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Research report

Early identification of posttraumatic stress following military deployment: Application of machine learning methods to a prospective study of Danish soldiers

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ABSTRACT

Background: Pre-deployment identification of soldiers at risk for long-term posttraumatic stress psychopathology after home coming is important to guide decisions about deployment. Early post-deployment identification can direct early interventions to those in need and thereby prevents the development of chronic psychopathology. Both hold significant public health benefits given large numbers of deployed soldiers, but has so far not been achieved. Here, we aim to assess the potential for pre- and early post-deployment prediction of resilience or posttraumatic stress development in soldiers by application of machine learning (ML) methods.

Methods: ML feature selection and prediction algorithms were applied to a prospective cohort of 561 Danish soldiers deployed to Afghanistan in 2009 to identify unique risk indicators and forecast long-term posttraumatic stress responses.

Results: Robust pre- and early postdeployment risk indicators were identified, and included individual PTSD symptoms as well as total level of PTSD symptoms, previous trauma and treatment, negative emotions, and thought suppression. The predictive performance of these risk indicators combined was assessed by cross-validation. Together, these indicators forecasted long term posttraumatic stress responses with high accuracy (pre-deployment: AUC=0.84 (95% CI=0.81–0.87), post-deployment: AUC=0.88 (95% CI=0.85–0.91)).

Limitations: This study utilized a previously collected data set and was therefore not designed to exhaust the potential of ML methods. Further, the study relied solely on self-reported measures.

Conclusions: Pre-deployment and early post-deployment identification of risk for long-term posttraumatic psychopathology are feasible and could greatly reduce the public health costs of war.

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1. Introduction

Deployment to war zones places military personnel at significant risk for posttraumatic stress disorder (PTSD (Gates et al., 2012)). While the majority of deployed soldiers have been shown to be resilient following warzone exposure (Andersen et al., 2014; Bonanno et al., 2012), a minority of military personnel develop severe psychopathology that can be unremitting across the life course with enduring PTSD symptomatology (Gates et al., 2012), increased risk of suicide (Nock et al., 2014), and increased health problems and mortality (Boscarino, 2006). As such, posttraumatic stress pathology presents with broad public health costs to the individual and society. The costs of PTSD and depression of deployed soldiers alone are estimated to be between 4 and 6 billion dollars a year for U.S. soldiers (Tanielian, 2009).

In recent years, efforts to reduce the burden of PTSD in the military have focused on methods for increasing resilience through 'resilience building' training among soldiers prior to deployment (Cornum et al., 2011). This approach is heavily criticized, and so far there is scant evidence for the success of these endeavors or that individuals can be trained to be resilient

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(Skeffington et al., 2013; Steenkamp et al., 2013). An alternative approach to targeting posttraumatic stress in the military is to identify individuals at risk at an early point in time. However, at this point in time, accurate early prediction of individual risk has not yet been achieved (Galatzer-Levy et al., 2014; Kessler et al., 2014).

Primary prevention relies on the identification of pre-deployment risk factors that robustly identify individuals at risk (Skeffington et al., 2013), which could then allow prevention of PTSD-susceptible individuals from being exposed to combat trauma. While pre-deployment risk factors have been identified (Brewin et al., 2000; DiGangi et al., 2013; Ozer et al., 2003), pre-deployment identification of individuals at risk has so far not been achieved. Secondary prevention, on the other hand, is the timely initiation of preventive therapy before symptoms become chronic, and relies on early post-deployment identification of individuals at risk (Skeffington et al., 2013). Both preventive measures can significantly reduce the public health burden of war. It is unlikely that all individuals who would go on to develop posttraumatic stress psychopathology could be identified prior to deployment. This is due to the fact that many trauma related factors have been shown to be causally important for the development of PTSD including combat exposure, perceived life threat, neuroendocrine response, and emotional responses (Yehuda and LeDoux, 2007), as have post-deployment risk factors such as lack of social support and additional traumatic experiences (Brewin et al., 2000). Further, most research on pre-deployment risk assesments to date has focused solely on symptom assessment, leaving out potentially important predictive information (Bryant, 2011).

The goal of pre- or early post-deployment identification of vulnerable individuals may be achievable by integration of multiple risk indicators identified across previous studies (Galatzer-Levy et al., 2014; Karstoft et al., 2015). By application of data driven machine learning (ML) methods that can integrate large sets of information, we might be able to identify models that provide optimal sensitive and specific forecasting of a later outcome such as post-deployment posttraumatic stress pathology (Kessler et al., 2014).

In this study, we apply ML algorithms to investigate the potential of prospectively identifying vulnerable and resilient individuals in a representative cohort of Danish soldiers who deployed to Afghanistan in 2009. Specifically, we test if resilience or posttraumatic stress can be predicted pre- and early post-deployment by utilizing information on demographic information, psychological characteristics, trauma-related factors, and early symptomatology.

2. Materials and methods

2.1. Participants

This study is part of a prospective, longitudinal investigation of Danish soldiers who deployed to Afghanistan as part of the International Security Assistance Forces' Operation Enduring Freedom (OEF). In total, 743 soldiers registered for deployment in February 2009. Of these, 141 did not participate in the pre-deployment assessment. Furthermore, 37 did eventually not deploy, and three were killed in Afghanistan. One was excluded due to outlying (>3 SDs above mean at all assessments) PCL scores, leaving a total study sample of $N=561$. Of the study sample, 95% were male, and the mean age was 26.2 years. Average length of deployment was 189 days. Half of the sample (49.5%) had never deployed to war zones before, 29.8% reported one previous deployment, and the remaining 20.7% had deployed at least two times previously. For a thorough description of design and methodology, see Andersen et al. (2014).

Participants were assessed at six time points: 5–6 weeks *before* deployment, *during* deployment, 1–3 weeks after *return*, 3 months after deployment, 7 months after deployment, and 2.5 years after return. Of the 561 who responded before deployment, 487 (86.6%) also responded during deployment, 461 (82.2%) responded at return, 287 (52.2%) responded 3 months after deployment, 255 (45.5%) responded 7 months after deployment, and 456 (81.3%) responded 2.5 years after deployment.

Participation was voluntary and all data were treated with confidentiality. Written informed consent was obtained from all participants at the pre-deployment assessment. The study was approved by the Danish Data Protection Agency.

2.2. Measures

For the outcome measure, we included data from all assessments. For predictor variables, we included data from the *before* and *return* assessments.

Descriptive data included *age, gender, children (y/n), parents' divorce (y/n), education level, previous psychological treatment (y/n), smoking (y/n), alcohol intake, years in the military, number of previous deployments, short/long term military contract, combat solider (y/n), and length of deployment.*

Further, a range of psychometric measures was included based on previously found associations to posttraumatic stress outcomes. *PTSD symptoms* were assessed via the PCL-C, a 17-item measure corresponding to the PTSD symptoms of DSM-IV (Weathers et al., 1993). Symptoms of *depression* were assessed with Beck's Depression Inventory (BDI (Beck et al., 1988)), and other common *psychiatric problems* were assessed by application of the Symptoms Checklist (SCL (Derogatis and Cleary, 1977)). We assessed exposure to *previous trauma exposure* through the Traumatic Life Events Questionnaire (Kubany et al., 2000). *Social support* was assessed by the Perceived Social Support Scale (Zimet et al., 1988), and the NEO-PI-r (Costa and McCrae, 2008) was applied to assess personality traits (openness to experience, conscientiousness, extraversion, agreeableness, and neuroticism). *Intelligence* was retrieved from the participants' conscription examination, obtained by a validated test of intelligence used by the Danish military for more than 50 years (Teasdale et al., 2011). *Positive and negative emotion* was assessed in the Positive and Negative Affection Schedule (PANAS Watson et al., 1988). We used the World Assumptions Scale (Janoff-Bulman, 1992) to assess assumptions about the world, and the White Bear Suppression Inventory (Wegner and Zanakos, 1994) to measure thought suppression.

2.2.1. Outcome measure

The study's outcome measure is a dichotomized variable of *resilience* versus *PTSD-symptomatology* based on a previously conducted Latent Growth Mixture Modeling (LGMM) analysis conducted on all six PCL-assessments in this study (Andersen et al., 2014). Resilience is often conceptualized as the absence of PTSD, while posttraumatic stress is defined as meeting diagnostic criteria for PTSD. However, both these definitions lack construct validity as individuals can be highly symptomatic and not meet DSM-based diagnostic criteria for PTSD, while individuals with relatively low symptomatology can meet PTSD criteria (Galatzer-Levy and Bryant, 2013). As such, resilience is better defined as little or no PTSD symptomatology following an aversive or life-threatening event, while posttraumatic stress reactions are better conceptualized as varying levels of PTSD symptomatology in the period after exposure to a potentially traumatic event. We focused on trajectories at the primary outcome because of evidence that

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