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Prospective Memory in Posttraumatic Stress Disorder

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Abstract

Objectives: Neuropsychological studies of posttraumatic stress disorder (PTSD) have revealed deficits in attention/working memory, processing speed, executive functioning, and retrospective memory. However, little is known about prospective memory (PM) in PTSD, a clinically relevant aspect of episodic memory that supports the encoding and retrieval of intentions for future actions. **Methods:** Here we examined PM performance in 40 veterans with PTSD compared to 38 trauma comparison (TC) veterans who were exposed to combat but did not develop PTSD. All participants were administered the Memory for Intentions Test (MIST; Raskin, Buckheit, & Sherrod, 2010), a standardized and validated measure of PM, alongside a comprehensive neurocognitive battery, structured diagnostic interviews for psychiatric conditions, and behavioral questionnaires. **Results:** Veterans with PTSD performed moderately lower than TC on time-based PM, with errors primarily characterized as PM failure errors (i.e., omissions). However, groups did not differ in event-based PM, ongoing task performance, or post-test recognition of PM intentions for each trial. Lower time-based PM performance was specifically related to hyperarousal symptoms of PTSD. Time-based-performance was also associated with neuropsychological measures of retrospective memory and executive functions in the PTSD group. Nevertheless, PTSD was significantly associated with poorer PM above and beyond age and performance in retrospective memory and executive functions. **Conclusions:** Results provide initial evidence of PM dysfunction in PTSD, especially in strategic monitoring during time-based PM tasks. Findings have potential implications for everyday functioning and health behaviors in persons with PTSD, and deserve replication and future study. (*JINS*, 2016, *22*, 724–734)

Keywords: Posttraumatic stress disorder, Neuropsychology, Cognitive abilities, Prospective memory, Memory, Anxiety

INTRODUCTION

Posttraumatic stress disorder (PTSD) is a psychiatric condition that develops in response to a traumatic event and affects approximately 8% of the general population and between 10% and 25% of veterans (Hoge, Auchterlonie, & Milliken, 2006; Kessler, Sonnega, Bromet, Hughes, & Nelson, 1995). In recent years, much research has been devoted to the intersection of emotional and cognitive symptoms in PTSD to further understanding of the nature of this disorder and guide the development of novel treatments.

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A large body of research shows that individuals with PTSD exhibit poorer neurocognitive functioning compared to individuals without PTSD, including those exposed to similar traumas and those without trauma exposure (Scott et al., 2015). Neurocognitive domains most commonly affected include episodic memory, attention, executive functions, and information processing speed (e.g., Aupperle, Allard, et al., 2012; Koenen et al., 2001; Vasterling et al., 2002). These deficits are generally moderate in magnitude (Brewin, Kleiner, Vasterling, & Field, 2007; Scott et al., 2015) and associated with social, occupational, and treatment difficulties (Geuze, Vermetten, de Kloet, Hijman, & Westenberg, 2009; Nijdam, de Vries, Gersons, & Olff, 2015; Wrocklage et al., 2016).

Studies to date have focused primarily on retrospective memory (e.g., learning and prompted delayed recall of

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a word list, passage, or design), and little is known about prospective memory (PM) in PTSD, despite its potential clinical and functional relevance (see Zogg, Woods, Sauceda, Wiebe, & Simoni, 2012). PM refers to memory for an intention that might be recalled at an appropriate time in the future without explicit prompting. PM is involved in several everyday tasks and health behaviors, such as remembering to mail a letter on the way home from work, take a medication at a particular time of day, go to an appointment, or return an email to a colleague. Of particular clinical importance, several studies in other psychiatric and neurological disorders have shown that dysfunction in PM is strongly and uniquely associated with important functional outcomes, including medication non-adherence (Woods et al., 2009), engagement in risky behaviors (Weinborn et al., 2013), unemployment (Woods et al., 2011), poorer treatment outcomes (Withall, Harris, & Cumming, 2009), and declines in instrumental activities of daily living (Pirogovsky, Woods, Filoteo, & Gilbert, 2012).

Recall of a PM intention usually occurs in the context of other ongoing activities and necessitates interruption of these activities with either external or internal cues, which are most commonly classified as event- or time-based PM cues, respectively. In event-based PM, recall of an intention or action is cued by an external reminder, such as seeing a pharmacy and then recalling one's intention to fill a prescription. Time-based PM involves recalling an intention at a particular point in time (e.g., go to the pharmacy in 1 hr) and, as such, relies more heavily on internal self-monitoring abilities (McDaniel & Einstein, 2000). Successful PM functioning requires the effective interaction of multiple cognitive processes over a period of time, including the formation and encoding of an intention, maintenance for that intention (or intention-cue pairing) during intervening tasks and demands, selective attention to ignore distracting information during intervening tasks, self-initiated retrieval after an appropriate cue, inhibition of incorrect intentions, and execution of a correct intention (Kliegel, Martin, McDaniel, & Einstein, 2001). Unsurprisingly then, PM performance is dependent on the integrity of prefrontal and (to a lesser degree) mediotemporal memory systems (Burgess, Gonen-Yaacovi, & Volle, 2011; Gordon, Shelton, Bugg, McDaniel, & Head, 2011).

Cognitive and neuroanatomical models of brain-behavior associations in PTSD support the hypothesis that PM functioning might be affected in individuals with PTSD. Current cognitive models of PTSD suggest that hyperarousal and noradrenergic dysfunction may divert attentional resources to extraneous stimuli, which may disrupt prefrontally mediated goal-based attention and encoding of information (Etkin, Gyurak, & O'Hara, 2013; Eysenck, Derakshan, Santos, & Calvo, 2007). This disruption may affect multiple aspects of PM, such as monitoring behavior or inhibition of inappropriate responses.

In fact, attention, inhibition, and retrospective memory, cognitive domains essential for effective PM, appear to be particularly affected in a proportion of individuals with PTSD (Aupperle, Melrose, Stein, & Paulus, 2012; Brewin et al., 2007; Scott et al., 2015) and have been proposed to play a role in both the establishment (e.g., vivid, trauma-related memories) and maintenance (e.g., attentional control of trauma-related thoughts) of the disorder (Brewin, Gregory, Lipton, & Burgess, 2010; McNally, 2006). Furthermore, the profile of retrospective memory dysfunction in PTSD is most consistent with difficulties in "executive" aspects of encoding and retrieval (Samuelson et al., 2006; Scott et al., 2015; Twamley et al., 2009), implicating dysfunction in prefrontal memory systems in PTSD. Specifically, individuals with PTSD have difficulty with initial encoding of information, although minimal forgetting occurs over time, and recognition discrimination is most often unaffected (Cohen et al., 2013; Yehuda, Golier, Halligan, & Harvey, 2004).

Paralleling these findings, functional neuroanatomical models of PTSD have highlighted frontolimbic pathophysiology in PTSD, characterized by reductions in hippocampal volumes and prefrontal cortical thickness, as well as altered patterns of neural activation in medial and dorosolateral prefrontal cortex, and hippocampal and parahippocampal regions (Aupperle, Allard, et al., 2012; Hayes, Hayes, & Mikedis, 2012; Woodward et al., 2009).

PM might also be implicated in PTSD through its negative association with symptoms of depression and anxiety. Higher depressive symptoms are reliably related to worse time-based PM in both clinical and nonclinical samples (Altgassen, Kliegel, & Martin, 2009; Li, Weinborn, Loft, & Maybery, 2013; Rude, Hertel, Jarrold, Covich, & Hedlund, 1999), while findings regarding depression and event-based PM tasks are equivocal (Altgassen et al., 2009; Arnold, Bayen, & Böhm, 2015). Thus, difficulties in PM are primarily observed on tasks that require greater cognitive resources or self-initiation (e.g., time-based tasks), which supports the interpretation that PM deficits are driven by diminished attentional allocation in depression (Li, Weinborn, Loft, & Maybery, 2014). Relatively fewer studies have examined effects of anxiety on PM. In nonclinical samples, state anxiety, or one's current experience of anxiety symptoms, has been negatively related to performance on event-based PM tasks, while event-based PM results for trait anxiety, referring to one's baseline level of anxiety, have been less consistent (Arnold et al., 2015; Harris & Cumming, 2003; Harris & Menzies, 1999). No studies appear to have examined the relationship between time-based PM and anxiety.

One recent study examined associations between PM and PTSD. Using a single-group design with 40 veterans, McFarland and colleagues (2016) reported that PTSD symptom severity was negatively associated with performance on a focal, event-based PM task, even after accounting for contributions from retrospective memory. Moreover, PTSD symptom severity was more associated with PM performance than depression severity. Although this study provides intriguing data on associations between PTSD and PM, several critical questions remain about the pattern and extent of potential PM dysfunction in PTSD. For example, no prior study has been conducted examining PM performance

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in PTSD against a comparison sample, limiting conclusions that can be drawn about the profile of PM performance in patients with PTSD. Moreover, time-based PM has not been examined in PTSD, despite its additional reliance on executive functions and potentially greater theoretical relevance to PTSD. Lastly, McFarland et al. (2016) restricted analyses of cognitive mechanisms contributing to PM (e.g., executive functioning) by only examining retrospective memory.

The aims of the present study were to examine the nature and extent of PM deficits in PTSD. We hypothesized that PTSD would be associated with worse PM performance, especially on time-based tasks in which higher self-directed cognitive resources would be required. We also examined the profile of PM (i.e., errors, performance on the ongoing task, PM recognition) to examine the pattern of PM dysfunction in PTSD. Secondary aims included examining whether: (1) PM was associated with particular PTSD symptom dimensions; and (2) PM functioning correlated with performance on standard clinical tests of executive function, episodic memory, and processing speed in the PTSD sample.

METHODS

Participants

Forty veterans with current PTSD and 38 trauma comparison (TC) participants who were exposed to combat but never met criteria for PTSD were recruited between August 2009 and December 2014. Participants were recruited from the Veterans Affairs (VA) Connecticut Healthcare System through referrals from other National Center for PTSD (NCPTSD) studies; *via* flyers placed within public spaces within the hospital and primary care, mental health, and polytrauma clinics; and outreach in veteran communities. No participants were inpatients at the time of enrollment. Participants were part of a larger psychological and neuroimaging study at the Clinical Neurosciences Division of the NCPTSD.

We excluded participants with histories of severe psychiatric illness (e.g., psychotic disorders), neurological disease, head injuries with a loss of consciousness of greater than 30 min or post-traumatic amnesia of greater than 24 hr, attention deficit/hyperactivity disorder, learning disorders, or had verbal IQ estimates of <70 based on the Wechsler Test of Adult Reading (WTAR; Wechsler, 2001). Participants with current benzodiazepine use were excluded due to their significant cognitive effects (Barker, Greenwood, Jackson, & Crowe, 2004). Participants in the PTSD group with substance use disorders were not excluded to recruit a representative sample of veterans with PTSD. We allowed participants in the TC group with current or lifetime diagnoses of substance abuse, although substance dependence was excluded from this group. All participants underwent urine toxicology screens before the neurocognitive evaluation to ensure abstinence.

Participants who were visibly intoxicated or positive for any drug except cannabis were rescheduled to a later date and asked to maintain abstinence. Because of the difficulty distinguishing recent from residual cannabis use in urine (Goodwin et al., 2008), participants who tested positive for cannabis were allowed to continue if: (1) they denied cannabis use the day of the evaluation; and (2) if the assessor made behavioral observations that the participant was not intoxicated. Six participants had positive screens for cannabis, including three PTSD and three TC.

All participants provided written, informed consent, and the study received Institutional Review Board approval from both VA Connecticut and Yale University. Participants were financially compensated for participating.

MEASURES

Prospective Memory

The proprietary version of the Memory for Intentions Test (MIST; Raskin, Buckheit, & Sherrod, 2010), was administered as a measure of PM abilities. This standardized, performance-based test consists of eight PM tasks over 30 min that are balanced by type of cue (i.e., time-based *vs*. event-based), mode of response (i.e., physical *vs*. verbal), and delay (i.e., 2 min *vs*. 15 min). During the entire task, participants are asked to complete word search puzzles unrelated to the PM tasks, which minimizes continuous active rehearsal of the prescribed intentions. Participants are given a digital clock with which they can monitor the time. Each PM trial is scored from 0 to 2 points, with one point awarded for a correct response and one point awarded for responding (in some manner) at the appropriate time (±15% of the target) or to the appropriate cue. Each trial contributes to three of the MIST's six subscales (range = 0–8), which are summed to create a summary score ranging from 0 to 48. In addition, an eight-item, three-choice recognition trial is administered at the end of the test for each PM task. Prior studies demonstrate that the MIST displays adequate psychometric characteristics and reliability, as well as evidence of construct validity (Kamat et al., 2014; Raskin, 2009; Raskin et al., 2010; Woods, Moran, Dawson, Carey, & Grant, 2008).

We examined the following primary variables: (1) summary score; (2) time-based trials; and (3) event-based trials. In addition, we generated separate error type totals for the time-based and event-based scales (range, 0–4). Consistent with prior studies (Woods et al., 2008), errors were coded as PM failure (i.e., no response omission errors), loss of time (i.e., executing an intention ≥15% target time), task substitution (e.g., responding verbally instead of with an action or *vice versa*), or loss of content (i.e., awareness that a response is required but failure to recall the content) errors.

Neuropsychological Assessment

Participants were also administered a comprehensive neuropsychological assessment designed to be sensitive to potential neurocognitive effects associated with PTSD. The measures chosen for correlational analyses were drawn from

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the domains of attention/working memory [Digit Span and Letter-Number Sequencing Total Scores from the Wechsler Adult Intelligence Scale-Fourth Edition (WAIS-IV; Wechsler, 2008), d-prime from the Conners' Continuous Performance Test II (Conners, 2000)], executive functions [Trailmaking Number-Letter Switching, Color-Word Interference Condition, and Verbal Fluency Switching from the Delis Kaplan Executive Functioning System (DKEFS; Delis, Kaplan, & Kramer, 2001)], retrospective memory [California Verbal Learning Test-Second Edition Trials 1–5 (CVLT-II; Delis, Kramer, Kaplan, & Ober, 2000), Rey-O Complex Figure Test Delayed Recall (Meyers & Meyers, 1995)], and speed of information processing [Coding and Symbol Search subtests from the WAIS-IV (Wechsler, 2008), DKEFS Trail Making Number Sequencing (Delis et al., 2001). All participants performed above published cutoffs on all indices of performance validity [e.g., Test of Memory Malingering (Tombaugh & Tombaugh, 1996) Trial 1 or 2 > or = 45, Digit Memory Test (Hiscock & Hiscock, 1989) > or = 90% accuracy, CVLT Forced Choice ≥14].

Psychiatric Assessment

All participants were administered the Clinician Administered PTSD Scale (CAPS; Blake et al., 1995), widely considered the gold standard PTSD assessment, by extensively trained clinicians. PTSD was diagnosed according to DSM-IV criteria. TC participants never met criteria for a PTSD diagnosis, and none qualified for partial PTSD according to criteria from Pietrzak and colleagues (2012). Participants also completed the Structured Clinical Interview for DSM-IV (SCID-IV; First, Spitzer, Gibbon, & Williams, 2002) to assess for comorbid and exclusionary disorders.

Behavioral and Functional Assessments

The Combat Exposure Scale (Keane et al., 1989) provided a measure of combat severity. The Beck Depression Inventory-2 (BDI-2; Beck, Steer, & Brown, 1996) was used as a measure of depressive symptomatology. Military-related concussions were evaluated by postdoctoral fellows or neuropsychologists with a modified version of the Military Acute Concussion Evaluation (French, McCrea, & Baggett, 2008), a structured interview querying blast exposures, details of head injuries with loss or alteration of consciousness, and post-concussive symptoms. A neuropsychologist independently assessed traumatic brain injury (TBI) severity using American Congress of Rehabilitation Medicine (1993) criteria.

Statistical Analyses

Independent samples *t* tests and χ^2 tests (where appropriate) were performed to examine between-group differences in demographic and psychiatric variables. All variables from the MIST were non-normally distributed (Kolmogrov-Smirnov $p < .05$), and thus Wilcoxon rank-sum tests (complemented with Cohen's *d* measure of effect size) were used to assess between-group differences on MIST primary variables. We further examined the specificity of between-group differences by conducting correlational analyses between MIST variables and both depression and combat exposure and performing multiple regressions predicting PM while including relevant covariates (e.g., TBI, substance use disorders).

To examine associations between MIST variables and neuropsychological measures, *Z* scores were created from raw scores across the whole sample, which were then averaged to generate putative composite measures of neurocognitive functioning within that domain. Neuropsychological measures in which higher scores reflected worse performance were multiplied by −1 so that lower scores always reflected worse performance. Spearman's *rho* correlation coefficients were conducted to examine associations among MIST variables, neuropsychological *Z* scores, and PTSD symptoms. We examined associations with specific PTSD symptom clusters using a well-validated, four-factor emotional numbing symptom model that separates PTSD symptoms into re-experiencing, avoidance, numbing, and hyperarousal symptoms (Asmundson, Stapleton, & Taylor, 2004). The critical alpha level was set at .05.

RESULTS

Demographics and Mental Health

As shown in Table 1, PTSD and TC groups were well matched on demographics, including age, education, race/ethnicity, and gender. Participants were generally equivalent on WTAR IQ estimates. As would be expected, groups differed in BDI-2 scores and alcohol and substance use disorders.

Prospective Memory Performance

Descriptive data for the MIST subscales and errors are displayed in Table 2. As shown in the table, the PTSD group performed significantly worse than the TC group on the MIST summary score (Cohen's $d = -0.60$). Individuals with PTSD performed significantly worse on time-based trials ($d = -0.58$) but did not display significantly worse performance on event-based trials ($d = -0.41$). Moreover, performance on the multiple choice recognition trial and ongoing word search task did not differ between the groups ($ps > .10$). To examine specific errors contributing to time-based PM dysfunction, follow-up analyses of error types on time-based trials were conducted. As shown in Table 2, individuals in the PTSD group showed greater time-based PM failure errors (i.e., omissions; $d = 0.63$), but no significant differences for other time-based PM errors.

Association with Comorbidities, Symptom Dimensions, and Neuropsychological Performance

Follow-up analyses examined whether depression, combat exposure, or substance use disorders could account for the

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Table 1. Demographic, military, and mental health characteristics of the samples

	PTSD (n = 40)	Trauma comparison (n = 38)
Age (years)	35.2 (9.8)	32.9 (8.9)
Education (years)	13.7 (1.8)	14.5 (1.9)
Sex (men, %)	34 (85.0%)	35 (89.5%)
Race [a]		
Caucasian	23 (57.5%)	27 (71.5%)
African-American	5 (12.5%)	4 (10.5%)
Hispanic	7 (17.5%)	4 (10.5%)
Other/unknown	5 (12.5%)	3 (7.9%)
Clinician administered PTSD Scale total score**	72.6 (14.2)	14.5 (13.5)
Combat Exposure Scale total**	21.9 (10.5)	14.3 (8.1)
Beck Depression Inventory-2 total**	25.6 (10.2)	9.3 (7.8)
WTAR Verbal IQ estimate	103.3 (9.4)	104.6 (8.3)
Mild TBI (%)	21 (52.5%)	15 (39.5%)
Lifetime alcohol use disorders*	22 (55.0%)	10 (26.3%)
Lifetime drug use disorders^	11 (32.4%)	4 (10.5%)
Current alcohol use disorders*	7 (17.5%)	1 (2.6%)
Current drug use disorders*	5 (12.5%)	0 (0.0%)

Note. PTSD = posttraumatic stress disorder; TBI = traumatic brain injury; WTAR = Wechsler Test of Adult Reading.
[a]The χ^2 test compares Caucasian to all other groups.
^$p < .10$.
*$p < .05$.
**$p < .01$.

above findings. Considering that the confidence interval for the event-based PM effect size, although null, overlapped with that observed time-based PM, we conducted our follow-up correlational analyses using both MIST summary score to capture overall PM performance and the time-based scale to capture the specific PM deficit evidenced in this cohort. Depression symptoms were not significantly associated with MIST summary score or performance on time-based trials in either the whole sample or the PTSD group (all $ps > .10$). Depression symptoms were significantly associated with performance on event-based trials in the whole sample ($rho = -.25$; $p = .035$) but not in the PTSD sample alone ($rho = -.13$; $p = .445$). Combat exposure was not significantly associated with any MIST variable of interest in either the whole sample or PTSD group (all $ps > .10$).

We examined the influence of TBI and lifetime and current substance use disorders (including alcohol) by including each variable in separate regressions predicting MIST summary score. TBI ($\beta = -0.006$; $p = .957$), current substance use disorders ($\beta = 0.16$; $p = .166$), and lifetime substance use disorders ($\beta = -0.10$; $p = .377$) were not significant explanatory variables in these models, and PTSD remained a significant predictor of MIST summary scores even after their inclusion ($p < .05$). We also conducted supplementary analyses by excluding the seven PTSD individuals with current alcohol/substance use disorders and re-running Wilcoxon rank-sum tests for prior significant results. Results remained significant for MIST summary score ($p = .026$; $d = -0.69$), time-based trials ($p = .014$; $d = -0.65$), and time-based PM failure errors ($p = .037$; $d = 0.61$) even after excluding these individuals.

Correlational analyses revealed that PTSD hyperarousal symptoms were negatively associated with performance on time-based trials ($rho = -.25$; $p = .025$) across the whole sample, such that those with higher symptoms showed worse performance. PTSD numbing symptoms were associated at a trend level with performance on time-based trials ($rho = -.22$; $p = .057$) across the whole sample. All other associations between PTSD symptom clusters and MIST time-based scores were non-significant ($p > .10$).

As shown in Table 3, within the PTSD group, MIST summary score and performance on time-based trials were both significantly correlated with measures of executive functioning ($ps < .05$) and retrospective memory ($ps < .05$). Speed of information processing and attention domains were not significantly associated with any MIST variables of interest in the PTSD group ($ps > .10$). In the TC group, performances on time-based trials were significantly associated with measures of executive functioning and speed of

Table 2. Memory for Intentions Test (MIST) performance by group

	PTSD (n = 40)				Trauma comparison (n = 38)					
MIST variables	Median	IQR	Mean	*SD*	Median	IQR	Mean	*SD*	*p*	*d*
Summary score	42.0	39.0, 45.0	40.5	8.0	45.0	42.0, 48.0	44.2	3.5	.023	–0.60
Event-based trials	8.0	8.0, 8.0	7.3	1.7	8.0	8.0, 8.0	7.8	0.6	.202	–0.41
Timed-based trials	6.5	5.5, 7.0	6.3	1.4	7.0	6.0, 8.0	7.0	1.0	.016	–0.58
PM failure errors	0.0	0.0, 1.0	0.6	1.0	0.0	0.0, 0.0	0.2	0.5	.011	0.63
Task substitution errors	0.0	0.0, 1.0	0.5	0.7	0.0	0.0, 0.0	0.2	0.5	.203	0.35
Loss of content errors	0.0	0.0, 1.0	0.4	0.6	0.0	0.0, 1.0	0.4	0.6	.780	0.12
Loss of time errors	0.0	0.0, 0.0	0.2	0.5	0.0	0.0, 0.0	0.2	0.4	.333	0.22
Recognition posttest	8.0	8.0, 8.0	7.9	0.4	8.0	8.0, 8.0	7.9	0.3	.759	–0.12
Word search	30.0	26.0, 35.0	31.8	11.3	32.0	28.0, 37.0	32.8	9.9	.277	–0.10

Note. *p*-Values represent Wilcoxon rank-sum tests for between group differences. MIST = Memory for Intentions Test; PM = prospective memory; PTSD = posttraumatic stress disorder.

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Table 3. Associations between prospective memory performance and neuropsychological functioning in the PTSD group

Neuropsychological *Z* score	MIST summary score	MIST time-based trials	MIST event- based trials
Executive functioning	0.43**	0.50**	0.17
Attention	0.20	0.22	0.25
Speed of information processing	0.25	0.26	0.18
Retrospective memory	0.36*	0.37*	0.27

Note. Data presented are Spearman's correlations. MIST = Memory for Intentions Screening Test; PTSD = posttraumatic stress disorder.
*$p < .05$.
**$p < .01$.

information processing but not with other domains ($ps > .10$; Table 4).

Independent Contribution of PTSD to Time-Based PM

To examine the independent contribution of PTSD to MIST time-based scores above and beyond age and relevant neuropsychological factors, we conducted hierarchical regressions in the whole sample, with age and retrospective memory and executive functioning *Z* scores entered in the first step, followed by PTSD diagnosis. Even though age was not significantly different in the two groups, aging is associated with declines in performance on laboratory-based PM tasks (Henry, MacLeod, Phillips, & Crawford, 2004). In our sample, age was significantly associated with MIST time-based score across the whole sample (*rho* = –.34; $p = .003$) and within the PTSD group (*rho* = –.32; $p = .013$). As shown in Table 5, in the first step of a hierarchical regression analysis predicting MIST time-based score, age and executive functioning were significant in the model but the memory *Z* score was not; the model accounted for significant variance ($R^2 = 0.24$). When PTSD diagnosis was entered in the second step, it was a significant explanatory variable in the model and accounted for significant change in variance (R^2 change = 0.04), and a significant overall R^2 (0.28).

DISCUSSION

The current study examined the nature and extent of PM dysfunction in PTSD. Prior studies have shown that PTSD is associated with dysfunction in inhibition, working memory, and retrospective memory (Aupperle, Melrose, et al., 2012; Polak, Witteveen, Reitsma, & Olff, 2012; Scott et al., 2015), and a recent study showed that PTSD symptom severity was associated with performance on a focal, event-based PM task. Here, we extend this literature and show that during an ecologically relevant, performance-based test of PM, veterans with PTSD displayed more time-based PM omission failures than a trauma-exposed comparison group.

Importantly, associations between PTSD and PM were not better explained by deficits in other relevant neurocognitive abilities, such as executive functions and retrospective memory, nor were they explained by age. These results are not likely due to between-group demographic differences, as groups were relatively well matched on these variables. Group differences also persisted after adjusting for relevant confounds and comorbidities. Moreover, groups were equivalent in performance on the ongoing word search task completed during PM cue-intention encoding and recall, suggesting that differences were unlikely to be due to limited overall task engagement. Taken together, these data suggest that PTSD may be associated with a specific deficit in PM.

In the context of McDaniel and Einstein's (2000) multiprocess theory, the observed pattern of PM performance suggests that individuals with PTSD have difficulties with PM tasks when strategic monitoring cognitive loads are increased. More specifically, while individuals with PTSD displayed numerically lower performance in both time-based (e.g., "In 15 minutes, use that paper to write the number of medications you are currently taking") and event-based tasks (e.g., "When I hand you a postcard, self-address it"), they only evidenced significantly worse performance on time-based tasks compared to TC participants. Of interest, these results contrast somewhat with those of McFarland et al. (2016), who reported that PTSD symptom severity was

Table 4. Associations between prospective memory performance and neuropsychological functioning in the TC group

Neuropsychological *Z* score	MIST summary score	MIST time-based trials	MIST event- based trials
Executive functioning	0.24	0.33*	0.07
Attention	0.07	0.16	–0.03
Speed of information processing	0.24	0.34*	0.18
Retrospective memory	0.20	0.26	0.01

Note. Data presented are Spearman's correlations. MIST = Memory for Intentions Screening Test; TC = trauma comparison.
*$p < .05$.

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Table 5. Hierarchical regression predicting MIST summary score

	F, p	R^2	R^2 *Change, p*	*ß*	*t*	*p*
Step1	7.82, <.001	0.24	—			
Age				−.33	2.81	.006
Memory				.02	0.17	.866
Executive functioning				.26	2.24	.028
Step 2	7.13, <.001	0.28	0.041, .047			
Age				−.33	2.91	.005
Memory				−.01	0.13	.897
Executive functioning				.20	1.66	.101
PTSD				−.20	2.02	.047

Note. MIST = Memory for Intentions Test; PTSD = posttraumatic stress disorder.

associated with reduced performance on an focal event-based PM task with a single prospective memory cue.

Theoretical models of PM have proposed that time-based PM is more heavily dependent on self-generated monitoring and retrieval processes associated with cognitive control (McDaniel & Einstein, 2000), which is associated with the integrity of prefrontal circuitry and associated executive functions (Einstein, McDaniel, Richardson, Guynn, & Cunfer, 1995) implicated in PTSD (Aupperle, Melrose, et al., 2012). In contrast, event-based PM typically relies on externally prompted, less effortful, and more automatic retrieval (Einstein et al., 1995). In the context of these models, it may be that individuals with PTSD have greater difficulty accurately completing future intentions when tasks require greater internally guided allocation of cognitive resources.

Analyses of error types on time-based trials suggested that the PTSD group made more PM failure errors (i.e., omissions) than the TC group but did not differ in other time-based errors (e.g., loss of content, task substitutions). In the setting of intact recognition and ongoing task performance, these data suggest that individuals with PTSD may have had difficulty with the process of strategically monitoring time to detect the proper moment at which to enact their planned intention (McDaniel & Einstein, 2000). Adaptive time-based PM monitoring typically exhibits a J-shaped curve in which a brief initial monitoring spike occurs, followed by less frequent monitoring until the target time approaches, when monitoring greatly increases in frequency until the intention is executed.

Such adaptive clock-checking behavior has been shown to be strongly related to time-based PM (Doyle et al., 2013), can be disrupted in neuropsychiatric populations (e.g., schizophrenia; Shum, Ungvari, Tang, & Leung, 2004), and is associated with deficits in executive functions and retrospective memory (Doyle et al., 2013). Analyses of the cognitive correlates of PM provided further evidence to support this interpretation, as they revealed moderate correlations with executive functions and retrospective memory in the PTSD group. However, since we did not specifically measure time monitoring, the possible contribution of retrospective memory failures cannot be dismissed. Future studies are needed to examine the role of strategic clock-checking behaviors in PTSD and determine if efforts to support such processes (e.g., increasing task importance, introducing intermittent salient monitoring reminders) can enhance or normalize PM (Woods et al., 2014).

Of note, the PTSD group did not differ from TC in event-based PM, which is a relatively more automatic process (McDaniel & Einstein, 2000). This is particularly true in the case of the proprietary version of the MIST in which the cues are overtly displayed to the examinee (cf., the research version of the MIST, which uses more subtle cues; Woods et al., 2008), thus greatly reducing cue monitoring and detection demands. Even so, the effect size confidence intervals for time-based and event-based PM did not differ in the present study, although null hypothesis significance testing revealed a deficit in the former but not the latter.

Thus, we cannot confidently state that PTSD is not associated with deficits in event-based PM, which is a complex and multifaceted construct. In fact, McFarland and colleagues (2016) found that PTSD symptom severity was associated with performance on a focal event-based PM task, although no comparison with a non-PTSD group was conducted. Future studies may, therefore, wish to exploit the relative strategic and automatic monitoring demands of event-based PM to determine under what conditions such deficits emerge (and are abated) in PTSD. For example, manipulations of cue focality (Kliegel, Jäger, & Phillips, 2008), cue salience, ongoing task demands, and the semantic relatedness of cue-intention pairings (Woods, Dawson, Weber, & Grant, 2010) may prove interesting in PTSD.

The discrepancy between time-based and event-based PM in the current study is consistent with prior results from major depression, which have shown worse time-based PM but relatively intact event-based PM (Li et al., 2013). Unexpectedly, in the current study, depression symptoms were associated with event-based PM across the whole sample, although this correlation was not significant in the PTSD group. It was noteworthy, however, that depressive symptoms were not associated with overall or time-based PM in the current study, although PTSD numbing symptoms (which are theoretically related to dimensions of depression) did exhibit trend-level associations with PM performance.

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Taken together with previous results, individuals with depression and those with PTSD may show similar difficulties with self-initiated monitoring and retrieval during PM, although these difficulties may arise from divergent mechanisms that result in similar cognitive control dysfunction. Future studies may benefit from large-scale psychiatric samples to delineate the dimensional symptoms of PTSD, depression, and anxiety that are associated with specific patterns of PM dysfunction.

Analyses of dimensional PTSD symptoms found specific associations between a cluster of hyperarousal symptoms and both the MIST summary score and time-based score, with a marginally significant association with PTSD numbing symptoms. In contrast, McFarland et al. (2016) reported correlations between all symptom clusters and event-related PM performance. Discrepancies between our results may reflect differences in PM task parameters.

Relevant to the current study, hyperarousal symptoms of PTSD include sleep disturbance, difficulty concentrating, irritability, hypervigilance, and an exaggerated startle response. These symptoms have been associated with dysfunction in noradrenergic systems (Arnsten, Raskind, Taylor, & Connor, 2015; Pietrzak et al., 2013), which modulate the response of cortical regions to allocate resources according to task demands by enhancing interactions within top-down prefrontal cortical systems involved in attention and executive control (Aston-Jones & Cohen, 2005). Given convincing evidence of prefrontal cortical dysfunction in PTSD (e.g., Liberzon & Sripada, 2008), one possibility is that PM difficulties are driven by noradrenergic system dysfunction and associated inefficiencies in resource allocation (e.g., hypervigilance to extraneous stimuli); this speculation awaits future study.

Limitations of this study should be acknowledged and include the exclusive focus on veterans with PTSD and a limited sample of women. An additional limitation is the substance exclusion criteria that resulted in significant substance use comorbidity in the PTSD group, with less comorbidity in the TC group. We recruited the PTSD sample to extend generalizability and be generally representative of the veteran PTSD population. Although our supplementary analyses showed that these comorbid conditions, including substance use disorders, were not associated with PM in the PTSD sample, we cannot positively assert that PTSD is associated with PM in the absence of such comorbidities nor that these comorbidities will not have additive or synergistic effects on PM performance in prospective studies that are properly powered to answer such complex questions. We also did not directly assess monitoring behavior (e.g., clock-checking), although this is strongly related to time-based PM performance (Doyle et al., 2013).

In addition, performance was close to ceiling on event-based trials, reflecting a common challenge in event-based PM tasks, which involve more automatic retrieval. Use of subtle or non-focal event-based cues in future studies may reduce ceiling effects. Moreover, this cross-sectional study cannot determine whether group differences reported here represent acquired dysfunction or pre-existing vulnerabilities. Previous longitudinal and twin studies have suggested that neurocognitive performance discrepancies in some domains may represent both vulnerability factors for and consequences of PTSD (Gilbertson et al., 2006; Marx, Doron-Lamarca, Proctor, & Vasterling, 2009; Parslow & Jorm, 2007), although measures of executive control have typically been omitted from such studies.

Despite these limitations, the current study provides initial evidence of time-based PM dysfunction in PTSD. Future studies should seek to replicate these findings and examine whether such deficits are found in civilians with PTSD. To further examine mechanisms of PM dysfunction in PTSD, future studies could manipulate the ongoing PM task (e.g., word search puzzle) by adding trauma-related stimuli, which could theoretically exacerbate PM deficits and provide insights into the underlying architecture of observed performance differences. Given prior findings in depression and other relevant disorders (Li et al., 2013; Poquette et al., 2013), future work could also examine the effects of delay interval on PM dysfunction in PTSD. Furthermore, although prior studies have shown that PM dysfunction is associated with important functional outcomes, such as medication adherence (Poquette et al., 2013), the contribution of PM dysfunction to functional outcomes in PTSD (e.g., treatment outcomes; Withall et al., 2009) remains unexplored. If time-based PM dysfunction is driven by problems in strategic monitoring and retrieval, interventions that target these aspects of PM (e.g., self-regulatory strategies) might prove valuable, especially since time-based PM robustly predicts everyday functioning outcomes in other populations (Weinborn et al., 2013; Woods et al., 2009).

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REFERENCES

Altgassen, M., Kliegel, M., & Martin, M. (2009). Event-based prospective memory in depression: The impact of cue focality. *Cognition and Emotion*, *23*(6), 1041–1055.

American Congress of Rehabilitation Medicine. (1993). Definition of mild traumatic brain injury. *Journal of Head Trauma Rehabilitation*, *8*(3), 86–87.

https://doi.org/10.1017/S1355617716000564 Published online by Cambridge University Press

Arnold, N.R., Bayen, U.J., & Böhm, M.F. (2015). Is prospective memory related to depression and anxiety? A hierarchical MPT modelling approach. *Memory*, *23*, 1215–1228. http://doi.org/10.1080/09658211.2014.969276

Arnsten, A.F.T., Raskind, M.A., Taylor, F.B., & Connor, D.F. (2015). The effects of stress exposure on prefrontal cortex: Translating basic research into successful treatments for post-traumatic stress disorder. *Neurobiology of Stress*, *1*, 89–99. http://doi.org/10.1016/j.ynstr.2014.10.002

Asmundson, G.J.G., Stapleton, J.A., & Taylor, S. (2004). Are avoidance and numbing distinct PTSD symptom clusters? *Journal of Traumatic Stress*, *17*(6), 467–475. http://doi.org/10.1007/s10960-004-5795-7

Aston-Jones, G., & Cohen, J.D. (2005). An integrative theory of locus coeruleus-norepinephrine function: Adaptive gain and optimal performance. *Annual Review of Neuroscience*, *28*, 403–450. http://doi.org/10.1146/annurev.neuro.28.061604.135709

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. http://doi.org/10.1001/archgenpsychiatry.2011.1539

Aupperle, R.L., Melrose, A.J., Stein, M.B., & Paulus, M.P. (2012). Executive function and PTSD: Disengaging from trauma. *Neuropharmacology*, *62*(2), 686–694. http://doi.org/10.1016/j.neuropharm.2011.02.008

Barker, M.J., Greenwood, K.M., Jackson, M., & Crowe, S.F. (2004). Persistence of cognitive effects after withdrawal from long-term benzodiazepine use: A meta-analysis. *Archives of Clinical Neuropsychology*, *19*(3), 437–454. http://doi.org/10.1016/S0887-6177(03)00096-9

Beck, A.T., Steer, R.A., & Brown, G.K. (1996). *Beck Depression Inventory-II*. San Antonio, TX: Harcourt Brace.

Blake, D.D., Weathers, F.W., Nagy, L.M., Kaloupek, D.G., Gusman, F.D., Charney, D.S., & Keane, T.M. (1995). The development of a clinician-administered PTSD scale. *Journal of Traumatic Stress*, *8*(1), 75–90. http://doi.org/http://doi.org/10.1002/jts.2490080106

Brewin, C.R., Gregory, J.D., Lipton, M., & Burgess, N. (2010). Intrusive images in psychological disorders: Characteristics, neural mechanisms, and treatment implications. *Psychological Review*, *117*(1), 210–232. http://doi.org/10.1037/a0018113

Brewin, C.R., Kleiner, J.S., Vasterling, J.J., & Field, A.P. (2007). Memory for emotionally neutral information in posttraumatic stress disorder: A meta-analytic investigation. *Journal of Abnormal Psychology*, *116*(3), 448–463. http://doi.org/10.1037/0021-843X.116.3.448

Burgess, P.W., Gonen-Yaacovi, G., & Volle, E. (2011). Functional neuroimaging studies of prospective memory: What have we learnt so far? *Neuropsychologia*, *49*(8), 2246–2257. http://doi.org/10.1016/j.neuropsychologia.2011.02.014

Cohen, B.E., Neylan, T.C., Yaffe, K., Samuelson, K.W., Li, Y., & Barnes, D.E. (2013). Posttraumatic stress disorder and cognitive function: Findings from the mind your heart study. *The Journal of Clinical Psychiatry*, *74*(11), 1063–1070. http://doi.org/10.4088/JCP.12m08291

Conners, C.K. (2000). *Conners' Continuous Performance Test II (CPT II V. 5)*. North Tonawanda, NY: Multi-Health Systems Inc.

Delis, D.C., Kaplan, E., & Kramer, J.H. (2001). *Delis-Kaplan executive function system (D-KEFS)*. San Antonio, TX: Psychological Corporation.

Delis, D.C., Kramer, J.H., Kaplan, E., & Ober, B.A. (2000). *California Verbal Learning Test - Second Edition: CVLT-II*. San Antonio, TX: Pearson.

Doyle, K.L., Loft, S., Morgan, E.E., Weber, E., Cushman, C., Johnston, E., … Hiv Neurobehavioral Research Program Hnrp Group. (2013). Prospective memory in HIV-associated neurocognitive disorders (HAND): The neuropsychological dynamics of time monitoring. *Journal of Clinical and Experimental Neuropsychology*, *35*(4), 359–372. http://doi.org/10.1080/13803395.2013.776010

Einstein, G.O., McDaniel, M.A., Richardson, S.L., Guynn, M.J., & Cunfer, A.R. (1995). Aging and prospective memory: Examining the influences of self-initiated retrieval processes. *Journal of Experimental Psychology. Learning, Memory, and Cognition*, *21*(4), 996–1007.

Etkin, A., Gyurak, A., & O'Hara, R. (2013). A neurobiological approach to the cognitive deficits of psychiatric disorders. *Dialogues in Clinical Neuroscience*, *15*(4), 419–429.

Eysenck, M.W., Derakshan, N., Santos, R., & Calvo, M.G. (2007). Anxiety and cognitive performance: Attentional control theory. *Emotion*, *7*(2), 336–353. http://doi.org/10.1037/1528-3542.7.2.336

First, M.B., Spitzer, R.L., Gibbon, M., & Williams, J.B. (2002). *Structured Clinical Interview for DSM-IV-TR Axis I Disorders, Research Version, Patient Edition. (SCID-I/P)*. New York: Biometrics Research, New York State Psychiatric Institute.

French, L., McCrea, M., & Baggett, M. (2008). The military acute concussion evaluation (MACE). *Journal of Special Operations Medicine*, *8*(1), 68–77.

Geuze, E., Vermetten, E., de Kloet, C.S., Hijman, R., & Westenberg, H.G.M. (2009). Neuropsychological performance is related to current social and occupational functioning in veterans with posttraumatic stress disorder. *Depression and Anxiety*, *26*(1), 7–15. http://doi.org/10.1002/da.20476

Gilbertson, M.W., Paulus, L.A., Williston, S.K., Gurvits, T.V., Lasko, N.B., Pitman, R.K., & Orr, S.P. (2006). Neurocognitive function in monozygotic twins discordant for combat exposure: Relationship to posttraumatic stress disorder. *Journal of Abnormal Psychology*, *115*(3), 484–495. http://doi.org/10.1037/0021-843X.115.3.484

Goodwin, R.S., Darwin, W.D., Chiang, C.N., Shih, M., Li, S.-H., & Huestis, M.A. (2008). Urinary elimination of 11-Nor-9-carboxy-9-tetrahydrocannnabinol in cannabis users during continuously monitored abstinence. *Journal of Analytical Toxicology*, *32*(8), 562–569.

Gordon, B.A., Shelton, J.T., Bugg, J.M., McDaniel, M.A., & Head, D. (2011). Structural correlates of prospective memory. *Neuropsychologia*, *49*(14), 3795–3800. http://doi.org/10.1016/j.neuropsychologia.2011.09.035

Harris, L.M., & Cumming, S.R. (2003). An examination of the relationship between anxiety and performance on prospective and retrospective memory tasks. *Australian Journal of Psychology*, *55*(1), 51–55. http://doi.org/10.1080/00049530412331312874

Harris, L.M., & Menzies, R.G. (1999). Mood and prospective memory. *Memory*, *7*(1), 117–127. http://doi.org/10.1080/741943717

Hayes, J.P., Hayes, S.M., & Mikedis, A.M. (2012). Quantitative meta-analysis of neural activity in posttraumatic stress disorder. *Biology of Mood & Anxiety Disorders*, *2*(1), 9. http://doi.org/10.1186/2045-5380-2-9

Henry, J.D., MacLeod, M.S., Phillips, L.H., & Crawford, J.R. (2004). A meta-analytic review of prospective memory and aging. *Psychology and Aging*, *19*(1), 27–39. http://doi.org/10.1037/0882-7974.19.1.27

https://doi.org/10.1017/S1355617716000564 Published online by Cambridge University Press

Hiscock, M., & Hiscock, C.K. (1989). Refining the forced-choice method for the detection of malingering. *Journal of Clinical and Experimental Neuropsychology*, *11*(6), 967–974. http://doi.org/10.1080/01688638908400949

Hoge, C.W., Auchterlonie, J.L., & Milliken, C.S. (2006). Mental health problems, use of mental health services, and attrition from military service after returning from deployment to Iraq or Afghanistan. *The Journal of the American Medical Association*, *295*(9), 1023–1032. http://doi.org/10.1001/jama.295.9.1023

Kamat, R., Weinborn, M., Kellogg, E.J., Bucks, R.S., Velnoweth, A., & Woods, S.P. (2014). Construct validity of the Memory for Intentions Screening Test (MIST) in healthy older adults. *Assessment*, *21*(6), 742–753. http://doi.org/10.1177/1073191114530774

Keane, T.M., Fairbank, J.A., Caddell, J.M., Zimering, R.T., Taylor, K.L., & Mora, C.A. (1989). Clinical evaluation of a measure to assess combat exposure. *Psychological Assessment*, *1*(1), 53. http://doi.org/http://doi.org/10.1037/1040-3590.1.1.53

Kessler, R.C., Sonnega, A., Bromet, E., Hughes, M., & Nelson, C.B. (1995). Posttraumatic stress disorder in the National Comorbidity Survey. *Archives of General Psychiatry*, *52*(12), 1048–1060. http://doi.org/http://doi.org/10.1001/archpsyc.1995.03950240066012

Kliegel, M., Jäger, T., & Phillips, L.H. (2008). Adult age differences in event-based prospective memory: A meta-analysis on the role of focal versus nonfocal cues. *Psychology and Aging*, *23*(1), 203–208. http://doi.org/10.1037/0882-7974.23.1.203

Kliegel, M., Martin, M., McDaniel, M.A., & Einstein, G.O. (2001). Varying the importance of a prospective memory task: Differential effects across time-and event-based prospective memory. *Memory*, *9*(1), 1–11.

Koenen, K.C., Driver, K.L., Oscar-Berman, M., Wolfe, J., Folsom, S., Huang, M.T., & Schlesinger, L. (2001). Measures of prefrontal system dysfunction in posttraumatic stress disorder. *Brain and Cognition*, *45*(1), 64–78. http://doi.org/10.1006/brcg.2000.1256

Liberzon, I., & Sripada, C.S. (2008). The functional neuroanatomy of PTSD: A critical review. *Progress in Brain Research*, *167*, 151–169. http://doi.org/10.1016/S0079-6123(07)67011-3

Li, Y.R., Weinborn, M., Loft, S., & Maybery, M. (2013). Patterns of prospective memory impairment among individuals with depression: The influence of cue type and delay interval. *Journal of the International Neuropsychological Society*, *19*(6), 718–722. http://doi.org/10.1017/S1355617713000180

Li, Y.R., Weinborn, M., Loft, S., & Maybery, M. (2014). Cognitive control processes underlying time-based prospective memory impairment in individuals with high depressive symptomatology. *Acta Psychologica*, *149*, 18–23. http://doi.org/10.1016/j.actpsy.2014.02.010

Marx, B.P., Doron-Lamarca, S., Proctor, S.P., & Vasterling, J.J. (2009). The influence of pre-deployment neurocognitive functioning on post-deployment PTSD symptom outcomes among Iraq-deployed Army soldiers. *Journal of the International Neuropsychological Society*, *15*(6), 840–852. http://doi.org/10.1017/S1355617709990488

McDaniel, M.A., & Einstein, G.O. (2000). Strategic and automatic processes in prospective memory retrieval: A multi-process framework. *Applied Cognitive Psychology*, *14*(7), S127–S144.

McFarland, C.P., Clark, J.B., Lee, L.O., Grande, L.J., Marx, B.P., & Vasterling, J.J. (2016). Event-based prospective memory among veterans: The role of posttraumatic stress disorder symptom severity in executing intentions. *Journal of Clinical and Experimental Neuropsychology*, *38*(2), 251–260. http://doi.org/10.1080/13803395.2015.1102203

McNally, R.J. (2006). Cognitive abnormalities in post-traumatic stress disorder. *Trends in Cognitive Sciences*, *10*(6), 271–277. http://doi.org/10.1016/j.tics.2006.04.007

Meyers, J.E., & Meyers, K.R. (1995). *Rey Complex Figure Test and Recognition Trial: Professional Manual*. Odessa, FL: Psychological Assessment Resources, Inc.

Nijdam, M.J., de Vries, G.-J., Gersons, B.P.R., & Olff, M. (2015). Response to psychotherapy for posttraumatic stress disorder: The role of pretreatment verbal memory performance. *The Journal of Clinical Psychiatry*, e1023–e1028. http://doi.org/10.4088/JCP.14m09438

Parslow, R.A., & Jorm, A.F. (2007). Pretrauma and posttrauma neurocognitive functioning and PTSD symptoms in a community sample of young adults. *The American Journal of Psychiatry*, *164*(3), 509–515. http://doi.org/10.1176/appi.ajp.164.3.509

Pietrzak, R.H., Gallezot, J.-D., Ding, Y.-S., Henry, S., Potenza, M.N., Southwick, S.M., … Neumeister, A. (2013). Association of posttraumatic stress disorder with reduced in vivo norepinephrine transporter availability in the locus coeruleus. *JAMA Psychiatry*, *70*(11), 1199–1205. http://doi.org/10.1001/jamapsychiatry.2013.399

Pietrzak, R.H., Goldstein, R.B., Southwick, S.M., & Grant, B.F. (2012). Psychiatric comorbidity of full and partial posttraumatic stress disorder among older adults in the United States: Results from wave 2 of the National Epidemiologic Survey on Alcohol and Related Conditions. *The American Journal of Geriatric Psychiatry*, *20*(5), 380–390. http://doi.org/10.1097/JGP.0b013e31820d92e7

Pirogovsky, E., Woods, S.P., Filoteo, J.V., & Gilbert, P.E. (2012). Prospective memory deficits are associated with poorer everyday functioning in Parkinson's disease. *Journal of the International Neuropsychological Society*, *18*(6), 986–995. http://doi.org/10.1017/S1355617712000781

Polak, A.R., Witteveen, A.B., Reitsma, J.B., & Olff, M. (2012). The role of executive function in posttraumatic stress disorder: A systematic review. *Journal of Affective Disorders*, *141*(1), 11–21. http://doi.org/10.1016/j.jad.2012.01.001

Poquette, A.J., Moore, D.J., Gouaux, B., Morgan, E.E., Grant, I., Woods, S.P., & HNRP Group. (2013). Prospective memory and antiretroviral medication non-adherence in HIV: An analysis of ongoing task delay length using the memory for intentions screening test. *Journal of the International Neuropsychological Society*, *19*(2), 155–161. http://doi.org/10.1017/S1355617712001051

Raskin, S.A. (2009). Memory for intentions screening test: Psychometric properties and clinical evidence. *Brain Impairment*, *10*(01), 23–33.

Raskin, S.A., Buckheit, C., & Sherrod, C. (2010). *Memory for intentions test (MIsT)*. Lutz, FL: Psychological Assessment Resources.

Rude, S.S., Hertel, P.T., Jarrold, W., Covich, J., & Hedlund, S. (1999). Depression-related impairments in prospective memory. *Cognition & Emotion*, *13*(3), 267–276.

Samuelson, K.W., Neylan, T.C., Metzler, T.J., Lenoci, M., Rothlind, J., Henn-Haase, C., … Marmar, C.R. (2006). Neuropsychological functioning in posttraumatic stress disorder and alcohol abuse. *Neuropsychology*, *20*(6), 716–726. http://doi.org/10.1037/0894-4105.20.6.716

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. *Psychological Bulletin*, *141*(1), 105–140. http://doi.org/10.1037/a0038039

https://doi.org/10.1017/S1355617716000564 Published online by Cambridge University Press

Shum, D., Ungvari, G.S., Tang, W.-K., & Leung, J.P. (2004). Performance of schizophrenia patients on time-, event-, and activity-based prospective memory tasks. *Schizophrenia Bulletin*, *30*(4), 693–701.

Tombaugh, T.N., & Tombaugh, P.W. (1996). *Test of Memory Malingering: TOMM*. North Tonawanda, NY: Multi-Health Systems.

Twamley, E.W., Allard, C.B., Thorp, S.R., Norman, S.B., Hami Cissell, S., Hughes Berardi, K., … Stein, M.B. (2009). Cognitive impairment and functioning in PTSD related to intimate partner violence. *Journal of the International Neuropsychological Society*, *15*(06), 879–887. http://doi.org/10.1017/S135561770999049X

Vasterling, J.J., Duke, L.M., Brailey, K., Constans, J.I., Allain, A.N. Jr., & 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. http://doi.org/http://doi.org/10.1037/0894-4105.16.1.5

Wechsler, D. (2001). *Wechsler Test of Adult Reading: WTAR*. San Antonio, TX: Psychological Corporation.

Wechsler, D. (2008). *Wechsler Adult Intelligence Scale–Fourth Edition (WAIS–IV)*. San Antonio, TX: NCS Pearson.

Weinborn, M., Moyle, J., Bucks, R.S., Stritzke, W., Leighton, A., & Woods, S.P. (2013). Time-based prospective memory predicts engagement in risk behaviors among substance users: Results from clinical and nonclinical samples. *Journal of the International Neuropsychological Society*, 1–11. http://doi.org/10.1017/S1355617712001361

Withall, A., Harris, L.M., & Cumming, S.R. (2009). The relationship between cognitive function and clinical and functional outcomes in major depressive disorder. *Psychological Medicine*, *39*(3), 393–402. http://doi.org/10.1017/S0033291708003620

Woods, S.P., Dawson, M.S., Weber, E., Gibson, S., Grant, I., & Atkinson, J.H. (2009). Timing is everything: Antiretroviral nonadherence is associated with impairment in time-based prospective memory. *Journal of the International Neuropsychological Society*, *15*(1), 42–52. http://doi.org/10.1017/S1355617708090012

Woods, S.P., Dawson, M.S., Weber, E., & Grant, I. (2010). The semantic relatedness of cue-intention pairings influences event-based prospective memory failures in older adults with HIV infection. *Journal of Clinical and Experimental Neuropsychology*, *32*(4), 398–407. http://doi.org/10.1080/13803390903130737

Woods, S.P., Doyle, K.L., Morgan, E.E., Naar-King, S., Outlaw, A.Y., Nichols, S.L., & Loft, S. (2014). Task importance affects event-based prospective memory performance in adults with HIV-associated neurocognitive disorders and HIV-infected young adults with problematic substance use. *Journal of the International Neuropsychological Society*, *20*(6), 652–662. http://doi.org/10.1017/S1355617714000435

Woods, S.P., Moran, L.M., Dawson, M.S., Carey, C.L., & Grant, I. (2008). Psychometric characteristics of the memory for intentions screening test. *The Clinical Neuropsychologist*, *22*(5), 864–878. http://doi.org/10.1080/13854040701595999

Woods, S.P., Weber, E., Weisz, B.M., Twamley, E.W., Grant, I., & HIV Neurobehavioral Research Programs Group. (2011). Prospective memory deficits are associated with unemployment in persons living with HIV infection. *Rehabilitation Psychology*, *56*(1), 77–84. http://doi.org/10.1037/a0022753

Woodward, S.H., Kaloupek, D.G., Grande, L.J., Stegman, W.K., Kutter, C.J., Leskin, L., … Eliez, S. (2009). Hippocampal volume and declarative memory function in combat-related PTSD. *Journal of the International Neuropsychological Society*, *15*(06), 830–839. http://doi.org/10.1017/S1355617709990476

Wrocklage, K.M., Schweinsburg, B.C., Krystal, J.H., Trejo, M., Roy, A., Weisser, V., … Scott, J.C. (2016). Neuropsychological functioning in veterans with posttraumatic stress disorder: Associations with performance validity, comorbidities, and functional outcomes. *Journal of the International Neuropsychological Society*, *22*(4), 399–411. http://doi.org/10.1017/S1355617716000059

Yehuda, R., Golier, J.A., Halligan, S.L., & Harvey, P.D. (2004). Learning and memory in Holocaust survivors with posttraumatic stress disorder. *Biological Psychiatry*, *55*(3), 291–295.

Zogg, J.B., Woods, S.P., Sauceda, J.A., Wiebe, J.S., & Simoni, J.M. (2012). The role of prospective memory in medication adherence: A review of an emerging literature. *Journal of Behavioral Medicine*, *35*(1), 47–62. http://doi.org/10.1007/s10865-011-9341-9

https://doi.org/10.1017/S1355617716000564 Published online by Cambridge University Press