Supplementary Materials for:

Oculomotor Suppression and Location Priming in Schizophrenia

Sonia Bansal[1], Nicholas Gaspelin[2],Benjamin M. Robinson[1], Britta Hahn[1], Steven J. Luck[3], James M. Gold[1]

[1]Maryland Psychiatric Research Center, Department of Psychiatry, University of Maryland School of Medicine

[2]Department of Psychology, Binghamton University State University of New York

[3]Center for Mind & Brain and Department of Psychology, University of California, Davis

Contact information for corresponding author:

Sonia Bansal

E-mail: sbansal@som.umaryland.edu
Maryland Psychiatric Research Center,
Department of Psychiatry
University of Maryland School of Medicine
55 Wade Avenue
Catonsville, MD 21228, USA
Telephone: (410) 402-6881
Fax: (410) 401- 7198

Contents Pg.

1. DETAILED METHODS

1.1. Participants

The participants consisted of 46 PSZ (including 8 meeting the criteria for schizoaffective disorder) and 41 HCS. Diagnosis was established using a best estimate approach in which information from a Structured Clinical Interview for DSM-IV was combined with a review of medical records at a consensus diagnosis meeting chaired by one of the authors (JMG). HCS were recruited from the community via local community businesses and online advertisements; they were free from a lifetime diagnosis of a psychotic disorder, current Axis I disorder, neurological disorder, or cognitively-impairing medical disorder, and had no family history of psychosis in first-degree relatives. None of the participants had clinically significant ophthalmological problems or uncorrected refractive errors, and all had normal color vision as assessed by an Ishihara color vision test. A number of standardized neuropsychological measures were administered to examine current and premorbid cognitive functioning in PSZ and HCS: (1) the MATRICS Consensus Cognitive Battery (MCCB, Nuechterlein et al, 2006); (2) the Wide Range Achievement Test 4 (WRAT-4, Wilkinson and Robertson, 2006); (3) the Wechsler Test of Adult Reading (WTAR, Wechsler, 2001); and (4) the Wechsler Abbreviated Scale of Intelligence (WASI, Wechsler, 1999). Further, we had a reliable measure of visual working memory capacity (K) from a change localization task and a measure of executive control (overall d') from a 12-AX-CPT task (see Gold et al., 2018 for detailed descriptions). Symptoms in PSZ were assessed using the Brief Psychiatric Rating Scale (BPRS; Overall and Gorham, 1962).

Demographic information, neuropsychological test scores, and psychiatric ratings are provided in Table 1 (main manuscript). PSZ and HCS were well matched on

demographic variables, except that PSZ had fewer years of educational attainment than HCS, an expected consequence of the disease. However, the groups were well matched on parental education.

1.2 Apparatus

Stimuli were displayed on a LCD monitor at a viewing distance of 100 cm. The display had a black background (< 0.1 cd/m^2). A gray fixation cross (23.3 cd/m^2, 0.1° × 0.1°) was continuously visible in the center of the display except during the intertrial interval. A video-based tower-mounted eye tracker (EyeLink 1000, SR Research, Mississauga, Ontario, Canada) with a sampling rate of 1000 Hz was used for recording eye position. The participant's head was stabilized by a chin and forehead rest. The eye tracker was calibrated prior to each trial block using a 9-point calibration procedure. Experimental programs were written in MATLAB using the PsychToolbox extensions (Brainard, 1997).

1.3 Stimuli and procedure

The stimuli and task were based on those used by Gaspelin et al. (2019) and are illustrated in Figure 1. Each search display contained six items distributed at equal distances around an invisible circle with a radius of 4.5°. Each array contained one diamond (a 2.25° by 2.25° square, rotated 45°), one circle (2° diameter), two triangles (2° in height and base), and two hexagons (1.75° by 2°). The stimuli were drawn in pink (23.3 cd/m^2, x =.65, y =.34) or green (23.3 cd/m^2, x =.29, y =.63). One item (the singleton) was drawn in one of these colors, and the other items were drawn in the other color. The singleton was pink among green for half the participants in each diagnostic group and green among pink for the other half. Each shape contained a black line subtending 0.30°

× 0.05° that was tilted 45° to the left or right. This line was much smaller than shown in Figure 1. The tilt of the line inside each shape (left or right) varied randomly and independently on each trial.

The target was the circle for half the participants and the diamond for the other half (factorially crossed with the singleton color and the diagnostic group so that the colors and shapes were properly controlled). Participants searched for the target shape and reported the tilt of the enclosed line by pressing one of two buttons on a gamepad (left shoulder button for left-tilted and right shoulder button for right-tilted). The locations of the target and singleton varied randomly from trial to trial, with the constraint that the singleton was never the target item. We did not explicitly require an eye movement to the target, but the line within the target was too small to be accurately perceived without fixating the target.

Trials began with the presentation of a blank intertrial interval screen for 500 ms. This was followed by a screen containing the fixation cross; this screen remained visible until the participant maintained fixation within a 1.5° radius of the central fixation point for 500 ms. The search array then appeared and remained visible until the button-press response. If participants took too long to respond (more than 3000 ms), a time-out display appeared with the text “Too Slow” for 500 ms and the trial was discarded. If the response was incorrect, a 200-Hz tone sounded for 500 ms. The blank screen for the next trial then appeared.

The location of the target shape was selected at random on each trial, independent of the location of the previous-trial target (see Figure 1C). Thus, the location of the target

on the previous trial (trial n – 1) was completely uninformative about the target location on the current trial (trial n). This yielded two types of trials: *repeat-location* trials (1/6th of trials), on which the current-trial target appeared at the same location as the previous-trial target, and *change-location* trials (5/6th of trials), on which the current-trial target location was different from the previous-trial target location.

Participants first practiced the search task for two blocks of 32 trials, which were excluded from analysis. The main experiment consisted of eight blocks of 32 trials, yielding 256 trials. Participants received feedback about their mean RT and accuracy following each block.

1.4. Analysis

Eye-tracking analysis was conducted offline. A combined velocity (30°/s) and acceleration (8,000°/s^2) threshold was used to define saccades. As in our previous studies (Gaspelin et al., 2017; Gaspelin et al., 2019), we focused on the first eye movement on each trial. Subsequent eye movements are difficult to interpret given that the retinotopic positions of the objects are no longer controlled once gaze has left the central fixation cross.

Saccade landing position was classified by defining wedge-shaped interest areas surround each item in the display; each wedge was a segment of an annulus surrounding central fixation, centered on the search item, with an inner radius of 1.5° and an outer radius of 7.5°. Saccadic latency was measured as the start time of the first saccade that landed in one of the segments (to exclude small adjustments of gaze near the fixation cross). We excluded trials with abnormal manual response times (less than 200 ms or greater than 2000 ms), trials in which participants made no eye movement, and trials with

abnormal saccade latencies (less than 50 ms or greater than 1000 ms). These criteria led to the exclusion of a modest percentage of trials, which did not differ significantly across groups (PSZ: M=10.57%, SD=10.15%; HCS: M=9.86%, SD=6.92%; t(85)=0.38, p=0.71). Additionally, we excluded trials with manual response errors from all analyses except manual response error analyses.

We quantified oculomotor performance in two ways. First, to examine suppression of the color singleton, we compared the percentage of first saccades that landed on a given stimulus type (target, nonsingleton distractor, or singleton). Because there were four nonsingleton distractors on each trial, but only one singleton and one target, we quantified fixation rates for the nonsingleton distractor as the average across each of the four nonsingleton distractors. Second, to examine location priming effects, we broke down the percentage of first saccades that were directed to each type of search item: the current target, the primed distractor (i.e., the location of the previous-trial target), and the average unprimed distractor (the average of the distractor locations that were not the same as the location of the previous-trial target).

When examining these variables, it is important to deal with issues of nonindependence. For example, as the proportion of fixations of the target increases, this necessarily decreases the proportion of fixations to the singleton and nonsingleton distractors. We therefore avoided using ANOVAs with all of the possible saccade destinations and instead used a series of planned t tests to compare pairs of saccade destinations (see also Gaspelin et al., 2017; Gaspelin & Luck, 2018). Independent-samples t tests were used for comparisons of PSZ and HCS; paired t tests were used for within-group comparisons of different trial types. For analyses that did not suffer from this

issue (e.g., RT analyses), we used ANOVAs, with the Greenhouse-Geisser correction for violations of sphericity when a given factor contained more than two levels. The two different target shapes (diamond versus circle) and the two different color combinations (pink singletons among green distractors or vice versa) did not meaningfully impact performance, so the data were aggregated across these variables.

To examine associations between task performance, neurocognitive measures, and clinical symptoms, we computed Spearman rho correlations. All statistical analyses were performed using MATLAB and JASP (JASP v. 0.8.5; jasp262 stats.org).

REFERENCES:

1. Brainard, D. H. (1997). The psychophysics toolbox. *Spatial vision*, *10*(4), 433-436.
2. Gaspelin, N., Leonard, C.J., Luck, S.J. (2017). Suppression of overt attentional capture by salient-but-irrelevant color singletons. *Attention, Perception, & Psychophysics*, 2017:1–18.
3. Gaspelin, N., & Luck, S. J. (2018). Combined electrophysiological and behavioral evidence for the suppression of salient distractors. *Journal of cognitive neuroscience*, *30*(9), 1265-1280.
4. Gaspelin, N., Gaspar, J. M., & Luck, S. J. (2019). Oculomotor inhibition of salient distractors: Voluntary inhibition cannot override selection history. *Visual cognition*, *27*(3-4), 227-246.
5. Gold, J. M., Robinson, B., Leonard, C. J., Hahn, B., Chen, S., McMahon, R. P., & Luck, S. J. (2018). Selective attention, working memory, and executive function as potential independent sources of cognitive dysfunction in schizophrenia. *Schizophrenia bulletin*, *44*(6), 1227-1234.
6. Nuechterlein KH, Green MF. MATRICS Consensus Cognitive Battery, Manual Los Angeles, CA: MATRICS Assessment Inc; 2006.
7. Overall, J. E., & Gorham, D. R. (1962). The brief psychiatric rating scale. *Psychological reports*, *10*(3), 799-812.
8. Wechsler D Wechsler Abbreviated Scale of Intelligence. (WASI): Psychological Corporation; 1999
9. Wilkinson, G. S., & Robertson, G. J. (2006). Wide range achievement test (WRAT4). *Lutz, FL: Psychological Assessment Resources*.

2. INITIAL SACCADE DESTINATION: REPEAT VS. CHANGE-LOCATION TRIALS

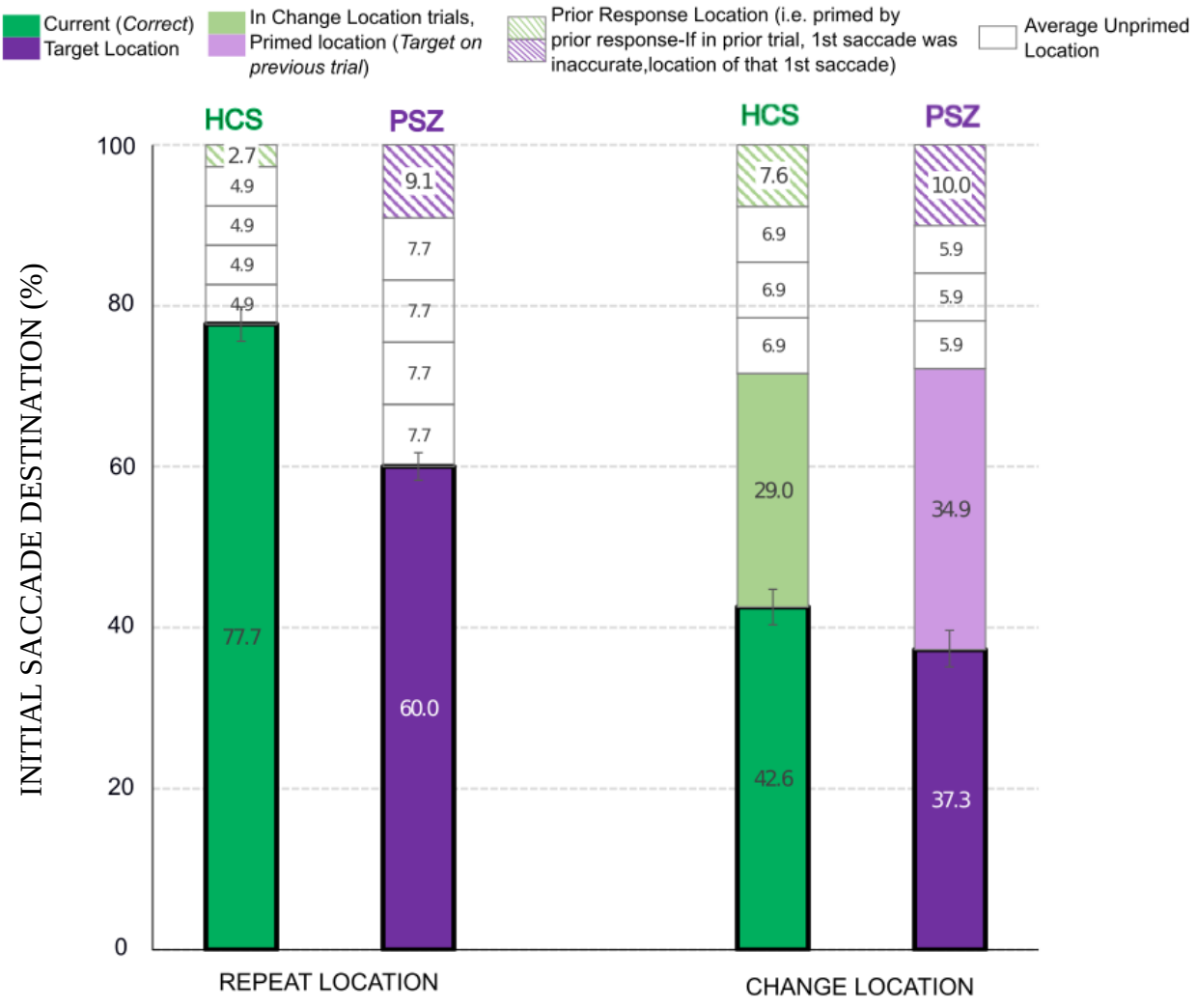
As a secondary analysis that is related to the manual response measures, we compared the proportion of saccades directed to the target location on repeat-location trials versus change-location trials. As reported in the main manuscript, first saccades in both groups were more likely to be directed to the target on repeat-location trials than on change-location trials (main effect of trial type, $F_{1,85} = 689.15$, $p<0.001$, $\eta^2_p=0.89$). However, PSZ were less accurate overall in directing initial gaze to the target (main effect of group, $F_{1,85}=18.79$,$p<0.001$,$\eta^2_p= 0.18$). This lower accuracy led to the difference in priming effects for the two trial types being greater in HCS than in PSZ, as evidenced by a significant Group X Trial type interaction effect, $F_{1,85}=32.35$, $p<0.001$,$\eta^2_p=0.28$).

This may be related to the overall lower probability of the first saccade being directed to the target in PSZ than in HCS. Specifically, when the first saccade on the previous trial went to a location other than the target, the location of this saccade may be primed more than the location of the actual target. To examine this possibility, we broke down initial saccades into:

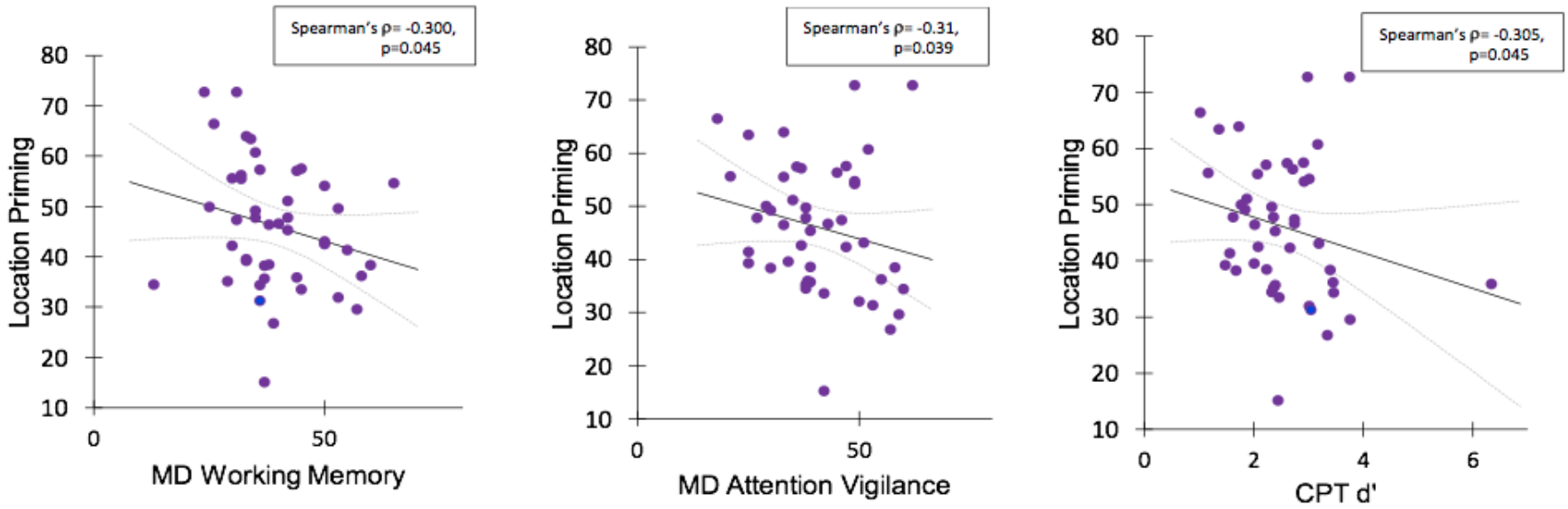
(i) Current (correct) target location
(ii) Prior response location (I.e. "inaccurate" oculomotor response to non-target location)
(iii) Primed Location (Target on previous location for Change-Location trials)
(iv) Average Unprimed location

Consistent with this hypothesis, we found that PSZ were more likely to direct eye movements to the previously attended **nontarget** location (versus any other distractor) than were HCS (see Figure below), leading a main effect of group ($F_{1,85}=44.67$, $p<0.001$, $\eta^2_p=0.3$) and a significant Group X Target Location Repetition interaction effect($F_{1,85}=6.16$, $p=0.015$, $\eta^2_p=0.07$). This pattern indicates that PSZ more strongly represent the location they actually attended on the previous trial compared

to HCS, consistent with the hyperfocusing hypothesis. This would also counteract the priming effect related to the actual target location, explaining why the data initially shown in Figure 5B show a greater priming effect for HCS than for PSZ.



3. CORRELATION SCATTER PLOTS



Correlation between location priming and neurocognitive measures in the patient (PSZ) group.

We observed significant correlations between location priming (percentage of saccades to primed location minus unprimed location) and the working memory and attention-vigilance cognitive domains from the MATRICS battery in PSZ, such that greater priming was associated with reduced working memory and attention-vigilance. An independent measure of working memory capacity, change localization K, showed the same direction of correlation but did not reach statistical significance. Second, we observed a significant negative correlation between location priming and a measure of executive control (overall d') from a 12-AX-CPT task (see Gold et al., 2017 for detailed description), indicating that poorer control was associated with a greater priming by the previous trial's target location.