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Sensorimotor Transformation Deficits for Smooth Pursuit in First-Episode Affective Psychoses and Schizophrenia

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Abstract

Background—Smooth pursuit deficits are an intermediate phenotype for schizophrenia that may result from disturbances in visual motion perception, sensorimotor transformation, predictive mechanisms, or alterations in basic oculomotor control. Which of these components are the primary causes of smooth pursuit impairments and whether they are impaired similarly across psychotic disorders remain to be established.

Methods—First-episode psychotic patients with bipolar disorder ($n = 34$), unipolar depression ($n = 24$), or schizophrenia ($n = 77$) and matched healthy participants ($n = 130$) performed three smooth pursuit tasks designed to evaluate different components of pursuit tracking.

Results—On ramp tasks, maintenance pursuit velocity was reduced in all three patient groups with psychotic bipolar patients exhibiting the most severe impairments. Open loop pursuit velocity was reduced in psychotic bipolar and schizophrenia patients. Motion perception during pursuit initiation, as indicated by the accuracy of saccades to moving targets, was not impaired in any patient group. Analyses in 138 participants followed for 6 weeks, during which patients were treated and psychotic symptom severity decreased, and no significant change in performance in any group was revealed.

Conclusions—Sensorimotor transformation deficits in all patient groups suggest a common alteration in frontostriatal networks that dynamically regulate gain control of pursuit responses using sensory input and feedback about performance. Predictive mechanisms appear to be sufficiently intact to compensate for this deficit across psychotic disorders. The absence of significant changes after acute treatment and symptom reduction suggests that these deficits appear to be stable over time.

Keywords

First-episode psychosis; frontostriatal networks; motion processing; prediction; pursuit eye movements; sensorimotor transformation

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Smooth pursuit eye movement deficits are well established in schizophrenia patients and their unaffected relatives and are regarded as intermediate phenotypes for the disorder (1–4). While some studies suggest that motion perception deficits may contribute to eye-tracking abnormalities (5,6), other data point to deficits in sensorimotor transformation and in extraretinal pursuit generation (7–9). The present study was designed to evaluate different smooth pursuit components to identify the neural substrates of pursuit impairment and to investigate the specificity of such deficits across affective psychosis and schizophrenia.

Detailed analyses of distinct smooth pursuit components such as visual motion processing, sensorimotor transformation (i.e., the utilization of motion information and feedback about performance accuracy), predictive mechanisms, and basic oculomotor control are required to identify specific alterations within neural systems that can impair eye tracking. Motion perception provides the retinal velocity signal needed to initiate tracking in response to the onset of target motion, especially in the “open loop” period before visual feedback is available about performance accuracy. Pursuit of low predictability target motion relies on ongoing dynamic sensorimotor transformations, while tracking highly predictable oscillating target movement relies more heavily on internally generated predictive models of target motion (10). Core regions of the neural network for smooth pursuit involve extrastriate area V5, which is crucial for motion perception (11), the frontal eye fields (FEF), which play an important role in sensorimotor transformations that control the gain of oculomotor output (12,13), frontostriatal systems that regulate predictive pursuit (14), and cerebellopontine circuitry that controls basic oculomotor function (15). Studies in animal models provide evidence for the distinct roles of these systems in pursuit and paradigms for evaluating their integrity (16). For example, while V5 lesions disrupt motion processing and therefore impair catch-up saccade accuracy (17), FEF lesions impair sensorimotor transformations needed for pursuit maintenance but leave motion perception unimpaired (12,15,18).

In addition to questions about the specific neural system alterations that cause pursuit impairments in schizophrenia, there are also questions about the relative severity of pursuit impairments in other psychotic disorders and whether they are associated with the same specific pursuit abnormalities. Smooth pursuit alterations have been reported in patients with affective psychoses (19–24). Studies have reported similar deficits of sensorimotor transformation in mood disorders and schizophrenia (21,23), and there are preliminary data that bipolar patients may be more severely impaired during extraretinal processing for predictive pursuit compared with patients with schizophrenia (25). Limitations of prior studies comparing affective disorders and schizophrenia include small samples, pooling of patients with different affective disorders and those with and without psychotic features, and different medication treatments across affective disorders and schizophrenia that can differentially affect pursuit responses. The present study evaluated first-episode psychotic patients with bipolar disorder, unipolar depression, and schizophrenia, who were antipsychotic-naïve or had brief cumulative lifetime exposure to antipsychotics, on a set of pursuit paradigms selected to assess visual motion processing, sensorimotor function, and predictive pursuit mechanisms.

Methods and Materials

Participants

One hundred thirty-five first-episode patients comprising 50 women (38.4%) from inpatient and outpatient services from two sites, the University of Pittsburgh and the University of Illinois at Chicago, met DSM-IV criteria for bipolar I disorder with psychosis (BDP), unipolar depression with psychosis (UDP), or a schizophrenia spectrum disorder (Schiz) (Table 1). The latter group consisted of patients with schizophrenia ($n = 69$), schizophreniform disorder ($n = 4$), and schizoaffective disorder, depressed subtype ($n = 4$). Diagnoses were determined at consensus conferences, which were conducted 4 to 8 weeks after patients had given consent,

using all available clinical data, including results from the Structured Clinical Interview for DSM-IV (26). Time since first psychotic symptom did not differ between patient groups [$F_{\text{group}}(2,120) = 1.02, p = .36$] or between sites [$F_{\text{group} \times \text{site}}(2,120) = .48, p = .62$]. On the Brief Psychiatric Rating Scale (BPRS) (27), psychotic bipolar patients were less symptomatic than other patient groups [$F(2,130) = 5.13, p = .007$, post hoc: $p_{\text{BDPvsUDP}} = .01, p_{\text{BDPvsSchiz}} < .001$] (Table 1). There were no group difference across sites with respect to BPRS scores [$F_{\text{group} \times \text{site}}(2,124) = .61, p = .55$].

One hundred thirty healthy control participants including 58 women (44.6%) without history of Axis I disorders (Structured Clinical Interview for DSM-IV for Axis I Disorders [SCID-I]) or any known history of psychotic or mood disorder in first-degree relatives were recruited from the surrounding communities via advertisements. There were no group differences across recruitment sites in age [$F_{\text{group} \times \text{site}}(3,256) = .34, p = .80$] or estimated premorbid IQ [$F_{\text{group} \times \text{site}}(3,256) = 1.61, p = .19$] (Table 1).

Inclusion criteria for all participants included: 1) age between 15 and 45 years, 2) no known systemic or neurological disease, 3) no history of head trauma with loss of consciousness > 10 min, and 4) no substance dependence for at least 1 year and no substance abuse for at least 1 month. Only 25 of 135 patients had been treated previously in their lifetime with antipsychotic medication (8 BDP, 6 UDP, 11 Schiz), typically at emergency room visits before entering our clinical service. Accordingly, median cumulative lifetime exposure to antipsychotics in previously treated patients was 1.5 weeks (range up to 6 weeks). Three patients had been treated with mood stabilizers within the prior month (one BDP on valproate for 2 weeks, one UDP on gabapentin for 5 weeks, and one Schiz on valproate for 4 weeks). All preexisting medication was tapered and then discontinued at least 72 hours before testing except for four patients (two BDP, one UDP, one Schiz) who were on antidepressants; the latter are not considered to influence pursuit performance (28). All patients were off benzodiazepines for at least 48 hours before testing. The study was approved by the Institutional Review Boards of the University of Pittsburgh and the University of Illinois at Chicago, and all participants provided written informed consent. Data were collected from 1993 through 2008.

Stimulus Presentation and Eye Movement Measurement

Pursuit tasks were similar at both sites. During testing, participants had a minimum of 20/40 far acuity, with or without correction. Eye movement studies were performed in a darkened black room in which participants were seated with their heads immobilized by a chin rest with forehead and occipital restraints. In Pittsburgh, participants were placed at the center of a circular black arc (1-m radius). The visual stimulus was a red laser spot (3 mm) projected by a mirror and mounted on a rotary stage platform that moved the target across the display arc (New England Affiliated Technologies, Lawrence, Massachusetts). In Chicago, participants sat 1.39 m from the center of a flat screen display (1.82 × 2.44 m) on which a white .5° target was presented on a black background with a cathode-ray tube (CRT) projection system (Christie Digital Marquee 8500, Ultra CRT, Christie Digital Systems, Cypress, California). Participants were instructed via intercom to follow the moving target with their eyes as precisely as possible. Eye movement data were inspected online during testing, and re-alerting instructions were given if participants became inattentive. Eye movement recording was performed using infrared sensors mounted on spectacle frames (Model 210, Applied Science Laboratories, Inc., Bedford, Massachusetts). Fixation targets were presented for 5 sec at 0°, ±3°, 6°, 9°, 12°, and 15° before or after each task to calibrate the eye movement data.

Eye movement data were digitized at 500 Hz and then filtered with a nonlinear transition band between 20 Hz and 65 Hz for eye position and velocity data and 30 Hz and 65 Hz for acceleration data. Data from each trial were visually inspected to eliminate blinks and other artefacts. Saccade onset was defined as the point when eye acceleration exceeded 1000°/sec².

and saccade end points were identified at 25% of peak deceleration. Measurement resolution allowed detection of saccades with amplitudes on the order of $.25^\circ$. All saccades and a 10-msec interval following the end point of saccades were excluded from data before calculating smooth pursuit gain, which reflects the ratio of eye to target velocity. All eye movement data were scored blind to participant characteristics.

Oscillating Task—This task assessed sustained smooth pursuit of predictable oscillating target motion (Figure 1A). The paradigm was similar to an oscillating sinusoidal waveform, except that across the center of the display screen the target moved at a constant speed (29). This was done for three reasons. First, it facilitated measurement of maintenance gain by allowing comparison of average pursuit velocity to a constant stimulus velocity. Second, it provided a more direct comparison with pursuit gain measures on the ramp tasks. Third, it eliminated demands during the constant velocity epochs for ongoing dynamic adjustment of pursuit velocity and acceleration as required when tracking sinusoidal target motion. Oscillating targets moved back and forth across the screen covering $\pm 17^\circ$ in total. Beyond the positions of $\pm 12^\circ$, target speed gradually decelerated to reverse its direction at $\pm 17^\circ$, at which point it immediately accelerated again until it reached and maintained a constant speed between $\pm 12^\circ$. Blocks of target oscillation with a particular constant target speed (8° , 16° , 24° , or $32^\circ/\text{sec}$) between $\pm 12^\circ$ included 13, 15, 23, and 31 side-to-side target movements, respectively. The primary parameter of interest was maintenance gain between $\pm 10^\circ$ of target sweeps.

Ramp Task—In this task, participants tracked targets that moved at an unpredictable time, direction, and speed from center fixation (Figure 1B). Each trial started with central fixation for 2 sec to 4 sec before targets moved at a constant speed either to the left or the right at one of five target speeds (4° , 8° , 16° , 24° , or $32^\circ/\text{sec}$). The target was extinguished after reaching $\pm 15^\circ$ and reappeared at the central fixation position after a 1-sec delay to begin the next trial. Target conditions were presented in a randomized order, with each condition presented four times, resulting in a total of 40 trials (4 repetitions $\times$ 5 speeds $\times$ 2 directions). In the event that participants reduced pursuit velocity near the end of ramps, such data were removed from analyses before calculating pursuit gain. Parameters of interest were maintenance gain and latency of pursuit initiation (time for pursuit velocity to reach $2^\circ/\text{sec}$ for at least 20 msec if that preceded the first saccade).

Step-Ramp Task—This task was similar to the ramp task except that after initial central fixation for 2 sec to 4 sec, the target stepped 3° to the left or right before continuing in that direction at either 4° , 8° , 16° , or $24^\circ/\text{sec}$ (Figure 1C). This task assesses the use of visual motion information in the “open loop” period before visual feedback about performance influences pursuit responses. It consisted of 32 trials (4 repetitions $\times$ 4 speeds $\times$ 2 directions) presented in a fixed pseudorandom order. Parameters of primary interest were the position error of the initial catch-up saccade and open loop gain during the first 100 msec of pursuit after the initial catch-up saccade. These parameters together provide data regarding how the oculomotor system uses visual motion information (11). Maintenance gain in the remaining interval of closed loop pursuit beyond the first 100 msec and latency of the initial catch-up saccade were also measured.

Statistical Analysis

Measures of parameters of interest were averaged across identical trials. Since we did not find evidence for an interaction of target direction with group using four-way repeated measures analyses of variance (ANOVAs) (target direction $\times$ target speed $\times$ site $\times$ group), leftward and rightward tracking performance were combined in three-way repeated measures ANOVAs (target speed $\times$ site $\times$ group). There were no significant interactions of group and site for any parameter of interest, indicating that patient groups performed similarly across sites. The robust

effects of target speed on tracking performance are not presented in detail, as target speed effects did not differ across groups (target speed $\times$ group) for any parameter of interest. Based on these analyses, measures were averaged across sites and target speeds in figures for presentation of results. For post hoc comparisons to follow up on ANOVA effects, the results of the least significant difference procedure are reported. Spearman's rank correlations between oculomotor parameters and BPRS ratings, time since first psychotic symptom, and cumulative lifetime exposure to antipsychotic medication did not reveal significant relationships.

Results

Pursuit Maintenance

With the oscillating target task (Figure 2), maintenance gain did not differ between the four groups. In contrast, maintenance gain differed significantly between groups in the step-ramp task: $F_{\text{group}}(3,251) = 7.52, p < .001$, and the ramp task: $F_{\text{group}}(3,256) = 5.43, p = .001$. In the step-ramp task, psychotic bipolar patients had lower maintenance gain than all other participants (post hoc: $p_{\text{BDPvsUDP}} < .001, p_{\text{BDPvsSchiz}} < .001, p_{\text{BDPvsHealthy}} < .001$), and schizophrenia patients had reduced maintenance gain compared with healthy participants (post hoc: $p_{\text{SchizvsHealthy}} = .042$) (Figure 2). In the ramp task, all patient groups had decreased pursuit gain compared with healthy participants (post hoc: $p_{\text{BDPvsHealthy}} < .001, p_{\text{UDPvsHealthy}} = .016, p_{\text{SchizvsHealthy}} = .007$), and psychotic bipolar patients had lower maintenance gain than schizophrenia patients (post hoc: $p_{\text{BDPvsSchiz}} = .002$) (Figure 2).

Open Loop Pursuit

Open loop gain (Figure 3A) during the first 100 msec of postsaccadic pursuit on the step-ramp task differed significantly between groups [$F_{\text{group}}(3,248) = 3.16, p = .025$], with psychotic bipolar patients (post hoc: $p_{\text{BDPvsHealthy}} = .008$) and schizophrenia patients (post hoc: $p_{\text{SchizvsHealthy}} = .017$) demonstrating lower open loop gain than healthy participants. Spatial error of the initial catch-up saccade on the step-ramp task (Figure 3B) and latency of pursuit initiation on the ramp task did not differ between groups (Figure 3C). The latency of the initial catch-up saccade on the step ramp task differed significantly between groups [$F_{\text{group}}(3,252) = 3.53, p = .016$] with psychotic bipolar patients demonstrating the longest saccade latencies (post hoc: $p_{\text{BDPvsUDP}} = .001, p_{\text{BDPvsSchiz}} = .001, p_{\text{BDPvsHealthy}} = .006$).

Follow-Up Assessment

A total of 138 participants (18 BDP, 14 UDP, 59 Schiz, and 47 healthy) were available for follow-up testing after 6 weeks of treatment. This subsample did not differ from the full sample in sociodemographic features, baseline clinical ratings, or oculomotor performance. At follow-up, BPRS scores were significantly reduced in all patient groups compared with baseline [$F_{\text{group} \times \text{time}}(2,78) = 5.06, p = .009$] with improvement in BPRS ratings being significantly greater in patients with psychotic bipolar disorder (-11.4 [SD = 11.7], 23.5% change) and psychotic unipolar depression (-15.0 [SD = 8.6], 30.3% change) than in schizophrenia patients (-6.8 [SD = 9.0], 13.1% change). Most patients (85/91, 93%) were treated with low to moderate doses of antipsychotics including risperidone ($n = 69$, mean dosage 3.0 mg [SD = 1.9]), olanzapine ($n = 6$, mean dosage 9.2 mg [SD = 5.8]), haloperidol ($n = 4$, mean dosage 4.8 mg [SD 2.5]), aripiprazole ($n = 3$, mean dosage 20 mg [SD 8.7]), quetiapine ($n = 2$, both on 100 mg), and one patient on perphenazine (4 mg). Furthermore, 18 patients (1 BDP, 9 UPD, 8 Schiz) received antidepressants, and 4 patients (2 BDP, 1 UPD, 1 Schiz) were treated with mood stabilizers at follow-up testing. Exploratory analyses of the pursuit data revealed no patient group differences in change from baseline, i.e., no significant group by time interactions. Tables with means and standard deviations of all parameters for each task from the full baseline sample and the follow-up sample are available in Supplement 1.

Discussion

This study examined alterations in component aspects of smooth pursuit eye movement responses and their diagnostic specificity in first-episode psychosis patients with either bipolar disorder, unipolar depression, or schizophrenia. By restricting our sample to first-episode patients who were mostly antipsychotic-naïve or had been treated previously for only a very short period, we diminished potential confounds that may result from illness chronicity or differential medication treatment across patient groups. Our results demonstrate that the open loop pursuit and pursuit maintenance are impaired in first-episode psychoses and that this is more pronounced in psychotic bipolar disorder than in schizophrenia and psychotic unipolar depression. Motion perception per se as indicated by accuracy of catch-up saccades to moving targets in the step-ramp task was not impaired in any patient group. The lack of abnormality of pursuit responses in the oscillating target task suggests that basic oculomotor systems are intact in these patient groups and that predictive signals are sufficiently intact to compensate for sensorimotor impairments evident in the ramp-tracking tasks. These findings indicate a deficit in frontostriatal networks involved in the dynamic gain control of pursuit responses across psychotic disorders. There were no systematic correlations between oculomotor parameters and psychopathological symptom severity. Follow-up in a subset of participants following acute treatment and clinical stabilization did not reveal any differential recovery from or worsening of deficits across patient groups.

Common Sensorimotor Transformation Deficits Across Psychotic Disorders

Our findings document impaired pursuit maintenance in the early course of illness across schizophrenia and psychotic affective disorders on ramp tasks where performance is heavily dependent upon sensorimotor transformation. Open loop pursuit on the step-ramp task was impaired in psychotic bipolar disorder and schizophrenia but not in psychotic unipolar depression. Normal pursuit latencies in all three patient groups make it unlikely that gross attentional impairment caused these pursuit deficits. Also, accuracy of initial catch-up saccade amplitudes in the step-ramp task was not altered in any patient group. Since catch-up saccade accuracy on the step-ramp task requires a precise analysis of target speed to compensate for additional movement that occurs between the time when the saccade is planned and when it is completed, this finding suggests sufficient integrity of visual motion perception to guide eye movements to moving targets (11,21,23,30). While visual motion signals were used effectively to guide catch-up saccades and to drive the onset of pursuit responses, reduced open loop gain in psychotic bipolar and schizophrenia patients provides evidence of a diminished capacity for using this motion information for sensorimotor transformations in the pursuit system. These findings, together with a reduced capacity to use feedback about tracking error to dynamically adjust pursuit responses during the ramp tasks, indicate that alterations in sensorimotor transformation processes represent important causes of pursuit impairments in schizophrenia and psychotic bipolar disorder (9,31).

From a functional neuroanatomy perspective, these findings suggest that motion processing in area V5 is sufficiently intact to guide saccadic responses to moving targets, but the use of this motion information for sensorimotor transformations in the pursuit system is impaired. Functional neuroimaging studies in schizophrenia have not shown a consistent alteration of V5 activation during pursuit (32–34), but V5 activity appears to be decoupled from pursuit velocity in schizophrenia patients relative to their association in healthy subjects (35). These observations suggest that a disturbed downstream usage of motion information contributes to pursuit deficits in schizophrenia more than primary alterations in V5 function and motion perception per se. This interpretation is consistent with a model that dysfunctions within frontostriatal networks (8,16), which uses sensory information and extrastriate signals to guide

the dynamic regulation of pursuit gain, may represent a final common pathway for alterations in brain function underlying abnormal pursuit eye movements across psychotic disorders.

Imaging studies in schizophrenia support this hypothesis by demonstrating reduced activation during pursuit in a cortical network for sensorimotor transformation that includes the frontal and supplementary eye fields, ventral premotor cortex, basal ganglia, and anterior cingulate (32,34,36). Although not evaluated during smooth pursuit, imaging studies in patients with bipolar disorder using other paradigms have demonstrated abnormalities of frontostriatal networks early in the course of illness (37). Other evidence for shared dysfunction of frontal neural networks across psychotic disorders comes from structural imaging studies showing altered connectivity (38), reduced prefrontal gyrification associated with cognitive impairment (39), and reduced left medial frontal gray matter volume (40) across bipolar disorder and schizophrenia.

Predictive Pursuit

The absence of significantly impaired pursuit of oscillating targets, which relies heavily on internally generated prediction of target motion and rule-based learning, implies that the higher-order cognitive predictive mechanisms for sustained pursuit were sufficiently spared in all patient groups to compensate for sensorimotor transformation impairments seen on the ramp tasks. This intact performance establishes that the basic motor components of oculomotor systems for pursuit are not impaired in these psychotic disorders. Notably, our oscillating task does not require dynamic adjustments of pursuit velocity and acceleration as with sinusoidal tasks or abrupt reversals in target direction as with triangular or trapezoidal waveforms, which have been used to demonstrate pursuit deficits in many previous studies of schizophrenia (3, 29,41). Without these task demands, patients were able to precisely match eye velocity to that of the predictable target movement even at high target speeds and perform as well as healthy individuals. Predictive modulation of pursuit could be maintained by sufficiently intact components or compensatory activity in frontostriatal and frontothalamo-cerebellar circuitry that have been shown to modulate prediction, planning, and rule-based learning during pursuit in both healthy individuals and patients with schizophrenia (32,42–44).

Diagnostic Specificity

With respect to questions about the relative severity and qualitative differences in pursuit impairments between affective psychoses and schizophrenia, the present findings extend our previous reports by using a wider range of tasks, examination of unipolar and bipolar psychotic patients that has not been done previously, and short-term follow-up after clinical stabilization (21,23). The finding that sensorimotor transformation during pursuit maintenance was most severely impaired in first-episode patients with psychotic bipolar disorder suggests that frontostriatal function is significantly altered in the early course of this illness and may be even more heavily disrupted in this specific way than in schizophrenia. In contrast to other groups, patients with psychotic bipolar disorder needed more time, i.e., had longer latencies, to generate an initial catch-up saccade on the step-ramp task, and yet even with more time for response preparation, they still had the most impaired maintenance gain. The observation of impaired sensorimotor transformation during pursuit in the bipolar patients is consistent with reduced maintenance of manual force steadiness and velocity scaling (45) and persistent neurocognitive deficits early in bipolar disorder (46,47).

Sensorimotor impairments in psychotic bipolar patients may be caused by intrinsic frontostriatal disturbances or the adverse impact of affective (limbic) alterations on these systems (37,40). The latter possibility is consistent with reports from functional magnetic resonance imaging studies using cognitive paradigms in which increased activation of emotional brain areas was associated with reduced prefrontal function in bipolar disorder

(48). Our results from follow-up studies of our patients suggest that sensorimotor impairments in the pursuit system persist after clinical stabilization as do neuropsychological deficits (47).

In contrast to psychotic bipolar disorder and schizophrenia, we found sensorimotor transformation in psychotic unipolar depression to be impaired only during pursuit maintenance on the ramp task. This finding is in line with findings that frontostriatal networks may be affected differently and perhaps less severely in psychotic unipolar depression compared with psychotic bipolar disorder and schizophrenia (21,49).

Future Perspectives

The present findings point to several promising directions of research. First, the study highlights the presence of sensorimotor deficits across psychotic disorders that require further investigation to determine their pathophysiology and potential familiarity. Second, the findings point to alterations in frontostriatal systems that support visual sensorimotor transformations across psychotic disorders, suggesting that disturbances in this circuitry, whether via similar or different etiologic mechanisms, may be a common final pathway related to pursuit impairments associated with psychotic disorders (50). Functional neuroimaging studies using smooth pursuit paradigms may better define the underlying alterations in neural systems that lead to shared sensorimotor deficits across psychotic disorders. Third, the especially robust alterations of pursuit in psychotic bipolar patients require further investigation and replication. While our follow-up data suggest persistent deficits, longer-term follow-up is needed to establish if this is a stable trait or changes differentially relative to other psychotic disorders over the course of illness. Last, the observation that patients in all groups could perform our oscillating target task without impairment may be heuristically important, and future studies may follow up on this observation to identify the specific neurophysiological impairments in the pursuit system that impair pursuit on other tasks in patients with psychotic disorders while leaving pursuit performance on this task unaffected.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Figure 1.

Examples of a healthy subject at 8°/sec trials from paradigms used to evaluate smooth pursuit performance: target (dotted), eye position (black, upper trace), and eye velocity data. Saccades and blinks were removed from eye position and velocity data. Data are presented for the (A) oscillating, (B) ramp, and (C) step-ramp tasks. We note a) periods when pursuit maintenance velocity gain was assessed, b) pursuit initiation latency in the ramp task, c) the period when open loop velocity gain was assessed in the step-ramp task, as well as d) error of the initial catch-up saccade on the step-ramp task.

Figure 2.

Mean smooth pursuit maintenance gain with oscillating, step-ramp, and ramp tasks measured in first-episode psychosis patients with bipolar disorder ($n = 34$), unipolar depression ($n = 24$), schizophrenia ($n = 77$), and healthy participants ($n = 135$). Values represent group means averaged across target speeds and sites with standard errors, $*p < .05$, $**p < .01$, $***p < .001$.

Figure 3.

Mean open loop gain on the step-ramp task (A), catch-up saccade accuracy on the step-ramp task (B), and pursuit latency on the ramp task (C) measured in first-episode psychosis patients with bipolar disorder ($n = 34$), unipolar depression ($n = 24$), schizophrenia ($n = 77$) and healthy participants ($n = 135$). Values represent group means averaged across target speeds and sites with standard errors, $*p < .025$, $**p < .008$. w, with.

Table 1

Demographic and Clinical Characteristics of Matched Groups of First-Episode Patients with Psychotic Disorders and Healthy Participants

	Psychotic Bipolar Disorder (<i>n</i> = 34)	Psychotic Unipolar Depression (<i>n</i> = 24)	Schizophrenia Spectrum Disorder (<i>n</i> = 77)	Healthy Participants (<i>n</i> = 130)
Pittsburgh/Chicago, <i>n</i>	11/23	11/13	53/24	88/42
Mean Age, Years (SD)	25.0 (7.9)	23.7 (7.1)	25.7 (7.0)	26.2 (6.9)
Mean IQ (SD)	96.4 (16.9)	96.3 (18.9)	95.8 (9.6)	98.9 (7.8)
Median Time Since First Psychotic Symptom, Months	3	4.7	11.7	NA
Mean BPRS (SD)	40.5 (9.8)	46.5 (7.8)	48.6 (8.3)	NA

BPRS, Brief Psychiatric Rating Scale; IQ, intelligence quotient; NA, not applicable.