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Neurocognitive Function and Suicide in U.S. Army Soldiers

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This prospective cohort study used administrative data from the Army Study to Assess Risk and Resilience in Servicemembers to examine associations between neurocognitive functioning and subsequent suicidal events among Regular Army enlisted soldiers during the years 2004–2009. Cases were all soldiers who completed the Army's Automated Neuropsychological Assessment Metrics

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(ANAM) computerized testing battery prior to documented suicide attempt (n = 607), ideation (n = 955), or death (n = 57). Controls were an equal-probability sample of 9,893 person-months from other soldiers. Exploratory factor analysis of five ANAM tests identified a general neurocognitive factor that excluded the mathematic processing test (MTH). When examined separately in logistic regression analyses that controlled for sociodemographics and prior mental health diagnosis, both the general neurocognitive factor (logit [β] = −.197 to −.521; $p < .01$) and MTH (β = −.024 to −.064; $p < .05$) were associated with all outcomes. When both predictors were examined simultaneously, the general neurocognitive factor continued to be associated with all outcomes (β = −.164 to −.417; $p < .05$) and MTH continued to be associated with suicide attempt (β = −.015; p = .046) and ideation (β = −.014; p = .018). These small but robust associations suggest that future research must continue to examine the extent to which objective neurocognitive tests may enhance understanding and prediction of suicide risk.

Impairment in various aspects of neurocognitive functioning has been found in retrospective case–control studies of suicide attempters relative to other psychiatric patients and healthy controls, particularly in the domains of decision making, problem solving, verbal fluency, and memory (Jollant, Lawrence, Olie, Guillaume, & Courtet, 2011; Richard-Devantoy, Berlim, & Jollant, 2014a,b). Suicide ideation appears to be associated with impairments in cognitive flexibility (Marzuk, Hartwell, Leon, & Portera, 2005; Miranda, Gallagher, Bauchner, Vaysman, & Marroquin, 2012), whereas evidence of impaired decision making among ideators is mixed (Sheftall et al., 2015; Westheide et al., 2008). Studies examining neurocognitive predictors of suicide death are lacking. In addition to their value in the search for endophenotypes of suicidal behavior (Courtet, Gottesman, Jollant, & Gould, 2011; Mann et al., 2009), neurocognitive measures have potential to enhance risk detection. The objective nature of neurocognitive tests offers advantages over current risk assessment methods based on clinician observation and self-report (Nock et al., 2013). Suicide prediction and issues around self-report have become an especially important priority in the U.S. Army, which experienced a sharp increase in suicidal behavior during the wars in Afghanistan and Iraq (Schoenbaum et al., 2014; Ursano, Kessler, Heeringa, et al., 2015). While the Army has put in place screening systems for soldiers to self-report suicide ideation, many soldiers are reluctant to report problems due to concerns about stigma and negative career impact (Warner et al., 2011), creating a significant obstacle to prevention programs that rely on self-disclosure.

Despite widespread implementation of screening (Appenzeller, Warner, & Grieger, 2007; Warner et al., 2007a,b) and prevention (Ramchand, Acosta, Burns, Jaycox, & Pernin, 2011) programs, identifying soldiers at risk of suicide ideation, attempt, or death remains a significant challenge. These efforts could be improved by leveraging the vast array of objective, administrative data the Army collects on its soldiers. Whereas prior studies using administrative data have produced valuable information related to the sociodemographic, service-related, and mental health correlates of suicidal behavior (Bachynski et al., 2012; Bell, Harford, Amoroso, Hollander, & Kay, 2010; Black, Gallaway, Bell, & Ritchie, 2011; Gilman et al., 2014; Kessler et al., 2015; Logan, Skopp, Karch, Reger, & Gahm, 2012; Schoenbaum et al., 2014; Street et al., 2015; Ursano, Kessler, Heeringa, et al., 2015; Ursano, Kessler, Stein, et al., 2015), many administrative variables with potential to enhance risk detection have yet to be examined. Among these are indicators of neurocognitive functioning from tests administered to soldiers prior to deployment. These tests were designed to provide baseline data in the event of deployment-related traumatic brain injury, but might be useful as well in predicting suicidality.

Here, we examine associations of neurocognitive functioning with subsequent suicide-related outcomes among Regular Army enlisted soldiers using a consolidated administrative data file constructed for the Army Study to Assess Risk and Resilience in Servicemembers (Army STARRS; www.armystarrs.org; Ursano et al., 2014). Whereas previous studies used small clinical or convenience samples and often relied on retrospective assessments, we present here a population-level prospective study of the associations between measures of neurocognitive functioning and subsequent administratively recorded nonfatal suicide attempts, administratively recorded suicide ideation, and suicide deaths.

METHOD

Sample

The Army STARRS Historical Administrative Data Study integrates 38 Army and Department of Defense (DoD) administrative data systems, including those in which suicidal events (ideation, attempts, and death) are medically documented. It includes individual-level person-month records for all soldiers on active duty between January 1, 2004, and December 31, 2009 (*N* = 1.66 million; Kessler et al., 2013). The current longitudinal cohort study focused on records for the 975,057 Regular Army soldiers on active duty during this time (excluding activated Army National Guard and Army Reserve). Data were analyzed using a discrete-time survival framework with person-month as the unit of analysis (Willett & Singer, 1993), such that each month in the career of a soldier was treated as a separate observational record. Cases were limited to enlisted soldiers who completed neurocognitive testing prior to a suicidal event, resulting in 607 suicide attempters, 955 suicide ideators, and 57 suicide decedents. Cases with documentation of multiple suicidal events were classified based on the first occurrence of the most severe type of event (i.e., prioritizing suicide death over attempt over ideation; Figure S1).

Using an equal-probability 1:200 sample of control person-months stratified by gender, rank, time in service, deployment status (never, currently, previously), and historical time, we identified those who completed neurocognitive testing prior to their sampled person-month record (*N* = 9,893). Control person-months excluded officers (including warrant officers), soldiers with a documented suicidal event (attempt, ideation, death), and person-months during which a soldier died (e.g., due to combat, homicide, accident, illness). Each control person-month was assigned a weight of 200 to adjust for under-sampling. Soldiers with multiple neurocognitive assessment records were excluded, as we could not determine why the tests were re-administered (e.g., technical problems; Cernich, Brennana, Barker, & Bleiberg, 2007) or how those factors may have affected test validity.

Measures

Suicidal Events. Suicide attempters were identified using: records from the Department of Defense Suicide Event Report (DoDSER; Gahm et al., 2012), a DoD-wide surveillance mechanism that aggregates information on suicidal behaviors via a standardized form completed by medical providers at DoD treatment facilities, and ICD-9-CM E95x diagnostic codes (E950-E958, indicating self-inflicted poisoning or injury with suicidal intent) from the Military Health System Data Repository (MDR), Theater Medical Data Store (TMDS), and TRANSCOM (Transportation Command) Regulating and Command & Control Evacuation System (TRAC^{2}ES), which together provide health care encounter information from military and civilian treatment facilities, combat operations, and aeromedical evacuations. The E959 code (late effects of a self-inflicted injury) was excluded, as it confounds the temporal relationships between the predictor variables and the suicide attempt (Walkup, Townsend, Crystal, & Olfson, 2012). Suicide ideators were identified using DoDSER records and MDR, TMDS, and TRAC^{2}ES records containing the ICD-9-CM V62.84 code indicating suicide ideation, coding options which were not in use prior to 2006. Suicide decedents were identified using records from the Armed Forces Medical Examiner Tracking System (AFMETS; Table S1).

Neurocognitive Functioning. Neurocognitive functioning was assessed by the Army's Automated Neuropsychological Assessment Metrics (version 4) Traumatic Brain Injury Battery (ANAM4™ TBI), a computerized battery of tests assessing neurocognitive functioning (e.g., response speed, attention/concentration, immediate and delayed memory, spatial processing, decision processing speed and efficiency) (C-SHOP, 2007). The system operates in Microsoft Windows™ on IBM-compatible notebook and desktop computers (C-SHOP, 2007). ANAM test results are stored within an administrative data system included in the Army STARRS Historical Administrative Data Study (HADS; Table S1). We selected five tests from the Army's ANAM4 TBI-MIL battery: *Code Substitution Learning* (CDS), assessing associative learning; *Procedural Reaction Time* (PRO), assessing processing speed; *Mathematical Processing* (MTH), assessing working memory; *Matching to Sample* (M2S), assessing visual spatial memory; and *Code Substitution Delayed* (CDD), assessing delayed memory. We excluded *Simple Reaction Time*, a test of visuomotor processing speed and attention, as it has lower cognitive processing demands than other tests in the battery and is rarely associated with traditional neurocognitive measures and constructs (C-SHOP, 2007). We also excluded the *Go/No-Go* test, a recent addition to the battery assessing response inhibition, because it was administered to very few soldiers in our 2004–2009 sample. We measured test performance using *throughput*, a continuous score based on the number of correct responses per unit of available response time, combining measures of both speed and accuracy (C-SHOP, 2007). Throughput is a general performance index measuring cognitive efficiency (Thorne, 2006) and is believed to best reflect the processes underlying ANAM tests (Short, Cernich, Wilken, & Kane, 2007).

Sociodemographic and Mental Health Factors. Given that both neurocognitive test performance and suicidal behavior correlate with sociodemographic and mental health factors, we included such factors as covariates in our analyses. Sociodemographic variables (gender, age at neurocognitive testing, education, race/ethnicity) were drawn from the DoD Defense Manpower Data Center (DMDC) Master Personnel and Transaction Files (Table S1). Using MDR, TMDS, and TRAC^{2}ES records, we created an indicator variable for previous mental health diagnosis from ICD-9-CM mental disorder codes (e.g., major depression, posttraumatic stress disorder, personality disorders), excluding postconcussion syndrome, tobacco use disorder, and supplemental V-codes (Table S2).

Analysis Procedures

All analytic procedures were conducted using SAS version 9.3 (SAS Institute Inc., 2011). Analyses focused first on the prediction of suicide attempts. We then tested the extent to which findings replicated in the prediction of suicide ideation and suicide death. This allowed us to test whether neurocognitive functioning is predictive of suicide attempts specifically, or of suicidal thoughts and behaviors more generally.

We removed outliers from each case–control sample based on the same criteria used in establishing ANAM normative/reference groups for the Army population (C-SHOP, 2007). Specifically, scores on each test were excluded if they: (1) exceeded six standard deviations from the mean reaction time or (2) were in the top 1% of speed and simultaneously in the bottom 1% of accuracy (i.e., percent correct). We also removed scores that were likely invalid due to a low percentage of correct responses ($\leq$ 56%; C-SHOP, 2007).

Given the ANAM's design as a measure of general cognitive functioning (C-SHOP, 2007), as well as factor analytic studies indicating that tests in the ANAM library can be represented by a small number of common domains or functions (Bleiberg, Kane, Reeves, Garmoe, & Halpern, 2000; Kabat, Kane, Jefferson, & DePino, 2001), an exploratory factor analysis with maximum likelihood extraction and promax rotation was conducted using the five ANAM throughput scores (CDS, PRO, MTH, M2S, CDD). We examined associations of the resulting factor score with subsequent suicide-related outcomes using a series of logistic regression analyses. Based on evidence that suicidal events among soldiers increased during the study period (Schoenbaum et al., 2014; Ursano, Kessler, Heeringa, et al., 2015), all regression equations included dummy predictors for calendar year and month. Coefficients of other predictors can consequently be interpreted as averaged within-month associations. Prospective associations of the neurocognitive predictors with each suicide-related outcome were first examined in separate univariate models (controlling only for historical time). Those analyses were repeated in multivariate models that controlled for socio demographics (gender, age at neurocogintive testing, education, race/ethnicity), and history of mental health diagnosis prior to testing. We then examined neurocognitive predictors and covariates simultaneously in multivariate models predicting each outcome. Standard errors were corrected for sample weighting. Parameter estimates for ANAM predictor variables are reported as logits (β).

RESULTS

Preliminary Analyses

Among those who completed neurocognitive testing, sociodemographic correlates of suicide attempt included being: female, less educated, White non-Hispanic, and younger at the time of neurocognitive testing, and receiving a mental health diagnosis prior to testing (Table 1). Approximately 80% of suicide attempters and 83% of controls completed neurocognitive testing in the prior 12 months, with no difference between groups in time since test administration, $t(661.1) = 0.10$, $p = .92$. A total of 329 soldiers (25 attempters, 304 controls) were excluded due to invalid scores or as outliers on one or more tests.

All bivariate correlations between throughput scores were significant (r = .18–.66), with MTH having the only correlations below .30. Using the entire case–control sample, exploratory factor analysis with maximum likelihood extraction indicated a single, unrotated factor solution based on an eigenvalue >1 (3.36) and the scree plot. All tests had adequate item loadings (>0.40) except for MTH (.35). We excluded MTH and repeated the factor analysis with the remaining four tests, which again supported a single-factor solution and generated similar item loadings (Table 2). In subsequent regression analyses, we used the factor score from this "general neurocognitive factor" (based on CDS, PRO, M2S, and CDD), as well as the MTH throughput score, as our neurocognitive predictors.

Neurocognitive Functioning and Suicide Attempt

In logistic regression models that controlled only for historical time, lower scores on both the general neurocognitive factor ($\beta = -.128$; $p = .005$) and MTH ($\beta = -.037$; $p < .0001$) predicted subsequent suicide attempt (Table 3). When sociodemographics and mental health diagnosis prior to testing

TABLE 1
Characteristics of Regular Army Enlisted Suicide Attempters, Ideators, and Decedents Who Completed Neurocognitive Testing, Versus Controls[a]

	Controls (*N* = 9,893)		Cases: Suicide attempters (*N* = 607)			Cases: Suicide ideators (*N* = 955)			Cases: Suicide decedents (*N* = 57)		
	n	%	*n*	%	χ^2	*n*	%	χ^2	*n*	%	χ^2
Gender											
Female	874	8.8	92	15.2	30.11*	103	10.8	4.51*	1	1.8	3.55
Male	9,019	91.2	515	84.8		852	89.2		56	98.2	
Age at testing											
17–20	1,499	15.2	171	28.2	129.40*	215	22.5	72.08*	13	22.8	11.19*
21–24	3,404	34.4	250	41.2		358	37.5		17	29.8	
25–29	2,481	25.1	114	18.8		232	24.3		20	35.1	
30–34	1,261	12.7	39	6.4		75	7.9		1	1.8	
35–39	850	8.6	23	3.8		51	5.3		3	5.3	
40+	398	4.0	10	1.6		24	2.5		3	5.3	
Education											
<High School[b]	1,696	17.1	195	32.1	101.07*	301	31.5	148.44*	10	17.5	1.15
High School	7,445	75.3	387	63.8		619	64.8		43	75.4	
Some College	395	4.0	17	2.8		20	2.1		1	1.8	
College+	357	3.6	8	1.3		15	1.6		3	5.3	
Race											
White	6,519	65.9	440	72.5	13.12*	690	72.3	17.69*	44	77.2	4.78
Black	1,641	16.6	80	13.2		126	13.2		8	14.0	
Hispanic	1,190	12.0	64	10.5		96	9.9		2	3.5	
Asian	377	3.8	14	2.3		32	3.4		2	3.5	
Other	166	1.7	9	1.5		11	1.2		1	1.8	
Mental health diagnosis prior to testing[c]											
Yes	2,647	26.8	297	48.9	152.21*	489	51.2	291.04*	25	43.9	8.51*
No	7,246	73.2	310	51.1		466	48.8		32	56.1	

[a]Case–control sample includes enlisted Regular Army soldiers (i.e., excluding officers and members of the U.S. Army National Guard and Army Reserve) on active duty during the years 2004–2009. *Cases* are the subset of soldiers who completed neurocognitive testing prior to their administratively documented suicidal outcome. *Controls* are soldiers who completed the neurocognitive testing prior to their sampled person-month record, representing a subset of a 1:200 stratified probability sample of all active duty Regular Army person-months in the population, exclusive of soldiers with a nonfatal suicidal behavior and all person-months involving a death (i.e., due to suicide, combat, homicide, injury, or illness). All records in the 1:200 control sample were assigned a weight of 200 to adjust for the undersampling of months not associated with a suicidal behavior.

[b]<High School includes: General Educational Development (GED) credential, home study diploma, occupational program certificate, correspondence school diploma, high school certificate of attendance, adult education diploma, and other nontraditional high school credentials.

[c]Mental health diagnosis prior to testing was determined based on ICD-9 mental disorder codes (Table S2).

*$p < .05$, two-tailed.

were added as covariates, both the general neurocognitive factor ($\beta = -.197$; $p < .0001$) and MTH ($\beta = -.024$; $p = .001$) continued to show a significant association with suicide attempt. The predictors remained significant when they were entered simultaneously in the same multivariate model, although their effects were decreased: general neurocognitive

TABLE 2

Bivariate Correlations and Factor Loadings of Automated Neuropsychological Assessment Metrics (ANAM) Throughput Scores among Regular Army Enlisted Suicide Attempters and Controls[a]

	ANAM throughput score correlations[b]				Single-factor loadings[c]	
ANAM test	CDS	PRO	MTH	M2S	All tests included	MTH excluded
Code Substitution Learning (CDS)	–				0.85	0.86
Procedural Reaction Time (PRO)	0.50*	–			0.61	0.59
Mathematical Processing (MTH)	0.29*	0.33*	–		0.35	–
Matching to Sample (M2S)	0.46*	0.41*	0.24*	–	0.57	0.56
Code Substitution Delayed (CDD)	0.66*	0.39*	0.18*	0.41*	0.73	0.74

[a]Case–control sample includes enlisted Regular Army enlisted (i.e., excluding officers and members of the U.S. Army National Guard and Army Reserve) on active duty during the years 2004–2009. *Cases* are the subset of soldiers who completed neurocognitive testing prior to their administratively documented suicidal outcome. *Controls* are soldiers who completed the neurocognitive testing prior to their sampled person-month record, representing a subset of a 1:200 stratified probability sample of all active duty Regular Army person-months in the population, exclusive of soldiers with a nonfatal suicidal behavior and all person-months involving a death (i.e., due to suicide, combat, homicide, injury, or illness). All records in the 1:200 control sample were assigned a weight of 200 to adjust for the undersampling of months not associated with a suicidal behavior.

[b]Correlations within the suicide ideation and suicide decedent case–control samples were nearly identical to those presented above.

[c]Based on exploratory factor analysis with maximum likelihood estimation.

*$p < .05$, two-tailed.

TABLE 3

Univariate Associations of Neurocognitive Functioning with Subsequent Suicide Attempt, Ideation, and Death among Regular Army Enlisted Soldiers[a,b]

	Suicide attempt (N = 607)		Suicide ideation (N = 955)		Suicide death (N = 57)	
Neurocognitive predictors[c]	β	p	β	p	β	p
General neurocognitive factor	−.128	.005	−.232	<.0001	−.423	.005
Mathematical Processing (MTH)	−.037	<.0001	−.037	<.0001	−.066	.006

β = parameter estimate (logit).

[a]Case–control sample includes enlisted Regular Army soldiers (i.e., excluding officers and members of the U.S. Army National Guard and Army Reserve) on active duty during the years 2004–2009. *Cases* are the subset of soldiers who completed neurocognitive testing prior to their administratively documented suicidal outcome. *Controls* are soldiers who completed the neurocognitive testing prior to their sampled person-month record, representing a subset of a 1:200 stratified probability sample of all active duty Regular Army person-months in the population, exclusive of soldiers with a nonfatal suicidal behavior and all person-months involving a death (i.e., due to suicide, combat, homicide, injury, or illness). All records in the 1:200 control sample were assigned a weight of 200 to adjust for the undersampling of months not associated with a suicidal behavior.

[b]Logistic regression models examined univariate associations (controlling only for historical time) of neurocognitive functioning with each outcome (suicide attempters, ideators, and decedents).

[c]General factor score is based on the throughput scores of four tests: Code Substitution (CDS), Procedural Reaction Time (PRO), Matching to Sample (M2S), and Code Substitution Delayed (CDD). The Mathematical Processing (MTH) throughput score was examined as a separate variable.

TABLE 4
Multivariate Associations of Neurocognitive with Subsequent Suicide Attempt, Ideation, and Death among Regular Army Enlisted Soldiers[a,b]

	Suicide attempt (N = 607)		Suicide ideation (N = 955)		Suicide death (N = 57)	
Neurocognitive predictors[c]	β	p	β	p	β	p
Entered separately						
General neurocognitive factor	−.197	<.0001	−.287	<.0001	−.521	.001
Mathematical Processing (MTH)	−.024	.001	−.027	<.0001	−.064	.024
Entered simultaneously						
General neurocognitive factor	−.164	.001	−.256	<.0001	−.417	.011
Mathematical Processing (MTH)	−.015	.046	−.014	.018	−.044	.081

β = parameter estimate (logit).

[a]Case–control sample includes enlisted Regular Army soldiers (i.e., excluding officers and members of the U.S. Army National Guard and Army Reserve) on active duty during the years 2004–2009. *Cases* are the subset of soldiers who completed neurocognitive testing prior to their administratively documented suicidal outcome. *Controls* are soldiers who completed the neurocognitive testing prior to their sampled person-month record, representing a subset of a 1:200 stratified probability sample of all active duty Regular Army person-months in the population, exclusive of soldiers with a nonfatal suicidal behavior and all person-months involving a death (i.e., due to suicide, combat, homicide, injury, or illness). All records in the 1:200 control sample were assigned a weight of 200 to adjust for the undersampling of months not associated with a suicidal behavior.

[b]Logistic regression analyses controlled for historical time, gender, education, race, age at testing, and mental health diagnosis prior to testing. Neurocognitive predictors were first entered individually, then simultaneously, in models that controlled for these covariates.

[c]General neurocognitive score is based on the throughput scores of four tests: Code Substitution (CDS), Procedural Reaction Time (PRO), Matching to Sample (M2S), and Code Substitution Delayed (CDD). The Mathematical Processing (MTH) throughput score was examined as a separate variable.

factor (β = −.164; p = .001); MTH (β = −.015; p = .046) (Table 4).

Neurocognitive Functioning and Suicide Ideation or Death

These analyses were repeated separately with suicide ideators and suicide decedents. Among those who completed neurocognitive testing, ideator characteristics differed from those of controls in a pattern similar to attempters, whereas differences between decedents and controls were significant only for age at testing and mental health diagnosis prior to testing (Table 1). Ideators (t[1,091.2] = 0.17, p = .86) and decedents, (t[9,948] = 0.80, p = .42) did not differ from controls in time since test administration. ANAM testing occurred within the prior 12 months for 79.9% of ideators and 84.2% of decedents (vs. 83.0% of controls). Identification of test outliers resulted in the exclusion of 364 soldiers from the ideator analyses (60 cases, 304 controls) and 310 soldiers from the decedent analyses (four cases, 306 controls). All bivariate correlations between throughput scores in the ideator and decedent case–control samples were significant and nearly identical to those reported for attempters in Table 2.

In univariate models that controlled only for historical time, suicide ideation was predicted by poorer performance on the general neurocognitive factor (β = −.232; p < .0001) and MTH (β = −.037; p < .0001) (Table 3). When sociodemographics and mental health diagnosis prior to testing were added as covariates, both the general neurocognitive factor (β = −.287; p < .0001) and MTH (β = −.027; p = .001) continued to show a significant association with suicide ideation. The predictors remained significant when they were entered simultaneously in the same multivariate model: general neurocognitive factor, ($\beta = -.256$; $p < .0001$); MTH ($\beta = -.014$; $p = .018$) (Table 4).

Suicide death was also predicted by poorer performance on the general neurocognitive factor ($\beta = -.423$; $p = .005$) and MTH ($\beta = -.066$; $p = .006$) in univariate analyses. The associations persisted when sociodemographics and mental health diagnosis prior to testing were added as covariates: general neurocognitive factor ($\beta = -.521$; $p = .001$); MTH ($\beta = -.064$; $p = .024$). Results were similar when these predictors were entered simultaneously; however, only the general neurocognitive factor remained significant ($\beta = -.417$; $p = .011$), whereas MTH trended toward significance ($\beta = -.044$; $p = .081$) (Table 4).

Effects of Mood at the Time of Testing

It is possible that the observed association between neurocognitive performance and suicidality could be due to participants' mood during the time of test administration (e.g., those with low mood may have slower performance). As such, we repeated the multivariate analyses with participant mood included as an additional covariate (along with sociodemographics and mental health diagnosis prior to testing). The ANAM battery includes a self-assessment of current mood across seven dimensions: vigor (high energy level), happiness (positive disposition), depression (dysphoria), anger (negative disposition), fatigue (low energy level), anxiety (anxiety level), and restlessness (motor agitation). For each mood category, respondents are presented with a series of six adjectives (e.g., *Shaky*) and asked to rate the degree to which each adjective describes how they feel using a 7-point Likert scale (0 = *not at all* to 6 = *very much*). Adjective ratings are then averaged to create a score for each mood category (Johnson, Vincent, Johnson, Gilliland, & Schlegel, 2008).

The previous results were unchanged when examining the general neurocognitive factor and MTH separately: Both variables predicted suicide attempt, ideation, and death after controlling for sociodemographics, mental health diagnosis prior to testing, and mood at the time of testing (results not shown). Results were similar when the predictors entered simultaneously; however, only the general neurocognitive factor remained a significant predictor of attempt ($\beta = -.175$; $p < .0001$), ideation ($\beta = -.135$; $p = .008$), and death ($\beta = -.368$; $p = .025$), whereas MTH was no longer associated with any outcome ($\beta = -.010$ to $-.043$; $p = .092$–$.16$).

DISCUSSION

We examined prospective associations between neurocognitive functioning and the subsequent onset of suicide attempts, suicide ideation, and suicide deaths. This examination yielded two key findings. First, the results revealed small but significant associations between decreased neurocognitive functioning, as measured by a general neurocognitive factor and mathematical processing (assessing working memory), and increased risk of each of the suicide-related outcomes assessed. Second, these associations remained even after adjusting for sociodemographics and mental health diagnosis prior to testing.

These prospective findings across multiple suicide-related outcomes, which remained after adjusting for meaningful covariates, reveal a small but robust relationship between decreased neurocognitive functioning and suicidality. These effects were observed in a representative sample of predominantly young, healthy soldiers, suggesting that neurocognitive testing, in combination with other predictors, may contribute useful information about future risk for medically serious suicidal events. Additional research is needed to identify the extent to which suicide risk is associated with impairment in specific cognitive domains. While useful as a general measure of neurocognitive functioning, the Army's ANAM TBI battery is not optimal for parsing out the specific neurocognitive deficits associated with suicide risk.

Although mathematical processing (a measure of working memory) was not significantly associated with suicide death after adjusting for the general neurocognitive factor, power to detect significant effects among decedents was likely limited by the small number of cases, a frequent and long-recognized problem due to the low base rate of suicide deaths (Pokorny, 1983; Rosen, 1954). It also is possible that the discrepant findings for fatal versus nonfatal suicidal events indicate that tests of mathematical processing are not sensitive to the cognitive profile of soldiers who die by suicide. Conversely, the findings may represent legitimate differences between those populations, which, despite many overlapping risk factors, are not identical. Consistent with prior studies (Nock et al., 2008), soldiers with documented suicide ideation or attempt were more likely than controls to be female, whereas those who died by suicide were more likely to be male. Fatal and nonfatal suicidal behaviors are also associated with different patterns of psychiatric morbidity and level of suicidal intent (Beautrais, 2001, 2003; Brent et al., 1988). We were unable to account for suicidal intent in this analysis of Army/DoD administrative data, but prior studies have found that risk factors for self-injury differ based on whether or not there was intent to die (Nock & Kessler, 2006). However, there is evidence from clinical, neurobiological, and family heritability studies that those who make a suicide attempt or die by suicide have similarities not shared with ideators (Brent & Mann, 2005; Linehan, 1986; Mann, 2003). These issues may be resolved with future studies that are able to include a larger number of suicide decedents.

This study has seven noteworthy limitations. First, the findings may not be representative of all enlisted soldiers, as baseline neurocognitive testing is typically conducted only with soldiers who are preparing to deploy. Similarly, the findings may not generalize to officers, who were excluded from the sample due to the small proportion with neurocognitive assessment data. These results also may not apply to the general population, which differs from the Army in several potentially important ways (e.g., sociodemographics, stressors). Second, our use of medically documented outcomes means that we likely captured the most severe events, but not those that were never reported. Soldiers and civilians with suicide ideation or attempt often do not receive treatment (Bruffaerts et al., 2011; Kessler, Berglund, Borges, Nock, & Wang, 2005; McKibben et al., 2014) and, therefore, would not be captured by medical records. Suicidal events that never come to medical attention may have different associations with neurocognitive functioning. Ideation, in particular, may go unreported to health care providers. We also cannot account for undocumented suicidal behavior that occurred prior to testing (e.g., pre-enlistment suicidality), or how those experiences may have influenced test scores. Third, these administrative data do not capture some elements that are important in classifying suicide attempts (e.g., lethality, intent to die). In addition, suicide-related outcomes are subject to coding errors and changes in policy and procedures. Fourth, our analyses did not control for a number of other potentially important variables, including deployment history and other life stressors (Nock et al., 2013; Ursano, Kessler, Stein, et al., 2015). Fifth, although the ANAM's simple reaction time test was excluded due to its low cognitive demands and weak associations with traditional neurocognitive measures and constructs (C-SHOP, 2007), several studies have found it is a sensitive indicator of cognitive changes and impairments (Cernich, Reeves, Sun, & Bleiberg, 2007; Reeves et al., 2006; Warden et al., 2001). Inclusion of that test may have altered the results. Sixth, we were unable to examine the Go/No-Go test, which had not been administered to enough of the soldiers in our sample to include in the current study. It will be important for future studies to include this test, given the potential relevance of impulsivity to suicidal behavior (Jollant et al., 2011). Seventh and finally, the observed effects were small in magnitude and, conceptually, it is not clear why performance on a general neurocognitive factor and a measure of mathematical processing would be predictive of suicidal outcomes. It is possible that poor performance on these measures is a proxy for general psychological distress; however, the observed effects remained even after controlling for measures of psychological distress/disorder. The mechanism through which these measures are associated with suicidal outcomes remains an important question for future study.

With these limitations in mind, our findings raise the possibility that neurocognitive testing may have value in understanding and assisting in the detection of suicide risk among soldiers by providing objective indicators that can supplement current strategies. However, its unique value in clinical decision making for individual soldiers is extremely limited, if it exists at all. Such data are probably most useful as components of a risk prediction (e.g., machine learning) algorithm that draws on other risk indicators from a wide range of sources (e.g., Kessler et al., 2015) and for furthering our understanding of the neurobiology of suicide risk.

Although neurocognitive testing is currently administered prior to deployment, it is possible that risk detection could be aided by collecting baseline neurocognitive data at an earlier point (e.g., during accession). Many soldiers report a pre-enlistment history of suicidal behavior and mental disorders (Rosellini et al., 2015; Ursano, Heeringa, et al., 2015), and the initial months of Army service are a high risk period for suicide attempts (Ursano, Kessler, Stein, et al., 2015). The utility of earlier neurocognitive screening in detecting suicide risk will be further examined in the Army STARRS New Soldier Study (Ursano et al., 2014), a survey of soldiers in their first week of basic training that includes an assessment of neurocognitive domains found to be associated with suicidal behavior and other adverse mental health outcomes (e.g., Thomas et al., 2013).

It is important to note that the ANAM is not designed to measure suicide risk. Risk detection might be substantially improved by incorporating tests of cognitive domains that have demonstrated stronger and more consistent associations with suicidal behavior, such as decision making, problem solving, verbal fluency, and memory (Jollant et al., 2011; Richard-Devantoy et al., 2014a,b), or tests designed to measure aspects of suicide-specific cognition (Cha, Najmi, Park, Finn, & Nock, 2010; Harrison, Stritzke, Fay, Ellison, & Hudaib, 2014; Nock et al., 2010). In addition, recent DoD efforts to develop mobile neurocognitive assessment platforms (Elsmore, Reeves, & Reeves, 2007; Lathan, Spira, Bleiberg, Vice, & Tsao, 2013) may eventually provide opportunities to monitor neurocognitive correlates of suicide risk among soldiers in forward-deployed environments where standard computer-based test administration is unfeasible. This might be an important capability given the impairments in cognitive functioning that service members can experience during combat deployment (Vasterling et al., 2006) or while operating in other extreme environments (Lathan et al., 2013).

CONCLUSIONS

These preliminary findings raise the possibility that decreased neurocognitive functioning could indicate a diathesis for suicidal thoughts and behavior (Lowe et al., 2007). Future studies should examine the utility of other, more specific neurocognitive tests in risk detection among soldiers, and whether associations between specific neurocognitive domains and suicide-related outcomes are modulated by different experiences and environmental exposures (e.g., combat, interpersonal conflict, legal problems).

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SUPPORTING INFORMATION

Additional Supporting Information may be found in the online version of this article:

Figure S1. Overlap among Regular Army enlisted suicide attempters (N = 607), ideators (N = 955), and decedents (N = 57) who previously completed neurocognitive testing.

Table S1. List and brief descriptions of administrative data systems in the Army STARRS Historical Administrative Data Study (HADS) included in the current study.

Table S2. International Classification of Diseases, Ninth Revision–Clinical Modification (ICD-9-CM) codes used to identify mental disorders.