemispheric fronto–parieto–temporal network has been previously identified as important to gesture behavior.[22] Previous studies have found disrupted functional connectivity, reduced gray matter volume, reduced cortical thickness, and inappropriate activation within this network in schizophrenia patients.[10,22,23,43] Additionally, Steines and colleagues have found a promising link between self-reports of gesturing and the role of the inferior frontal gyrus in processing gestures in healthy subjects.[44] While the gesture network has not been explicitly examined in CHR individuals, preliminary work suggests that gesture performance in CHR individuals may be linked to cerebellar dysfunction.[5] Both the cerebellum and parts of the gesture network, such as the left inferior frontal cortex and left inferior frontal gyrus, have also been implicated in verbal working memory deficits.[45,46] The findings of the current study are consistent with this neural overlap between gesture and verbal working memory. This further supports the connection between gesture and cognitive function and indicates that self-report measures may be sensitive to such mechanistic processes.

In addition to lower verbal learning performance, SRGP was related to higher risk of developing psychosis, as indicated by the correlation with the SHARP risk calculator score. This leaves open the possibility that gesture deficits, in particular gesture performance deficits, may be a biomarker for psychosis risk. Consistent with this, previous work has shown that motor abnormalities such as dyskinesia[47] and behaviorally-coded motor abnormality indices predict conversion to psychosis.[32,48] This study is the first to show that gesture performance deficits, which represent a more complex motor behavior, may also have value for predicting conversion. To better understand the potential for gesture performance to predict the development of psychosis, future work should replicate the present findings and extend them into a longitudinal framework.

Finally, it is notable that these distinct findings, in which gesture abnormalities related to performance and interpretations showed diverging effects, point to the value of assessing multiple gesture processes and the potential for doing so efficiently through self-report. The divergence between these constructs suggests that future research may do well to simultaneously examine distinct gesture processes, so as to better understand the shared and distinct mechanisms that underlie them. Previous work has not attempted this, in part because measuring gesture processes has been burdensome and time consuming. In this study, using very brief measures of gesture processes (ie, 3 items), we were able to replicate a number of previous findings. Notably, the present study used a multimethod assessment strategy, demonstrating gesture self-reports converge with interview and behavioral measures in important ways. Expanding the development and use of self-report gesture measures will allow larger studies to examine multiple gesture processes simultaneously, when this would otherwise be impossible. In sum, self-report is a versatile and efficient method of assessing gesture abnormalities, which holds promise for advancing CHR research.

While there are many strengths to the study, including sample size and the use of clinical controls, there are limitations as well. First, in the current study, we focused our analyses on gesture performance and interpretation; future studies should consider assessing all 3 aspects of gesture and include perception. Second, gesture abnormalities were only assessed via self-report in the current study. Future studies should directly validate the self-report gesture measure alongside behavioral coding of observed gesture or perhaps another method like informant reports. Finally, that there were no significant differences across groups in terms of gesture performance may indicate a limitation of our self-report measure. Nonetheless, the findings within the CHR group suggest gesture performance self-reports may still be picking up on valuable information and deficits consistent with previous research. Given that the present study used only 2 gesture performance items, future work may successfully detect group differences with a more formal gesture scale, with a larger number of items. Additionally, given that gesture usually occurs in a social context, future work should add additional items that tap into the impaired matching of speech and gesture information seen in patients with schizophrenia. Despite these limitations, this study advances our understanding of gesture abnormalities in CHR individuals by demonstrating the specificity of gesture interpretation deficits to CHR individuals and that less gesture performance in the CHR group is linked to lower verbal learning and higher conversion risk.

Acknowledgments

The authors have declared that there are no conflicts of interest in relation to the subject of this study.

Funding

This work was supported by the National Institute of Mental Health (Grant R01MH120088).

References

1. Woods SW, Addington J, Cadenhead KS, *et al*. Validity of the prodromal risk syndrome for first psychosis: findings from the North American Prodrome Longitudinal Study. *Schizophr Bull.* 2009;35(5):894–908. doi: 10.1093/schbul/sbp027.
2. Gupta T, Osborne KJ, Mittal VA. Abnormal gesture perception and clinical high-risk for psychosis. *Schizophr Bull.* 2021;47(4):938–947. doi: 10.1093/schbul/sbab056.
3. Millman ZB, Goss J, Schiffman J, Mejias J, Gupta T, Mittal VA. Mismatch and lexical retrieval gestures are associated with visual information processing, verbal production, and symptomatology in youth at high risk for psychosis. *Schizophr Res.* 2014;158(1-3):64–68. doi: 10.1016/j.schres.2014.06.007.
4. Mittal VA, Tessner KD, McMillan AL, Delawalla Z, Trotman HD, Walker EF. Gesture behavior in unmedicated schizotypal adolescents. *J Abnorm Psychol.* 2006;115(2):351–358. doi: 10.1037/0021-843X.115.2.351.
5. Osborne KJ, Bernard JA, Gupta T, *et al*. Beat gestures and postural control in youth at ultrahigh risk for psychosis. *Schizophr Res.* 2017;185:197–199. doi: 10.1016/j.schres.2016.11.028.
6. McNeill D. *Hand and Mind: What Gestures Reveal about Thought*. Chicago, IL: University of Chicago Press; 1996. https://press.uchicago.edu/ucp/books/book/chicago/H/bo3641188.html
7. Millman ZB, Roemer C, Vargas T, Schiffman J, Mittal VA, Gold JM. Neuropsychological performance among individuals at clinical high-risk for psychosis vs putatively low-risk peers with other psychopathology: a systematic review and meta-analysis. *Schizophr Bull.* 2022;48(5):999–1010. Published online March 25, doi: 10.1093/schbul/sbac031.
8. Seidman LJ, Giuliano AJ, Meyer EC, *et al*; North American Prodrome Longitudinal Study (NAPLS) Group. Neuropsychology of the prodrome to psychosis in the NAPLS consortium: relationship to family history and conversion to psychosis. *Arch Gen Psychiatry.* 2010;67(6):578–588. doi: 10.1001/archgenpsychiatry.2010.66.
9. Walther S, Mittal VA. Why we should take a closer look at gestures. *Schizophr Bull.* 2016;42(2):259–261. doi: 10.1093/schbul/sbv229.
10. Stegmayer K, Moor J, Vanbellingen T, *et al*. Gesture performance in first- and multiple-episode patients with schizophrenia spectrum disorders. *Neuropsychobiology*. 2016;73(4):201–208. doi: 10.1159/000446116.
11. Walther S, Stegmayer K, Sulzbacher J, *et al*. Nonverbal social communication and gesture control in schizophrenia. *Schizophr Bull.* 2015;41(2):338–345. doi: 10.1093/schbul/sbu222.
12. Walther S, Eisenhardt S, Bohlhalter S, *et al*. Gesture performance in schizophrenia predicts functional outcome after 6 months. *Schizophr Bull.* 2016;42(6):1326–1333. doi: 10.1093/schbul/sbw124.
13. Bucci S, Startup M, Wynn P, Baker A, Lewin TJ. Referential delusions of communication and interpretations of gestures. *Psychiatry Res.* 2008;158(1):27–34. doi: 10.1016/j.psychres.2007.07.004.
14. Lincoln SH, Norkett EM, Frost KH, Gonzalez-Heydrich J, D'Angelo EJ. A Developmental perspective on social-cognition difficulties in youth at clinical high risk for psychosis. *Harv Rev Psychiatry.* 2017;25(1):4–14. doi: 10.1097/HRP.0000000000000125.
15. Pinkham AE, Penn DL, Perkins DO, Graham KA, Siegel M. Emotion perception and social skill over the course of psychosis: a comparison of individuals "at-risk" for psychosis and individuals with early and chronic schizophrenia spectrum illness. *Cognit Neuropsychiatry.* 2007;12(3):198–212. doi: 10.1080/13546800600985557.
16. van Harten PN, Walther S, Kent JS, Sponheim SR, Mittal VA. The clinical and prognostic value of motor abnormalities in psychosis, and the importance of instrumental assessment. *Neurosci Biobehav Rev.* 2017;80:476–487. doi: 10.1016/j.neubiorev.2017.06.007.
17. Damme KSF, Park JS, Vargas T, Walther S, Shankman SA, Mittal VA. Motor abnormalities, depression risk, and clinical course in adolescence. *Biol Psychiatry Glob Open Sci.* 2022;2(1):61–69. doi: 10.1016/j.bpsgos.2021.06.011.
18. Damme KSF, Park JS, Walther S, Vargas T, Shankman SA, Mittal VA. Depression and psychosis risk shared vulnerability for motor signs across development, symptom dimensions, and familial risk. *Schizophr Bull.* 2022;48(4):752–762. doi: 10.1093/schbul/sbab133.
19. Alibali MW, Kita S, Young AJ. Gesture and the process of speech production: we think, therefore we gesture. *Lang Cogn Process.* 2000;15(6):593–613. doi: 10.1080/016909600750040571.
20. Goldin-Meadow S. The role of gesture in communication and thinking. *Trends Cogn Sci.* 1999;3(11):419–429. doi: 10.1016/S1364-6613(99)01397-2.
21. Stegmayer K, Bohlhalter S, Vanbellingen T, *et al*. Structural brain correlates of defective gesture performance in schizophrenia. *Cortex J Devoted Study Nerv Syst Behav.* 2016;78:125–137. doi: 10.1016/j.cortex.2016.02.014.
22. Viher PV, Stegmayer K, Kubicki M, *et al*. The cortical signature of impaired gesturing: findings from schizophrenia. *Neuroimage Clin.* 2017;17:213–221. doi: 10.1016/j.nicl.2017.10.017.
23. Wüthrich F, Viher PV, Stegmayer K, *et al*. Dysbalanced resting-state functional connectivity within the praxis network is linked to gesture deficits in schizophrenia. *Schizophr Bull.* 2020;46(4):905–915. doi: 10.1093/schbul/sbaa008.
24. Addington J, Piskulic D, Liu L, *et al*. Comorbid diagnoses for youth at clinical high risk of psychosis. *Schizophr Res.* 2017;190:90–95. doi: 10.1016/j.schres.2017.03.043.
25. McAusland L, Buchy L, Cadenhead KS, *et al*. Anxiety in youth at clinical high risk for psychosis. *Early Interv Psychiatry.* 2017;11(6):480–487. doi: 10.1111/eip.12274.
26. Segrin C. A meta-analytic review of social skill deficits in depression. *Commun Monogr.* 1990;57(4):292–308. doi: 10.1080/03637759009376204.
27. Pavlidou A, Viher PV, Bachofner H, *et al*. Hand gesture performance is impaired in major depressive disorder: a matter of working memory performance? *J Affect Disord.* 2021;292:81–88. doi: 10.1016/j.jad.2021.05.055.
28. Heerey EA, Kring AM. Interpersonal consequences of social anxiety. *J Abnorm Psychol.* 2007;116(1):125–134. doi: 10.1037/0021-843X.116.1.125.
29. Reinecke KCH, Dvoretska D, Joraschky P, Lausberg H. Fidgeting behavior during psychotherapy: hand movement structure contains information about depressive symptoms. *J Contemp Psychother.* 2020;50(4):323–329. doi: 10.1007/s10879-020-09465-5.
30. Dean DJ, Walther S, Bernard JA, Mittal VA. Motor clusters reveal differences in risk for psychosis, cognitive functioning, and thalamocortical connectivity: evidence for vulnerability subtypes. *Clin Psychol Sci J Assoc Psychol Sci.* 2018;6(5):721–734. doi: 10.1177/2167702618773759.

31. Mittal VA, Tessner KD, Trottman HD, *et al*. Movement abnormalities and the progression of prodromal symptomatology in adolescents at risk for psychotic disorders. *J Abnorm Psychol.* 2007;116(2):260–267. doi: 10.1037/0021-843X.116.2.260.
32. Mittal VA, Walker EF. Movement abnormalities predict conversion to Axis I psychosis among prodromal adolescents. *J Abnorm Psychol.* 2007;116(4):796–803. doi: 10.1037/0021-843X.116.4.796.
33. Mittal VA, Ellman LM, Strauss GP, *et al*. Computerized assessment of psychosis risk. *J Psychiatry Brain Sci.* 2021;6(3):e210011. doi: 10.20900/jpbs.20210011.
34. Miller TJ, McGlashan TH, Woods SW, *et al. Structured Interview for Prodromal Symptoms*. Washington, DC: APA PsychTests; 1999.
35. First MB, Williams JB, Karg RS, Spitzer RL. *Structured Clinical Interview for DSM-5, Research Version*. Washington, DC: American Psychiatric Association; 2015.
36. Carleton RN, Thibodeau MA, Teale MJN, *et al*. The center for epidemiologic studies depression scale: a review with a theoretical and empirical examination of item content and factor structure. *PLoS One.* 2013;8(3):e58067. doi: 10.1371/journal.pone.0058067.
37. Wilkinson GS, Robertson GJ. *WRAT-4: Wide Range Achievement Test Administration Manual*. Lutz, FL: Psychological Assessment Resources Inc.; 2006.
38. Keefe RSE, Goldberg TE, Harvey PD, Gold JM, Poe MP, Coughenour L. The brief assessment of cognition in schizophrenia: reliability, sensitivity, and comparison with a standard neurocognitive battery. *Schizophr Res.* 2004;68(2-3):283–297. doi: 10.1016/j.schres.2003.09.011.
39. Brandt J, Benedict RHB. *Hopkins Verbal Learning Test – Revised (HVLT-R) | Psychology Resource Centre*. Lutz, FL: Psychological Assessment Resources Inc.; 1991. https://psycentre.apps01.yorku.ca/wp/hopkins-verbal-learning-test-revised-hvlt-r/
40. Zhang T, Xu L, Tang Y, *et al*; SHARP (ShangHai At Risk for Psychosis) Study Group. Prediction of psychosis in prodrome: development and validation of a simple, personalized risk calculator. *Psychol Med.* 2019;49(12):1990–1998. doi: 10.1017/S0033291718002738.
41. Damme KSF, Schiffman J, Ellman LM, Mittal VA. Sensorimotor and activity psychosis-risk (SMAP-R) scale: an exploration of scale structure with replication and validation. *Schizophr Bull.* 2021;47(2):332–343. doi: 10.1093/schbul/sbaa138.
42. Straube B, Green A, Sass K, Kircher T. Superior temporal sulcus disconnectivity during processing of metaphoric gestures in schizophrenia. *Schizophr Bull.* 2014;40(4):936–944. doi: 10.1093/schbul/sbt110.
43. Walther S, Mittal VA, Stegmayer K, Bohlhalter S. Gesture deficits and apraxia in schizophrenia. *Cortex.* 2020;133:65–75. doi: 10.1016/j.cortex.2020.09.017.
44. Steines M, Nagels A, Kircher T, Straube B. The role of the left and right inferior frontal gyrus in processing metaphoric and unrelated co-speech gestures. *Neuroimage* 2021;237:118182. doi: 10.1016/j.neuroimage.2021.118182.
45. Eyler LT, Jeste DV, Brown GG. Brain response abnormalities during verbal learning among patients with schizophrenia. *Psychiatry Res.* 2008;162(1):11–25. doi: 10.1016/j.pscychresns.2007.03.009.
46. Marvel CL, Desmond JE. Functional topography of the cerebellum in verbal working memory. *Neuropsychol Rev.* 2010;20(3):271–279. doi: 10.1007/s11065-010-9137-7.
47. Mittal VA, Walker EF, Bearden CE, *et al*. Markers of basal ganglia dysfunction and conversion to psychosis: neurocognitive deficits and dyskinesias in the prodromal period. *Biol Psychiatry.* 2010;68(1):93–99. doi: 10.1016/j.biopsych.2010.01.021.
48. Callaway DA, Perkins DO, Woods SW, Liu L, Addington J. Movement abnormalities predict transitioning to psychosis in individuals at clinical high risk for psychosis. *Schizophr Res.* 2014;159(2-3):263–266. doi: 10.1016/j.schres.2014.09.031.