Anomalous Use of Context During Task Preparation in Schizophrenia: A Magnetoencephalography Study

Dara S. Manoach, Adrian K.C. Lee, Matti S. Hämäläinen, Kara A. Dyckman, Jesse S. Friedman, Mark Vangel, Donald C. Goff, and Jason J.S. Barton

**Background:** Impaired ability to use contextual information to optimally prepare for tasks contributes to performance deficits in schizophrenia. We used magnetoencephalography and an antisaccade task to investigate the neural basis of this deficit.

**Methods:** In schizophrenia patients and healthy control participants, we examined the difference in preparatory activation to cues indicating an impending antisaccade or prosaccade. We analyzed activation for correct trials only and focused on the network for volitional ocular motor control—frontal eye field (FEF), dorsal anterior cingulate cortex (dACC), and the ventrolateral and dorsolateral prefrontal cortex (VLPFC, DLPFC).

**Results:** Compared with control subjects, patients made more antisaccade errors and showed reduced differential preparatory activation in the dACC and increased differential preparatory activation in the VLPFC. In patients only, antisaccade error rates correlated with preparatory activation in the FEF, DLPFC, and VLPFC.

**Conclusions:** In schizophrenia, reduced differential preparatory activation of the dACC may reflect reduced signaling of the need for control. Greater preparatory activation in the VLPFC and the correlations of error rate with FEF, DLPFC, and VLPFC activation may reflect that patients who are more error prone require stronger activation in these regions for correct performance. These findings provide the first evidence of abnormal task preparation, distinct from response generation, during volitional saccades in schizophrenia. We conclude that schizophrenia patients are impaired in using task cues to modulate cognitive control and that this contributes to deficits inhibiting prepotent but contextually inappropriate responses and to behavior that is stimulus bound and error prone rather than flexibly guided by context.

**Key Words:** Anterior cingulate cortex, antisaccade, cognitive control, frontal eye field, lateral prefrontal cortex, schizophrenia.
Prior functional neuroimaging studies of antisaccades in schizophrenia have produced conflicting reports of either decreased (23,24) or no difference (25–28) in FEF activation compared with control subjects. Other studies variably report reduced activation of the lateral PFC, dACC, insula, thalamus, and striatum in patients and their healthy relatives (23–27,29,30). Discrepant findings may reflect task differences, the inclusion of error trials, and group differences in the timing of the hemodynamic response (28). Two event-related potential studies reported reduced contingent negative variation during antisaccades versus prosaccades in schizophrenia, suggesting that patients failed to modulate cognitive control based on task demands (31,32). As no prior study has distinguished preparatory activation from that due to planning and generating the motor response, it is unclear which processes contribute to increased antisaccade errors in schizophrenia.

In the present study, we exploited the msec temporal resolution of magnetoencephalography (MEG) to restrict our analyses to neural activity during task preparation during correct trials only. We compared groups on the difference in activation between antisaccades, which require a high level of control, and prosaccades, which are relatively automatic responses, in the volitional ocular motor control network, FEF, dACC, VLPFC, and DLPPC. This comparison addressed our primary hypothesis that schizophrenia patients would show reduced modulation of preparatory activation in response to cues indicating that a high versus low level of control was required. We also tested the hypothesis that preparatory activation in the FEF would predict antisaccade error rate, as it does in monkey neurophysiology studies (8).

Methods and Materials

Participants

Twenty-five outpatients with schizophrenia were recruited from an urban mental health center. With the exception of one patient who took fluphenazine, all patients had been maintained on stable doses of atypical antipsychotic medications for at least 6 weeks. Diagnoses were confirmed with Structured Clinical Interviews for DSM-IV Axis I Disorders (33). Clinical status was characterized with the Positive and Negative Syndrome Scale (34), the Scale for the Assessment of Negative Symptoms (35), and the Brief Psychiatric Rating Scale (36). Twenty healthy control participants, screened to exclude a personal history of mental illness (Structured Clinical Interviews for DSM-IV Axis I Disorders, Non-patient Edition [37]) or a family history of schizophrenia spectrum disorder, were recruited from the community by poster and website advertisements. Two control participants were excluded, one for excessive blink artifacts and one for an antisaccade error rate greater than two standard deviations higher than the group mean. All participants were screened to exclude substance abuse or dependence within the preceding 6 months and any independent conditions that might affect brain function. The final groups of 25 schizophrenia patients and 18 control participants did not differ significantly in age, sex, handedness (38,39), or mean parental education (Table 1). The study was approved by the Partners Human Research Committee and all participants gave written informed consent.

Procedures

Please see our prior publication for details of the saccadic paradigm and MEG analysis (40).

Table 1. Means, Standard Deviations, and Group Comparisons of Demographic Data and Rating Scale Scores

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Healthy Control Participants</th>
<th>Schizophrenia Patients</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>31 ± 10</td>
<td>34 ± 13</td>
<td>.86</td>
<td>.39</td>
</tr>
<tr>
<td>Sex</td>
<td>10 M/6 F</td>
<td>19 M/6 F</td>
<td>Phil = .21</td>
<td>.20</td>
</tr>
<tr>
<td>Handedness</td>
<td>81 ± 40</td>
<td>76 ± 38</td>
<td>.39</td>
<td>.69</td>
</tr>
<tr>
<td>Parental Education (Years)</td>
<td>15.5 ± 3.5</td>
<td>14.4 ± 2.4</td>
<td>1.17</td>
<td>.25</td>
</tr>
<tr>
<td>Age of Onset</td>
<td>25 ± 6</td>
<td>12 ± 11</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Length of Illness (Years)</td>
<td>10 34</td>
<td>12 ± 11</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BPRS</td>
<td>14 ± 8</td>
<td>13 ± 5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PANSS Positive</td>
<td>15 ± 5</td>
<td>Mild</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PANSS Negative</td>
<td>15 ± 5</td>
<td>Mild</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SANS</td>
<td>29 ± 17</td>
<td>Questionable</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The Phi value is the result of a Fisher’s exact test.
BPRS, Brief Psychiatric Rating Scale; F, female; M, male; PANSS, Positive and Negative Syndrome Scale; SANS, Scale for the Assessment of Negative Symptoms.

Saccadic Paradigm. The task consisted of a pseudorandom sequence of prosaccade and antisaccade trials that were balanced for right and left movements. Each saccadic trial lasted 4 seconds and began with an instructional cue, which, at 300 msec, was replaced by a central fixation ring. At 2 seconds, the fixation ring shifted to either the right or left of center for 1 second. This was the stimulus to which participants responded. During the final second of the trial, the fixation ring returned to center. Task details are provided in Figure 1. We analyzed the preparatory interval, which was the first 2 seconds of the trial before the appearance of the imperative stimulus. Saccadic trials were intermixed with intervals of fixation lasting 2, 4, or 6 seconds. Fixation intervals provided breaks and their lengths were varied to decrease the predictability of trial onset and thereby enhance attention. Participants performed eight runs of the task, each lasting 5 minutes 22 seconds, for a total time of approximately 1 hour. The experiment generated a total of 278 prosaccades, 285 antisaccades, and 107 fixation trials. The horizontal and vertical components of eye movements were recorded concurrently with the MEG, using two pairs of bipolar electro-oculogram electrodes.

MEG Data Acquisition. Magnetoencephalography data were acquired inside a magnetically shielded room (IMEDCO, Hagendorf, Switzerland) using a dc-SQUID Neuromag VectorView system (Elekta-Neuromag, Helsinki, Finland) comprising 306 sensors arranged in triplets of two orthogonal planar gradiometers and a magnetometer, distributed at 102 locations around the entire scalp. During the MEG recording, the position and orientation of the head with respect to the MEG sensor array were determined with four head position indicator coils.

Structural Magnetic Resonance Imaging Acquisition. Two T1-weighted high-resolution structural images were acquired for spatial normalization and cortical surface reconstruction using a 3.0T Siemens (Erlangen, Germany) Trio whole-body high-speed imaging device equipped for echo planar imaging and a three-dimensional magnetization prepared rapid acquisition gradient-echo sequence.

Scoring of Eye Movement Data. Electro-oculogram data were scored in MATLAB (Mathworks, Natick, MA) using a partially
automated program that determined the directional accuracy of each saccade with respect to the required response and the latency from stimulus onset. Only correct trials were analyzed. A breakdown of trial exclusions for MEG analysis and their rationale is provided in Supplement 1. Latency and error rate analyses included all scorable trials, regardless of blinks, losses of fixation, or prior errors. Error rate data were logit-transformed before analysis. We employed analyses of variance with factors for group (schizophrenia patients, healthy control participants) and trial type as a repeated measure and their interaction.

**Offline Analysis of MEG Data.** All channels were processed using the signal-space separation method (41). The data of three patients were also processed using spatiotemporal signal-space separation (42) with a correlation of limit value of .95 or higher to suppress magnetic artifact due to dental work. For offline averaging, each participant’s continuous MEG data were low-pass filtered at 40 Hz. The waveforms for correct prosaccades and antisaccades were then averaged for each participant. A 200 msec interval before the appearance of the cue was used as baseline and subtracted from each epoch before the trial was added to the average.

For source estimation, the geometry of each participant’s cortical surface was reconstructed from three-dimensional structural magnetic resonance imaging (MRI) data using FreeSurfer software (http://surfer.nmr.mgh.harvard.edu). To display activity in the sulci, inflated cortical surfaces were employed in visualization. The forward solution was calculated using a single-compartment boundary element model (43) with the inner skull surface segmented from the MRI data. The head position information from the start of each run was used in the calculation of the forward solution for each run. Activity at each cortical location was estimated every 4 msec using the anatomically constrained linear estimation approach (44–46). In calculating the average dipole waveforms, the orientation of the dipole moment was loosely constrained to the cortical normal direction by setting source variances for the transverse current components to be .1 times the variance of the currents normal to the cortical surface (47). The inverse solutions were temporally smoothed by integrating over an interval extending 2 msec in each direction.

**Intersubject Registration for Group Analysis.** Each participant’s inflated cortical surface was registered to a template brain by optimally aligning individual sulcal-gyral patterns (48). Individual data were registered to the averaged cortical surface and the results were averaged across participants.

**Region of Interest Definition.** We defined regions of interest (ROIs) for the FEF, VLPFC, DLPFC, and dACC using anatomical labels provided by an automated cortical surface-based parcellation (49). We used sulcal anatomical labels for ROIs on the lateral cortical surface, since MEG is best able to detect tangential sources (i.e., those in sulci rather than on gyri on the lateral surface). We used the superior and inferior precentral sulci as the FEF ROI (40,50), since the FEF is located in and around the superior and inferior portions of the precentral sulcus and gyrus (51–54). The DLPFC and VLPFC ROIs were defined as the superior and inferior frontal sulci, respectively. We defined the dACC ROI by combining the anterior cingulate sulci and gyri and dividing them into dorsal and rostral segments by drawing a line perpendicular to the intercommissural plane at the anterior boundary of the genu of the corpus callosum (55). As we had no a priori basis to expect lateralized effects for these regions, our ROIs included both hemispheres.

**Evaluation of Preparatory Activation.** We examined ROI activation in the preparatory (cue-stimulus) interval from 0 to 2000 msec locked to the appearance of the task cue (Figure 1). Activity was averaged across all of the vertices in each ROI at each 4-msec epoch for antisaccades and prosaccades in each participant.

We first compared activation for antisaccades versus prosaccades within each group using pairwise t tests. We considered a difference to be significant only if five consecutive 4-msec epochs met a threshold of p < .05. This method corrects for multiple comparisons over time and sets the overall alpha to p < .05 (56).

To compare groups on activation for antisaccades versus prosaccades and to test the hypothesis that preparatory activation predicts error rate, we performed a mixed model regression. We treated participant as a random effect and regressed activation on the following fixed covariates: logit transformed error rate, the interaction of error rate with group, and a full factorial of time interval (at six 250-msec epochs from 500 msec to 2000 msec), group, and ROI. Using this model, we used analysis of variance to assess the effects of: 1) group and the interaction of group by ROI on activation; and 2) error rate and the interaction of error rate with group on activation. We then examined each ROI separately to determine the direction and timing of both group differences in activation and the relations of activation with error rate.

To compare the groups on activation in each ROI, we used pairwise t tests and bootstrapping analyses. Our index of...
activation was the difference between antisaccade (AS) and prosaccade (PS) activation normalized by the sum of activation, i.e., \((AS - PS)/(AS + PS)\), in each participant at each ROI. We normalized the difference score to mitigate against the effects of variation in the amplitude of the MEG signal across participants and groups. The normalized difference scores were compared between groups at each 4-msec epoch using pairwise \(t\) tests.

As a second confirmatory analysis of group differences, we employed a bootstrapping procedure (57) to test for sustained differences in activity between groups at each ROI. These analyses used the normalized difference scores for each participant averaged over 250-msec windows, between 500 msec and 2000 msec after cue onset. The bootstrapping procedures are described in Supplement 1.

To examine the relations between preparatory activity and antisaccade error rate in each ROI, we regressed activation on error rate, time interval, group, and the group by time interaction. A compound symmetric error model was assumed for the repeated measures of activation at the six time intervals within participant. Hypothesis testing was based on sequential sums of squares.

### Results

#### Behavioral Data

Schizophrenia patients made more errors than control subjects \((F_{1,41} = 4.23, p = .05)\) and there was a group by task interaction \((F_{1,41} = 4.70, p = .04)\), reflecting that while patients...
made almost twice as many antisaccade errors as control subjects (21 ± 16% vs. 11 ± 11%; t41 = 2.95, p = .004, effect size [ES] = .52), they did not differ in prosaccade errors (5 ± 5 vs. 4 ± 3%; t41 = .31, p = .75, ES = .17). Overall, patients responded more slowly than control subjects on correct trials but not significantly so (t1,41 = 2.42, p = .13), and this did not differ by task (t1,41 = .05, p = .81; antisaccades: 318 ± 72 vs. 288 ± 47 msec, t41 = 1.57, p = .12; ES = .35; prosaccades: 269 ± 72 vs. 241 ± 39 msec, t41 = 1.47, p = .15; ES = .34).

Preparatory MEG Activation

The mixed model regression of activation, including all ROIs, showed a highly significant group by region interaction (χ² = 44.7, p = 1.1 × 10⁻⁹), indicating that group differences in activation depend strongly on ROI.

Separate analysis of each ROI revealed that in the FEF, both groups showed greater activation for antisaccades than prosaccades, which first reached significance at 828 msec for both groups and showed greater activation for antisaccades than prosaccades: 318 ± 72 vs. 288 ± 47 msec, t41 = 1.57, p = .12; ES = .35; prosaccades: 269 ± 72 vs. 241 ± 39 msec, t41 = 1.47, p = .15; ES = .34).

Table 2. Regressions of Preparatory Activation for Antisaccades Versus Prosaccades on Logit Transformed Error Rate with t Tests for Each Group at the Six 250-msec Epochs from 500 msec to 2000 msec Following the Cue

<table>
<thead>
<tr>
<th>Region</th>
<th>F</th>
<th>p</th>
<th>Error × Group</th>
<th>Control Subjects</th>
<th>Patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>FEF</td>
<td>1.57</td>
<td>.21</td>
<td>5.83 .02a</td>
<td>−.14 .89</td>
<td>.75 .46</td>
</tr>
<tr>
<td></td>
<td>750</td>
<td></td>
<td>3.59 .00a</td>
<td>1.06 .30</td>
<td>2.16 .04a</td>
</tr>
<tr>
<td></td>
<td>1000</td>
<td></td>
<td>2.47 .01a</td>
<td>−1.08 .29</td>
<td>2.79 .01a</td>
</tr>
<tr>
<td>DLPFC</td>
<td>.16</td>
<td>.69</td>
<td>9.08 .005a</td>
<td>−1.22 .24</td>
<td>1.81 .08</td>
</tr>
<tr>
<td></td>
<td>500</td>
<td></td>
<td>1.18 .26</td>
<td>−1.36 .19</td>
<td>2.88 .009a</td>
</tr>
<tr>
<td></td>
<td>750</td>
<td></td>
<td>1.08 .31</td>
<td>−1.96 .07</td>
<td>2.66 .13</td>
</tr>
<tr>
<td>VLPFC</td>
<td>3.10</td>
<td>.08</td>
<td>.00 .95</td>
<td>.83 .42</td>
<td>−.31 .76</td>
</tr>
<tr>
<td></td>
<td>500</td>
<td></td>
<td>1.96 .26</td>
<td>.76 .46</td>
<td>.61 .55</td>
</tr>
<tr>
<td></td>
<td>750</td>
<td></td>
<td>2.89 .13</td>
<td>.21 .83</td>
<td>1.9 .07</td>
</tr>
<tr>
<td></td>
<td>1000</td>
<td></td>
<td>1.08 .29</td>
<td>.93 .12</td>
<td>1.2 .24</td>
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<tr>
<td></td>
<td>1250</td>
<td></td>
<td>1.08 .29</td>
<td>.40 .44</td>
<td>2.28 .03a</td>
</tr>
<tr>
<td></td>
<td>1500</td>
<td></td>
<td>1.08 .29</td>
<td>.40 .44</td>
<td>2.28 .03a</td>
</tr>
<tr>
<td></td>
<td>1750</td>
<td></td>
<td>1.08 .29</td>
<td>.94 .36</td>
<td>2.23 .04a</td>
</tr>
<tr>
<td>dACC</td>
<td>.28</td>
<td>.60</td>
<td>2.73 .11</td>
<td>−.44 .66</td>
<td>1.27 .21</td>
</tr>
<tr>
<td></td>
<td>500</td>
<td></td>
<td>1.96 .29</td>
<td>−.91 .38</td>
<td>1.19 .24</td>
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<td>1.96 .29</td>
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<td>1.96 .29</td>
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<td>1.03 .31</td>
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<td></td>
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<td></td>
<td>1.96 .29</td>
<td>.02 .99</td>
<td>.91 .37</td>
</tr>
</tbody>
</table>

AS, antisaccade; dACC, dorsal anterior cingulate cortex; DLPFC, dorsolateral prefrontal cortex; FEF, frontal eye field; VLPFC, ventrolateral prefrontal cortex.

Discussion

The present findings provide the first evidence of abnormal task preparation, distinct from response generation, during volitional saccades in schizophrenia. Patients made more antisaccade errors than control participants and during correct antisaccade versus prosaccade trials, showed an abnormal pattern of preparatory activation in the network for volitional ocular motor control. Specifically, while healthy control subjects responded to cues indicating that the impending task would require a high (antisaccade) versus low (prosaccade) level of control with sustained significant increases in network activation, patients failed to show these sustained significant increases in either the dACC or DLPFC and differed significantly from control participants in the dACC. In contrast, in the VLPFC, patients showed an earlier, greater, and more sustained increase in preparatory activation than control participants. Finally, preparatory activation of the FEF, DLPFC, and VLPFC predicted antisaccade error rate in patients only. We interpret these findings to reflect that schizophrenia patients show aberrant use of task cues to modulate cognitive control and that this contributes to deficient inhibition of prepotent but contextually inappropriate responses.

According to current theory, the dACC, DLPFC, and VLPFC are key components of a network for implementing task control (58,59). In the ocular motor system, these regions are thought to exert top-down control on the FEF (10), the key cortical region for
generating volitional saccades (60). The dACC and DLPFC show greater functional MRI activation for antisaccades versus prosaccades (17–19) and lesions are associated with increased antisaccade errors (20–22). While the relative specialization of each region is a topic of active study, current models propose that in response to contextual cues, the dACC signals the need for adjustments in control and modulates the involvement of the DLPFC, which coordinates processing across the brain to support performance (11,61). In healthy control participants the remarkably similar timing of increased differential activation for antisaccades vs. prosaccades in the dACC, DLPFC, and FEF (Figure 2) is consistent with the theory that the dACC and DLPFC act together to exert control over the FEF in preparation for a challenging task. In the context of these models, reduced preparatory dACC activation in schizophrenia may reflect impaired recognition and signaling of the need for greater control and may lead to reduced DLPFC recruitment (61). Other potentially compatible interpretations of reduced dACC activation include that it reflects impaired motivation, attention, and recognition and preparation for response conflict.

The finding of increased differential preparatory activation of the VLPFC in schizophrenia was unexpected and should therefore be considered preliminary. Accumulating evidence suggests that the VLPFC contributes to task rule representation and inhibitory control (22,58,62). One plausible interpretation of the pattern of findings in schizophrenia is that to compensate for reduced top-down control by the dACC, patients increase the engagement of processes mediated by the VLPFC. These processes may include

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updating and maintaining the task set and increasing inhibitory control. This increased engagement may be reflected in the markedly earlier and stronger recruitment of VLPFC in patients than control participants who, in contrast to patients, showed relatively less VLPFC than DLPC or dACC activation (Figure 2).

The pattern of findings in patients resonate with a recent meta-analysis of functional neuroimaging studies of executive function in schizophrenia that revealed weaker dACC and DLPC activation in the context of greater VLPFC activation (63). This suggests that this pattern of regional recruitment is general to tasks requiring cognitive control in schizophrenia, regardless of task and response modality. The present study adds to this literature by demonstrating anomalous function of the cognitive control network specifically during task preparation that predicts deficient task performance.

Increased activation in the DLPC, VLPFC, and FE during correct trials predicted more antisaccade errors in patients. While errors reflect a failure of response inhibition, activation reflects the magnitude of the difference in activation between antisaccades and prosaccades during correct trials. Thus, these relations may reflect that within the schizophrenia group, individuals who are more prone to errors (i.e., have a higher error rate) require stronger top-down control from lateral PFC and stronger inhibition of the FE to successfully inhibit prepotent responses. This interpretation assumes that saccadic inhibition requires neuronal inhibition in the FE. Evidence for this comes from studies of monkey FE showing that antisaccade versus prosaccade cues result in reduced neuronal firing (8) and that infusions of a gamma-aminobutyric acid agonist interfere with the generation of volitional saccades, while a gamma-aminobutyric acid antagonist facilitates them (64,65). As MEG source signals primarily reflect postsynaptic currents, it is possible that increased MEG activation of the FE reflects increased inhibitory input. The relations of error rate with lateral PFC activation are consistent with its putative role in modulating FE activity during antisaccades. Only in the dACC did relations of activation with error rate not reach significance. It is unclear whether the dACC directly modulates FE activity or whether it does so via the lateral PFC (10). If the latter option, the less direct influence of the dACC on FE activity may account for its weaker relations with error rate. The lack of any significant relations of activation with error rate in control participants may reflect the more restricted range of errors.

The present findings suggest that abnormal preparatory recruitment of the cognitive control network in response to task cues contributes to antisaccade errors in schizophrenia. But abnormal preparation is unlikely to be the only culprit. Other possible contributors include less efficient implementation of inhibition, slower activation of the antisaccade task goal (e.g., (66)), and perseveration of prior responses that interferes with performance (28,62,66–68). By allowing an examination of temporally separated epochs of task performance, MEG can delineate spared and impaired processes.

A limitation to the interpretation of the present findings is that we did not investigate whether they reflect a specific deficit in the use of context to prepare or a more general deficit in the ability to prepare. In addition, we did not directly compare groups on activation for single trial types, leaving open the possibility that an abnormal response to task cues on prosaccade rather than, or in addition to, antisaccade trials accounts for our findings. For example, increased preparatory activation on prepotent prosaccades, along with reduced activation on the more effortful antisaccades, consistent with the cortical inefficiency hypothesis of schizophrenia (69–71), could account for reduced differential activity. Previous work, however, shows normal functional MRI activation for prosaccades, but not antisaccades, in patients with schizophrenia (e.g., (25,28)). The present findings of an elevated error rate for antisaccades, but not prosaccades, and that antisaccade error rate correlates with preparatory activation in patients suggests that abnormal preparation for antisaccades is an important contributor to the group differences we observed. Finally, the effects of chronic illness and antipsychotic medications may have contributed to our results. Prior work has shown reduced neural and behavioral responses to contextual cues in first-episode antipsychotic-naive patients using an A-X version of the Continuous Performance Test. This indicates that abnormal context processing is present early in the illness, before treatment with medications (2). In the present study, although it is difficult to ascribe the pattern of increased, decreased, and comparable activation in schizophrenia to medication or chronicity, we cannot exclude a contribution from these factors.

In summary, the present findings suggest that patients with schizophrenia are less able to use contextual cues to mobilize cognitive resources in preparation for challenging tasks. This deficit may compromise their ability to rapidly adjust behavior in response to the demands of the moment. These dynamic adjustments are fundamental to adaptive, flexible behavior and impairments may contribute to behavior that is stimulus bound and error prone rather than flexibly guided by context.

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