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# Spontaneous head movements during virtual clinical interviews help predict 12-months clinical outcomes in youth at clinical high risk for psychosis

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Identifying predictors of clinical and functioning outcomes in individuals at clinical high risk (CHR) for psychosis is essential to early intervention and symptom monitoring. While motor abnormalities have been established as core features of psychosis vulnerability, the prognostic value of social motor behavior, particularly head movements during social interactions, remains underexplored despite being readily accessible and measurable by clinicians. We analyzed 10-minute of video recordings from virtual clinical interviews involving 72 individuals at CHR using an open-access video-based head tracking tool to quantify spontaneous head movements. In a longitudinal study, we examined associations between head movements, symptom severity, and global functioning at baseline and 12-month follow-up. At baseline, results showed that total amount of head movements were positively correlated with positive symptoms ($\rho = 0.37$), negative symptoms ($\rho = 0.28$), particularly social anhedonia ($\rho = 0.30$) and avolition ($\rho = 0.31$), and social functioning ($\rho = -0.33$). Head movements at baseline also predicted worsening of avolition ($R^2 = 0.36$, $\beta = 0.0002$, $p = <0.05$), and disorganized symptoms (trouble with focus and attention; $R^2 = 0.24$, $\beta = 0.0002$, $p = <0.05$) at 12-months, controlling for baseline symptomatology. Taken together, the results suggested that spontaneous head movements captured during virtual clinical interviews represent a sensitive social behavioral marker of symptom severity and future clinical course in individuals at CHR. The automated and ecological nature of the assessment offers a promising avenue for scalable and objective risk prediction and monitoring.

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## INTRODUCTION

Predicting the clinical trajectory and functional outcomes of individuals at clinical high risk (CHR) for psychosis is a growing priority in psychiatry research. The CHR syndrome is marked by the emergence of subthreshold psychotic symptoms[1] and significant deficits in social functioning[2]. Elevated social impairments during this stage has been associated with greater social and occupational dysfunction in later phases of psychosis[3], suggesting that early functional difficulties in adolescence may contribute to a more severe course of the illness. Movement abnormalities, strongly linked to global functioning, have gained attention as potential early indicators of psychosis, reflecting a core underlying vulnerability[4]. For example, spontaneous dyskinetic movements are more frequent in schizotypal adolescents compared to healthy and psychiatric controls[5]. In individuals at CHR, neuromotor abnormalities have been associated with attenuated psychotic symptoms[6], and have demonstrated predictive value for conversion to psychosis[7]. Elevated dyskinetic movements in this population have also been linked with more impaired role functioning and, crucially, to poorer social functioning one-year later[8]. Similarly, neurological soft signs have been shown to significantly predict the progression of negative symptoms over a one-year period[9]. These longitudinal findings have been particularly important in highlighting the relationship between motor abnormalities, symptomatology, and psychosocial function.

More recently, social motor behaviors have received increasing attention in the psychosis spectrum, as they usually reflect, non-exclusively, motor abnormalities within a social context[10,11]. Nonverbal behaviors such as hand gestures, facial expressions and head movements hold strong clinical potential for enhancing psychosis risk assessment and monitoring illness trajectory[12–16]. For example, spontaneous head movements during social interaction have been linked with negative symptoms, particularly blunted affect and emotional withdrawal, in individuals with schizophrenia[17]. Additionally, Lavelle et al., (2013) found that patients who exhibited more listener head nodding during conversations showed increased positive symptoms[18]. In individuals at CHR, frequency and amplitude of head movements have been associated with a range of negative and positive symptoms, including social anhedonia, avolition and disorganized communication[15,19]. Despite these promising findings, it remains unclear whether such nonverbal behaviors, especially spontaneous head movements, can prospectively predict symptom severity or long-term functional outcomes.

During social interactions, head movements are fundamental as they are performed spontaneously by both speaker and listeners

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**Table 1.** Sociodemographic characteristics, clinical symptoms and social and role functioning of participants.

| | Baseline ($N = 72$) | 12 Months ($N = 59$) | Statistic | *P* values |
|---|---|---|---|---|
| Gender | | | | |
| Female | 32 (44.4%) | 24 (40.7%) | | |
| Male | 27 (37.5%) | 24 (18.6%) | | |
| Other | 13 (18,1%) | 11 (40.7%) | | |
| Age (years) | 23.29 ± 4.1 | 23.14 ± 4.2 | | |
| Race | | | | |
| African American | 12 (16.7%) | 11 (18.6%) | | |
| American Indian | 1 (1.39%) | 1 (1.69%) | | |
| Asian | 10 (13,9%) | 8 (13.6%) | | |
| Caucasian | 34 (47.2%) | 27 (45.8%) | | |
| Pacific islanders | 1 (1.39%) | 1 (1.69%) | | |
| More than one race | 11 (15.3%) | 8 (13.6%) | | |
| Unknown | 3 (4.17%) | 3 (5.08%) | | |
| SIPS | | | | |
| P5 – Disorganized communication | 1.49 ± 1.20 | 1.41 ± 1.02 | W = 297 | 0.316 |
| N1 – Social Anhedonia | 1.42 ± 1.40 | 1.40 ± 1.34 | W = 444 | 0.644 |
| N2 - Avolition | 1.68 ± 1.36 | 1.57 ± 1.27 | W = 529 | 0.190 |
| N3 – Expression of emotion | 0.85 ± 1.37 | 0.76 ± 1.08 | W = 289 | 0.638 |
| D3 – Trouble with focus and attention | 1.93 ± 1.13 | 1.60 ± 1.28 | W = 522.5 | 0.118 |
| Positive symptom subscale | 10.57 ± 3.31 | 9.02 ± 3.64 | W = 1162 | **0.0003** |
| Negative symptom subscale | 7.79 ± 5.75 | 7.05 ± 4.99 | W = 925 | **0.014** |
| Disorganized symptom subscale | 3.97 ± 2.59 | 3.07 ± 2.43 | W = 925.5 | **0.0005** |
| GFS | 7.09 ± 1.39 | 7.40 ± 1.40 | W = 293.5 | **0.025** |
| GFR | 7.23 ± 2.07 | 7.43 ± 1.67 | W = 315.5 | 0.420 |

Mean ± standard deviation. Percentages of participants per time point are shown in parentheses for Gender and Race. Baseline and 12-month values are compared using paired Wilcoxon rank tests.
Significant differences ($p < 0.005$) are indicated in bold.
*SIPS* Structured Interview for Psychosis-Risk Syndromes, *GFS* Global Functioning – Social, *GFR* Global Functioning – Role.

to convey semantic concepts, emotion, involvement in the conversation, or to signal turn-taking[20,21]. Head movements are also readily accessible by clinicians and increasingly easy to capture. While traditionally assessed through manual coding methods[22], recent technological and methodological advancements have enabled more efficient and objective assessments of social behavior. Tools such as Motion Energy Analysis[23–25] or machine learning-based pose estimation programs[26,27] have enhanced the precision and scalability of analyzing nonverbal behavior using 2D video recordings of both in-person and virtual social interactions involving individuals with mental disorders.

The present longitudinal study aimed to replicate and extend our prior findings in a novel context. Specifically, we tested whether the total amount of spontaneously produced head movements during virtual clinical interviews reflect symptom severity and predict symptomatology and functional outcome at baseline and after 12 months in individuals at CHR for psychosis. Each participant was recorded during an online structured clinical interview, and the first 10 minutes of footage were processed using an open-access machine learning-based head tracking program. We analyzed the resulting head motion time series to calculate the total amount of head movement spontaneously produced by the participants. Participants returned 12 months later to assess symptoms severity and global functioning. Based on our previous study and similar findings linking head movement to symptomatology in CHR individuals[15,19], we first hypothesized that more head movement at baseline would be associated with increased severity of symptoms affecting social functioning and behavior at baseline, as well as with impaired global functioning. We further hypothesized that baseline head movement would also predict both symptom severity and functional outcome at 12-months follow-up.

**Table 2.** Correlations of baseline participants' head movements and baseline symptomatology and global functioning measures.

| | Baseline | |
|---|---|---|
| | Total amount of head movement | |
| Baseline | ρ | *P* values |
| SIPS | | |
| P5 – Disorganized communication | 0.16 | 0.176 |
| N1 – Social Anhedonia | 0.30 | **0.012** |
| N2 - Avolition | 0.31 | **0.007** |
| N3 – Expression of emotion | 0.08 | 0.513 |
| D3 – Trouble with focus and attention | 0.15 | 0.215 |
| Positive symptom subscale | 0.37 | **0.001** |
| Negative symptom subscale | 0.28 | **0.019** |
| Disorganized symptom subscale | 0.20 | 0.091 |
| GFS | -0.33 | 0.**006** |
| GFR | 0.01 | 0.944 |

*SIPS* Structured Interview for Psychosis-Risk Syndromes, *GFS* Global Functioning – Social, *GFR* Global Functioning – Role.
Spearman correlation analyses were used. Significant correlations ($p < 0.005$) are indicated in bold.

## RESULTS

Over the course of 12 months, positive symptoms (SIPS Positive symptom subscale), negative symptoms (SIPS Negative symptom subscale) and disorganized symptoms (SIPS Disorganized symptom subscale) significantly decreased, for the entire sample. Additionally, social functioning (GFS) significantly increased whereas role functioning (GFR) did not change (Table 1).

For the Positive symptoms subscale, 67,8% of the participants ($n = 40$) improved, 23,7% ($n = 14$) worsened, and 8,5% ($n = 5$) remained stable. For the Negative symptoms subscale, 57.6% ($n = 34$) improved, 28.8% ($n = 17$) worsened and 8,5% ($n = 5$) remained stable. For the Disorganized symptoms subscale, 57.6% ($n = 34$) improved, 23.7% ($n = 14$) worsened, and 15.2% ($n = 9$) remained stable. Notably, three participants converted to a psychotic disorder at 12-months follow-up.

Concerning our first hypothesis of head movements being linked to clinical symptoms and global functioning at baseline, correlation analyses showed that increased total amount of head movements were positively correlated with the SIPS N1 symptoms (social anhedonia), N2 symptoms (avolition), and the positive and negative symptom subscales (see Table 2). Additionally, the total amount of head movement was negatively correlated with GFS. All correlations survived FDR multiple correction. These correlations showed that the higher N1 symptoms (social anhedonia), N2 symptoms (avolition) and positive and negative symptom subscales, the more spontaneous head movements were

**Table 3.** Hierarchical linear regression analysis.

| | Block I: Baseline outcomes | | | | Block II: Head movement at Baseline | | | |
|---|---|---|---|---|---|---|---|---|
| | $R^2$ | F | β | P value | $\Delta R^2$ | F | β | P value |
| SIPS | | | | | | | | |
| P5 | 0.34 | 30.2 | 0.542 | **<0.001** | 0.006 | 15.2 | 0.0000 | 0.457 |
| N1 | 0.15 | 9.75 | 0.369 | **0.003** | 0.011 | 5.28 | 0.0001 | 0.402 |
| N2 | 0.277 | 21.08 | 0.480 | **<0.001** | 0.086 | 15.37 | 0.0002 | **0.009** |
| N3 | 0.035 | 2.00 | 0.139 | 0.163 | 0.001 | 1.01 | 0.0000 | 0.803 |
| D3 | 0.176 | 11.7 | 0.458 | **0.001** | 0.063 | 8.46 | 0.0002 | **0.039** |
| Positive symptom subscale | 0.332 | 28.3 | 0.647 | **<0.001** | 0.000 | 13.9 | 0.0000 | 0.828 |
| Negative symptom subscale | 0.421 | 39.2 | 0.564 | **<0.001** | 0.004 | 19.6 | 0.0002 | 0.528 |
| Disorganized symptom subscale | 0.227 | 16.12 | 0.431 | **<0.001** | 0.014 | 8.56 | 0.0001 | 0.324 |
| GFS | 0.228 | 16.26 | 0.457 | **<0.001** | 0.003 | 8.11 | 0.0000 | 0.661 |
| GFR | 0.188 | 12.8 | 0.324 | **<0.001** | 0.046 | 8.28 | -0.0002 | 0.076 |

*SIPS* Structured Interview for Psychosis-Risk Syndromes, *GFS* Global Functioning – Social, *GFR* Global Functioning – Role.
Significant effects ($p < 0.005$) are indicated in bold.

produced by CHR participants. Moreover, participants with less social functioning produced more spontaneous head movements during the clinical interviews.

Linear regression analyses indicated that the total amount of head movement at baseline predicted N2 symptoms (avolition; $R^2_{adj} = 0.18$, $F = 13.5$, $\beta = 0.0003$, $p = <0.001$), D3 symptoms (trouble with focus and attention; $R^2_{adj} = 0.08$, $F = 6.05$, $\beta = 0.0002$, $p = 0.017$), and the negative symptom subscale ($R^2_{adj} = 0.06$, $F = 4.39$, $\beta = 0.0007$, $p = 0.041$) of the SIPS at 12 months. Concerning our second hypothesis, hierarchical linear regression analyses tested whether head movements at baseline predicted the course of symptomatology and global functioning at 12 months, in addition to baseline scores (Table 3). Results showed that more head movements at baseline significantly accounted for 8.6% of the variance for 12-month N2 symptoms (avolition) and 6.3% of the variance for 12-month D3 symptoms (trouble with focus and attention). By adding head movements to baseline symptom severity, the models accounted for 36% of the variance of avolition and 24% of the variance of trouble with focus and attention at 12 months.

## DISCUSSION

We examined spontaneous head movements during virtual clinical interviews of individuals at CHR for psychosis and their associations with symptom severity and global functioning. Our primary findings indicated that participants who exhibited more head movements tended to report higher levels of positive and negative symptoms, particularly social anhedonia and avolition, as measured with the Structured Interview for Psychosis-Risk Syndromes[28]. These findings align with our previous work conducted using in-person interviews, where we also found that certain positive (e.g., disorganized communication) and negative symptoms (e.g., avolition, reduced emotional expression) were associated with head movement features such as amplitude and speed[15]. These findings suggest that increased total amount of head movement may reflect neuromotor dysfunctions. Motor abnormalities, such as dyskinesia, erratic movement patterns, or increased postural sway, are frequently observed in individuals at CHR and have been linked to more severe negative symptoms[9,29–31]. Furthermore, we found that greater head movement was associated with less social functioning, as measured with the Global Functioning Scale[2]. This is consistent with prior work showing that elevated dyskinetic movements in upper body, including head movements, were associated with deficits in psychosocial functioning in individuals at CHR[8]. The neural mechanisms underlying the link between motor abnormalities and psychosocial impairments have been investigated. Specifically, the striatum (responsible for processing novel stimuli and initiation of behavioral responses) plays a central role connecting the basal ganglia (responsible for motor control and executive functions) with the prefrontal cortex (responsible for decision making and social behavior regulation)[32,33]. Dysfunction within these circuits, previously demonstrated in the CHR population[34], likely contributes to both abnormal motor behaviors[35] and disruptions in higher-order cognitive and affective processes essential for social functioning[36]. It is worth noting that previous work has found multiple clusters of motor behavior in CHR samples, identifying subgroups with dyskinesia, psychomotor slowing, of neurological soft signs, each showing distinct patterns of aberrant connectivity between the thalamus and sensorimotor regions[37]. Although we did not assess motor performance in our sample, it is possible that such distinct subgroups were also present and may have contributed to the observed variability in head movements.

Additionally, we found that spontaneous head movements measured at baseline could predict SIPS rating for avolition (item N2) and trouble with focus and attention (item D3) at 12-month follow up, even when controlling for baseline symptoms severity. Avolition is a core negative symptom in the psychosis spectrum, characterized by a diminished ability to initiate and sustain goal-directed behaviors[38]. It has been consistently associated with psychomotor slowing, reduced activity level but also impaired gesture performance in schizophrenia, as it impairs the motivational and expressive processes necessary for internally motivated gesture production[39–42]. However, these characteristics have typically been assessed with self-report, clinician-rated scales, or actigraphy, which often lack the precision of head movements measurements. The present findings demonstrate that increased spontaneous head movement during social interaction may serve as a prognostic indicator of the future course of avolition. This aligns with neurodevelopmental models of schizophrenia and supports evidence that motor abnormalities can precede the onset of illness by several years[29,43].

In schizophrenia, less structured motor patterns have been shown to predict excitement and disorganization[44]. It is possible that difficulties with focus and attention hinder proper action planning and adaptative reaction to its interactive partner's behavior, which could, in turn, result in more erratic head movements. Notably, the movements measured in the present

study were produced during social interactions. Head movements are known to play a critical role in managing conversational flow[45] and serve as indicators of listening and agreement[46]. Producing such behaviors requires perception, interpretation, selection and planning of socially appropriate responses. It is well-established that individuals at CHR for psychosis experience impairments in social cognition, particularly in perceiving, interpreting and processing social signals[47]. Growing evidence also suggests deficits in nonverbal behavior performance in this population[15,16,48]. Therefore, it is important to emphasize that the head movements were assessed in a social interaction context and may reflect broader social and communicative dysfunctions rather than purely motor abnormalities. This interpretation is further supported by our finding that role functioning at 12 months tended to be negatively associated with the amount of head movement, although the effect did not reach significance ($p = 0.076$), highlighting the potential relevance of spontaneous social behavior for real-world functional outcomes.

Although we found that the symptoms tended to decline over 12 months, the magnitude of change was relatively small. While statistical significance does not necessarily imply clinical significance, which refers to the practical importance of changes for patients, the observation that the majority of individuals at CHR show improvement over time is consistent with the literature[49–51]. A key challenge, however, is identifying the minority of individuals who go on to experience worsening symptoms. For example, although "trouble with focus and attention" did not significantly change over 12 months and was not correlated with head movement at baseline, its severity at follow-up was significantly predicted by baseline head movement. This suggests that head movements during social interaction may reflect early attentional or cognitive control difficulties that become more apparent over time, underscoring the importance of early behavioral marker assessment. The use of computerized assessments and virtual clinical interviews has great potential to maximize reach and scalability. A major strength of this study lies in its novel methodological approach to assessing spontaneous head movements during virtual social interactions. The advantage of such an automatic methodology is the reduction in the need for extensive training and time-burden associated with clinicians' manual coding of nonverbal behavior and motor abnormalities. The automatic measurement of these movements can be readily implemented in future clinical assessments and hold significant promise for psychosis risk assessment and prognosis.

Several limitations of the current study warrant discussion. First, the assessment of head movements was only performed at baseline. Follow-up measures would have enabled comparisons between symptom severity trajectories and changes in head movements over time. Notably, given the small number of conversions to a psychotic disorder observed, it was not possible to conduct statistical analyses to examine the potential relationship between head movements and conversion status. Second, our analysis relied on virtual interactions. Although the videos were manually reviewed, this format lacks the standardization found in laboratory-based clinical assessments. Similarly, it may not elicit the same behaviors as real-world social interactions. Additionally, social interactions are inherently bidirectional. with both interactors influencing each other[52]. Therefore, the head movements measured in the present study may also reflect participants' ability to synchronize with their interviewers[53]. A recent study analyzing virtual clinical interviews found that individuals at CHR for psychosis exhibited reduced interpersonal head synchrony compared to healthy controls, and that it was associated with social anhedonia (Lozano-Goupil et al., in Revision). Further interactive study involving individuals at CHR are needed to disentangle internal motor abnormalities from deficits in interpersonal synchrony. Finally, a key limitation of this study is the lack of detailed speech annotations. Incorporating speech transcription, defining turn-taking, quantifying speech production, and coding emotional content could yield valuable insights into the functional role of head movements and their associations with symptoms severity and global functioning.

To conclude, we analyzed short video clips during virtual clinical interviews using automated approaches to assess the amount of head movements of individuals at CHR for psychosis and their associations with symptomatology and global functioning 12 months later. Our findings offer new insights into the links between the expression of abnormal head movements and the progression of symptomatology and functional decline in the CHR population. The use of virtual assessments combined with video-based body tracking methods hold promise not only for advancing research but also for the development of scalable and objective tools for screening, psychosis risk detection, and symptoms monitoring. The data also provide further support for the prognostic significance of psychomotor disturbance in people at risk for psychotic disorders.

## METHODS

### Participants

A total of 72 CHR participants with usable video data were selected from a larger sample recruited across six study sites (Northwestern University, Yale University, University of Georgia, Temple University, Emory University, and the University of California Irvine). In this sample, 59 CHR participants returned for their 12-month follow up clinical interview. The inclusion criteria were as follow: a) age 12-34, b) meeting Structured Interview for Psychosis-Risk Syndromes (SIPS)[28] criteria for prodromal syndrome, c) no diagnosable psychotic disorder (e.g., schizophrenia, schizoaffective disorder, psychosis, brief psychotic disorder, mood disorder with psychotic features), d) no ongoing substance use disorder other than alcohol or cannabis use disorder e) no ongoing or history of head injury, tic disorder, neurological disorder. Recruitment materials included printed and electronic fliers, radio and public transportation advertisements, and mailouts to community health care providers. Participants were also referred from other ongoing CHR studies. The study was approved by the institutional review board of Northwestern University. All adult participants provided informed consent. Minors provided written assent, and their parents or guardians provided written consent.

### Measures

The Structured Interview for Psychosis-Risk Syndromes (SIPS) version 5.6.1[28] was administered at baseline and at 12 month follow up. No intervention was administered at any site during the study period. However, participants may have received clinical care as deemed necessary, including pharmacological treatment, psychosocial support, or case management. As these data were not systematically documented, analyses examining differences by type of care were not feasible. Clinical interviews and assessments were conducted online via Zoom by trained staff, advanced doctoral students and postdoctoral professionals. Assessors passed official SIPS training certified by the creator of the scale. The SIPS was used to detect the presence of a psychosis-risk syndrome and to determine CHR status. The Structured Clinical Interview for DSM-5, Research Version (SCID; First, 2015) was used to determine the presence of other mental disorders and determine participant inclusion status. Clinical symptom ratings served as the primary outcome measure. In addition to computing the totals for the Positive, Negative, and Disorganized symptom subscales of the SIPS, we derived compositive measure of SIPS items specifically related to social functioning and behavior (P5-Disorganized communication; N1-Social anhedonia, N2-

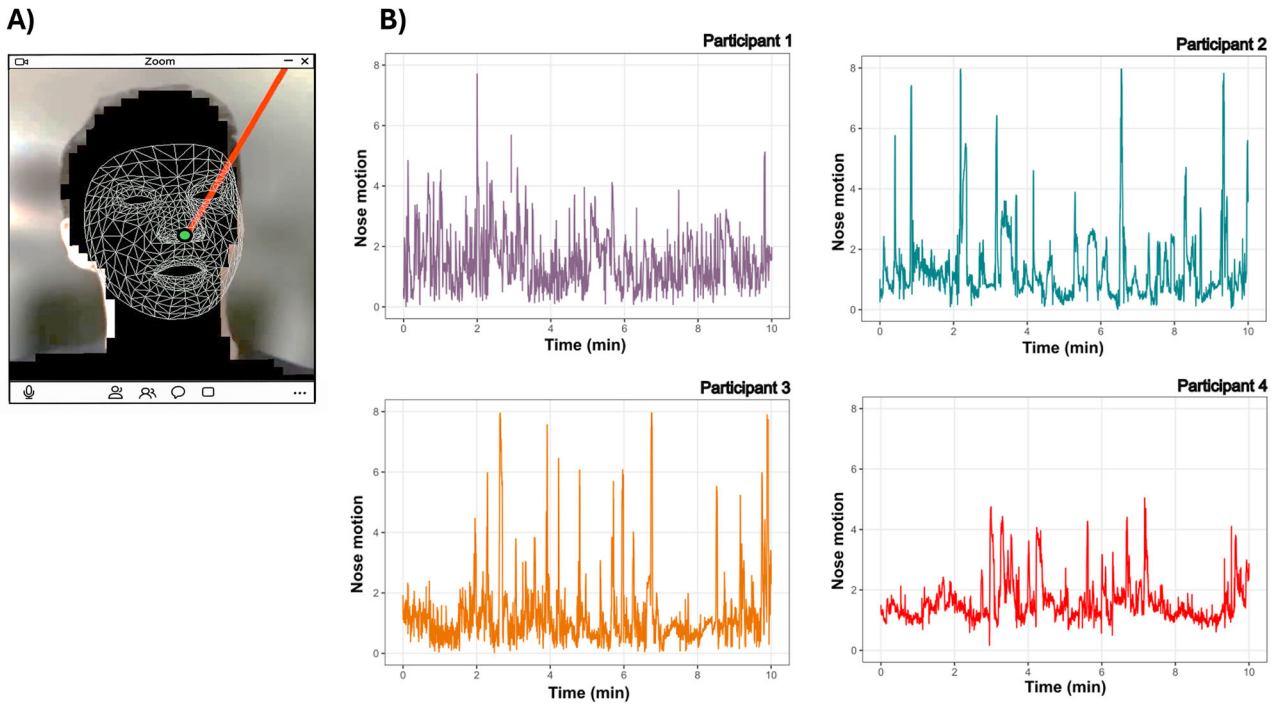


**Fig. 1 Example of head tracking and nose motion timeseries. A** Screenshot of the head tracking of a participant, with the MediaPipe Face Mesh model and the nose landmark highlighted in green. **B** Filtered and normalized nose motion timeseries across all three axes, shown for four participants.

Avolition, N3-Expression of emotion, D3-Trouble with focus and attention).

Social and role functioning was assessed at baseline and at 12 month follow up using the Global Functioning Scale: Social and Role (GFS/R)[2] and constituted the secondary outcome measure. The GFS queried peer relationships, peer conflict and family involvement. The GFR assessed performance, and the amount of support needed in the individuals' primary role.

### Head movements

The first 10 minutes of virtual clinical interviews at baseline were used to assess participants' head movements. During these first 10 minutes, the assessor collected demographic information, asking about pronouns, family, history of psychosis in the family, school, work, and religion, and could also cover living situation, history of moving, social life, and medication, depending on the pace of the questions and answers. Therefore, the interview content was generally neutral and uniform across the participants. Thin slices of behavior (1 to 10 minutes) have been shown to be sufficient for identifying alterations in social behavior, specifically head movements[15] and facial expressions[48]. To ensure accurate head tracking and approximate standardization, each video was manually verified by the experimenter prior analysis, based on the following criteria: a fixed background (no camera movement), the participant being seated, full visibility of the head, and no interruption during the interview. Interviews were recorded using Zoom's built-in recording feature in every site, so all videos share the same framerate (25 Hz), automatically determined by the Zoom software.

Footage was processed using Google's MediaPipe Face Mesh program, an open-access tool that estimates 468 3D face landmarks from a 2D video. The MediaPipe program outputted three timeseries per landmark: x and y coordinates normalized to [0.0, 1.0] based on image width and height respectively, and a z coordinate representing relative depth (with smaller values indicating landmarks closer to the camera, as the center of the head is the origin). To compute head movements, we selected the three timeseries corresponding to the nose landmark (see Fig. 1). We filtered the timeseries by applying a 3$^{rd}$-order zero-phase Butterworth filter with a frequency cutoff of 5 Hz. We then normalized the data between participants by centering (subtracting the mean) and rescaling (dividing by the standard deviation) each timeseries. Following previous studies on head movement in CHR individuals, we calculated the total amount of head movement by computing the Euclidean distance across the thee axes for obtaining the nose motion, and then we summed the resulting values over time[15,19,54].

### Statistical analysis

As clinical characteristics were not normally distributed, they were compared between Baseline and 12-month follow-up using paired Wilcoxon rank tests. Spearman correlation analyses were performed between total amount of head movements and clinical measures (SIPS symptoms and GFS/R) at baseline. Linear regressions analyses were used to predict the outcome measures at 12 months with head movements at baseline. Hierarchical linear regression analyses were applied to test the additional contribution of baseline head movements on the course of the outcome measures. We explored the effect of the baseline symptomatology and global functioning values (first step) and the additional contribution of baseline head movement variable (second step) on 12-month follow-up symptomatology and global functioning values.

## DATA AVAILABILITY

The data that support the findings of this study are available on request from the corresponding author JLG. The data are not publicly available due to them containing information that could compromise research participant consent.

## CODE AVAILABILITY

The code used to extract the 3D head trajectories from the videos is freely available via the software MediaPipe Face Mesh. The code used to compute the head motor

variables is available upon request from the corresponding author JLG. Head tracking was conducted using Python 3.12.3, and movement analysis and statistical tests were performed in RStudio 2024.12.

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## COMPETING INTERESTS

The authors declare no competing interests.

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