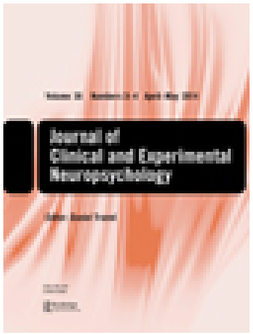

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Neuropsychological measurement of inhibitory control in posttraumatic stress disorder: An exploratory antisaccade paradigm

Matthew Reinhard[a], Nathaniel Allen[a], Ling M. Wong[a] and Barbara L. Schwartz[b]

[a]War Related Illness and Injury Study Center, Veterans Affairs Medical Center, Washington, DC, USA; [b]Mental Health Service, Veterans Affairs Medical Center, Washington, DC, USA

ABSTRACT

Objective: The aim of the study was to uncover inhibitory control dynamics and assess antisaccade eye-tracking tasks for relevance in a veteran posttraumatic stress disorder (PTSD) population. *Method*: Participants were 36 veterans enrolled at the Washington DC Veterans Affairs Medical Center. The groups (PTSD diagnosed vs. controls) did not vary between age and sex. Participants completed a testing battery of clinical neuropsychological measures and two different eye-tracking conditions, one that utilized face stimuli and one with standard shape stimuli, which test pro- (PS) and antisaccade (AS) eye movements. *Results*: Veterans with PTSD, $t(33) = 2.2$, $p = .04$, took longer to respond than controls in the standard condition AS. In the face condition, a group by task interaction was seen with increased latency for PTSD veterans in the AS versus PS task, $F(3, 33) = 3.99$, $p = .05$, with a large overall effect (Hedges' $g = 1.18$, $p < .001$) compared to controls. After controlling for depression, analyses suggested that only the face condition AS task significantly predicted dimensions of PTSD symptomology measured by the Clinician Administered PTSD Scale (CAPS) for veterans with PTSD. *Conclusions*: This is the first study to extend AS findings to PTSD and suggests a specific capability to measure inhibitory control using eye-tracking technology. We discuss the notion that reduced capacity to regulate facial-related processing affects cognitive and attentional control networks of PTSD patients, potentially representing a core cognitive deficit.

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Eye tracking; inhibitory control; neuropsychology; posttraumatic stress disorder; saccade

Inhibitory control in posttraumatic stress disorder (PTSD)

Posttraumatic stress disorder (PTSD) is known to be associated with information processing deficits and hyperarousal to threat-related stimuli, and is most often conceptualized as heightened "bottom-up" arousal coupled with a dysfunction of inhibitory control networks. Functional neuroimaging studies have uncovered facial processing differences in PTSD groups versus controls, displaying hyperactivity in the amygdala along with hypoactivation of the ventromedial prefrontal cortex, rostral and dorsal anterior cingulate cortex, and thalamus (Etkin & Wager, 2007). Relatively few PTSD behavioral studies have examined responses to attentional tasks engaging cognitive control networks with both neutral and affective stimuli. However, some studies have found evidence for an attentional bias in PTSD participants for emotionally negative stimuli (Hayes, VanElzakker, & Shin, 2012) as measured by the Stroop interference paradigm, such that response time is increased when PTSD participants name the color of trauma-related words as opposed to neutral words (J. G. Beck, Freeman, Shipherd, Hamblen, & Lackner, 2001; El Khoury-Malhame et al., 2011; McNally, Kaspi, Riemann, & Zeitlin, 1990). From a functional neuroimaging perspective, two published studies have shown significant differences between PTSD groups and controls in the anterior cingulate and visual cortex, but did not display the slowed response times to trauma-related versus neutral words (Bremner et al., 2004; Shin et al., 2001). It is possible that with a more sensitive inhibitory control task, distinctions between performance on neutral and affective stimuli could be more accurately described.

Eye tracking and PTSD

From a neurobehavioral measurement standpoint, it is possible that subtle changes in brain function would benefit from task measurements not contingent upon

CONTACT Matthew Reinhard Matthew.Reinhard@va.gov War Related Illness and Injury Study Center, Veterans Affairs Medical Center, Room 3B-203 (Stop 127), 50 Irving Street NW, Washington, DC 20422-0002, USA

Present affiliation for Matthew Reinhard and Barbara L. Schwart is Department of Psychiatry, Georgetown University Medical School, Washington, DC, USA

distal motor response inhibition or reaction time from behavioral observer. Modern eye-tracking technology provides a way to noninvasively assess eye movements continuously, recording data by the millisecond, which provides direct feedback not only when a response is generated but also on the velocity, direction, and amplitude of eye movement. Several recent studies have utilized sensitive eye tracking in PTSD populations to assess attentional bias to threat and found that PTSD groups attend to trauma-relevant threat images more than non-trauma-exposed groups (Thomas, Goegan, Newman, Arndt, & Sears, 2013) and are more likely to initially fixate on trauma-related words (Felmingham, Rennie, Manor, & Bryant, 2011); PSTD groups maintain attention longer to fearful and disgusted facial expressions than to happy facial expressions (Armstrong, Bilsky, Zhao, & Olatunji, 2013); and veterans with higher level of PTSD symptoms had larger pupil dilation and spent more time looking at negatively valenced pictures than veterans with fewer PTSD symptoms (Kimble, Fleming, Bandy, Kim, & Zambetti, 2010), and have demonstrated increased number of initial eye fixations to trauma-related words (Felmingham et al., 2011). Falconer et al. (2008) found that Clinician Administered PTSD Scale (CAPS) scores were positively correlated with failure to inhibit responses during emotional face trials. However, none of the previous research has utilized eye tracking to directly measure inhibitory control in PTSD by applying an antisaccade task. As the current literature suggests that threat-related stimuli differentially impact attention in PTSD, we included a modified version of the antisaccade task with face stimuli, as well as a classic symbolic shape version.

The antisaccade task and inhibitory control

The antisaccade task (AS) is designed to measure voluntary control of eye movements. The neurophysiology and neuroanatomy underlying saccadic eye movement has been well studied and reviewed in the literature with extensive knowledge derived from lesion studies, functional neuroimaging, animal neurophysiology at the single neuronal level, and human behavioral experiments (Moschovakis, Scudder, & Highstein, 1996) . First introduced by Peter Hallett (1978), the AS requires a subject to first direct their gaze to a central fixation point that is replaced by a visual target appearing on either the left or right side of the central fixation point. The subject is instructed to look in the *opposite* direction to the target. The AS involves inhibitory control mechanisms to suppress the prepotent response to look toward the target (i.e., generate a prosaccade). Performance in the AS relies on a network of structures including the dorsolateral prefrontal cortex, supplementary eye fields, presupplementary motor area, frontal eye fields, superior colliculus, right inferior frontal cortex, and dorsal anterior cingulate cortex, as well as brain stem, cerebellum, thalamus, and both direct and indirect pathways of the basal ganglia structures (De Weijer et al., 2010; Munoz & Everling, 2004; Wiecki & Frank, 2013).

The AS has been studied extensively in neurological and psychiatric populations to examine visual attention and inhibitory control disturbances. More than 25 years ago Guitton, Buchtel, and Douglas (1985) showed that patients with frontal lobe lesions in the dorsolateral and mesial cortex make more antisaccade errors than healthy controls. Other diseases with significant antisaccade performance differences between test groups and controls include Alzheimer's disease (Currie, Ramsden, McArthur, & Maruff, 1991); HIV (Merrill, Paige, Abrams, Jacoby, & Clifford, 1991); Parkinson's disease (Kitagawa, Fukushima, & Tashiro, 1994); and progressive supranuclear palsy (Pierrot-Deseilligny, Rivaud, Pillon, Fournier, & Agid, 1989). Fukushima et al. (1988) showed a significant difference in antisaccade error rate in patients with schizophrenia while subsequent research has revealed impaired performance in such wide-ranging disorders as bipolar disorder (García-Blanco, Perea, & Salmerón, 2013); obsessive-compulsive disorder (OCD; Lennertz et al., 2012); attention deficit hyperactivity disorder (ADHD; Schwerdtfeger et al., 2013); autism (Mosconi et al., 2009) and social anxiety (Wieser, Pauli, & Mühlberger, 2009). Our review of the literature uncovers no study of AS performance within a PTSD population, which is surprising given over 20 years of accumulated neuroscience literature investigating brain-based biobehavioral differences between PTSD participants and controls, and that the AS task in particular can provide significant insight into frontal inhibitory control deficits.

The goal of the current study was to measure inhibitory control deficits in PTSD. Specifically, we examined whether individuals with PTSD would show deficits relative to controls in two AS tasks: the standard task, with symbolic square and circle stimuli, and a separate task utilizing faces (neutral and fearful expressions) from the NimStim face set (Tottenham et al., 2009). We first hypothesized that the PTSD group would make significantly more antisaccade errors and be slower to generate correct antisaccade responses in both tasks, reflecting an inhibitory control impairment relative to control participants. Secondly,

we predicted that the introduction of socially salient stimuli would be more sensitive to inhibitory control mechanisms and would show larger effect size differences between groups than the standard condition.

We also hypothesized that standard clinical neuropsychological tasks thought to measure inhibitory control or aspects of executive functioning will detect cognitive performance differences but standard and face AS will be most sensitive to group differences. General cognitive performance, measured by factors such as IQ, have consistently been shown to have an inverse relationship with the severity of PTSD symptoms, even after controlling for combat exposure (McNally & Shin, 1995). If we conceptualize inhibitory control as a core component of PTSD, as has been suggested in the literature (Scott et al., 2015; Leskin & White, 2007; Shucard, McCabe, & Szymanski, 2008), it stands to reason that PTSD self-reported symptomatology will be associated with AS performance as well as clinical neuropsychological performance. We explored whether domains of PTSD symptomatology could be predicted with saccades or clinical neuropsychological performance, with the hypothesis that introducing socially salient information (i.e., face) combined with inhibitory control (i.e., face AS) would be the best predictor of psychiatric sequela.

Method

Participants

Participants were recruited from outpatient clinics at a large metropolitan Veterans Affairs Medical Center (VAMC). This study was approved by the Institutional Review Board at the VAMC, and written informed consent was obtained from all participants prior to testing. Participants in both groups were required to be between the ages of 18–60 years and serve military tours, though were not required to deploy to an active combat zone. PTSD+ participants were required to meet the following additional criteria: (a) diagnosis of PTSD according to the Mini International Neuropsychiatric Interview (MINI; Lecrubier et al., 1997); and (b) confirmation of an existing, documented diagnosis in their medical record by at least one of the following: (i) service connection of >0% for PTSD; (ii) score of ≥50 on the PTSD Checklist–Military Version (PCL), with all three diagnostic criteria met (Weathers, Huska, & Keane, 1991); (iii) PTSD diagnosis listed in Active Problems; (iv) PTSD diagnosis in an encounter over the past year; and (v) score of ≥50 on the CAPS, with all diagnostic criteria met (Blake et al., 1990). Participants in both groups were excluded if they met any of the following criteria: (a) substance abuse within the past 3 months; (b) prescribed opioids or benzodiazepines; (c) history of seizure disorder or cerebrovascular disorder (i.e., stroke); head trauma or postconcussion syndrome according to the VA Traumatic Brain Injury Screen; or significant medical disorders (e.g., cancer, multiple sclerosis, HIV), hepatic, renal, pulmonary, endocrine, or cardiovascular disease that could potentially affect central nervous system (CNS) function; or (d) visual difficulties noted in medical record (cataracts, eye surgeries), or participant reported visual problems or demonstrated visual difficulties when asked to complete tasks during the testing. PTSD+ participants were excluded if they met any of the following additional criteria: (a) Axis I or II diagnosis prior to deployment; (b) comorbid mental health disorder not in the anxiety or depression spectrum. PTSD– participants, our control population, were excluded if they met any of the following additional criteria: (a) Axis I diagnosis according to the MINI, or (b) Axis I or II diagnosis according to the medical record.

Measures

The Mini International Neuropsychiatric Interview (MINI; Lecrubier et al., 1997) is a brief, clinician administered, structured interview designed to assess *Diagnostic and Statistical Manual of Mental Disorders–Fourth Edition* (*DSM–IV*; American Psychiatric Association, 2000) and International Classification of Diseases–10th Revision (ICD–10; Centers for Disease Control and Prevention 2016) psychiatric disorders and used in the current study for purposes of determining inclusion/exclusion. The Clinician Administered PTSD Scale (CAPS; Blake et al., 1990) was used to diagnose current PTSD (within the past month) or lifetime diagnosis of PTSD. The dependent measures were CAPS total score and symptom cluster scores (CAPS B, reexperiencing; CAPS C, avoidance; CAPS D, arousal). The Beck Depression Inventory–II (BDI–II; A. T. Beck, Steer, & Brown, 1996) was used to measure depression and assess how it correlates with other outcomes (cognition, PTSD, eye tracking).

Clinical neuropsychological measures

Commonly used neuropsychological measures included: Test of Premorbid Functioning (TOPF; NCS Pearson Corporation, 2009); Trail Making Test (TMT) A and B (Reitan & Wolfson, 1985); Stroop Color and Word Test (Golden & Freshwater, 2002) utilizing the number of words correctly read in 45-s format with

interference score; The Digit Symbol Coding and Digit Span Backwards, longest digit span backward (LDSB) subtests of the Wechsler Adult Intelligence Scale–IV (WAIS–IV; Wechsler, 2008); and Conners' Continuous Performance Test–II (CPT–II; Conners et al., 2000) omission rate (OR), commission rate (CR), and *d'*.

Eye movement measures

Data were collected using a SensoMotoric eye tracker at a rate of 240 Hz using iView X 2.2.4 software, and Presentation (Neurobehavioral Systems, v. 12.2) was used to present stimuli onto an Acer AL1715 monitor. Participants were seated 560 mm from the computer screen in a head rest containing the camera. The participant's head was comfortably stabilized by an ergonomic chin rest and forehead rest. A plastic plexiglass molded notch gently held the participant's nose in place to further reduce head movement. No other equipment touched the participant's head or other body part. Prior to each task block, eye location was calibrated using a 9-point system. Using high-speed saccade detection in the iView software, fixations were required to have >80 ms duration and <100 pixel dispersion, meaning that within any given window of 80 ms, the eye location did not move further than 100 pixels in any direction. Saccades were required to have 75–800° s^{-1} peak velocity, with peak velocity occurring between 20 and 80% of saccade length. Using these criteria and position data from the right eye, fixations and saccades were identified automatically by the iView Event Detector software. Saccades identified by the iView Event Detector software were identified as invalid and excluded from analyses if they met any of the following criteria: (a) latency <75 ms or >1000 ms after target onset; (b) amplitude <4.67° (i.e., width of face stimulus); (c) end position was within the central area of the screen (width of central area = 4.67°); or (d) start or end positions were located off the extent of the computer screen.

Eye-tracking procedures

Standard condition

This task utilized square and circular objects as stimuli (Figure 1). Each trial began with a fixation period lasting 1700 ms, in which participants viewed a centrally presented circle (width = 2.67°) and two peripheral squares (width = 2.67°) 13.6° to the left and right of center. After the fixation period, the circle would disappear from the center and immediately replace one of the peripheral squares for a "target" period of 1000 ms. During the intertrial interval, lasting 500 ms, the screen would go blank before repeating the fixation period. Participants completed 15 trials in each block. Within each condition, there were two tasks (prosaccade, PS, and antisaccade, AS) and two blocks of each task. Blocks were performed in a predetermined order: prosaccade, antisaccade, prosaccade, and antisaccade. Participants were instructed to look in the same direction as the target in the PS, and in the direction opposite the target in the AS. Stimuli were presented on a black background. Trial order was randomized prior to the experiment and remained set for all participants.

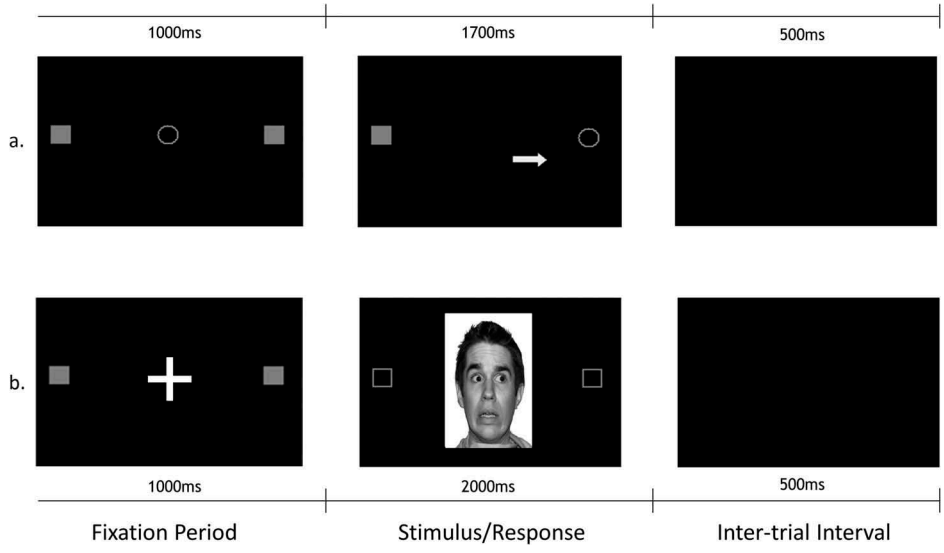

Figure 1. A. Standard condition. B. Face condition. The arrow and eye direction in the stimulus/response section indicates the direction of a correct saccade for prosaccade trials.

Face condition

Faces derived from the NimStim face set were modified such that eye gaze would indicate which peripheral square the participant should direct gaze towards (Schwartz, Vaidya, Howard, & Deutsch, 2010). Each trial began with a central, white fixation cross lasting 1000 ms. The target stimulus lasted 2000 ms and consisted of a face (width = 4.67°) looking either to the left or to the right. The target appeared in the center of the screen concurrently with peripheral squares (width = 2.67°) 13.6° to the left and right of center. Participants were instructed to look in the same direction as the eye gaze in the PS, and in the direction opposite the eye gaze in the AS. Participants completed eight trials in each block, half of which expressed a "neutral" face and half of which expressed "fear" faces. Blocks were performed in a predetermined order: prosaccade, antisaccade, prosaccade, and antisaccade, for a total of 32 trials. During the intertrial interval, lasting 500 ms, the screen was black.

Analyses

A Student's t test (or χ^2 for categorical variables) was performed using SPSS to compare the demographic variables between the two groups as well as for the Test of Premorbid Functioning scores. For all analyses, a probability (p) value <.05 was considered statistically significant.

The eye-tracking conditions (standard/face) are two distinct experiments and cannot be directly compared as they differ in such important parameters as the number of trials and timing of presentation. Additionally, the face stimuli are larger and more complex so that increased processing time is expected. Because the standard and face conditions were conceptually and methodologically distinct, analysis and interpretation of each condition were conducted separately. Two dependent measures in each condition were examined. First was error rate, which was defined as the percentage of trials in which the first saccade was in the incorrect direction. Second was latency of the first accurate saccade, which was examined only in correct trials. We refer to error rate and latency as saccade dependent measures. For the standard condition, an analysis of covariance (ANCOVA) with Group (PTSD+ vs. PTSD–) × Task (prosaccade vs. antisaccade) + TOPF as covariate was run for each saccade measure. For the face condition, an ANCOVA with Group × Task × Emotion (neutral vs. fearful face) + TOPF as covariate was run for each saccade dependent measure. The TOPF was included as a predictor because the mean scores differed between groups (see Results section, Table 1). In order to correct against sample size error, we compared the effect of the face versus the standard task using the bias-adjusted Hedges's g statistic with an independent two-tailed Student's t test. This calculation was made for all clinical neuropsychological measures and eye-tracking results between groups. Effect sizes were set at <0.40 = small, 0.40–0.70 = moderate, and >0.70 = large (Higgins & Green, 2011). To explore whether neuropsychological and/or eye-tracking measures may predict PTSD symptoms, we used multiple linear regression (PTSD+ group only) with BDI scores to assess the relative variance of each measure.

Table 1. Sample demographics and characteristics.

	Control (n = 19)	PTSD[a] (n = 17)	t	p
Sex[b]	5 F, 14 M	7 F, 10 M	0.09	.76
Age (years)	46.7 (10.3)	45.9 (9.1)	0.33	.74
TOPF	43.5 (11.0)	34.0 (10.1)	3.62	<.001
BDI	6.8 (5.7)	26.3 (15.0)	−7.69	<.001
CAPS total	—	64.5 (19.2)		
CAPS B	—	16.7 (6.8)		
CAPS C	—	28.1 (10.6)		
CAPS D	—	20.5 (7.1)		

Note. PTSD = posttraumatic stress disorder; TOPF = Test of Premorbid Functioning; BDI = Beck Depression Inventory; CAPS = Clinician Administered PTSD Scale; F = female; M = male.
[a]Due to scheduling or technical constraints, not all 17 PTSD participants completed all eight blocks of eye-tracking tasks. The demographic p values did not change in level of significance once accounting for these exclusions. [b]Chi square test was used for comparison of sex distribution.

Results

Sample characteristics

A total of 36 male and female veterans aged 25–59 years participated in this study. Due to scheduling conflicts or technical interruptions on the day of testing, the full eight blocks were not available from all participants across both conditions, resulting in a slightly different sample size in analysis. The sample for the standard condition task consisted of 19 control participants and 16 participants with PTSD. The sample for the face condition task consisted of 19 control participants and 17 participants with PTSD.

Demographic information for the total sample is shown in Table 1. In both conditions, groups did not differ in age (both $p > .71$) or sex (both $p > .56$), but the PTSD group exhibited higher levels of depressive symptoms on the BDI–II (both $p < .001$) and lower TOPF scores (both $p < .001$). One PTSD participant with PTSD did not complete the CPT. For one other PTSD+ participant who completed the face condition only, digit span backward and CPT scores were not available.

Saccade performance

Standard condition

To assess differences in performance in the prosaccade relative to the antisaccade task in the standard condition, an ANCOVA for Group × Task interaction was calculated with TOPF as covariate. Both the PTSD+ and control groups made more errors, $F(3, 32) = 39.84$, $p < .001$, and exhibited increased latency, $F(3, 32) = 8.83$, $p < .01$, in the AS. Neither the Group × Task interaction nor the group comparison was significant for either measure (all $p > .07$). However, the PTSD+ group showed a significant large effect for slowed AS latency during a direct comparison to controls (Hedges's $g = 0.76$, $p = .04$; Table 2), and the Group × Task interaction for latency appeared to be trending towards significance ($p = .11$). Valid gaze coordinates were recorded during 95.0% of the test period.

Face condition

A Group × Task × Emotion ANCOVA with TOPF as covariate found that groups did not differ in error rate, $F(5, 30) = 1.16$, $p = .28$, but that the PTSD group did exhibit higher overall latency, $F(5, 30) = 22.74$, $p < .001$. The Group × Task interaction was significant, such that this increase was more pronounced in the AS, $F(4, 31) = 3.99$, $p = .05$. There was a large effect for AS latency in the PTSD group (Hedges's $g = 1.18$, $p = .001$; Table 3). However, there was neither an effect for task, nor a Group × Task × Emotion interaction (all $p > .28$).

Table 2. Group differences in neuropsychological and eye-tracking means for standard condition.

Outcome	Control	PTSD	*t*	*g*	*p*
Neuropsychological measures					
Trail Making Test					
A	28.4 (11.1)	40.2 (20.7)	2.05	0.69	.05*
B	64.0 (26.2)	98.3 (62.5)	2.01	0.68	.05*
Stroop					
Word	100.1 (16.3)	88.8 (23.4)	1.67	0.56	.10
Color	72.5 (13.6)	65.5 (12.4)	1.53	0.52	.14
Color Word	42.1 (10.9)	42.9 (16.8)	0.16	0.05	.87
Digit Symbol Coding	67.7 (19.2)	63.0 (15.3)	0.78	0.26	.44
Backwards Digit Span					
Longest	3.6 (1.2)	3.1 (1.4)	0.96	0.32	.35
Total score	8.9 (2.7)	8.0 (2.5)	1.04	0.35	.30
CPT					
% Omissions	0.5 (0.6)	3.8 (6.8)	2.07	0.71	.05*
% Commissions	21.7 (13.6)	32.5 (23.6)	1.67	0.57	.11
d'	1.01 (0.4)	0.75 (0.5)	1.77	0.61	.08
Eye-tracking measures					
Prosaccade error rate (%)	1.8 (3.9)	6.1 (9.0)	1.88	0.64	.07
Prosaccade latency (ms)	368 (150)	372 (131)	0.89	0.03	.93
Antisaccade error rate (%)	24.0 (15.7)	33.1 (25.4)	1.26	0.44	.22
Antisaccade latency (ms)	408 (106)	509 (155)	2.20	0.76	.04*

Note. PTSD = posttraumatic stress disorder; CPT = Continuous Performance Test. Standard deviations in parentheses.
*$p < .05$.

Table 3. Group differences in neuropsychological and eye-tracking means for face condition.

Outcome	Control	PTSD	*t*	*g*	*p*
Neuropsychological measures					
Trail Making Test					
A	28.5 (11.2)	39.4 (20.7)	1.99	0.65	.05*
B	64.6 (26.0)	101.7 (62.2)	2.35	0.77	.02*
Stroop					
Word	99.7 (16.8)	88.9 (21.9)	1.67	0.54	.10
Color	71.8 (13.9)	65.3 (12.1)	1.50	0.49	.14
Color Word	41.5 (11.1)	41.2 (16.5)	0.08	0.02	.94
Digit Symbol Coding	66.1 (19.0)	62.5 (14.4)	0.63	0.21	.53
Backwards Digit Span					
Longest	3.6 (1.3)	3.1 (1.4)	1.01	0.33	.31
Total score	8.9 (2.7)	7.9 (2.4)	1.21	0.40	.23
CPT					
% Omissions	0.5 (0.6)	3.8 (6.8)	2.08	0.68	.04*
% Commissions	20.1 (10.6)	32.5 (23.6)	2.01	0.66	.05*
d'	1.0 (0.3)	0.8 (0.4)	2.06	0.70	.04*
Eye-tracking measures					
Prosaccade error rate (%)	21.2 (16.7)	13.1 (25.6)	1.07	0.36	.29
Prosaccade latency (ms)	485 (114)	555 (152)	1.50	0.51	.14
Antisaccade error rate (%)	25.1 (25.5)	23.3 (28.0)	0.20	0.07	.85
Antisaccade latency (ms)	440 (124)	633 (195)	3.50	1.18	.001**

Note. PTSD = posttraumatic stress disorder; CPT = Continuous Performance Test. Standard deviations in parentheses.
*$p < .05$. **$p < .01$

Though there was no overall effect of emotional expression, an independent-samples *t*-test revealed that PTSD participants were slower to react on AS neutral ($M = 682$ ms, $SD = 144$ ms) and AS fear ($M = 573$ ms, $SD = 279$ ms) than controls ($M = 464$ ms, $SD = 154$ ms, $p > .001$; $M = 413$ ms, $SD = 117$ ms, $p = .03$, respectively). All other comparisons were nonsignificant (all $p \geq .08$). Valid gaze coordinates were recorded during 94.6% of the test period.

Tables 2 and 3 (standard and face conditions, respectively) display mean scores and standard deviations for neuropsychological and eye-tracking measures. An independent-samples *t*-test revealed that the PTSD+ group exhibited slowed performance times on TMT A (both $p = .05$) and TMT B (both $p < .05$). The PTSD group also exhibited worse performance on the CPT task, observed as more omissions (both $p < .04$) and, for participants in the face condition only, more commissions, and lower *d'* (both $p < .05$).

Based on results from Tables 2 and 3, we selected only the TMT and CPT along with saccade error rate and latency to predict variance in PTSD symptoms. For the PTSD+ group, linear regression models with BDI scores and neuropsychology measures were used to predict CAPS scores as outcome (Table 4). We found that neither CAPS subscores nor total score were predicted by performance on the CPT or TMT A and B (all $p > .08$). However, significant correlations were seen between AS latency, $r(16) = -.59$, $p = .02$, and

Table 4. Linear regression of PTSD+ veterans' face condition results to predict CAPS symptoms.

		Face Condition			
	Outcome	ΔR^2	R^2	F	p
Prosaccade error rate (%)	CAPS Total	.08	0.38	5.67	0.02*
	CAPS B	.01	0.21	2.99	0.09
	CAPS C	.10	0.31	3.42	0.07
	CAPS D	.07	0.33	3.25	0.07
Prosaccade latency (ms)	CAPS Total	.02	0.31	4.41	0.04*
	CAPS B	.01	0.21	3.05	0.08
	CAPS C	.01	0.21	3.04	0.08
	CAPS D	.07	0.23	3.21	0.07
Antisaccade error rate (%)	CAPS Total	.15	0.46	7.07	0.01*
	CAPS B	.15	0.36	5.04	0.03*
	CAPS C	.03	0.23	3.13	0.08
	CAPS D	.19	0.39	5.43	0.02*
Antisaccade latency (ms)	CAPS Total	.10	0.49	5.85	0.02*
	CAPS B	.18	0.41	5.79	0.02*
	CAPS C	.01	0.21	2.84	0.10
	CAPS D	.16	0.44	4.76	0.03*

error rate, $r(16) = .66$, $p < .01$, with CAPS total score in the face condition, indicating a significant relationship between slowed response time and increased errors with higher PTSD severity. In a linear regression model that included BDI, prosaccade latency and error rate were significant for CAPS total while both antisaccade error rate were significant for CAPS B (reexperiencing), D (arousal), and CAPS total (all $p \leq .03$; see Table 4). No associations were observed in the standard condition (all $p > .17$), and only face condition results were reported.

Discussion

This study provides evidence of a method to measure alterations in inhibitory control and is the first to extend findings of AS differences in PTSD that have been shown in those with disorders of known brain dysfunction (i.e., Alzheimer's disease, HIV, schizophrenia, and others). The PTSD+ group took longer to correctly respond (latency) in the AS standard condition than the non-PTSD group, and the error rate and latency were significantly greater in the AS for both groups, the latter finding being somewhat expected given that the AS requires inhibition of a response versus the prosaccade. Moreover, using a face condition, a Group × Task interaction was seen, such that the PTSD+ group took significantly longer to correctly respond (latency) in the AS versus PS condition than the non-PTSD group. This supports our approach that imbedding socially salient content (i.e., face) during an inhibitory control task (i.e., AS) results in a measurable behavioral change in PTSD versus controls even after adjusting for premorbid IQ. In PTSD, a reduced capacity to process social information may affect other forms of information processing by increasing demand on cognitive and attentional control networks.

It is reasonable that areas of dysfunction uncovered from PTSD neuroimaging research, (e.g., prefrontal, cingulate cortex, and limbic regions) are important for both emotional and cognitive functioning, thereby influencing a wide range of neuropsychological performance. Aupperle et al. (2012) showed that women with PTSD performed worse than controls on complex visuomotor processing speed (i.e., Digit Symbol Test) and an inhibitory control task (i.e., Stroop color–word interference), and that corresponding hypoactive dorsolateral prefrontal cortex functioning was associated with PTSD, while greater lateral prefrontal activation was associated with better neurocognitive performance and lower levels of PTSD. Swick, Honzel, Larsen, Ashley, and Justus (2012) recently showed more errors in a go/no-go task in a PTSD group versus controls that requires motor response inhibition. This indicates that even nonemotional neuropsychological and/or neuroscience tasks can be sensitive to cognitive difficulties and/or the associated conditions in individuals with PTSD. In the present study, some clinical neuropsychological tasks (TMT A & B and CPT) showed significant differences between groups (Tables 2 and 3) but the Stroop, Digit Span, and Digit Symbol Coding did not. However, these clinical neuropsychological tests were not created for targeting deficits in psychiatric populations and are purposefully devoid of affective emotional or social content, as eliciting an emotional response would be considered a distractor variable for assessment of cognitive areas such as sustained attention, inhibiting prepotent responses, or executive functions. Furthermore, veterans with PTSD showed lower scores on the verbal IQ estimate (TOPF), which supports previous research suggesting that pretrauma IQ is negatively associated with PTSD development (Buckley, Blanchard, & Neill, 2000). It was important to note that TOPF estimates showed no significant correlation to any of the saccade tasks across both conditions, which may indicate that these measures are not influenced by IQ. Nonetheless, in an era of expanding technology, the role for clinical neuropsychological assessment of cognitive deficits and/or differences in psychiatric populations could become fundamental to diagnosis and treatment.

We took only those neuropsychological tasks (CPT and TMT A & B) that appeared to show PTSD group differences, along with PS and AS error rate and latency to assess whether CAPS scores were related to performance for PTSD-positive veterans. Our finding

that the AS error rate and latency in the face condition was predictive of PTSD symptoms (CAPS B, D, and total score) in a combined model with BDI scores may reflect measurable behavioral differences underlying psychiatric symptoms of PTSD. That reexperiencing and arousal (B and D) versus avoidant symptoms (C) are predicted by AS performance supports inhibitory control conceptualization of PTSD. In the PS face tasks, error rate and latency were also significantly predictive of only CAPS total, yet the change in variance was not as substantial as with the AS tasks. Avoidant symptoms likely reflect a secondary process level of the more maladaptive attempts at behavioral control of the disorder, whereas primary deficits of inhibitory control may more accurately depict measureable cognitive deficits of PTSD. It is important to note that neither the TMT A & B nor the CPT–II measures predicted CAPS when combined in a model with depression scores. Eye movement technology provides data by the millisecond, thought to happen outside of conscious control, which may have allowed for the additional sensitivity needed to uncover a significant finding. Even so, it is the combination of assessing for inhibitory control (i.e., AS versus PS) with the addition of socially salient stimuli (versus nonface) that allows for the brain behavior differences to be seen in conjunction with PTSD psychiatric symptoms. This is not then simply due to sensitivity of an eye-tracking instrument but rather the way it is deployed/manipulated by the neuropsychologist to target areas of brain dysfunction we might expect in PTSD as supported by 20 years of neuroscientific inquiry. Otherwise we might expect that CAPS scores would predict PS in the face condition, or even AS performance in the standard condition.

Limitations and future directions

This is an exploratory study, and results must be considered with limitations in mind. The sample size was relatively small despite being sufficient to detect differences between groups, and it is uncommon to see large samples in eye tracking especially in a clinical population (Armstrong & Olatunji, 2012; Jamadar, Fielding, & Egan, 2013). Negative findings must be interpreted with particular caution. For example, a larger sample may provide sufficient power to detect subtle group differences in the fear versus neutral face trials, though we did include significant mean differences for the benefit of future research. However, previous research has suggested that neutral faces are better conceptualized as emotionally ambiguous instead of "nonemotive" (Cooney, Atlas, Joormann, Eugène, & Gotlib, 2006), and even participants free of mental health concerns may interpret neutral faces as negative (Lee, Kang, Park, Kim, & An, 2008). We do not know test–retest reliability using our particular arrangement of the eye-tracking stimuli, but this could be measured in a future study. The PTSD group generally did poorer on the CPT–II, a test that has been previously shown to reflect impaired performance in PTSD groups (Jenkins, Langlais, Delis, & Cohen, 2000; Vasterling et al., 2002). That said, reduced antisaccade performance has also been shown in children with ADHD (Klein, Raschke, & Brandenbusch, 2003), and we did not formally assess learning disabilities and in-depth educational history. Future study with our population of adults with PTSD should include more formal attentional disorder background investigation.

Some findings are counterintuitive at first glance. In the face condition, for controls, prosaccade latency shows a slower mean than during antisaccade latency (Table 3). However, a comparison of the means shows that they are not significantly different (t = 0.574, p = .29). Furthermore, the control group appears to have made more prosaccade errors than the PTSD group in the face condition, but this again is not significant (Table 3). The standard deviations for error rate are large, and it is likely that a combination of a small sample size and limited amount of face trials affected variability and indicates the need to replicate these preliminary findings. The face stimuli, which are visually complex, likely create more "presaccade" eye movement as participants scan the facial region, perhaps influencing error measurement irrespective of diagnostic category. This kind of scanning can also be measured explicitly in future experiments and with larger samples. Based on our current findings we have most confidence interpreting statistically significant differences between groups when moderate to large effect sizes were found.

Functional neuroimaging studies using this task could also refine our understanding of the mechanisms underlying these controls of action and their alterations in mood and anxiety disorders. Another important line of future research is whether a neurobiologically proximal antisaccade endophenotype could be derived from task performance and harnessed to effectively identify and characterize susceptibility genes as has been projected for schizophrenia by Hutton and Ettinger (2006).

We found that PTSD-diagnosed veterans demonstrated a different pattern of reflexive eye movement than those without PTSD, most notably with our manipulation of antisaccade performance with a task containing socially salient stimuli. This suggests measurable biobehavioral differences as a function of

diagnosis. This has potential implications for Veterans Affairs and the Department of Defense as recent research literature is replete with studies attempting to detangle PTSD from mild traumatic brain injury (mTBI) outcomes, and a method for measuring PTSD associated cognitive–behavioral performance would be useful, especially if brain behavior performance can be measured rather than relying solely on subjective self-reporting of symptoms and subsequent statistical control. It is possible that an entry into the diagnostic conundrum for mTBI/PTSD may be through development of a behavioral measure for PTSD and one that places demands on areas of brain shown to be important targets based on the neuroscience literature. Inhibitory control through an antisaccade task based on socially salient information utilizing computer based eye-tracking technology could be one way to accomplish this. However, the National Institute of Mental Health's (NIMH) Research Domain Criteria (RDoC) concept whereby a construct like cognitive control dysregulation represents a central component of an impairment spectrum rather than a categorically distinct diagnosis (e.g., PTSD vs. mTBI) is relevant to further inquiry in the area as it pertains to the myriad of conditions with potential AS deficits or differences.

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References

American Psychiatric Association. (2000). *Diagnostic and statistical manual of mental disorders, revised* (p. 943). Washington, DC: Author.

Armstrong, T., Bilsky, S. A., Zhao, M., & Olatunji, B. O. (2013). Dwelling on potential threat cues: An eye movement marker for combat-related PTSD. *Depression and Anxiety*, *30*(5), 497–502. doi:10.1002/da.22115

Armstrong, T., & Olatunji, B. O. (2012). Eye tracking of attention in the affective disorders: A meta-analytic review and synthesis. *Clinical Psychology Review*, *32*(8), 704–723. doi:10.1016/j.cpr.2012.09.004

Aupperle, R. L., Allard, C. B., Grimes, E. M., Simmons, A. N., Flagan, T., Behrooznia, M., … Stein, M. B. (2012). Dorsolateral prefrontal cortex activation during emotional anticipation and neuropsychological performance in posttraumatic stress disorder. *Archives of General Psychiatry*, *69*(4), 360–371. doi:10.1001/archgenpsychiatry.2011.1539

Beck, A. T., Steer, R. A., & Brown, G. K. (1996). *Beck depression inventory-II*. San Antonio, TX: The Psychological Corporation.

Beck, J. G., Freeman, J. B., Shipherd, J. C., Hamblen, J. L., & Lackner, J. M. (2001). Specificity of Stroop interference in patients with pain and PTSD. *Journal of Abnormal Psychology*, *110*(4), 536–543. doi:10.1037/0021-843x.110.4.536

Blake, D., Weathers, F. W., Nagy, L., Kaloupek, D., Klauminzer, G., Charney, D., & Keane, T. (1990). *Clinician-administered PTSD scale (CAPS)* (pp. 1–9). Boston, MA: National Center for Posttraumatic Stress Disorder.

Bremner, J. D., Vermetten, E., Vythilingam, M., Afzal, N., Schmahl, C., Elzinga, B., & Charney, D. S. (2004). Neural correlates of the classic color and emotional stroop in women with abuse-related posttraumatic stress disorder. *Biological Psychiatry*, *55*(6), 612–620. doi:10.1016/j.biopsych.2003.10.001

Buckley, T. C., Blanchard, E. B., & Neill, W. T. (2000). Information processing and PTSD: A review of the empirical literature. *Clinical Psychology Review*, *20*(8), 1041–1065. doi:10.1016/S0272-7358(99)00030-6

Centers for Disease Control and Prevention (CDC). (2016). International classification of diseases. 10th revision. Clinical Modification (ICD-10-CM). Internet. Electronic Citation. Retrieved October, 2016 from http://www.cdc.gov/nchs/icd/icd10cm.htm

Conners, C. K., Staff, M. H. S., Connelly, V., Campbell, S., MacLean, M., & Barnes, J. (2000). Conners' continuous performance Test II (CPT II v. 5). *Multi-Health Systems Inc*, *29*, 175–196.

Cooney, R. E., Atlas, L. Y., Joormann, J., Eugène, F., & Gotlib, I. H. (2006). Amygdala activation in the processing of neutral faces in social anxiety disorder: Is neutral really neutral? *Psychiatry Research: Neuroimaging*, *148*(1), 55–59. doi:10.1016/j.pscychresns.2006.05.003

Currie, J., Ramsden, B., McArthur, C., & Maruff, P. (1991). Validation of a clinical antisaccadic eye movement test in the assessment of dementia. *Archives of Neurology*, *48*(6), 644–648. doi:10.1001/archneur.1991.00530180102024

De Weijer, A. D., Mandl, R. C., Sommer, I. E., Vink, M., Kahn, R. S., & Neggers, S. F. (2010). Human fronto-tectal and fronto-striatal-tectal pathways activate differently during anti-saccades. *Frontiers in Human Neuroscience*, *4*. doi:10.1001/archneur.1991.00530180102024

El Khoury-Malhame, M., Lanteaume, L., Beetz, E. M., Roques, J., Reynaud, E., Samuelian, J.-C., … Khalfa, S. (2011). Attentional bias in post-traumatic stress disorder diminishes after symptom amelioration. *Behaviour Research and Therapy*, *49*(11), 796–801. doi:10.1016/j.brat.2011.08.006

Etkin, A., & Wager, T. D. (2007). Functional neuroimaging of anxiety: A meta-analysis of emotional processing in PTSD, social anxiety disorder, and specific phobia. *American Journal of Psychiatry*, *164*(10), 1476–1488. doi:10.1176/appi.ajp.2007.07030504

Falconer, E., Bryant, R., Felmingham, K. L., Kemp, A. H., Gordon, E., Peduto, A., … Williams, L. M. (2008). The neural networks of inhibitory control in posttraumatic stress disorder. *Journal of Psychiatry & Neuroscience: JPN*, *33*(5), 413.

Felmingham, K. L., Rennie, C., Manor, B., & Bryant, R. A. (2011). Eye tracking and physiological reactivity to threatening stimuli in posttraumatic stress disorder. *Journal of Anxiety Disorders*, *25*(5), 668–673. doi:10.1016/j.janxdis.2011.02.010

Fukushima, J., Fukushima, K., Chiba, T., Tanaka, S., Yamashita, I., & Kato, M. (1988). Disturbances of voluntary control of saccadic eye movements in schizophrenic patients. *Biological Psychiatry*, *23*(7), 670–677. doi:10.1016/0006-3223(88)90050-9

García-Blanco, A. C., Perea, M., & Salmerón, L. (2013). Attention orienting and inhibitory control across the different mood states in bipolar disorder: An emotional antisaccade task. *Biological Psychology*, *94*(3), 556–561. doi:10.1016/j.biopsycho.2013.10.005

Golden, C. J., & Freshwater, S. M. (2002). *The stroop color and word test: A manual for clinical and experimental uses*. Chicago, IL: Stoelting.

Guitton, D., Buchtel, H. A., & Douglas, R. M. (1985). Frontal lobe lesions in man cause difficulties in suppressing reflexive glances and in generating goal-directed saccades. *Experimental Brain Research*, *58*(3), 455–472. doi:10.1007/bf00235863

Hallett, P. E. (1978). Primary and secondary saccades to goals defined by instructions. *Vision Research*, *18*(10), 1279–1296. doi:10.1016/0042-6989(78)90218-3

Hayes, J. P., VanElzakker, M. B., & Shin, L. M. (2012). Emotion and cognition interactions in PTSD: A review of neurocognitive and neuroimaging studies. *Frontiers in Integrative Neuroscience*, *6*. doi:10.3389/fnint.2012.00089

Higgins, J. P. T., & Green, S. (Eds.). (2011). *Cochrane handbook for systematic reviews of interventions version 5.1.0 [updated March 2011]*. The Cochrane Collaboration. Retrieved from www.cochrane-handbook.org

Hutton, S. B., & Ettinger, U. (2006). The antisaccade task as a research tool in psychopathology: A critical review. *Psychophysiology*, *43*(3), 302–313. doi:10.1111/j.1469-8986.2006.00403.x

Jamadar, S. D., Fielding, J., & Egan, G. F. (2013). Quantitative meta-analysis of fMRI and PET studies reveals consistent activation in fronto-striatal-parietal regions and cerebellum during antisaccades and prosaccades. *Frontiers in Psychology*, *4*, 749. doi:10.3389/fpsyg.2013.00749

Jenkins, M. A., Langlais, P. J., Delis, D., & Cohen, R. A. (2000). Attentional dysfunction associated with posttraumatic stress disorder among rape survivors. *The Clinical Neuropsychologist*, *14*(1), 7–12. doi:10.1076/1385-4046(200002)14:1;1-8;ft007

Kimble, M. O., Fleming, K., Bandy, C., Kim, J., & Zambetti, A. (2010). Eye tracking and visual attention to threating stimuli in veterans of the Iraq war. *Journal of Anxiety Disorders*, *24*(3), 293–299. doi:10.1016/j.janxdis.2009.12.006

Kitagawa, M., Fukushima, J., & Tashiro, K. (1994). Relationship between antisaccades and the clinical symptoms in Parkinson's disease. *Neurology*, *44*(12), 2285–2285. doi:10.1212/wnl.44.12.2285

Klein, C. H., Raschke, A., & Brandenbusch, A. (2003). Development of pro- and antisaccades in children with attention-deficit hyperactivity disorder (ADHD) and healthy controls. *Psychophysiology*, *40*(1), 17–28. doi:10.1111/1469-8986.00003

Lecrubier, Y., Sheehan, D. V., Weiller, E., Amorim, P., Bonora, I., Sheehan, K. H., … Dunbar, G. C. (1997). The Mini International Neuropsychiatric Interview (MINI). A short diagnostic structured interview: Reliability and validity according to the CIDI. *European Psychiatry*, *12*(5), 224–231. doi:10.1016/s0924-9338(97)83296-8

Lee, E., Kang, J. I., Park, I. H., Kim, -J.-J., & An, S. K. (2008). Is a neutral face really evaluated as being emotionally neutral? *Psychiatry Research*, *157*(1–3), 77–85. doi:10.1016/j.psychres.2007.02.005

Lennertz, L., Rampacher, F., Vogeley, A., Schulze-Rauschenbach, S., Pukrop, R., Ruhrmann, S., … Wagner, M. (2012). Antisaccade performance in patients with obsessive–compulsive disorder and unaffected relatives: Further evidence for impaired response inhibition as a candidate endophenotype. *European Archives of Psychiatry and Clinical Neuroscience*, *262*(7), 625–634. doi:10.1007/s00406-012-0311-1

Leskin, L. P., & White, P. M. (2007). Attentional networks reveal executive function deficits in posttraumatic stress disorder. *Neuropsychology*, *21*(3), 275–284. doi:10.1037/0894-4105.21.3.275

McNally, R. J., Kaspi, S. P., Riemann, B. C., & Zeitlin, S. B. (1990). Selective processing of threat cues in posttraumatic stress disorder. *Journal of Abnormal Psychology*, *99*(4), 398–402. doi:10.1037/0021-843x.99.4.398

McNally, R. J., & Shin, L. M. (1995). Association of intelligence with severity of posttraumatic stress disorder symptoms in Vietnam combat veterans. *The American Journal of Psychiatry*, *152*(6), 936. doi:10.1176/ajp.152.6.936

Merrill, P. T., Paige, G. D., Abrams, R. A., Jacoby, R. G., & Clifford, D. B. (1991). Ocular motor abnormalities in human immunodeficiency virus infection. *Annals of Neurology*, *30*(2), 130–138. doi:10.1002/ana.410300203

Moschovakis, A. K., Scudder, C. A., & Highstein, S. M. (1996). The microscopic anatomy and physiology of the mammalian saccadic system. *Progress in Neurobiology*, *50*(2–3), 133–254. doi:10.1016/s0301-0082(96)00034-2

Mosconi, M. W., Kay, M., D'cruz, A. M., Seidenfeld, A., Guter, S., Stanford, L. D., & Sweeney, J. A. (2009). Impaired inhibitory control is associated with higher-order repetitive behaviors in autism spectrum disorders. *Psychological Medicine*, *39*(09), 1559–1566.

Munoz, D. P., & Everling, S. (2004). Look away: The antisaccade task and the voluntary control of eye movement. *Nature Reviews Neuroscience*, *5*(3), 218–228. doi:10.1038/nrn1345

NCS Pearson Corporation. (2009). *Manual for the test of premorbid functioning (TOPF)*. San Antonio, TX: Author.

Pierrot-Deseilligny, C. H., Rivaud, S., Pillon, B., Fournier, E., & Agid, Y. (1989). Lateral visually-guided saccades in progressive supranuclear palsy. *Brain*, *112*(2), 471–487. doi:10.1093/brain/112.2.471

Reitan, R. M, & Wolfson, D. (1985). *The Halstead-Reitan neuropsychological test battery: Theory and clinical interpretation*. Tucson, AZ: Neuropsychology Press.

Schwartz, B. L., Vaidya, C. J., Howard, J. H.Jr,, & Deutsch, S. I. (2010). Attention to gaze and emotion in schizophrenia. *Neuropsychology*, *24*(6), 711–720. doi:10.1037/a0019562

Schwerdtfeger, R. M. H., Alahyane, N., Brien, D. C., Coe, B. C., Stroman, P. W., & Munoz, D. P. (2013). Preparatory neural networks are impaired in adults with attention-deficit/

hyperactivity disorder during the antisaccade task. *Neuroimage: Clinical*, *2*, 63–78. doi:10.1016/j.nicl.2012.10.006

Scott, J. C., Matt, G. E., Wrocklage, K. M., Crnich, C., Jordan, J., Southwick, S. M., ... Schweinsburg, B. C. (2015). A quantitative meta-analysis of neurocognitive functioning in posttraumatic stress disorder. doi:10.1037/a0038039

Shin, L. M., Whalen, P. J., Pitman, R. K., Bush, G., Macklin, M. L., Lasko, N. B., … Rauch, S. L. (2001). An fMRI study of anterior cingulate function in posttraumatic stress disorder. *Biological Psychiatry*, *50*(12), 932–942. doi:10.1016/s0006-3223(01)01215-x

Shucard, J. L., McCabe, D. C., & Szymanski, H. (2008). An event-related potential study of attention deficits in posttraumatic stress disorder during auditory and visual Go/NoGo continuous performance tasks. *Biological Psychology*, *79*(2), 223–233. doi:10.1016/j.biopsycho.2008.05.005

Swick, D., Honzel, N., Larsen, J., Ashley, V., & Justus, T. (2012). Impaired response inhibition in veterans with post-traumatic stress disorder and mild traumatic brain injury. *Journal of the International Neuropsychological Society*, *18*(05), 917–926. doi:10.1017/s1355617712000458

Thomas, C. L., Goegan, L. D., Newman, K. R., Arndt, J. E., & Sears, C. R. (2013). Attention to threat images in individuals with clinical and subthreshold symptoms of post-traumatic stress disorder. *Journal of Anxiety Disorders*, *27*(5), 447–455. doi:10.1016/j.janxdis.2013.05.005

Tottenham, N., Tanaka, J. W., Leon, A. C., McCarry, T., Nurse, M., Hare, T. A., … Nelson, C. (2009). The NimStim set of facial expressions: Judgments from untrained research participants. *Psychiatry Research*, *168*(3), 242–249. doi:10.1016/j.psychres.2008.05.006

Vasterling, J. J., Duke, L. M., Brailey, K., Constans, J. I., Allain, A. N., & Sutker, P. B. (2002). Attention, learning, and memory performances and intellectual resources in Vietnam veterans: PTSD and no disorder comparisons. *Neuropsychology*, *16*(1), 5–14. doi:10.1037/0894-4105.16.1.5

Weathers, F. W., Huska, J. A., & Keane, T. M. (1991). *PCL-M for DSM-IV*. Boston, MA: National Center for PTSD—Behavioral Science Division.

Wechsler, D. (2008). *Wechsler Adult Intelligence Scale 4th Edition (WAIS-IV)*. San Antonio, TX: Harcourt Assessment.

Wiecki, T. V., & Frank, M. J. (2013). A computational model of inhibitory control in frontal cortex and basal ganglia. *Psychological Review*, *120*(2), 329–355. doi:10.1037/a0031542

Wieser, M. J., Pauli, P., & Mühlberger, A. (2009). Probing the attentional control theory in social anxiety: An emotional saccade task. *Cognitive, Affective, & Behavioral Neuroscience*, *9*(3), 314–322. doi:10.3758/cabn.9.3.314