Abstract

Combat-related Post-Traumatic Stress Disorder (PTSD) poses complex challenges for policymakers that systems analysis could help elucidate. True population prevalence and future clinical need are highly uncertain, because individuals’ PTSD symptomatology may fluctuate in time. Though we increasingly measure policy outcomes, outcome metrics often address direct, short-term effects, so the impact on long-term prevalence is unclear. The PTSD burden involves a diverse set of actors across domains who independently make decisions based on incomplete information. Systems analysis can indicate how these local aspects of the PTSD burden jointly impact long-term prevalence and identify leverage points for PTSD mitigation.

This thesis presents a systems framework and stochastic modeling approach to predict PTSD prevalence and clinical demand over the decades following the current Operations Enduring Freedom (OEF) and Iraqi Freedom (OIF). The system developed in this study incorporates the literature on PTSD symptom dynamics and social factors governing its recognition and treatment in order to identify the structure and dynamics of the PTSD burden.

The simulation results indicate the extent to which PTSD is chronic, prevalent, and resistant to treatment. The best-case model predicts that 11-16% of OEF/OIF combat veterans will maintain a long-term need for PTSD services, and as many as 23% of OEF/OIF combat veterans will seek PTSD-related health care at least once in their lives. By controlling for symptom dynamics, model results account for a large component of the variation in empirically observed prevalence rates. Sensitivity and policy analyses show that care-seeking factors tend to have the most significant effect on long-term PTSD prevalence.

Model limitations and assumptions are documented, particularly regarding symptom and care-seeking dynamics and parameter interactions, to provide the basis for future empirical and analytical work to elaborate systemic complexities underlying military mental health. The current study specifically addresses OEF/OIF combat-related PTSD, however this approach may be generalized to other populations and mental health concerns.

This study has three main policymaking implications. First, study predictions regarding long-term PTSD prevalence and clinical demand can be used for clinical planning and resource allocation over time. Second, baseline model results indicate the long-term limits of current best practice PTSD mitigation efforts. Third, the study identifies effective policy levers by indicating the factors with the greatest direct impact on long-term PTSD prevalence.

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Chapter 1
Introduction and Problem Statement

1.1 An Overview of PTSD in the Military

Post-Traumatic Stress Disorder (PTSD) has emerged as a “signature injury” of Operation Enduring Freedom (OEF) and Operation Iraqi Freedom (OIF). Though the disorder was first recognized in the early 1980s, it has commanded “unprecedented attention and resources” in the military, research, and public spheres during OEF and OIF (National Council on Disability, 2009; Jones & Wessely, 2007).

The focus on PTSD during the current wars has led a more general increase in awareness and acceptance of military mental health issues both politically and culturally within the military. The psychological responses to combat trauma have posed an important challenge to individual combat veterans and militaries throughout history. In recent times, the PTSD burden has motivated increased appreciation of the psychological effects of combat trauma since its definition in the wake of the Vietnam War (Sundin, et al., 2010; Jones & Wessely, 2007). With pressure from veterans groups, Congress, and the public, as well as increasing demand for mental health care, the Department of Defense (DoD) and VA have expanded their response to this disorder in particular, especially over the past decade (VA Mental Health Services, 2014). The DoD has recognized the threat that PTSD poses to operational readiness, and the VA has recognized the significant physical and mental comorbidities and long-term risks that veterans with PTSD often have. Both agencies have introduced programs and policies to mitigate the PTSD burden, including large-scale screening programs, educational and outreach programs to encourage mental health awareness and care-seeking, and programs to improve and standardize the treatments offered to PTSD patients.

Empirical studies have increasingly been conducted over the past decade to characterize in near real time the PTSD morbidity resulting from OEF and OIF, as well as to assess the direct effects of individual policies on the metrics they are designed to address. However, little is known about how these policies impact long-term PTSD prevalence and clinical usage writ large, nor how the effects of such policies interact across domains and agencies.
1.2 Problem Statement

The PTSD burden presents complex challenges that implicate a diverse set of actors over the long term. On the individual level, the disorder is persistent, difficult to identify and resistant to treatment. PTSD symptomatology may follow a complex trajectory that differs from person to person, whereby symptoms may present, remit, and recur at varying periods. Similarly, PTSD is difficult to address on the population level. PTSD is prevalent among combat veterans, though a true prevalence rate is in part obscured by individuals’ changing symptomatology and cultural counter-incentives to accurately report symptoms. The disorder’s uncertain prevalence and resistance to treatment make clinical resource allocation particularly challenging.

The response to PTSD involves an array of decisionmakers, including individual servicemembers and veterans, command leaders, clinical policymakers and clinicians. These individuals make decisions that span a broad range of domains that impact the PTSD burden directly or indirectly, including decisions governing combat exposure and PTSD risk, PTSD recognition and treatment. Though decisions across domains are often made independently of one another, their effects may have significant impact on other decisional areas. In many cases, outcome metrics have been put into place to gauge the effectiveness of policies. However, these metrics are often short-term and localized, focusing directly on whether the policy in practice works as designed. Little research has been conducted thus far to understand how decisions taken across domains affect one another, nor how they jointly impact universal metrics, including long-term PTSD prevalence or clinical usage.

The current study describes the PTSD burden caused by OEF and OIF over the long-term. The model developed and presented in this thesis is designed to predict PTSD prevalence and clinical usage over the decades to come using known characteristics of the disorder and its treatment. This thesis also provides a framework for characterizing policies designed to mitigate the PTSD burden and demonstrates how the model can be used to predict the effect of policies and other changes on long-term PTSD prevalence and clinical usage. Though this study specifically addresses combat-related PTSD during OEF/OIF, the systems approach developed here may be generalizable to other populations and mental health outcomes. An important, novel result is that a dynamic model such as this one can be used to control for known, complex symptomatology in generating PTSD prevalence estimates. The current study demonstrates how a systems approach
to the psychological and decisional processes governing PTSD prevalence over time can improve our understanding of the structure and dynamics of the PTSD burden. Knowledge of the systemic properties of the PTSD burden can be used to predict prevalence, compare empirical studies, and assess policy options.

1.3 Key Implications

The research presented in the current study has four key implications:

1) *Understanding the time dynamics of PTSD*. Individuals with PTSD may express highly complex symptom patterns over time. This thesis indicates the implications of these heterogeneous trajectories on overall PTSD rates in any period. In particular, the model indicates the unobservable “true” PTSD rates implied at any time by empirically observed prevalence rates or clinical usage rates.

2) *Understanding the long-term implications of current best-case PTSD mitigation efforts*. The current study uses reported symptom dynamics and empirically observed recognition and care trends to predict long-term PTSD prevalence and clinical usage. The study thus demonstrates the limits of current-state recognition, care-seeking and treatment programs in terms of mitigating the PTSD burden. The study also predicts the annual clinical demand that can be expected over the decades to come.

3) *Indicating bottlenecks and predicting the impact of policies*. The study also provides a sensitivity and policy analysis designed to indicate how responsive PTSD prevalence is to each aspect of the mental health system. The sensitivity analysis provides an indication of which factors most limit PTSD mitigation. Similarly the policy analysis demonstrates how policies to change system factors can be analyzed *ex ante* and their outcomes predicted. The capacity for policy analysis will help decisionmakers understand the long-term implications of potential policies in terms of PTSD prevalence and clinical usage and help compare the quantitative benefits of prospective policies.

4) *Applying a framework for future policy analysis in military mental health*. This thesis provides a novel policy taxonomy that organizes policies across the military mental health system by their primary mechanism of action. A policy classification scheme
allows for policies to be compared in a more straightforward way and encourages the communication and assessment of policies based on their anticipated effect along consistent metrics. A taxonomic view of policy outcomes can enable an apples-to-apples comparison across broadly different policies based on systemic outcome metrics.

This thesis describes the systems framework underlying PTSD onset, trajectory and treatment in order to motivate the modeling approach used to predict PTSD prevalence and clinical usage among OEF/OIF servicemembers. Chapter 2 situates the current study within the relevant theoretical, empirical, policy and modeling literature. Chapter 3 motivates the modeling approach used and describes the model developed for this study. Chapter 4 presents model results and sensitivity and policy analyses. Chapter 5 presents key findings, policy implications, limitations and avenues for future work in this area.
Chapter 2

Literature Review

This thesis is informed by research that spans the theoretical and empirical psychology literature on PTSD, as well as studies describing PTSD recognition and care-seeking, policy evaluations and prior modeling efforts. The theoretical and empirical psychology literature offers insight into how the PTSD morbidity is defined, its prevalence among combat veterans, its long-term trajectories and prospects for treatment. Cultural and policy studies have assessed the social factors underlying PTSD recognition and care-seeking within the US military and veterans communities and describe the DoD and VA organizational response to the PTSD burden and its effectiveness. Finally, two modeling efforts are known to exist that identify short-term prevalence and cost estimates as a result of Operation Enduring Freedom (OEF) and Operation Iraqi Freedom (OIF).

2.1 What is PTSD?

PTSD is a mental health disorder marked by an extended, maladaptive response to trauma. PTSD is one of many psychological sequelae and disorders that can be brought on by trauma, but it is the only disorder for which traumatic exposure is required for diagnosis.

The current version of the Diagnostic and Statistical Manual of Mental Disorders (ADA, 2013) defines the characteristics of traumatic exposure and psychological symptoms required for a PTSD diagnosis. DSM-V specifies eight criteria that should be experienced to constitute a PTSD diagnosis. The individual must experience the following Posttraumatic Stress Symptoms (PTSS):

- a Traumatic Stressor (Criterion A)
- one Intrusion symptom (Criterion B)
- one Avoidance symptom (Criterion C)
- two symptoms of Negative Cognition and Mood (Criterion D)
- and two symptoms of Increased Arousal/ Reactivity (Criterion E)

Each symptom criterion must be experienced for more than one month (Criterion F), must impact the individual’s functioning (Criterion G) and must not be caused by medication, substance
use, or other illness (Criterion H) (VA, 2014; ADA, 2013).

Posttraumatic Stress Symptoms (PTSS) are typically considered adaptive coping mechanisms during the traumatic experience, though they are dysfunctional in everyday situations. PTSD is therefore often framed as a disorderly “failure to recover,” in which the individual maintains a stress response to the traumatic memory even after being removed from the traumatic situation to an objectively safe environment (Solomon, 1993). A number of theoretical models of PTSD have been developed in order to identify reasons why the individual is unable to recover adaptively from the traumatic memory. The theoretical literature provides useful relationships that can be exploited qualitatively to show how changes in one domain affect others.

2.2 Theoretical Models

The cognitive model of PTSD has been particularly influential in shaping empirical research and treatment design. This model has been in development for the past two decades, proposed first by Foa and colleagues (Leahy & Holland, 2012; cf. Foa & Riggs, 1993; Foa, Steteteke & Rothbaum, 1989) and more recently by Ehlers and Clark (2000). The Foa model states that a “fear structure” is created by the trauma and activated when the individual experiences cues that recall the trauma. The traumatic memory contradicts the individual’s basic schemas about the world (e.g. that is it safe, or that the individual can cope with them), and the individual is drawn to reconcile these thoughts in a maladaptive way.

The cognitive model as formulated by Ehlers & Clark (2000) represents PTSD as a disorder of cognition that adversely affects the individual’s ability to process a traumatic memory in a functional way. In the Ehlers-Clark model, the disorder is able to disturb the individual’s perception of their current, posttraumatic (viz. safe) situation. This perception and thus the traumatic response is able to change over time, explaining how complex symptom dynamics such as delayed onset might occur. Specifically, the individual’s appraisal of the traumatic event or its sequelae drives a disorderly traumatic response, and the appraisal may change in response to changes in the individual’s current life situation. The memory of the traumatic event may even be fragmented (such that the individual recalls aspects that bring about guilt or shame instead of an objective analysis of the full event) or repressed, surfacing only when a change in the individual’s
current situation triggers a change in the individual’s appraisal of the memory\(^1\) (Ehlers & Clark, 2000). The cognitive model framing motivates the manner in which clinicians typically identify a potential PTSD case and the mechanisms underlying its treatment.

Trauma can cause complex, heterogeneous mental health responses that differ in time and across individuals. PTSD is one of a number of possible psychological responses to trauma. Combat veterans also may experience other adverse psychological sequelae as a result of trauma with or without PTSD, including formal disorders such as depression and other psychological conditions such as guilt and shame. They may experience positive sequelae such as Post-Traumatic Growth (PTG)\(^2\) or no notable sequelae at all (Tedeschi & Calhoun, 2004; Fontana & Rosenheck, 1998). The degree of posttraumatic response may differ from individual to individual, even among similar individuals experiencing the same event (NCD, 2009).

Combat veterans may also experience subclinical PTSD, in which the individual experiences a number of PTSD symptoms but not enough to be formally diagnosed with PTSD. Subclinical PTSD may be experienced by as many as 14% of the population in addition to the full-PTSD population (Schnurr, et al., 2003). Many of those who experience subclinical PTSD go on to express full PTSD in the future, and those who are successfully treated for PTSD (i.e. whose symptoms remit to below the diagnostic threshold) may continue to experience subclinical symptomatology after treatment (Solomon, et al., 1989). The present study does not include subclinical PTSD because 1) its definition and prevalence is not consistent across empirical studies and 2) the fluctuation among full, subclinical, and no PTSD is not well documented in the empirical literature. For the purposes of this study and in keeping with PTSD diagnosis requirements, those with subclinical PTSD are considered asymptomatic.

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\(^1\) In the words of Ehlers & Clark (2000), “because some later event gives the original trauma or its sequelae a much more threatening meaning or because some of the stimuli that are particularly potent reminders of the traumatic event were not available until some time after.”

\(^2\) Psychological benefits and liabilities from trauma are not mutually exclusive. Individuals may experience various psychological benefits from trauma, such as PTG, even if they also experience PTSD symptoms (Fontana & Rosenheck, 1998).
2.3 Empirical Literature

Empirical research provides important information about the PTSD burden among military and veteran populations. However, empirical research in this domain has certain inherent limitations that can be complemented by other research methods. For example, empirical studies of PTSD offer very different pictures of PTSD rates depending on the sample studied, level of combat exposure, and time since the trauma (Ramchand, et al., 2010; Sundin, et al., 2010). Empirical studies may employ different symptom criteria in determining PTSD caseness, making it difficult to compare findings across studies. Widely accepted empirical studies have reported a current PTSD prevalence of 12-17% among OEF/OIF servicemembers, and the VA has reported a 31.5% ever-diagnosed rate of PTSD among OEF/OIF veterans seeking care (Hoge, et al., 2004; Schnell & Marshall, 2008; Milliken, et al., 2007; cf. Sundin, et al., 2010).

As a result of their heterogeneity, empirical studies may not be directly useful in predicting the risks of long term prevalence among new populations ex ante. This limitation may complicate policymakers’ decisions among alternative policies to address future risks and clinical resource demands, especially among a veteran population dispersed across the country.

Empirical studies have been useful in identifying the level of PTSD risk caused by various types of combat stressors. Fontana and Rosenheck (1999) propose a model of the causal relationship between trauma and PTSD response. They use empirical data to determine the strength of causal links governing the main categories of traumatic experience: fighting, death and injury of others, physical threat to oneself, killing others, participating in atrocities, harsh physical conditions and insufficient resources in the environment. These trauma categories have been generally validated in follow-on studies, and they are currently in use within the in-theater Mental Health Advisory Team (MHAT) studies to test in real time the PTSD risk associated with each stressor type.

2.4 Delayed Onset

The timing of psychological response to trauma is complex. Combat veterans may express a non-functional response to trauma during the traumatic event itself, known as a peri-traumatic Combat Stress Reaction (CSR). They also may maintain PTSD-like symptoms in the days and
weeks following the trauma, known as Acute Stress Disorder (ASD). Empirical studies have shown that those who experience CSR or ASD are more likely to express future PTSD. However, many who experience one of these peri-traumatic or acute responses will not develop PTSD. Similarly, many of those who do not express an early traumatic response will go on to express PTSD in the years following conflict, or delayed onset PTSD even decades later (Horesh et al., 2011; Solomon & Mikulincer, 2006). The presence and frequency of symptoms an individual expresses may wax and wane over the course of years (NCD, 2009; Schnurr et al., 2003; Bonanno, 2004).

Though most cases of PTSD will present in the first two years after the trauma, many of those with PTSD will first express symptoms more than five years after the trauma, so-called Delayed Onset PTSD, or late in life, known as Late-Onset Stress Symptomatology (LOSS) (Davison, et al., 2006; King, et al., 2007). Both features have a basis in psychological theory³ and have been observed empirically. This phenomenon is also consistent with recent anecdotal reports of late-life PTSD onset among Vietnam veterans (Mastony, 2013), as well as the sudden, intrusive memories of 1982 Lebanon War trauma portrayed vividly by Ari Folman, an Israeli director and war veteran, in the documentary Waltz with Bashir (Folman, 2008).

Many individuals with delayed onset PTSD experience subclinical PTSD before expressing full PTSD symptomatology, and delayed recognition or care-seeking may represent part or much of the delay to onset (Solomon, 1989). Delayed Onset has been challenged as an artifact of social factors such as delayed recognition or delayed care-seeking, and definitional questions have been posed as to whether Delayed Onset includes those with prior subclinical symptoms or if it arises in individuals who had never to date experienced symptomatology. Considerable evidence exists to suggest that Delayed Onset symptomatology represents approximately 6-15% of lifetime PTSD cases depending on the definition used and time of assessment (Andrews, et al., 2007). For the purposes of this study, delayed onset represents the addition of however many marginal symptoms are necessary for the individual to become diagnosable with PTSD (corresponding to definition 2 in Andrews, et al., 2007).

³ Both Delayed Onset PTSD and LOSS may be explained under the Ehlers-Clark cognitive model if the individual experiences a life event that causes them to re-appraise the traumatic memory in a maladaptive way.
2.5 Symptom Trajectories

PTSD is a chronic disorder, even with treatment, and those with PTSD express complex symptom patterns in time. Long-term PTSD prevalence rates and symptom dynamics are best understood by referring to longitudinal studies of Vietnam veterans. Schnurr, et al. (2003) examined data from the National Vietnam Veterans Readjustment Study (NVVRS), conducted in 1987, and Hawaii Vietnam Veterans Project (HVVP), conducted in 1994-1996. The data provide information about veterans’ current PTSD symptomatology at the time of the study as well as past PTSD symptomatology through the study period, an average of 22 years after entry into Vietnam. Schnurr, et al. find that 31% of veterans in the sample had ever experienced PTSD to date (known as ever-PTSD or lifetime PTSD, interchangeably), of which 15% had PTSD symptoms at the time of the interview. An additional 15% of the sample had ever experienced subclinical PTSD, and 8% of the sample had current subclinical PTSD at the time of the interview. While studies of WWII and Korean War veterans also suggest that PTSD persists into old age, it is more difficult to assess PTSD prevalence retroactively among these populations because of intergenerational cultural differences and difficulty composing a representative sample so many years later (Owens, et al., 2005).

For many servicemembers, PTSD symptoms are highly fluid on both short and long time scales. Each symptom cluster may wax and wane at different times and rates (IOM, 2007, p102). Thus, an individual with an active PTSD case may fluctuate among periods of full, subclinical, and asymptomatic PTSD. Individuals with PTSD largely can be categorized into four PTSD symptom trajectories based on the frequency, severity and timing of their symptoms: Remitting, Delayed Onset, Chronic and Unremitting, and Chronic and Intermittent (Schnurr, et al., 2003; c.f. Bonanno, 2004). A more detailed explanation of these trajectories can be found in Chapter 3.

In the short term, Grieger, et al. (2006) find that among servicemembers sustaining combat injury, symptoms wax and wane in the short term over the course of one year. While only 4.2% of their sample expressed PTSD symptoms one month after the trauma, 12.2% expressed PTSD at 7 months and 12.0% at 12 months. 79% of those who expressed PTSD at 7 months did not express symptoms at the one month follow-up.

In the long term, Schnurr, et al. (2003) find that 31% of the PTSD population do not experience their first symptoms until 2-5 years after entry, and 6.4% first experience symptoms 6
or more years later. Their study also shows that PTSD is highly chronic. Though they may not currently experience full PTSD, 55% of the ever-PTSD population had symptoms within one month prior to the interview data. Only 22% of the ever-PTSD population had no symptoms in the 3 months prior to interview, though 17% had remitted fully and expressed no symptoms in the 5 years prior to the interview. Among Israeli veterans of the 1982 Lebanon War, Solomon and Mikulincer (2006) demonstrate similar symptom fluctuation from one assessment to the next among approximately 20% of their sample population in a longitudinal, prospective study at 1, 2, 3 and 20 years after the war.

2.6 PTSD Recognition and Care-Seeking

Compounding symptom fluctuation, factors such as diagnostic test reliability and social pressures surrounding symptom reporting further complicate policymakers’ and researchers’ ability to assess population PTSD prevalence and make decisions over time. For example, recall bias during retrospective studies (Southwick, et al., 1997; Dohrenwend, 2006) and measurement variability from test to test (Wilkins, et al., 2011) may compromise the accuracy of any particular empirical study.

On the individual level, little is known about the time dynamics of PTSD recognition and care-seeking. An anonymous survey in 2004 suggested that 78% of recently deployed servicemembers screening positive for possible PTSD, depression or anxiety were aware that they had a possible mental health concern, while only 23-40% of those screening positive had pursued care in the preceding year (Hoge, et al., 2004). Stigma, lack of information, logistical barriers, and the fear of professional repercussions are the most frequent reasons why those with possible PTSD do not acknowledge mental health concerns in non-anonymized situations or seek care. To be sure, increasing attention has been paid over the course of the current wars to military mental health concerns, legitimizing and encouraging recognition of PTSD and care-seeking behavior from both a political and cultural standpoint. Programs such as the Post-Deployment Health Assessment (PDHA), Post-Deployment Health Re-Assessment (PDHRA), and implementation of a primary care screen for PTSD in the VA have been designed to mitigate these barriers to care provision and have seen modest success. However, in a program evaluation of the PDHRA, many servicemembers acknowledge that they conceal PTSD indicators on the PDHRA when asked in
an anonymous survey, and when compared with an anonymous survey, 43% of servicemembers excluded mental health concerns on the PDHRA (Bickman & Kelley, 2009).

While over the course of a war increased attention may be paid to military mental health concerns, this focus historically does not tend to persist over the long term. Solomon (1995) describes how military mental health “lessons” are “learned” over the course of a war and subsequently “forgotten” from generation to generation, as a result of changing psychological theory and political priority that tend to shift the long-term burden of trauma onto the individual. The time dynamics of PTSD recognition and care-seeking are thus highly complex and dependent on both individual symptomatology as well as dynamic social and political factors.

2.7 Treatment

Many formal treatments and informal interventions currently exist for PTSD. This model specifically addresses psychotherapies, in which PTSD is treated by talking with a mental health provider\(^4\). Formal psychotherapeutic treatments differ in the mechanism by which they work and the treatment target, as well as their effectiveness, likelihood of symptom recurrence. The choice of treatment to pursue depends on both personal and systemic factors. For example, personal preference and perceptions of treatment may impact treatment choice; an individual may not feel comfortable pursuing intrusive exposure-based treatments. Systemic factors such as geographic location and availability of clinicians trained in certain treatments may limit patients’ treatment options. If the “right” provider is not found at the “right” time, a “window of opportunity” may close, decreasing the likelihood that the individual will seek care (NCD, 2009, p4). Finally, factors such as clinician preferences, insurance policies and local clinical rules and best practices may impact the choice of treatments as well. Since 2008, the VA and DoD have initiated programs to standardize and disseminate best treatment practices, developing a Clinical Practice Guideline for PTSD that presents evidence-based treatments, as well as a VA program to educate clinicians in and require the availability of two EBTs, Prolonged Exposure and Cognitive Processing Therapy (VA Handbook 1160.05, 2012; van Minnen, et al., 2010; Cook, et al., 2013).

\(^4\) Pharmacological therapy is another important PTSD treatment method. Because the model assumes a cognitive theory of PTSD, the mechanisms underlying pharmacological treatments are outside its scope.
2.7.1 Formal and Informal Treatments

Prolonged Exposure (PE) and Cognitive Processing Therapy (CPT) are two leading evidence-based psychotherapies for PTSD and have both been validated, recommended, and disseminated by the VA to its clinicians (VA, 2010). In 2008, the VA required clinics to make PE or CPT available to patients from whom it is deemed clinically appropriate (VA Handbook 1160.05, 2012). Exposure therapies like PE are designed to re-expose the patient to the traumatic memory under clinician guidance in order to identify maladaptive memory fragments or responses to the trauma. Cognitive and behavioral therapies like CPT are designed to diffuse the link between the traumatic memory and the maladaptive symptoms it causes.

Many informal interventions also exist for PTSD. Though little research has been conducted on their effectiveness, many servicemembers and veterans with PTSD actively manage their symptoms over the long term with informal interventions. Informal interventions are often behavioral coping mechanisms targeted at mitigating the symptoms of PTSD, in contrast to formal therapies that address the traumatic memory directly. Popular informal interventions include yoga, veteran support groups, therapy animals, or clergy support. Yoga has been employed in contexts that specialize in military trauma or may be sought out by the individual independent of specialist advice. As a PTSD intervention, yoga specifically incorporates mindfulness and meditation that help abate symptoms (Libby, et al., 2012). Support groups and clerical services may be sought out by individuals with isolated symptomatic events or who express reluctance or stigma regarding formal treatment (Sayer, et al., 2009). Though informal interventions are often effective at managing symptoms, their effect does not typically persist beyond the intervention period (Niles, et al., 2012). Veterans tend to report high satisfaction with informal interventions, suggesting that while the effect of an informal intervention may not be sustained after the program’s end, veterans may choose to continue such interventions indefinitely.

2.8 Modeling

The current model simulates PTSD onset over the course of OEF/OIF combat. To date, there are two other known models that use simulative methods to study PTSD. The existing models provide insight into the number of PTSD cases that can be expected following OEF/OIF and the expected short term costs per servicemember related to the disorder. Because so little is known
about the mechanisms underlying PTSD, each model must incorporate certain assumptions that enable it to describe a precise aspect of the population PTSD burden. Models complement empirical studies by extrapolating the implications of empirical observed phenomena under various simulative conditions.

One existing model uses observed rates of acute stress symptoms and PTSD to predict PTSD onset given deployment characteristics. Atkinson, Guetz and Wein (2009) simulate a dose/response relationship to predict changes in PTSD prevalence over time as a function of OIF combat severity. Their dose/response mechanism assumes that each servicemember has an intrinsic stress threshold and is exposed to a random amount of stress in each month of deployment. If an individual ever experiences a cumulative stress level that is greater than their threshold, they are said to develop PTSD after a randomly distributed delay. Their model uses the historical ratio of American casualties to total deployed servicemembers in each month as a proxy for combat intensity.

While the Atkinson, Guetz & Wein model is designed to predict PTSD rates as a result of the current conflicts, the RAND model assumes a fixed rate of PTSD and uses care-seeking, treatment, comorbidity and employment characteristics to estimate two year costs due to the PTSD burden (Tanielian & Jaycox, 2008). The RAND model assumes ex ante that E-4 servicemembers have a 15% chance of developing PTSD and that those who develop PTSD will have a 30% chance of receiving care within two years. The RAND model simulates whether treatment is successful, at varying rates depending on the efficacy of the type of treatment provided. Costs incurred per servicemember include the cost of treatment as well as missed employment prospects and costs due to increased risk of suicide and comorbidity with PTSD. Their model develops two year costs from the servicemember perspective and thus does not consider the dynamics of population prevalence nor clinical demand.

The model developed and presented in this thesis uses aspects similar to each of the above studies. Like the Atkinson, Guetz & Wein model, the present model uses deployment characteristics to replicate PTSD onset by calendar year over the course of OEF/OIF. However, the present model uses a simplified mechanism of PTSD onset for two reasons. First, there is not yet consensus theoretically or empirically that a dose/response relationship governs PTSD onset. Many studies have suggested that a simple dose/response relationship does not fully describe the

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5 The present study includes OEF data whereas the Atkinson, Guetz & Wein study assesses OIF outcomes only.
complex relationship between traumatic experience and onset of symptoms (Rosen & Lilienfeld, 2008; Bowman & Yehuda, 2004; McNally, 2004). These studies note in particular that there is no consistent, quantifiable measure of a trauma “dose,” which clouds the measure of correlation, and that many counterfactual empirical studies exist that have not found a dose/response relationship. Second, compared to the Atkinson, Guetz & Wein model, the current model uses a measure of combat exposure that captures the distribution across all servicemembers in theater of a range of combat experiences. This measure is chosen because it captures the broad range of possible traumatic stressors proposed by Fontana & Rosenheck (1999) and is consistent with the measures of traumatic stressors included under the MHAT studies.

Like the RAND study, the present model uses rates of care-seeking and treatment efficacy to understand clinical usage and long-term outcomes. However, the present model also describes the trajectories of symptomatology, care-seeking and treatment success of individual servicemembers over the long term and considers prevalence dynamics in time.
Chapter 3
The Longitudinal Model

3.1 Choice of Modeling Structure

3.1.1 Purpose

The present study predicts how usage of clinical resources for PTSD will change over the decades following a military conflict. In particular, the purpose of the study is to understand how the temporal dynamics of PTSD symptomatology and the social factors influencing care-seeking behavior of the PTSD population impact clinical demand from period to period.

This study examines three factors that impact an individual’s use of clinical treatment resources for PTSD: PTSD caseness, PTSD recognition, and treatment. In order to enter formal treatment, the individual must 1) have PTSD symptoms sufficient for a diagnosis, 2) recognize this symptomatology as indicative of probable PTSD, and 3) choose to seek treatment and find an available treatment program. The probability of each factor, as well as its realization, may change in time and across communities. In particular, the two behavioral factors, recognition and care-seeking, may change as a result of changes in culture or policy. This study explores how these factors jointly impact PTSD prevalence and clinical resource demand over time.

In particular, the present study follows American servicemembers deployed to Iraq and Afghanistan as part of Operation Iraqi Freedom (OIF) and Operation Enduring Freedom (OEF) in order to predict 1) the number of combat veterans from these two wars who exhibit PTSD and 2) the demand for DoD and VA clinical resources for PTSD in each calendar year over five decades following combat. The timing of PTSD onset and remission, the effectiveness of PTSD treatment, and the impact of changes in policy on the likelihood of care-seeking have been described empirically at key points in time. This study applies and complements these empirical results by tracking the effects of these rates over time in terms of the levels of PTSD burden and clinical demand that they imply.

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6 Referred to herein as probable PTSD, in keeping with empirical literature. An individual with probable PTSD demonstrates (e.g. on a PTSD screen or self-assessment) sufficient symptoms to be diagnosed with PTSD. However, a case is not defined as PTSD until a clinician formally diagnoses the patient.
3.1.2 Context

The empirical literature on PTSD identifies the disorder’s symptomatology, prevalence and chronicity among military servicemembers and veterans. Key factors shown to impact the base PTSD rate include changes in operational factors such as tempo, intensity, length and number of deployments and pre-disposing factors such as prior trauma and psychological resilience. Empirical studies have demonstrated PTSD to be a chronic disorder with complex temporal dynamics. For example, PTSD onset may first occur after a long asymptomatic delay, symptoms may persist long after the trauma, and individuals with PTSD may fluctuate between symptomatic and asymptomatic periods.

Studies among the military and veteran populations have also elucidated social factors and policies that impact both treatment demand and its efficacy. Cultural factors and policy decisions influence servicemembers’ and veterans’ willingness or ability to pursue care, and these factors may change over time and differ across units or veteran communities. Some political decisions specifically target the PTSD burden, such as policies to implement post-deployment screening practices. Other policies address different domains but may impact the mental health sphere indirectly, such as policies to increase the number of deployments per servicemember.

The model presented in this study (referred to as the Longitudinal Model) focuses on certain aspects of the PTSD burden and its effect on clinical demand that have not yet been studied within a modeling framework. The Longitudinal Model is a Monte Carlo simulation that simulates a population of OEF/OIF servicemembers over the course of the war period. The Monte Carlo method was chosen for this study instead of other modeling approaches because it can capture both population- and individual-level dynamics.

The Longitudinal Model shares many characteristics with two existing population models (Tanielian & Jaycox, 2008; Atkinson, Guetz & Wein, 2009), but it also adds certain elements that enable it to explore long-term time dynamics in PTSD prevalence and care-seeking behavior. Key elements include a dynamic specification for PTSD caseness and two pathways to health for those with PTSD: spontaneous remission and treatment-based remission.
3.1.3 Key Model Elements

Dynamic PTSD Caseness

Existing PTSD prevalence models use a static indicator for PTSD caseness in order to determine the overall magnitude of the PTSD burden after a conflict (cf. Atkinson, Guetz & Wein, 2009; Tanielian & Jaycox, 2008). That is, once an individual is determined to have PTSD, they maintain this specification in all subsequent periods. The present model differs from previous models in that the PTSD specification in this model is dynamic. The Longitudinal Model allows for PTSD cases to remit as well as for symptoms to fluctuate from period to period. The dynamic health state specification enables the Longitudinal Model to predict and explain changes in empirical prevalence studies and actual clinical workload in time and to study the effect of changes in social factors and policies that impact care-seeking on PTSD prevalence in time. For example, surveys like the Post-Deployment Health Assessment (PDHA) do not capture all eventual PTSD cases because individuals may not experience symptoms at the time of assessment (Milliken, et al., 2007). The Longitudinal Model indicates how the timing of symptomatology impacts such assessments and how true prevalence and clinical need can be extrapolated from empirical results and known symptomatology dynamics. The Longitudinal Model uses empirical rates of remission and symptom density to capture how the PTSD burden changes in time.

Within the Longitudinal Model, the expected timing of PTSD onset and symptomatology is determined by a module that simulates PTSD onset and trajectory (referred to as the PTSD Onset and Trajectory Module) among OEF and OIF servicemembers. In the PTSD Onset and Trajectory Module, servicemembers are exposed to combat of random severity during periods of deployment. PTSD onset may occur as a result of this combat, with probability dependent on the severity of exposure. Onset may not occur immediately, and the time to onset is drawn randomly. Finally, once onset occurs, PTSD symptoms may take a complex trajectory. The PTSD case may either naturally remit or remain chronic. If chronic, the individual may not experience symptoms at all times, rather symptoms may wax and wane depending on the severity of the case and the life events the individual faces at any given time. These dynamics of onset and symptom fluctuation enable the model to accurately capture the PTSD burden at any time and predict clinical need.

7 The RAND model allows for PTSD to remit and recur as a result of treatment but does not address symptom fluctuation or spontaneous remission.
Return to Health

An individual with probable PTSD in a given period has two primary paths to return to health: spontaneous remission and treatment-based remission. These paths are not mutually exclusive; that is, an individual may experience spontaneous remission even while pursuing treatment. PTSD remission is defined as a life change such that Post-Traumatic Stress Symptoms (PTSS) are no longer likely to reoccur for an extended period. Specifying these two paths enables this study to consider the extent to which decisional factors impacting treatment affect long-term prevalence. The Longitudinal Model incorporates the likelihood of remission over time and its effects on future care-seeking.

Spontaneous Remission

An individual may naturally return to health via spontaneous remission. Spontaneous symptom remission may occur, for example, if the PTSS a servicemember experiences are transient (e.g. caused by a short-term life event) or if a substantial life event causes them to reassess the trauma in a positive way. Spontaneous remission of PTSD has been found to occur in roughly 20% of the PTSD population after an average of 8 years of symptomatology (Schnurr, et al., 2003).

Remission via Treatment

Symptoms may also remit via treatment. This path comprises two requisite steps: recognition and treatment. First, the individual must be recognized as having possible PTSD, either by their own incident-based observation (i.e. recognizing a symptomatic event as indicative of possible PTSD) or through a formal screen. The individual must then undergo successful treatment to remit the disorder.

In either case, remission may or may not be permanent. It is possible for PTSD to recur at a later date even after successful treatment depending on the type of PTSD the individual expresses, the type and quality of treatment provided, or future life events that the individual experiences (Tanielian & Jaycox, 2008).

These two paths to health are used to define states of a dynamic model that describes which psychological and social processes an individual has experienced at any given time. An individual’s state in each period indicates whether the individual is healthy or symptomatic in each period and, if symptomatic, which social processes have been undertaken along the path to health.
(see State Descriptions below). Certain states are not observably differentiable in practice. For example, if an individual has probable PTSD but does not recognize this fact, population level metrics will not differentiate their state from the healthy one without a screen or other observational tool.

Using dynamics that have been described empirically, it is possible to quantify the expected population distribution among these states over time. The model-predicted population distribution across states in a given period can help explain future observed dynamics and assess the magnitudes of competing effects. For example, if the percentage of individuals screening positive for PTSD decreases at some future date, the change may be interpreted by policymakers in two ways. The change could be an indication that either treatment programs have been successful in abating PTSD prevalence or that individuals have been discouraged from admitting their symptoms. In fact, both may be true, and predictions from the Longitudinal Model at the period in question can help explain the extent to which each effect drives the hypothetical result.

These insights could help indicate which types of policies are most likely to promote population health. For example, if it is predicted that a large percentage of the population has unobserved PTSD, policies that encourage PTSD recognition and screening may be predicted to have a large effect on long-term prevalence.

General Model Assumptions

The model incorporates a series of general assumptions. These assumptions hold for both the baseline model and the alternate model specifications. General model assumptions are described below.

- The model does not account for subclinical PTSD. Subclinical PTSD is not precisely defined in the psychological literature, but the term generally refers to a case in which the individual experiences sufficient symptomatology after trauma to impair functioning but does not meet full diagnostic criteria for PTSD. Subclinical PTSD may affect as many as 15% of the population in addition to the clinically diagnosed PTSD population (Schnurr, et al. 2003). For lack of empirical data on how subclinical PTSD manifests, it is excluded from this study. In particular, many of those who are successfully treated for PTSD within this model may in fact still maintain subclinical symptomatology. The continued presence
of symptoms even after successful treatment is possible because in many treatment efficacy studies, treatment success is defined in terms of whether the individual still has sufficient symptoms to be diagnosable after treatment, and not whether symptoms fully abate.

- **Constant treatment efficacy.** The probability of treatment success conditional on completion within the model is constant in time and for all servicemembers, with the exception of any policy changes that may occur (e.g. new, more efficacious treatments or a resource constraint causing a decrease in treatment efficacy). In reality, the probability of treatment success typically decreases with the delay from trauma to treatment and may also depend on factors such as age as PTSD complexity (Shalev, 1997). However, with little data qualifying the rate at which treatment efficacy decays with factors such as time, trauma severity, age, and treatment modality, the conservative, constant efficacy specification is assumed. Again, this assumption tends to cause model predictions to underestimate prevalence, especially among those who are treated later on.

  The effect of this assumption on clinical usage is uncertain, though its effect on clinical outcomes is negative. On the one hand, the assumption tends to increase clinical usage, as delayed treatment is unlikely to successfully remit symptoms and the individual is likely to require continued treatment. On the other hand, the poor clinical outcomes caused by delayed treatment may cause patients to become unsatisfied with treatment and decrease their willingness to seek continued treatment.

- **Model deployment ends in 2014.** Due to lack of information about future deployment rates to OEF and a drawdown strategy, the model only considers deployments in 2003-2014. In reality, deployment to OEF and related deployment to hostile areas in the region continue through the present. Thus, the number of servicemembers with PTSD and demanding clinical services in each year should absolutely be considered as a lower bound. Similarly, to the extent that returning servicemembers continue to redeploy, the percentage of servicemembers with PTSD and demanding clinical services may also rise as existing servicemembers continue to experience new combat trauma.
3.1.4 Policy Taxonomy

Policies and other interventions to address population PTSD largely fall within one of three categories: Exposure-Based, Recognition-Based, and Treatment-Based. These three categories correspond with the key decisional steps that individuals face along the aforementioned onset and remission paths. Specifically, policies targeting PTSD are largely designed to 1) alter the probability of PTSD by changing who is exposed to trauma and how frequently, 2) encourage recognition of PTSD by educating communities about military mental health issues or requiring PTSD screening, or 3) enable PTSD treatment by encouraging care-seeking behavior or making clinical resources more available.

These three categories comprise a policy taxonomy, organizing PTSD interventions by their underlying intended mechanism. Certain policies may impact the population PTSD burden via multiple channels; for example, an educational campaign to encourage care-seeking behavior (Treatment-Based) may also increase recognition of PTSD by calling attention to the signs and symptoms of the disorder among the intended population.

Organizing policies in this taxonomy can help increase clarity and comparison of interventions’ mechanisms and enables their effects to be predicted through modeling (Bradley, et al., 2007). The Longitudinal Model simulates individual servicemembers as they pass through states of symptomatology, recognition of PTSD symptomatology, and treatment. A change in policy can be represented by a change in one or more parameters within the model. Thus, before implementing the policy, the Longitudinal Model can be used to predict the magnitude of the policy’s effect on various outcome metrics by changing parameter values to reflect the new policy in its period of implementation, holding the rest of the model constant. The model can also indicate the sensitivity of metrics of interest to each parameter, demonstrating which policy changes are likely to have the greatest impact on those outcome metrics and which steps along the paths to remission most limit population health.

3.2 Model Structure – State Descriptions

The psychological and decisional processes described above, including the primary policy mechanisms, motivate the states and processes modeled in this study.
3.2.1 State Definitions

An individual servicemember’s state is defined in each period by a vector consisting of three true/false indicators that specify whether the servicemember is 1) Symptomatic, 2) Observed and 3) In Treatment. Specifically, the individual’s state in each period is determined by the value of the vector:

\[ S_i(t) = < I_i^{PTSD}(t), I_i^{Obs}(t), I_i^{Treat}(t) > \]

\( S_i(t) \) is the state of servicemember \( i \) in time \( t \), \( I_i^{PTSD}(t) \) is the indicator function that is true if servicemember \( i \) is symptomatic of PTSD in time \( t \) and false otherwise, \( I_i^{Obs}(t) \) is the indicator function that is true if servicemember \( i \) is observed as symptomatic of PTSD in time \( t \) and false otherwise, and \( I_i^{Treat}(t) \) is the indicator function that is true if servicemember \( i \) is in PTSD treatment in time \( t \) and false otherwise.

These three indicator variables together represent mutually exclusive and collectively exhaustive states that track each individual’s PTSD status and the interventions available to elicit remission (Figure 1). While there are eight possible combinations implied by the three indicator variables, only four have substantive real-world meaning within the scope of the current study. Table 1 describes the eight possible combinations and four model states. A detailed description of the indicators can be found in Appendix A.

![Figure 1. Mutually exclusive states used to track individuals symptomatology and care-seeking behavior in each period.](image-url)

<table>
<thead>
<tr>
<th>State Description</th>
<th>Indicator Vector</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asymptomatic, Not in Treatment</td>
<td>( &lt;0,0,0&gt; )</td>
</tr>
<tr>
<td>Symptomatic, Not Observed, Not in Treatment</td>
<td>( &lt;1,0,0&gt; )</td>
</tr>
<tr>
<td>Symptomatic, Observed, Not in Treatment</td>
<td>( &lt;1,1,0&gt; )</td>
</tr>
<tr>
<td>Entering Treatment</td>
<td>( &lt;1,1,1&gt; )</td>
</tr>
</tbody>
</table>
Table 1. States’ definitions with respect to underlying indicator values

<table>
<thead>
<tr>
<th>State</th>
<th>Symptomatic $I_{PTSD}$</th>
<th>Observed $I_{Obs.}$</th>
<th>In Treatment $I_{Treat.}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asymptomatic, Not in Treatment</td>
<td>False PCL &lt; 40</td>
<td>False</td>
<td>False Individual is not in a PTSD treatment program</td>
</tr>
<tr>
<td>Symptomatic, Not Observed, Not in Treatment</td>
<td>True PCL ≥ 40</td>
<td>False</td>
<td>False Individual is not in a PTSD treatment program</td>
</tr>
<tr>
<td>Symptomatic, Observed, Not in Treatment</td>
<td>True PCL ≥ 40</td>
<td>True Individual has either screened positive for PTSD or recognized PTSS</td>
<td>False Individual is not in a PTSD treatment program</td>
</tr>
<tr>
<td>Entering Treatment</td>
<td>True PCL ≥ 40</td>
<td>True Individual has either screened positive for PTSD or recognized PTSS</td>
<td>True Individual is in a PTSD treatment program</td>
</tr>
<tr>
<td>Not Studied (“Malingering”)</td>
<td>False</td>
<td>False</td>
<td>True</td>
</tr>
<tr>
<td>Not Studied (“False Positive”)</td>
<td>False</td>
<td>True</td>
<td>False</td>
</tr>
<tr>
<td>Not Studied (“False Positive”)</td>
<td>False</td>
<td>True</td>
<td>True</td>
</tr>
<tr>
<td>Not Studied (“Unintentional Care-Seeking”)</td>
<td>True</td>
<td>False</td>
<td>True</td>
</tr>
</tbody>
</table>

The states are defined as follows:

**Asymptomatic, Not in Treatment: < 0,0,0 >.** An individual in this state in period $t$ does not express sufficient PTSS to be diagnosed with PTSD in $t$. This individual is either healthy or is currently in an asymptomatic or subclinical period. A healthy individual in period $t$ has either never experienced PTSD through $t$ or has had a prior PTSD case that remitted prior to $t$. An asymptomatic or subclinical individual has an active case of PTSD but temporarily does not express sufficient PTSS for a positive screen or diagnosis in $t$. The individual is not in a PTSD treatment program and is not currently pursue PTSD-related mental health care.

**Symptomatic, Not Observed, Not in Treatment: < 1,0,0 >.** An individual in this state in period $t$ has sufficient symptoms in $t$ for probable PTSD but does not recognize these psychological effects as trauma-related PTSS. The individual is not in a PTSD treatment program and is not currently pursuing PTSD-related mental health care.
Symptomatic, Observed, Not in Treatment: < 1,1,0 >. An individual in this state has probable PTSD and accurately recognizes these psychological effects as trauma-related PTSS. The individual is aware that they may have PTSD either because they have been educated about the disorder and perceives their symptoms as trauma-related or because they positively screened for the disorder. The individual may be continuing a chronic, general PTSD therapy program that was begun in a prior period but is not beginning a new episode of care in t.

Entering Treatment: < 1,1,1 >. An individual in this state is currently entering a formal PTSD treatment program or is currently pursuing PTSD-related mental health care (e.g. at an informal Vet Center program). The individual has probable PTSD and has accurately recognized their symptoms.

3.2.2 Transition Definitions

Transitions between states from one period to the next may occur as a result of psychological processes, individual decisions, or policy interventions. It should be noted that the transitions between states as defined in the Longitudinal Model are not Markovian. That is, the transition probabilities in any given period depend on the individual’s prior history of state transitions. The non-Markovian property arises because certain transition probabilities within the model depend on either time or the history of previously visited states. For example, an individual’s probability of PTSD observation in a given period decreases with the number of consecutive periods of PTSD symptomatology. Similarly, the probability of transition from the asymptomatic state to one of the symptomatic states depends on whether the individual has an active PTSD case and whether they have been successfully treated. Though the non-Markovian specification adds analytical complexity, it enables the Longitudinal Model to capture period on period changes in recognition and care-seeking probabilities with respect to the amount of time the individual has experienced symptoms (see Distribution and Parameter Estimates below)\(^9\).

The possible transitions are described briefly below. A more detailed description including

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\(^8\) This state is described as Entering Treatment and not In Treatment for the purposes of the current study because treatment is assumed to occur instantaneously. This point will be elaborated in Section 3.3.3: Care-Seeking Model.

\(^9\) It is possible to create a set of states for which the transitions would be Markovian. However, doing so would compromise the intuitiveness of the set of states presented here by adding a series of states that have redundant real world meaning. Instead, the model relies on Monte Carlo simulation in lieu of an analytical solution.
real world examples is included in Appendix A.

*Transitions from the Asymptomatic State:*

Asymptomatic to Symptomatic/Unobserved: An individual may transition from the Asymptomatic state to the Symptomatic/Unobserved state as a result of three factors:

1) Fluctuating Symptoms  
2) A Change in Life Events or Resilience  
3) An Increase in Traumatic Exposure

Asymptomatic to Symptomatic/Observed: For the purposes of this analysis, transition from the Asymptomatic to Symptomatic/Observed state occurs indirectly. The individual first transitions from the Asymptomatic state to Symptomatic/Unobserved and then transitions from Symptomatic/Unobserved to Symptomatic/Observed within the same period. This analysis does not consider false positive screens.

Asymptomatic to In Treatment: Similarly, treatment entrance from the Asymptomatic state occurs indirectly in the current study. This analysis does not consider false positive screens or malingering (see Appendix A for further detail).
Transitions from the Symptomatic/Unobserved State:

Symptomatic/Unobserved to Asymptomatic: An individual may transition from the Symptomatic/Unobserved state to the Asymptomatic state as a result of two factors:

1) Symptom Fluctuation
2) A Change in Life Events or Resilience

Symptomatic/Unobserved to Symptomatic/Unobserved: An individual remains in the Symptomatic/Unobserved state if their symptoms do not naturally remit and they do not recognize their PTSS during the period.

Symptomatic/Unobserved to Symptomatic/Observed: An individual may transition from the unobserved state to the observed as a result of two factors:

1) A Positive Screen
2) A Symptomatic Episode.

Transitions from the Symptomatic/Observed State:

Figure 3. Possible Transitions from the Symptomatic/Unobserved state.

Figure 4. Possible transitions from the Symptomatic/Observed state.
Symptomatic/Observed to Asymptomatic: As in the Symptomatic/Unobserved state, an individual can transition from Symptomatic/Observed to Asymptomatic as a result of either temporary Symptom Fluctuation or a permanent, positive response to a life event or change in resilience.

Symptomatic/Observed to In Treatment: An individual transitions to the Treatment state if they enter a formal treatment program or pursues informal interventions.

Symptomatic/Observed to Symptomatic/Observed: An individual remains in the Observed state if their PTSS do not remit and they do not pursue care.

Transitions from the Treatment State:

Figure 5. Possible transitions from the Treatment state. Note: long-term treatment occurs in practice but is not considered in the present study.

In Treatment to Asymptomatic: An individual may transition from the treatment state to the asymptomatic state if treatment is successful. For the purposes of the Longitudinal Model, treatment is considered successful if the individual completes the prescribed program and the treatment has the effect of reducing the individual’s symptom level below the threshold for PTSD diagnosis.

In Treatment to Symptomatic/Observed: An individual may transition from the treatment state to the observed state as a result of three factors:

1) Drop Out
2) Unsuccessful Treatment
3) Chronic Treatment
In Treatment to In Treatment: Certain individuals, particularly those with a chronic or complex PTSD case, may remain in treatment long-term. Similarly, those in informal intervention programs (e.g. yoga or group therapy) may regularly pursue these interventions indefinitely. For the purposes of the current analysis, treatment is conducted instantaneously within one year.

3.3 Model Structure – Distribution and Parameter Estimates

The model is structured as a Monte Carlo simulation following a population of OEF and OIF servicemembers over the course of 50 years from entrance into the system. The model allows for overlapping cohorts to pass through the system. Groups of servicemembers may enter, deploy, discharge and exit the system in different periods. The model increments at yearly intervals. The Longitudinal Model algorithm is presented in Appendix B.

3.3.1 PTSD Onset and Trajectory Module

The PTSD Onset and Trajectory Module (Figure 6) determines the individual’s combat exposure due to deployment and whether PTSD onset occurs as a result. This module is run at the time of each deployment. The servicemember’s combat exposure for that deployment is drawn. As a result of combat exposure, it is determined whether PTSD onset will occur, and if PTSD is expected, the model determines the onset year and trajectory in which it is to occur.

Figure 6. PTSD Onset and Trajectory Model probability diagram. In each deployment period, the PTSD Onset and Trajectory model is run for each deployed servicemember.
The flow charts describing the Deployment and PTSD Onset and Trajectory algorithms are presented in Figures 7a and 7b.

Figure 7a. The Deployment Module algorithm, run in each model period, t. The Deployment Module determines which servicemembers will deploy in a combat period, assigns combat exposure, and determines whether each deploying servicemember will develop expected PTSD as a result of the deployment. The Deployment Module is passed through in non-combat period. The Symptomatology Module is presented in Figure 10a.

Figure 7b. The PTSD Onset and Trajectory Module algorithm, run for each servicemember with expected PTSD. The PTSD Onset and Trajectory Module determines the onset year and symptom trajectory for an individual with expected PTSD. The expected PTSD case may occur as a result of combat or if PTSD recurs after treatment.
Deployment

The timing, duration and severity of a servicemember’s combat exposure impact the probability of PTSD onset. The probability of PTSD is determined by the number of combat events the servicemember experiences. The probability distribution of the number of combat events depends on the servicemember’s deployment duration and the historical combat severity at the time of deployment. Cohorts are created to track servicemembers’ deployments and available dates.

**Deployment Timing and Duration**

The times and duration of deployment are determined by a simplified model of the Army and Marines deployment schedules for OEF and OIF. The services used a rotational schedule in which units deployed for a set Boots on the Ground (BoG) period, returned to garrison for Dwell time commensurate with the length of deployment, and then became available for deployment again (Bonds, et al., 2010; Atkinson, Guetz & Wein, 2009). During 2003-2007, the median Army deployment was 12 months in duration. During 2007-2008, the median Army deployment was 15 months in duration, and the Army returned to a 12 month median deployment in late 2008. The Army demonstrated a Boots on Ground/Dwell ratio of just over 1:1 through 2012, before returning to a 9 month deployment with more Dwell time (McIlvaine, 2011; Bonds, et al., 2010). The majority of servicemembers follow standard deployment lengths. For example in 2011, over 50% of the deployed population was in theater for the median deployment length (DMDC, 2012).

<table>
<thead>
<tr>
<th>Period</th>
<th>Army Deployment Length</th>
<th>Marine Deployment Length</th>
<th>BoG/Dwell Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>2003-2006</td>
<td>12 months</td>
<td>6 months</td>
<td>1:1</td>
</tr>
<tr>
<td>2007-2008</td>
<td>15 months</td>
<td>9 months</td>
<td>1:1</td>
</tr>
<tr>
<td>2009-2011</td>
<td>12 months</td>
<td>6 months</td>
<td>1:1</td>
</tr>
<tr>
<td>2012-2014</td>
<td>9 months</td>
<td>6 months</td>
<td>1:2</td>
</tr>
</tbody>
</table>

*Table 2. Deployment and dwell duration by period and service. Boots on Ground (BoG)/Dwell Ratio refers to the ratio of deployment time to subsequent rest time before a servicemember is available for another deployment.*
The PTSD Onset and Trajectory Module links combat severity and the likelihood of PTSD to the median soldier’s length of deployment. Publicly available, unit-level deployment data is limited. While more detailed data on deployment durations at the unit level may be deduced from press reports and other public information (cf. Atkinson, Guetz & Wein, 2009), there may be vast differences in the operational reasons for deviation from the standard deployment length. These operational differences may cause unobservable heterogeneity in the combat intensity distributions such units encounter. Thus, without additional data on how deviations in deployment duration correspond to deviations in combat intensity, the additional duration data cannot be assumed to provide greater accuracy with respect to PTSD rates. Further, individual servicemembers often change units after returning from deployment, such that a unit’s deployment schedule does not necessarily improve the accuracy of individual servicemembers’ deployment timing estimations. Using the median servicemember’s deployment also enables the Longitudinal Model to test the responsiveness of PTSD rates to broad, service-wide deployment policy positions. The effect of individual units’ deployment policies on unit PTSD prevalence could be assessed using the Longitudinal Model on a case-by-case basis given more precise data on their operational tempo.

Historical data on the number of Army and Marines servicemembers beginning deployment (inflows to theater) in each period are not publicly available. Further, even restricted DoD reports may vary from source to source depending on the proximity to combat and amount of time in theater required to be counted in the report (Belasco, 2009). The Defense Manpower Data Center (DMDC) provides aggregate quarterly data on the total number of troops deployed to OIF and OEF\(^\text{10}\). The DMDC reports the number, occasionally rounded to the thousand, of troops in each theater at quarter end\(^\text{11}\). Thus, Army and Marines inflows to each theater in each period must be calculated using the DMDC levels data and the deployment length assumptions above.

\(^{10}\) The DMDC reports these data at quarterly frequency for March 2012-present. Data from 2003-2011 is reported annually at the end of the third quarter. However, OIF Army and Marines data is available at quarterly frequency through 2008Q2 from Atkinson, Guetz & Wein, (2009). OEF data 2003-2004 is unavailable. Thus, OIF data 2008Q3-2011Q3 and OEF data 2005Q3-2011Q3 is treated at annual frequency. The model interpolates quarterly data from the annual data as much as possible (i.e. when at least one continuing cohort is available), but otherwise no additional interpolation is done (i.e. when only annual data is available, all troops are assumed to deploy in the same quarter). Finally, many reports include separate figures for servicemembers “Deployed from Locations of OEF/OIF/OND Other than U.S.” and involved in Overseas Contingency Operations. For lack of more detailed information on their deployment theater, these servicemembers are added to the OEF theater. This assumption is made for consistency and because most of these specifications are made in periods of low Iraq deployment.

\(^{11}\) This number is more comprehensive and thus often higher than the “Boots on the Ground” figure often reported in the press. The theater may include neighboring countries in which combat takes place, while the Boots on the Ground figure typically includes only Iraq or Afghanistan (Belasco, 2009).
The model calculates the number of servicemembers in each service (Army or Marines) that flow into each theater (Iraq or Afghanistan) in each quarter by subtracting the total number of servicemembers in that service and theater that are continuing their deployment from the historical current quarter level (Figure 8). In each period, continuing cohorts include any cohort previously deployed that has not yet completed the deployment duration specified by the deployment schedule for that service and quarter\(^\text{12}\). It is assumed that all servicemembers beginning a deployment remain deployed through the full deployment duration.

\[
\dot{N}_o^s(t) = \max \left( N_o^s(t) - \sum_{i=t-l_o^s(t)}^{t-1} \dot{N}_o^s(i), 0 \right)
\]

Troop inflow calculation by quarter, service and theater. \(N_o^s(t)\) is the total number (level) of servicemembers of service \(s\) (Army or Marines) historically deployed to operational theater \(o\) (Afghanistan or Iraq) in quarter \(t\); \(\dot{N}_o^s(t)\) is the number of servicemembers of service \(s\) beginning a new deployment (inflow) in theater \(o\) in quarter \(t\); and \(l_o^s(t)\) is the deployment length for service \(s\) at time \(t\) in quarters, rounded to the nearest quarter.

If the inflow is negative, its value is set to zero. A negative inflow indicates that historically, a certain number of the continuing servicemembers had deployments shorter than the median length. For lack of information about which deployed servicemembers are removed early from theater (e.g. which cohort they belong to, whether they experience relatively more or less severe combat), the Deployment Module assumes that remain in theater for the full deployment\(^\text{13}\).

\(^{12}\) The deployment duration is determined from the historical duration in effect at the end of deployment. For example, in 2005, the Army maintained 12 month deployments. Thus the 3 Army cohorts that began deployment in 2004Q2-2004Q4 remain deployed in 2005Q1. In 2007, the Army switched to 15 month deployments. Thus, the 4 Army cohorts that began deployment in 2006Q1-2006Q4 remain deployed in 2007Q1.

\(^{13}\) As a result, the model briefly overestimates the total number of servicemembers deployed during the quarter in question.
Given the number of servicemembers beginning deployment by service, theater, and quarter, $\dot{N}_o^\delta(t)$, the model then determines the composition of the deploying force. The deployment algorithm determines the number and timing of individual servicemembers’ deployments.

The deployment algorithm creates cohorts of servicemembers who deploy in the same period and are later available to redeploy at the same time. For each service and theater, the model creates a queue of cohorts available to deploy, $Q_o^\delta(t)$. In each quarter, if servicemembers are scheduled to deploy ($\dot{N}_o^\delta(t) > 0$), the model checks whether an appropriate cohort is available to deploy ($\|Q_o^\delta(t)\| > 0$). If a cohort is available, the first cohort on the queue (i.e. the cohort that has been available for the longest time) is deployed and removed from the queue. If a cohort is not available ($\|Q_o^\delta(t)\| = 0$), a new cohort consisting of $\dot{N}_o^\delta(t)$ never-deployed servicemembers is created and deployed.

If a previously deployed cohort is deployed, the individual servicemembers that deploy must be chosen from among that cohort. A servicemember is considered active if they have not yet discharged from the service. Let $\bar{N}_c(t)$ be the number of active servicemembers in the deploying cohort $c$. If there are fewer active servicemembers in the cohort than the force size scheduled to deploy ($\bar{N}_c(t) < \dot{N}_o^\delta(t)$), then $\dot{N}_o^\delta(t) - \bar{N}_c(t)$ new servicemembers are created, attached to cohort $c$, and deployed, such that the full deploying cohort fulfills the force size requirement for that quarter, service and theater. If the number of continuing servicemembers in the cohort is greater than or equal to the force size scheduled to deploy ($\bar{N}_c(t) \geq \dot{N}_o^\delta(t)$), then
\( \hat{N}_0(t) \) servicemembers are randomly selected from the cohort and deploy in \( t \). The remaining \( \hat{N}_c(t) - \hat{N}_0(t) \) servicemembers do not deploy in \( t \) but remain attached to cohort \( c \) and may deploy the next time that the cohort deploys.

The next available deploy date, \( A(c) \), is then calculated for the deploying cohort, \( c \). The deploying cohort is next available to deploy after the full length of the deployment and dwell time accorded afterward, according to the BoG/Dwell Ratio scheduled at the time of deployment. For a cohort deploying in \( t \):

\[
A(c) = t + l_s(t) + R_s(t) \times l_s(t)
\]

\( A(c) \) is the next available deployment date for cohort \( c \), \( t \) is the quarter of current deployment, \( R_s(t) \) is the scheduled BoG/Dwell Ratio for service \( s \) at time \( t \), and \( l_s(t) \) is the scheduled deployment length for service \( s \) at time \( t \).

The cohort is added at the end of the available cohort queue for the cohort’s service and theater in quarter \( A(c) \).

At the end of each year, individual servicemembers may discharge from the service and thus will not deploy thereafter. The deployment algorithm uses historical service continuation rates, which represent the fraction of servicemembers at the start of a year that are still in the active duty service at year end, to determine if and when individual servicemembers separate. Discharge is assessed annually for each servicemember while they still have Active military status. Discharge is governed by a Bernoulli random variable with probability equal to 1 minus the service continuation probability (referred to as the attrition rate).

The use of an annual discharge process is a simplifying assumption, as servicemembers typically sign long-term contracts of several years. However, the duration of such contracts could vary, as could the duration of training and dwell time before the first deployment. Similarly, contracts may be extended temporarily just before the reenlistment decision. This heterogeneity in contract specifications makes it challenging to devise a more accurate discharge model that describes the amount of time from the first deployment to the reenlistment decision.

The continuation rate did not significantly vary from year to year early in OIF/OEF, and has not been reported in later years. Following the approach taken by Atkinson, Guetz & Wein, the Longitudinal Model assumes a constant continuation rate of 0.83\textsuperscript{14} for both Army and Marines.

\textsuperscript{14} The continuation rate may have decreased later in OIF/OEF as a result of the increased strain caused by the 2007 surge and longer deployments. Data is not publicly available on the continuation rate later in the wars, so it is assumed to be constant.
based on publicly available data from the Congressional Budget Office (Golding & Adedeji, 2006). Using the constant, annual continuation trial yields an expected enlistment duration given by the inverse of the attrition rate (equal to 0.17), or 5.9 years from the date of first deployment. As described in Chapter 4, these assumptions provide deployment statistics consistent with historical data.

Combat Exposure during Deployment

Each servicemember is randomly assigned an amount of combat exposure in each of their deployments. The distribution of combat exposure varies with the length of deployment and relative severity of combat at that time.

Exposure is defined according to the Combat Experiences scale reported in the annual Mental Health Advisory Team (MHAT) studies. The Combat Experiences scale measures responses to a 30 item questionnaire that describes exposure to an array of possible types of combat experiences, such as exposure to an IED blast, death or injury of a fellow servicemember, killing an enemy combatant, or witnessing an abuse of the rules of war or Geneva Convention. The number of items to which an individual reports having been exposed during the current deployment is a measure of combat intensity. Though the scale only records whether a servicemember ever experienced each type of event and not the number, frequency or severity of such events, the events are not independent and many of these events may co-occur. Therefore, the most severe or frequent combat events would likely result in multiple measured combat experiences at once. This metric also has the advantage of being consistent with the broad range of types of traumatic experiences that may cause PTSD: Fighting, Killing, Perceived Threat to Oneself, Death of Others, and Atrocities (Fontana & Rosenheck, 1999; MHAT-9, 2013), as compared with other metrics that capture only one component of traumatic experience. Use of this metric also enables an apples-to-apples comparison of this study’s results with MHAT studies and any other psychological studies that use the MHAT questionnaire or data (e.g. Hoge, et al., 2004).

Not all MHAT studies publicly disclose the Combat Experiences data at the same level of granularity. Only the 2007 OIF MHAT-V study provides a histogram of that year’s responses (Figure 9). Other years’ reports omit correlations between items and many omit score frequencies.

---

15 The full Soldier/Marine Well-Being Survey, including the Combat Experiences questionnaire is available as Appendix B of the MHAT IV (2006) study.
such that it is not possible to observe the distribution of scores. However, the 2009 MHAT-VI study provides a time-series of the average Combat Experiences score, adjusted to reflect year-to-year differences in demographic information (e.g., combat role) and time deployed. The PTSD Trajectory and Onset Module accounts for year on year differences in combat intensity by scaling Combat Experiences in a given year by the ratio of average combat experiences in that year to the average combat experiences in 2007. Similarly, the model assumes that combat events arrive uniformly distributed in time. The average deployment length among MHAT-V respondents at the time of survey was 9 months (3/4 years). Thus, the Combat Experiences distribution is scaled by 4/3 times the deployment duration in years to adjust the Combat Experiences distribution to the servicemember’s deployment duration.

![Figure 9. The distribution of Number of Combat Experiences reported in the OIF MHAT-V study (2007). Combat Experience scores are shaded according to their respective Low, Medium, or High Combat Exposure bins.](image)

The Combat Experiences score for a servicemember in year $t$ is treated as a transformation of the raw Combat Experiences score random variable. The raw Combat Experiences score is distributed according to the reported 2007 OIF distribution (Figure 9). This random variable is transformed to adjust for combat severity and deployment duration. The raw score is drawn and then multiplied by a severity adjustment factor—to account for the historical difference in average Combat Experiences from across years and theaters—and a duration adjustment factor—to account for the difference in deployment duration from 2007 OIF survey respondents. The severity
adjustment factor is equal to the historical ratio of average Combat Experiences in operational theater $o$ in year $t$ divided by the average Combat Experiences in 2007 Iraq. The duration adjustment factor is equal to the ratio of the servicemember’s deployment duration to the 9 month average deployment experienced by 2007 OIF respondents at the time of the survey.

$$C_i^o(t) = C_{raw} \times \frac{\bar{C}^o(t)}{\bar{C}_{Iraq}(2007)} \frac{4l_s(t)}{3}$$

Combat Experiences score adjustment for year, deployment duration and theater. $ar{C}^o(t)$ is the historical average Combat Experiences score for theater $o$ in year $t$, $l_s(t)$ is the deployment duration in years for service $s$ in year $t$, $C_{raw}$ is the realized raw Combat Experiences score drawn according to the 2007 Iraq distribution and $C_i^o(t)$ is the random value representing the Combat Experiences score for servicemember $i$ deployed in theater $o$ in year $t$.

For deployments that span multiple calendar years, Combat Experiences are treated as occurring in the first calendar year of deployment for the purposes of assessing PTSD onset time, though the number of Combat Experiences is still scaled according to the full deployment duration.

The Combat Experiences score is then binned ordinally into Low, Medium, and High exposure levels to determine PTSD risk. The PTSD Onset and Trajectory Module bins exposure levels because, while greater combat experiences are known to correlate with increased PTSD probability, the differences in mental health outcomes are not statistically significant at a more granular specification of combat exposure. Specifically, the MHAT-V study reports the Acute Stress Reaction (ASR) symptom severity in the field among servicemembers at each Combat Experiences score. While ASR symptom severity increases monotonically with Combat Experiences score, the reported ASR symptom severity interquartile ranges overlap considerably among Combat Experience scores within a 5-10 point range. Thus increases in ASR are not statistically significant with respect to a marginal increase in Combat Experiences score, and it is more meaningful to use less granular combat exposure bins for the purposes of the present study (MHAT V, 2008).

PTSD Probability

In each deployment, the servicemember risks developing a PTSD case as a result of combat trauma. The PTSD Onset and Trajectory Module first determines whether the individual will or will not develop a PTSD case as a result of the deployment. If so, the individual is said to have Expected PTSD and the model then determines the year in which symptoms will first occur and
the type of PTSD case the individual will experience.

PTSD risk increases with respect to combat exposure level (Koenen, et al. 2003; MHAT-V, 2008). PTSD probability conditional on combat exposure level is determined by long-term empirical data from Vietnam veterans. While the MHAT studies report rates of in field ASR with respect to combat experiences, ASRs do not necessarily predict later PTSD. An ASR reported in the survey must have occurred within months of the traumatic experience, because only currently deployed servicemembers are surveyed in the MHAT studies and the average servicemember was surveyed 9 months into deployment. However, long term studies have shown that in most cases, PTSD onset first occurs over a year after the trauma (Schnurr, et al. 2003). Similarly, many of those who experience an ASR in field will fully recover and not go on to express later PTSD.

The model uses long-term rates of PTSD with respect to combat exposure among Vietnam veterans whose combat exposure was assessed using a similar questionnaire, calibrated to the types of combat experiences common in the Vietnam War (Koenen et al., 2003; Snow, et al. 1988). Combat exposure bins are calibrated so that the distribution of Low, Medium, and High combat exposure during an average year’s deployment is equivalent to the Vietnam veterans’ combat exposure distribution reported by Koenen et al. (2003). This calibration creates two implicit assumptions about OIF/OEF PTSD risk. First, using the empirical Vietnam quantiles to bin exposure creates the assumption that in terms of PTSD risk, the population combat exposure due to one year of deployment during OEF/OIF is equivalent to that of Vietnam, i.e. that the combat exposure scales are each calibrated for their respective wars and that for the same length of deployment, the same proportions of servicemembers of both wars are exposed to High, Medium and Low PTSD-generating combat. Second, the specification that long-term PTSD rates conditional on exposure level are equal between Vietnam and OEF/OIF creates the assumption that the OEF/OIF population is equally susceptible to PTSD risk as the Vietnam population. As further data on OEF/OIF PTSD prevalence rates emerge, these assumptions can be revisited.

Parameters

The Longitudinal Model assumes the Koenen et al. exposure level and PTSD probability distributions. The Koenen et al. surveys were taken 10-25 years after deployment and asked about contemporaneous symptomatology, thus the PTSD probabilities exclude the expected 18% of the PTSD population whose PTSD remitted prior to the surveys (see PTSD Trajectories, below, cf.
Schnurr et al, 2003). The Koenen et al. PTSD rates must be scaled by \( \frac{1}{(1-0.18)} = 1.22 \) to account for the remitted population in determining the risk of ever experiencing PTSD for use in the Longitudinal Model. In doing so (as in assigning PTSD Trajectory later), PTSD Trajectory is assumed to be independent of Combat Exposure Level, i.e. that servicemembers are equally likely to spontaneously remit symptoms regardless of their level of exposure.

Exposure and PTSD onset are each distributed multinomially according to the observed prevalence in the Koenen et al. study (Table 3). The cutoffs for the Low, Medium and High exposure bins represent an average one year deployment across all years and both theaters. Cutoffs are determined by finding the raw Combat Experiences scores corresponding to the specified quantiles and scaling by \( \frac{4C}{3C_{Iraq}(2007)} \), where \( 4/3 \) is the deployment duration adjustment factor for a one year deployment and \( C_{Iraq} \) represents the average historical combat exposures score across all years and both theaters. These cutoffs thus represent the threshold number of combat experiences in an average year’s deployment for each Combat Exposure Level.

| Combat Exposure Level | \( P[\text{Exposure Level}] \) | \( P[\text{PTSD}|\text{Exposure Level}] \) (from Koenen et al.) | \( P[\text{PTSD}|\text{Exposure Level}] \) (Scaled for Model) |
|-----------------------|-------------------------------|---------------------------------------------------------------|---------------------------------------------------------------|
| Low \((C < 8)\)       | 37.5\%                        | 5.7\%                                                        | 7.0\%                                                        |
| Medium \((8 \leq C < 21)\) | 41\%                          | 17.3\%                                                       | 21.1\%                                                       |
| High \((21 \leq C)\)  | 21\%                          | 36.1\%                                                       | 44.0\%                                                       |

_table 3. Exposure distribution and PTSD probabilities conditional on exposure level. Distribution of Exposure Level and conditional probabilities of PTSD from Koenen, et al. (2003). Cutoffs for number of Combat Experiences corresponding to each bin are calculated from exposure distribution given in MHAT V with respect to an average 12 month deployment._

The probability of PTSD conditional on exposure can be scaled to test different resilience training or enlistment policies that would impact the population’s expected rate of PTSD conditional on each level of exposure.

**Key Assumptions Regarding PTSD Onset:**

- *Exposure from multiple deployments is assumed to impact PTSD independently.* Reger, et al. (2009) show empirically that multiple deployments to OEF/OIF correspond to an increased risk for PTSD. Little is known theoretically about the mechanisms by which
repeated trauma (such as multiple deployments) affect PTSD risk. For lack of further information about the functional form of this relationship, the Longitudinal Model assumes that PTSD risk is memoryless in each deployment. That is, if an individual reaches a subsequent deployment without yet having had PTSD, the probability of PTSD in that deployment is equal to the probability of PTSD in the first deployment. The memorylessness assumption closely matches the ratio of PTSD prevalence among single and multiple deployers observed by Reger and colleagues (8.6% PTSD among single deployers, 13.0% PTSD among multiple deployers).

- **Exposure distribution and long-term PTSD probability distributions correspond to observed Vietnam War rates.** Little information is available on long-term PTSD rates with respect to combat exposure among OEF/OIF combat veterans. Thus, the model bins combat exposure at three levels and uses historical PTSD rates among Vietnam veterans to predict PTSD risk. This specification creates the assumptions that the bins represent both 1) the same population distribution in terms of combat exposure and 2) the same PTSD risk caused by the exposure.

### Time to PTSD Onset

The time at which PTSD symptoms first present after the trauma differs across cases. In many cases, PTSD symptoms present soon after the trauma. In these individuals, PTSD reflects a maladaptive persistence in a safe environment of functional traumatic response mechanisms. In other cases, however, PTSD symptom onset occurs long after the individual has returned from combat. In these delayed onset cases, PTSD may occur because the individual is forced to reassess the traumatic event in terms of new life events or situations, and the individual may do so maladaptively (Ehlers & Clark, 2000).

If the individual has Expected PTSD as a result of a particular deployment, the time to onset, \( t_{\text{Onset}} \), is then calculated and PTSD onset occurs \( t_{\text{Onset}} \) periods after that deployment\(^{16}\). In that period, the individual transitions from Asymptomatic to Symptomatic/Unobserved. This transition constitutes the *Increase in Traumatic Exposure* channel for the Asymptomatic to

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\(^{16}\) If the individual has Expected PTSD but the onset period has not yet occurred, they will deploy in that period and may generate another “case” of Expected PTSD. In this case, the time to onset will be revised to be the earlier of the remaining time to onset of the first “case” and the new time to onset of the current “case” of expected PTSD.
Symptomatic/Unobserved transition.

**Parameters**

The timing of PTSD onset and the trajectory and frequency of symptoms over time varies from person to person. The PTSD Onset and Trajectory Module uses the Schnurr, et al. (2003) observed distribution to determine the period in which an individual with Expected PTSD first expresses symptoms after the deployment period that causes the PTSD case (Table 4).

<table>
<thead>
<tr>
<th>Time since Combat Exposure (years)</th>
<th>P[PTSD Onset in Range]</th>
</tr>
</thead>
<tbody>
<tr>
<td>t ≤ 1</td>
<td>31.4%</td>
</tr>
<tr>
<td>1 &lt; t ≤ 2</td>
<td>30.5%</td>
</tr>
<tr>
<td>2 &lt; t ≤ 5</td>
<td>31.8%</td>
</tr>
<tr>
<td>5 &lt; t ≤ 22</td>
<td>6.4%</td>
</tr>
</tbody>
</table>

*Table 4. Probability of PTSD Onset occurring in four time ranges among Vietnam veterans who express probable PTSD by 1988. From Schnurr, et al. (2003).*

The Schnurr et al. study reports heterogeneous ranges of PTSD onset times. The Longitudinal Model assumes that the PTSD onset year within each range is distributed uniformly, such that the probability of onset occurring in a given year from deployment is equal to the probability of PTSD onset in the range containing that year divided by the number of years in that range.

PTSD Trajectory

Individuals with PTSD differ in the timing and frequency with which they express symptoms. PTSD symptomatology may follow complex, heterogeneous trajectories in the years following first onset (Bonanno, 2004). Symptoms may not present at all times, even among chronic PTSD cases, and individuals may fluctuate between symptomatic and asymptomatic periods. Schnurr, et al (2003) use cluster analysis to characterize types of PTSD by frequency and severity of symptoms and to determine the population prevalence of each PTSD Trajectory.

PTSD trajectory data are used within the Longitudinal Model to define future PTSD trajectories for servicemembers who experience PTSD. When a servicemember is determined to
have Expected PTSD, they are assigned one of four PTSD Trajectories that correspond to the clusters identified by Schnurr, et al. The servicemember’s PTSD Trajectory determines the frequency of their future symptoms. Symptom occurrence is determined by specifying PTSD remittance and recurrence probabilities, respectively the probabilities with which an individual with PTSD moves from the symptomatic to the healthy state and vice versa from period to period (Table 5). The Schnurr, et al. study reports average symptom density for each cluster, which is defined as the percentage of time that the individual expresses symptoms. The present study assumes that symptom presence is independent across periods for the purposes of specifying PTSD remittance and recurrence probabilities.

<table>
<thead>
<tr>
<th>PTSD Trajectory</th>
<th>Trajectory Prevalence</th>
<th>PTSD Remittance Probability</th>
<th>PTSD Recurrence Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Remitting</td>
<td>18%</td>
<td>0.125</td>
<td>0</td>
</tr>
<tr>
<td>Chronic, Intermittent</td>
<td>24%</td>
<td>0.75</td>
<td>0.25</td>
</tr>
<tr>
<td>Chronic, Unremitting</td>
<td>48%</td>
<td>0.01</td>
<td>0.99</td>
</tr>
<tr>
<td>Delayed Onset</td>
<td>10%</td>
<td>0.15</td>
<td>0.85</td>
</tr>
</tbody>
</table>

Table 5. PTSD Trajectory clusters and prevalence identified among Vietnam veterans (from Schnurr, et al., 2003). Probabilities of PTSD remittance and recurrence are determined from the average symptom density per cluster in the Schnurr, et al. study.

The four PTSD Trajectories and their behavior within the Longitudinal Model are defined as follows:

**Remitting:** The remitting PTSD cluster first expresses PTSD not long after trauma (average onset time less than two years, consistent with the general PTSD population mean). Individuals with remitting PTSD express PTSD for an average of 8 years before symptoms spontaneously remit and the individual improves (Schnurr, et al., 2003). In the Longitudinal Model, the probability of PTSD remittance in each period within this group is set to 12.5%, such that the expected remittance time is 8 years. Once symptoms remit, the probability of PTSD recurrence is defined to be zero, such that the individual
permanently improves\textsuperscript{17}. This subgroup accounts for 18\% of the Schnurr, et al. sample.

\textit{Chronic, Intermittent:} The chronic, intermittent PTSD cluster similarly first expresses PTSD not long after trauma. However, this group is not likely to spontaneously remit symptoms and will experience occasional, but disordered, symptoms indefinitely. The chronic, intermittent cluster expresses symptom density of approximately 25\%, such that they express full PTSD symptoms half of the time. Thus in any period, the probability of remittance in the next period (if the individual is currently symptomatic) is set to 75\% and the probability of recurrence in the next period (if the individual is currently asymptomatic) is also set to 25\%. This subgroup accounts for 24\% of the Schnurr, et al. sample.

\textit{Chronic, Unremitting:} The chronic, unremitting PTSD cluster also first expresses PTSD early after trauma. This group is also unlikely to spontaneously remit symptoms. Unlike the intermittent group, the chronic, unremitting group experiences debilitating symptoms most of the time. Symptom density in this group is upwards of 99\%, such that they experience full symptomatology nearly all of the time, indefinitely. The probability of PTSD remittance in the next period if the individual is currently symptomatic is thus set to 1\% and the probability of recurrence if the individual is healthy is 99\%. This subgroup accounts for 48\% of the Schnurr, et al. sample.

\textit{Delayed Onset:} The delayed onset PTSD cluster expresses symptoms much later after trauma. This group may indeed be healthy for a number of years upon return from combat, only developing PTSD after a life change causes the individual to reappraise the traumatic event years later. Average symptom density in this group is slightly lower, at 85\%, such that they experience full symptomatology relatively often and indefinitely, once onset occurs. This subgroup accounts for 10\% of the Schnurr, et al. sample.

In the PTSD Onset and Trajectory Module, PTSD Trajectory is chosen probabilistically with the exception of the Delayed Onset group. If onset occurs within the first 6 years, one of the

\textsuperscript{17} If the individual is subsequently deployed, they may experience a new episode of PTSD, but this onset is independent of the prior episode.
three early onset groups is chosen with probability equal to the prevalence in the Schnurr, et al. study. If onset occurs beyond the first 6 years, the individual is assigned to the Delayed Onset group with probability 1. The probability of PTSD remittance and recurrence are then assigned to the individual according to their PTSD Trajectory.

**Key assumptions regarding PTSD Onset:**

- *Mutual independence among combat severity, onset time, type.* The Longitudinal Model model assumes that the time to PTSD onset is independent of combat severity. Similarly, the PTSD Trajectory (i.e. trajectory and likelihood of remission) is assumed to be independent of both combat severity and time to PTSD onset, conditional on whether onset is early or delayed. In practice, it may be possible that high combat exposure leads to early, more complex, and chronic PTSD, but data were not available to support and implement such a refinement.

- *Uniform arrival times within ranges specified by Schnurr, et al. (2003).* The Schnurr, et al. (2003) study provides PTSD onset time distributions over a set of time ranges post-deployment. Within these ranges, it is assumed that the year of onset is uniformly distributed.

### 3.3.2 Observation Module

For an individual to pursue treatment or disability compensation, they must first be observed with a possible PTSD case. Observation can occur one of two ways: via a formal screen or informal, episodic recognition of possible PTSS.

Formal screens can be scheduled within the model for a specified subset of servicemembers at a specified time. A formal screen will have a specified sensitivity, or the probability that a true PTSD case is correctly identified as such. For example the PTSD Checklist has a sensitivity on the order of 0.8-0.9, depending on the cutoff point used to define PTSD caseness. A structured clinician interview is considered the gold standard method for identifying PTSD caseness and has a sensitivity near to 1\(^8\). In the period in which the formal screen is conducted, the probability of

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\(^8\) The sensitivity of the instrument in practice may vary drastically with other social factors that impact an individual’s response on the screening instrument. These factors could include stigma or fear of professional repercussions that reduces an individual’s willingness to truthfully disclose symptomatology and decrease the instrument’s sensitivity in the practical setting. Similarly, the instrument’s false positive rate could impact clinical
observation conditional on PTSD is temporarily set equal to the sensitivity of the screening instrument being used. In the baseline model, no formal screens are used.

In all other periods, observation may occur via episode-based, individual recognition of possible PTSS. Hoge, et al. (2004) observe that 78% servicemembers who screen positive for depression, anxiety or PTSD acknowledge that they have a possible mental health problem or need.

The baseline model uses the Hoge, et al. observed rate of acknowledged need as the base episode-based observation rate. The probability of recognition is scaled by a damping factor, $\beta^s$, where $\beta \in (0,1]$. The damping factor decreases with the number of consecutive symptomatic periods, $s$, because if the individual does not recognize their symptoms as PTSD-related in a given period after onset, all else being equal (i.e. without education or other interventions) it is less likely that they will attribute these symptoms to the trauma in the next period. That is, knowing that an individual did not immediately recognize symptoms as PTSD offers additional information about the individual, i.e. that they are not informed or not willing to admit mental health concerns, all else being equal (viz. that educational policies increasing mental health awareness have not been implemented), and suggests that the probability of observation should be updated downward in a Bayesian sense. It is still possible that observation may occur, for example if the first period’s symptoms were not severe or did not affect functioning, or if a new significant other or other community member recognizes the mental health concern. In the base case, $\beta$ is chosen to be $\frac{3}{4}$ so that only limited probability decay occurs. The probability of observation is reset to the base rate after each asymptomatic period, such that after a period of no symptoms, new symptomatology is more salient. The probability of observation $s$ years after a new period of symptomatology beginning in year $t$ is given by:

$$P(I_{\text{Obs}}(t+s)|I_{\text{PTSD}}(t), \ldots I_{\text{PTSD}}(t+s)) = \beta^s \ast P(I_{\text{Obs}}) \ast I_{\text{PTSD}}(t) \ast \ldots \ast I_{\text{PTSD}}(t+s)$$

$I_{\text{Obs}}(t)$ is the indicator function taking 1 if the individual observes their PTSD case in period $t$ and 0 otherwise. $P(I_{\text{Obs}})$ is the baseline probability of PTSD observation, $I_{\text{PTSD}}(t)$ is the indicator function taking 1 if the individual is symptomatic of PTSD in period $t$ and 0 otherwise, and $\beta^s$ is a damping factor in $[0,1]$ that describes the decreased probability of episodic observation after $s$ consecutive periods of PTSD symptomatology.

workload by encouraging individuals without probable PTSD to pursue treatment. The model could address these issues in more detail but these effects are ignored in this study.

19 As with other screening tools, this published rate provides an upper bound on the percentage of servicemembers with a problem who self-identify. Servicemembers who either do not receive education about PTSD or perceive a cultural or professional stigma surrounding PTSD and other mental health problems may not recognize their own symptoms as indicative of a possible problem.
Positive screening and incident-based observation are the only events that cause the transition from the Symptomatic/Unobserved to the Symptomatic/Observed state. If this transition does not occur and the individual did not remit symptoms for the period, then the individual remains in the Symptomatic/Unobserved state.

**Key Assumptions Regarding Observation:**

- *Probability of observation decreases in time since onset.* The current study assumes that, without external changes (such as education and outreach programs or screening events), individuals are increasingly unlikely to recognize symptoms as a mental health concern as time since PTSD onset passes. However, such programs can change the probability of episodic or screening observation, and those effects can be captured in the model.

### 3.3.3 Care-Seeking Model

Once the individual recognizes their possible PTSD, they may enter treatment. Entrance into treatment depends on both the individual’s decision to seek care and the availability of clinical resources to provide treatment. Following the convention in empirical studies, treatment is considered successful if it abates PTSD symptoms to a subclinical level. Successful treatment may not abate symptoms permanently, such that successfully treated PTSD cases recur at a later date with some probability.

A servicemember’s probability of seeking care is determined from Hoge et al. (2004). This study reports the percentage of those servicemembers who receive professional care from a mental health provider among those who screen positive for PTSD, depression and anxiety. The model assumes that an individual must first acknowledge a possible mental health problem in order to seek care. The probability of care seeking conditional on problem recognition is calculated from the Hoge study post-deployment Army rate of 30% care-seeking among positive screeners and 78% rate of problem recognition.

\[
P(I_{CS} | I_{Obs}) = \frac{P(I_{CS} | I_{PTSD})}{P(I_{Obs} | I_{PTSD})} = \frac{.3}{.78} = .38
\]

$I_{CS}$ is the indicator function taking 1 if the individual seeks care and 0 otherwise, and $P(I_{CS})$ is the base care-seeking rate in the first year of observation.
The model similarly assumes that the care-seeking behavior also decreases in probability with time of inaction after observation. That is, all else equal (without educational initiatives or new treatment programs that increase care-seeking behavior), knowing that an individual was aware of their PTSD case and chose not to pursue care in one period indicates that the individual is less likely to pursue care in the next. The probability of care-seeking \( r \) consecutive years after symptoms are recognized decreases by a factor of \( \beta^r_{\text{Care}} \). \( \beta_{\text{Care}} \) is chosen to be \( 3/4 \) (equal to \( \beta_{\text{Obs.}} \)) in the base case model.

\[
P(\text{ICS}(t + r) | I_{\text{Obs.}}(t) \ldots I_{\text{Obs.}}(t + r)) = \beta^r_{\text{Care}} * P(\text{ICs}) * I_{\text{Obs.}}(t) \ldots * I_{\text{Obs.}}(t + r)
\]

If the individual enters in time \( t \), they transition from Symptomatic/Observed to In Treatment in that period. Otherwise, if they do not spontaneously remit to the Asymptomatic state, they remain in the Symptomatic/Observed state.

Treatment Effect

If the individual enters treatment, they either complete the program or drops out mid-program. For the base case, the probability of treatment drop-out is taken from a recent study of treatment usage (Hoge, et al., 2014). In the case of dropout, treatment is considered unsuccessful and the individual transitions from the In Treatment state to the Symptomatic/Observed state.

Conditional on completion of the treatment, the program may or may not be successful in abating the individual’s symptoms to a sub-clinical level, and this symptom decrease may or may not be persistent. PTSD treatments differ greatly in terms of efficacy of remitting symptoms and persistence of this effect. The base case model assumes the use of Prolonged Exposure (PE) therapy, which is one of two so called evidence-based treatments (EBT) that the VA has mandated be made available to any veteran for whom an EBT is clinically appropriate\(^20\). The probability of treatment success using PE is 55% (Eftekhari, et al., 2013; Tanielian & Jaycox, 2008).

The model assumes that treatment lasts only one period in order to provide a conservative clinical workload estimate. In practice, a chronic PTSD case may remain in long-term treatment indefinitely in order to manage symptoms. This assumption is made such that in the model results,

\(^{20}\) Per VA Handbook 1160.05, 2012.
periods in which a servicemember is In Treatment represent years in which they initiate a new episode of care. The number of servicemembers transitioning to the In Treatment state in each year represents the minimum number of new treatment episodes the system must be able to sustain in that year. Thus, the model predicts the number of patients demanding a new episode of care that a clinic can expect in each year. Once in care, the model assumes that clinical staff will be able to assess how long the patient will be expected to remain and what resources will be necessary for the patient. If treatment is successful, the individual transitions from In Treatment to the Asymptomatic state in the next period. If treatment is unsuccessful (or if the individual remains in treatment for longer than one year), the individual transitions from In Treatment to the Symptomatic/Unobserved state.

Successful treatment may abate symptoms either temporarily or permanently. Treatment persistence refers to the length of time following successful treatment during which the treated individual remains asymptomatic. Data on treatment persistence is limited, but it is assumed that 25-55% of PTSD cases successfully treated with EBTs will recur in the future (Tanielian & Jaycox, 2008). If the individual experiences successful treatment, the model uses a random draw to determine whether or not their PTSD case will recur. If PTSD recurs, it is considered a new case and a new onset year and PTSD Trajectory is chosen for the individual as in initial PTSD onset.

The individual’s experience in the treatment program may impact their future willingness to pursue care in the event of future PTSD symptoms. A recent RAND study shows that 74% of veterans who have undergone a treatment program considered the experience somewhat helpful or helpful (Watkins, et al., 2011). The base case model assumes this rate as a proxy for likelihood to pursue treatment again in the event of future symptoms. The individual’s experience rating is randomly drawn independent of treatment outcome. If the experience is positive \( p = 0.74 \), the probability of future treatment remains the same. If the experience is negative \( p = 0.26 \), the probability of future treatment is reduced by \( \beta_{FutureCare} \), initially set to \( \frac{1}{2} \).

**Key Assumptions Regarding Care-Seeking**

- *Probability of Care-Seeking decreases in time.* The current study assumes that as time since recognition passes, the individual is less likely to choose to enter treatment (barring external levers such as education and outreach programs). The model also
assumes that a perceived negative treatment experience (even in the event of a positive outcome) may adversely impact an individual’s future willingness to seek treatment.

- **Treatment persistence.** Little longitudinal data exists on the long-term effect of PTSD treatment. Multiple scenarios will be run to test the effect of treatment persistence on clinical workload. Treatment persistence can vary from non-persistence, in which successful treatment lasts one period (i.e. remitting PTSD immediately but with no permanent effect on PTSD recurrence) to permanence, in which successful treatment reduces the probability of PTSD recurrence to 0. A 2008 RAND study that calculated the cost of treatment assumes a recurrence probability of 25-55% over two years after gold standard evidence-based treatments (Tanielian & Jaycox, 2008).

- **Treatment Duration.** Limited data exists on the distribution of treatment duration. An individual may pursue chronic treatment for a number of reasons, including the complexity of their case, comorbidities, and logistical constraints that delay appointment sessions. Further, data could not be found on how treatment duration impacts the probability of treatment success. Thus, within the Longitudinal Model, treatment is assumed to last one period. Though the one period assumption is certainly not the most accurate, it still allows for important intuition to be drawn from the model. By assuming that an individual is in the treatment state for one period, the number of servicemembers Entering Treatment in a given period can be thought of as the minimum number of new cases the mental health care system must be prepared to receive in each year. The assumption is also consistent with the treatment duration assumption made in the RAND (2008) model. The RAND model assumed a quarter on quarter independent treatment continuation probability of 0.80, such that the expected duration of treatment is equal to 5 quarters, or 1.25 years. Similarly, the expected duration of a PE treatment program is 8-12 weekly sessions, well within the one year model assumption.

The flow charts describing the Symptomatology and Treatment Module algorithms are presented in Figures 10a and 10b. These algorithms determine each servicemember’s state in each period.
Figure 10a. The Symptomatology Module, run in each period for each servicemember. The Symptomatology Module determines whether servicemember i will develop or remit PTSD symptoms in period t, and, if symptomatic, whether PTSD recognition or treatment will occur.
Figure 10b. The Treatment Module algorithm, run for servicemember i in the period following treatment. This Module determines whether treatment was successful in remitting symptoms, whether a new PTSD case will occur following temporarily successful treatment, and whether the individual’s experience in treatment will impact their future care-seeking behavior.
The key assumptions for each model domain are summarized in Table 6.

<table>
<thead>
<tr>
<th>Model Domain</th>
<th>Key Assumptions</th>
</tr>
</thead>
</table>
| General Model Assumptions     | 1) Subclinical PTSD treated as asymptomatic.  
                                  2) Constant treatment efficacy over time, servicemembers.  
                                  3) Model deployment ends in 2014.                                                                                                   |
| Regarding PTSD Onset          | 1) Multiple deployments impact PTSD onset independently  
                                  2) Average exposure bin distribution and long-term PTSD probability distributions correspond to observed Vietnam War rates |
| Regarding Time to Onset       | 1) Mutual independence among combat severity, onset time, PTSD type.  
                                  2) Uniform arrival times within ranges specified by Schnurr, et al. (2003).                                                          |
| Regarding Observation         | 1) Observation probability decreases in time since onset.                                                                                   |
| Regarding Care-Seeking        | 1) Care-seeking probability decreases in time since observation.  
                                  2) Treatment persistence follows the probability assumptions used in the RAND (2008) model  
                                  3) Treatment duration is equal to one model period and represents the year of treatment program entrance |

*Table 6. Key Longitudinal Model assumptions by model domain.*
Chapter 4
Results

This chapter presents the results of the model described in Chapter 3. First, this chapter reports the results of the Deployment Module, which describe how closely the model-generated servicemember population replicates the actual servicemember population. Second, the PTSD prevalence and care-seeking results are presented for the baseline model. Third, univariate sensitivity analysis is presented for the observation and treatment parameters. Fourth, the alternate model specifications are discussed and compared to baseline results. The PTSD prevalence and care-seeking results for the alternate models are included in an Appendix. Finally, the results of three sample policy interventions are discussed and compared to baseline results.

4.1 Deployment Module Results

The Deployment Module determines the timing and intensity of servicemembers’ combat experiences through the war period. This Deployment Module thus simulates the dynamics of PTSD risk on the population level across time and combat theater throughout the duration of Operation Enduring Freedom (OEF) and Operation Iraqi Freedom (OIF)/Operation New Dawn (OND). Deployment specifications are stylized for lack of detailed historical data on individual servicemembers’ deployment lengths and cycles, combat severity, and attrition from the services. Even with these assumptions, the deployment schedule generated by the model adheres closely with actual data on OEF and OIF deployments.

This model does not address deployments beyond 2014 and thus provides a lower bound on the number of PTSD cases. PTSD cases associated with OEF/OIF will continue to increase in number for at least as long as the wars continue and may extend beyond a future OEF drawdown as symptom onset may take as long as five years after the trauma in most cases. PTSD prevalence is also likely to increase as a percentage of the population if combat severity or deployment duration increase in the out years, or if returning servicemembers are redeployed.

The Deployment Module is consistent with aggregate data from a 2010 RAND study on Army OEF/OIF deployments (Bonds, et al., 2010). The RAND study is based on detailed, non-public, individual-level deployment data that includes deployment start and end dates made
available from the Defense Manpower Data Center (DMDC). The Deployment Module is generated from publicly available, aggregate, often rounded (to the nearest thousand) DMDC data on the number of servicemembers currently in theater at the end of each quarter. The RAND study only includes Active Duty Army deployment data, whereas the deployment data upon which this model is based does not break out Active Duty, National Guard, and Reserves deployments. The RAND study also does not include Marines data, and thus it cannot be used to assess the Deployment Module’s Marines results.

The Deployment Module closely follows trends in cumulative time deployed by year up to the end of the RAND study period in 2008. Figure 11 shows the cumulative time deployed by servicemembers in each model year\textsuperscript{21}. The model deviates from the RAND study primarily by underestimating early deployments. The RAND study shows a small percentage of servicemembers in their second cumulative year of deployment during 2003-2004, while second deployments in the model do not begin until 2005. This delay is due to the fact that aggregate deployment data were not available for OIF until March 2003 and for OEF until 2005. Thus, the model is not able to include deployments before OIF in 2003 and underestimates early deployment.

![Cumulative Time Deployed Diagram](image)

\textit{Figure 11. Number of servicemembers by cumulative time deployed from 2003 through the end of each indicated year.}

\textsuperscript{21} Figure 9 replicates the figure “Soldiers Accumulate Time Deployed as they Maintain High Troop Levels in OIF/OEF”, p15 of Bonds, 2010.
The cumulative deployment distribution generated by the model is assessed for accuracy by comparing results to a follow-on RAND report describing cumulative deployment from 2001 through 2011 by Active Component service (Baiocchi, 2013). In order to compare these results to the model, the RAND Active Component values must be scaled by the ratio of active duty to total service levels because the model results represent all service components. The Institute of Medicine (IOM) reported an average Active Component to total service level of 0.59 for the Army and 0.87 for Marines through end of 2010 (IOM, 2013).

The model slightly overestimates the total number of OEF/OIF servicemembers through 2011 and is more accurate for Army than Marines. The RAND study reports 403,171 Active Component Army and 122,714 Active Component Marines deployed to OEF/OIF/OND through 2011. Scaling by the ratio of active duty to total service levels, these figures suggest 682,062 Army and 140,927 Marines deployed from 2001-2011. The deployment module predicts 694,940 Army (1.89% Error) and 183,680 Marines (30.3% Error) through 2011. The error in the cumulative number of Marines can likely be attributed to the limited information available on the Marines deployment schedule. Much of the deployment data used in the model was aggregated annually by the DMDC and the model assumes that most Marines deployments last for 6 month periods, thus there is essentially no information available on the levels of the out of phase cohort. The total number of servicemembers (Army and Marines) is predicted to within 7% through 2011.

In terms of deployment dynamics, the model underestimates the number of servicemembers with 2-3 years of cumulative deployment and overestimates the number of servicemembers with 4+ years of cumulative deployment (Tables 7a and 7b). The error may be attributable to three factors in particular. First, limited information is available on differences in deployment among the Active Component and Reserves/National Guard. Second, the model’s deployment rotation is agnostic to a unit or servicemember’s number of prior deployments throughout the full war period. In practice, as operational requirements eased with respect to capacity after the surge, units likely had more discretion in terms of whom to deploy and could prioritize those with fewer prior deployments over those with more prior deployments. Finally, the model implements a uniform attrition assumption, whereby individuals discharge from the services with constant probability independent of service, cumulative deployment time, number of deployments, or severity of combat exposure. In practice, individuals with high cumulative deployment time may have different attrition or deployment characteristics (Baiocchi, 2013).
<table>
<thead>
<tr>
<th>Cumulative Time Deployed through 2011</th>
<th>Actual Cumulative Army AC Troops</th>
<th>Adjusted Actual Army Troops</th>
<th>Model-Predicted Army Troops</th>
<th>Percent Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>T ≤ 1 year</td>
<td>131,057</td>
<td>221,715</td>
<td>243,210</td>
<td>10%</td>
</tr>
<tr>
<td>1y &lt; T ≤ 2 y</td>
<td>135,876</td>
<td>229,867</td>
<td>211,660</td>
<td>-8%</td>
</tr>
<tr>
<td>2y &lt; T ≤ 3y</td>
<td>94,574</td>
<td>159,995</td>
<td>123,360</td>
<td>-23%</td>
</tr>
<tr>
<td>3y &lt; T ≤ 4y</td>
<td>35,705</td>
<td>60,404</td>
<td>103,880</td>
<td>72%</td>
</tr>
<tr>
<td>T &gt; 4y</td>
<td>5,959</td>
<td>10,081</td>
<td>12,830</td>
<td>27%</td>
</tr>
</tbody>
</table>

Table 7a. Actual and Model predicted Army troops by cumulative deployed time through 2011.

<table>
<thead>
<tr>
<th>Cumulative Time Deployed through 2011</th>
<th>Actual Cumulative Marines AC Troops</th>
<th>Adjusted Actual Marines Troops</th>
<th>Model-Predicted Marines Troops</th>
<th>Percent Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>T ≤ 1 year</td>
<td>66,459</td>
<td>76,323</td>
<td>83,080</td>
<td>9%</td>
</tr>
<tr>
<td>1y &lt; T ≤ 2 y</td>
<td>44,148</td>
<td>50,700</td>
<td>89,330</td>
<td>76%</td>
</tr>
<tr>
<td>2y &lt; T ≤ 3y</td>
<td>10,584</td>
<td>12,155</td>
<td>9,310</td>
<td>-23%</td>
</tr>
<tr>
<td>3y &lt; T ≤ 4y</td>
<td>1,362</td>
<td>1,564</td>
<td>1,960</td>
<td>25%</td>
</tr>
<tr>
<td>T &gt; 4y</td>
<td>161</td>
<td>185</td>
<td>0</td>
<td>-100%</td>
</tr>
</tbody>
</table>

Table 7b. Actual and Model predicted Marines (Table 1b) troops by cumulative deployed time through 2011. Actual Active Component (AC) cumulative numbers reported in RAND (2013). AC numbers are adjusted by the 2011 ratio of active duty to all (Active Duty, Reserves, National Guard) components (IOM, 2013). Model predictions begin in 2003Q1 for OIF, 2005Q3 for OEF; actual data begins 2001Q3.

The error in deployment dynamics may cause slight error in terms of the total number of servicemembers who ever experience PTSD but is unlikely to significantly affect model results. Table 8 describes the model-predicted percentage of servicemembers who ever experience PTSD by cumulative time deployed through 2011. The marginal rates of PTSD prevalence by cumulative time deployed can be used to estimate the error in PTSD prevalence caused by the model’s overestimation of servicemembers cumulatively deployed 3+ years relative to those cumulatively deployed 1-3 years. In particular, the model overestimates 43,436 Army troops deployed 3-4 years (at 49.4% ever-PTSD) and underestimates 36,635 Army troops deployed 2-3 years (at 36.6% ever-PTSD). The model exposes these servicemembers to 12.8pp marginal PTSD risk by overestimating their cumulative deployment time by an extra year. This additional PTSD risk causes the model to overestimate the number of ever-PTSD servicemembers by 5,560 troops.
(1.85\% of ever-PTSD population). Thus, the error in deployment dynamics is unlikely to have a significant effect on model results.

<table>
<thead>
<tr>
<th>Cumulative Time Deployed through 2011</th>
<th>Model-Predicted Army Ever-PTSD Rate</th>
<th>Model-Predicted Marines Ever-PTSD Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>T ≤ 1 year</td>
<td>22.0%</td>
<td>23.4%</td>
</tr>
<tr>
<td>1y &lt; T ≤ 2y</td>
<td>28.9%</td>
<td>29.3%</td>
</tr>
<tr>
<td>2y &lt; T ≤ 3y</td>
<td>36.6%</td>
<td>40.2%</td>
</tr>
<tr>
<td>3y &lt; T ≤ 4y</td>
<td>49.4%</td>
<td>60.2%</td>
</tr>
<tr>
<td>T &gt; 4y</td>
<td>63.2%</td>
<td>N/A</td>
</tr>
</tbody>
</table>

Table 8. Model-predicted Ever-PTSD rates for Army and Marines by cumulative time deployed through 2011.

The Deployment Module produces a servicemember population whose deployment characteristics largely track actual data through 2011. Therefore, model-generated metrics expressed in terms of absolute number of servicemembers may provide useful insight regarding the scope of the PTSD burden and clinical usage. However, the model does not include Navy or Air Force servicemembers, and deployment characteristics may have changed drastically as a result of operational tempo changes since 2011. As such, the total number of servicemembers in the model (1.03 million) is far lower than the total number of servicemembers reported to be involved in OEF/OIF through 2014 (2.7 million) (VA, 2015). Therefore, model-generated metrics will also be expressed in terms of the percentage of servicemembers they represent, so that results may be scaled accordingly.

4.2 PTSD Onset and Trajectory Model Assumptions

As discussed in Chapter 3, the baseline model assumptions are designed conservatively to underestimate PTSD rates at any time. Baseline parameters are summarized in Table 9.
<table>
<thead>
<tr>
<th>Observation Parameter</th>
<th>Value</th>
<th>Care-Seeking Parameter</th>
<th>Value</th>
<th>Treatment Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>P(Observation)</td>
<td>0.78</td>
<td>P(Treatment)</td>
<td>0.40</td>
<td>Treatment Efficacy</td>
<td>0.55</td>
</tr>
<tr>
<td>Decay in P(Observation)</td>
<td>0.75</td>
<td>Decay in P(Treatment)</td>
<td>0.75</td>
<td>Relapse Post Treatment</td>
<td>0.25</td>
</tr>
<tr>
<td>Treatment Capacity</td>
<td>Infinite</td>
<td>Dropout Probability</td>
<td>0.25</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Table 9. Baseline model parameters.*

The baseline model is designed to be highly conservative in order to provide a lower bound on PTSD prevalence in time. The baseline model assumes PTSD recognition and care-seeking probabilities at the high end of their empirical ranges and modest period to period decay in these parameters, such that servicemembers remain willing to recognize symptoms and seek care for an extended period after onset. It assumes that any servicemember who seeks treatment is able to enter treatment immediately and receives the most effective treatment possible, i.e. treatment efficacy is based on the most efficacious EBTs and an efficacy rate on the high end of the empirical range is used. The baseline model also assumes a strict definition of treatment dropout and a dropout probability at the low end of the empirical range. The probability of relapse following successful treatment is at the low end of the empirical range.

### 4.2.1 Key Baseline Assumptions

- *The baseline model assumes optimistic treatment efficacy rates.* The probability of treatment success conditional on completion is based on randomized controlled trials (RCTs) of the current “gold standard” psychotherapy evidence-based treatments (EBTs). Practical rates of treatment success will deviate from these rates in two important ways. First, EBTs may only be offered to a small percentage of the treated population, for reasons including constrained resources, limited clinician training, and patient comfort with these methods. Second, even among those whose treatment plan indicates the use of EBTs, the

---

22 All models assume the same combat exposure and PTSD onset mechanism, so that differences in PTSD prevalence and clinical usage are attributable only to differences in PTSD recognition, care-seeking behavior and treatment efficacy.
effectiveness rates of these treatment modalities in practice may be lower than the reported rates due to factors such as delays in appointment scheduling, clinician skill, and patient buy-in.

- **Reported treatment drop-out rates used for baseline model may be lower than practical rates of dropout.** Dropout rates may depend on the type of treatment provided, and may be as high as 50% for some treatment modalities23 (Schottenhauer, et al. 2008). Further, dropout rates as reported in Hoge, et al. (2014) and many other studies often use a strict definition for dropout. Other factors that compromise treatment effectiveness, such as inadequate care24 are reported separately. These factors are not considered in the model because while they compromise treatment effectiveness, certain individuals may still benefit from only a few sessions, and thus the extent to which these factors decrease treatment success is not known.

- **Reported observation rates used for baseline model may be higher than practical observation rates.** The probability of observation used in the baseline case represents the percentage of those screening positive for PTSD, depression, and anxiety who acknowledge a mental health problem in an anonymous survey. In practice, the recognition rate for the purposes of pursuing diagnosis and care may be far lower. One reason for this discrepancy is that social factors such as stigma, one’s belief that other combat veterans need and deserve help more than oneself, and fear of professional consequences may limit an individual’s willingness to acknowledge need in a non-anonymized context. Further, for the purposes of pursuing treatment in a mental health care facility, observation of PTSD typically entails a formal clinical assessment and diagnosis by a care provider such that the individual can obtain a referral to a mental health facility and begin a formal treatment program. Rates of diagnosis will be far lower than the anonymous observation rate due to

23 Some of the more effective treatment modalities, including Prolonged Exposure (PE), widely disseminated within the VA system and upon which model efficacy rates are based, are considered particularly invasive and uncomfortable for the patient. The intensity of the experience of these methods may increase a patient’s likelihood of dropping out of treatment.

24 Minimally adequate care is defined by Hoge, et al. (2014) as four or more visits in six months. Only 52% of those soldiers receiving mental health treatment for PTSD in that study received minimally adequate care.
the stigma associated with obtaining a diagnosis and logistical challenges involved with visiting a care provider.

4.2.2 Alternative Model Specifications

Table 10 describes alternative model specifications that represent realistic deviations from the baseline model. The baseline model can be thought of as a best-case scenario, in that observation probability, care-seeking behavior, and treatment characteristics are all designed to abate the PTSD burden as effectively as possible. The alternative models relax these assumptions in various ways.

<table>
<thead>
<tr>
<th>Model Name</th>
<th>Parameter Changes</th>
<th>Model Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>N/A</td>
<td>Assumes all treatment is EBT, EBT treatment efficacy is equal to the as-tested rate.</td>
</tr>
<tr>
<td>Constrained Treatment</td>
<td>Treatment Efficacy = 0.39, P(Care-Seeking) = 0.35, P(Recurs Post Treatment) = 0.40, P(Dropout) = 0.48, Decay in P(Care-Seeking) = 1/2</td>
<td>Relaxes optimal treatment assumption. Matches RAND (2008) practical EBT efficacy rate. Uses midpoint of RAND post-treatment recurrence assumption. Dropout probability includes probability of receiving less than minimally adequate care.</td>
</tr>
<tr>
<td>Constrained Treatment and Realistic Observation</td>
<td>Constrained Treatment parameters P(Observation) = 0.5, Decay in P(Observation) = 1/2</td>
<td>Uses constrained treatment parameters above as well as lower observation probability to reflect decreased willingness in non-anonymized situations to admit a mental health concern in light of stigma, professional, logistical concerns.</td>
</tr>
</tbody>
</table>

Table 10. Alternative model specifications.

Univariate sensitivity analysis is also conducted on each parameter to determine the responsiveness of model results to uncertainty or changes (e.g. increases in care-seeking behavior or improvements in treatment efficacy) in each parameter. The sensitivity analysis provides important information on opportunities for policy intervention. Many of the parameters of interest also represent targets of policy intervention or treatment development. The sensitivity shows the
extent to which investment in each of these areas stands to benefit the PTSD population and clinical burden over the long term.

4.3 PTSD Onset and Trajectory Model Results

The results discussed in this section refer to the baseline model. Alternate model results are presented in the next section and in more detail in the appendix.

4.3.1 PTSD Prevalence

Figure 12 shows the number (Figure 12a) and percentage (Figure 12b) of OEF/OIF Army and Marine servicemembers in each year who are affected by PTSD. Three measures of PTSD prevalence are considered: 1) the servicemembers who are currently symptomatic for PTSD in each indicated year, 2) the servicemembers who have an active case of PTSD in each indicated year but may or may not be symptomatic, and 3) the servicemembers who have ever experienced PTSD through the end of each indicated year. The Currently Symptomatic figure corresponds with the servicemembers who would screen positive on a hypothetical screen aimed at identifying current symptoms. The Active Case figure includes all Currently Symptomatic cases as well as servicemembers who do not exhibit current symptoms but whose PTSD has not permanently remitted. Those active cases who are not currently symptomatic thus may be missed by a screen that assesses current symptomatology. The Ever-PTSD figure includes all Active Cases as well as servicemembers who had once exhibited PTSD but whose PTSD has permanently remitted either naturally or though treatment. Those Ever-PTSD servicemembers who are not Active Cases may still develop a new case of PTSD in the future, either because they relapse after a successful treatment or because they redeploy and develop PTSD again as a result of the future deployment.
Among the servicemembers who deploy through 2014, the percentage Currently Symptomatic with PTSD in any period peaks in 2014 at 11.6%, and gradually declines through 2030 to 7.6% as those who recognize their symptoms and choose to pursue treatment gradually
recover. Currently symptomatic prevalence stays roughly constant at 6-8% through the end of the study period as chronic cases who do not pursue treatment or those for whom treatment is unsuccessful remain symptomatic.

Similarly, the percentage of servicemembers with an active case of PTSD peaks in 2014 at 17.9% of the population and declines to 14.0% by 2030. The percentage of servicemembers with an active PTSD case remains in the 11-14% range through the end of the study period.

The percentage of servicemembers who ever experience PTSD to date rises to 25.7% through the end of the deployment periods, as most cases experience first symptoms within the first 5 years after the trauma. This number rises monotonically to 28.9% as deployments end and delayed onset cases experience symptomatology.

### 4.3.2 PTSD Prevalence by Deployment Characteristics

Consistent with empirical results, multiple deployers experience PTSD at higher rates than single deployers (Figure 13). The percentage of single deployers who ever experience PTSD to date rises to 14.2% through 2014 and equals 17.8% through the end of the study. Among multiple deployers, the percentage who ever experience PTSD through 2014 is 33.4% (2.35x the single deployer rate). This percentage rises to 36.3% (2.04x the single deployer rate) through the end of the study. The ratio of PTSD risk among single and multiple deployers is consistent with the Atkinson, et al. model results and empirical studies that show a 1.64 odds ratio among these two populations (Reger, et al., 2009).

![Percentage of Servicemembers Ever PTSD by Deployments](image)

*Figure 13. Ever PTSD rates for single and multiple deployers.*
The Army and Marines exhibit largely similar PTSD prevalence and care-seeking behavior, even though their deployment characteristics are different. Figures 14a and 14b show the percent of servicemembers currently symptomatic and ever-PTSD, respectively, by service (Army or Marines) and theater (OEF or OIF). As these figures demonstrate, long term rates across services are largely similar within each theater. Short term currently symptomatic or ever-PTSD dynamics may differ slightly in each period. In particular, the Marines OEF cohort demonstrates an anomalous dip in 2008-2010 percentage currently and ever-PTSD, but this effect is an artifact of the assumptions made in the deployment module, which introduces a large number of new Marines to this theater in that period because of a sharp increase in theater inflow in that period and a lack of more precise data on prior deployment characteristics of those deployed.

The similarities in long-term PTSD rates between Army and Marines conditional on theater suggests that high operational tempo has a consistent effect on PTSD regardless of how deployment is structured (i.e. whether deployment cycles are 6 months on/6 months off or 1 year on/1 year off).

![Percentage of Servicemembers Currently Symptomatic for PTSD by Service, Theater](image)

**Figure 14a.** Percentage of Servicemembers currently symptomatic for PTSD by service (Army or Marines) and theater (OEF or OIF). The Marines OEF anomaly in 2010 can be attributed to a one-time, large influx of new Marines to this theater in this period, based on the assumptions made in the deployment module.
Figure 14b. Percentage of servicemembers ever symptomatic for PTSD by service (Army or Marines) and theater (OEF or OIF). The Marines OEF anomaly in 2010 can be attributed to a one-time, large influx of new Marines to this theater in this period, based on the assumptions made in the deployment module.

4.3.3 Comparison to Historical Data

Observed PTSD prevalence estimates for OEF/OIF vary significantly (Ramchand, et al., 2010). Empirical results differ considerably as a result of the demographic makeup of the sample and in no small part the temporal dynamics of symptomatology that this study is designed to address. The model’s performance can be assessed by comparing results with existing empirical studies; in turn, doing so offers a way to standardize and compare empirical results across studies by controlling for the temporal factors of each empirical study. The model can be used to replicate the deploying cohorts surveyed and the timing of the symptom assessment relative to deployment within a particular study. Standardizing empirical results by using the model in this fashion enables an apples-to-apples comparison across studies and may help identify differences in PTSD risk across empirical populations.

Model results are consistent with early results from the Millenium Cohort Study (MCS). The MCS study found new onset symptoms (using strict assessment criteria) in 7.6% of deployed servicemembers with combat exposure surveyed July 2004 - February 2006 (Smith, et al., 2008). In 2005, the model predicts 7.2% current PTSD among all servicemembers deployed through year end (5.3% error).
Similarly, model results also correspond with results from the Post-Deployment Health Assessment (PDHA), assessed directly after deployment and the Post-Deployment Health Reassessment (PDHRA), assessed 3-6 months after deployment. Milliken, et al. (2007) report the results of Army soldiers deployed to Iraq who were assessed with a PDHRA administered between June 2005 and December 2006. Assuming that these individuals were initially deployed January 2004-September 2005, the results from the study can be compared roughly to the model’s predictions of PTSD rates among those that deploy in 2004-2005. As a simplifying assumption, PDHA results can be compared to the model’s prediction of PTSD rates in the year of deployment and PDHRA results can be compared to the model’s prediction of PTSD rates in the year following deployment. Among Army soldiers deployed to Iraq in 2004-2005, the model predicts 6.1% current PTSD in the year of deployment and 9.5% current PTSD in the year following deployment. Using the strict criteria for the PTSD screen (≥3 responses out of 4), Milliken, et al. report 6.2% current PTSD among Active Duty Army (1.6% Error) and 6.3% (3.2% Error) among all Army components on the PDHA. They report 9.1% (4.4% Error) among Active Duty Army and 11.0% (13.6% Error) among all Army components on the PDHRA\textsuperscript{25}. The prevalence rate error may be attributable in part to the high treatment efficacy rate assumed in the baseline model. In terms of care-seeking, the model predicts 4.2% of the population will have entered treatment within the first year after deployment. Milliken, et al. that report 4.7% of Active Duty (10.6% Error) and 6.1% of all Army components (31.1% Error) were already under care for a mental health concern. The model’s low care-seeking estimate may occur because the PDHA is designed to refer positive screeners to care. Therefore, the rate of care-seeking by the time of the PDHRA may be higher in practice because of the PDHA referral program than the model’s spontaneous care-seeking probability without intervention.

Model predictions regarding single and multiple deployers are largely consistent with empirical data. Using strict criteria, Reger et al. (2009) report 8.6% current PTSD among Army OIF soldiers on their first deployment responding to the PDHRA in September 2005-April 2007. For comparison to model results, this sample can be proxied by currently symptomatic rates in the

\textsuperscript{25} The Active Duty Army results may be more comparable to the model results because the PTSD probability specification and deployment characteristics used in the model are based largely on studies of the Active Duty component and are treated as independent of component in the model. In reality, National Guard and Reserves servicemembers may have less support transitioning back to civilian life and more trouble accessing mental health services than the Active Duty component, leaving them more susceptible to later PTSD (Milliken, et al., 2007).
year following deployment among Army OIF soldiers deploying for the first time in 2005-2006. Among this cohort, the model predicts 8.0% current PTSD (7.0% Error). Among soldiers deploying for the second time during this period, Reger et al. report 13.0% current PTSD. Among second deployers, the model predicts 15.2% current PTSD (17.0% Error).

Finally, the model is consistent with VA prevalence data and may be used to assess whether prevalence rates among the VA care-seeking population are in fact representative of the full OEF/OIF population. Since 2011, the VA has regularly published the rate of PTSD and other mental health diagnoses among all VA patients but has raised questions as to how current and representative these rates are of all OEF/OIF servicemembers. The VA reports that through 2015Q1, 1,906,754 OEF/OIF/OND veterans (of roughly 2.7 million troops who have served in these wars to date) separated from the services and became eligible for VA care. Of these veterans, 1,158,359 have received VA care since 2002, and 364,894 (31.5% of the VA care-seeking population) have received a PTSD diagnosis at some point through 2015 (VA, 2015). Those with a single or co-morbid PTSD diagnosis comprise 55.1% of the 662,722 in the VA system that have any mental health diagnosis.

However, in recent press the VA has claimed that the rate of PTSD among the full veteran population (as opposed to the subpopulation of veterans who have sought VA care) is 20%\textsuperscript{26}, based on research published in RAND’s 2008 *Invisible Wounds of War* study (Reno, 2012, cf. Tanielian & Jaycox, 2008).

The VA figures-as-reported correspond closely with model results. The present study confirms that indeed, empirical studies conducted prior to the 2008 report would indicate a low ever-PTSD rate but that PTSD prevalence should be expected to rise in the years 2008-2012, approaching the 31.5% VA care-seeking rate. The model can be used to conduct a cohort study tracking the servicemembers who would have been included in the studies underlying the RAND prevalence rate. Much of the research underlying the RAND study was conducted in 2007 among those deployed in 2003-2005. Among this cohort, the model predicts an 11.6% current PTSD rate

\textsuperscript{26} The VA’s claim can be assessed by calculating the PTSD rates that they imply among the populations that complement the VA-treated population. The claimed 20% PTSD prevalence rate among the full OEF/OIF/OND service population (including all 2.7 million Active Duty, National Guard, Reserve and veterans) would imply a 11.4% prevalence rate among the 1.54 million servicemembers and veterans who have not sought care at the VA. A 20% PTSD prevalence rate among the full veteran population (the 1.9 million current veterans who have served in the two theaters) would imply a very low 2.2% prevalence rate among the 748,395 OEF/OIF/OND veterans who have not sought VA care.
in 2007 and 15.6% ever PTSD rate by 2007. However, among the same cohort in 2015, the model predicts 11.7% current PTSD and an ever-PTSD rate of 27.3%. The model predicts an ever-PTSD rate of 26.7% among the full servicemember population through 2015 (15.2% Error). This error is explained in part by the fact that the model estimate, unlike the VA, includes all combat veterans through 2015, including active servicemembers that deployed as recently as the year prior and may not yet have experienced onset.

Two factors in particular help explain why PTSD rates may be higher in the 2008-2012 period, even among those deployed and assessed earlier. First, multiple deployments, which increase the PTSD probability per servicemember, increased in these years. Many of those who deployed early in the OEF/OIF wars and did not exhibit symptoms in an early empirical assessment may have remained in active duty and redeployed later in the conflict, increasing their PTSD risk. Second, delayed onset increases the prevalence of lifetime PTSD among earlier deployers whose symptoms had not yet occurred at the time of the studies consulted in the RAND report. Thus, the higher 30% rate may indeed be representative of the full population lifetime PTSD prevalence at the time of the VA’s 2012 claims, and it is likely that the ever-PTSD rate has risen since the 2008 RAND study.

4.3.4 PTSD State Prevalence

The composition of the PTSD population changes over time in terms of symptom observation and care-seeking behavior (Figures 15-16). Analyzing the dynamics of the PTSD population composition at various time points could offer policy insights, as the composition indicates which factors most impede servicemembers’ PTSD remission at each point in time.

As shown in Figures 15 and 16, most of those with symptomatic PTSD in each period acknowledge their mental health concern in the baseline model, i.e. are either Observed or Entering Treatment. The unobserved PTSD population peaks in 2008 at 1.4% of the population, or 11.8% of the symptomatic population in each period, and remains just above 10% of the PTSD population through 2011. This rate suggests that in times of increasing PTSD, at least 1 in 10 cases do not recognize that they have a potential mental health concern.
Figure 15. PTSD Prevalence by current state. Percentage is expressed with respect to the servicemembers who have deployed at least once by each indicated year.

Figure 16. PTSD Population by Current State. Percentage is expressed with respect to servicemembers with an active case of PTSD in each indicated year.
The actual PTSD prevalence is higher than the currently symptomatic rate, as chronic PTSD sufferers may not experience symptoms in all periods. While many of those currently symptomatic are observed in each period, the observation process, and in particular, a formal screen, may easily miss the intermittent PTSD cases depending on when the screen occurs and how the screen is worded. Figure 15 shows that from 2009 onward, 5-7% of the servicemember population may have an active but asymptomatic PTSD case in each period. Figure 16 shows each PTSD state as a percentage of the PTSD population by period. The asymptomatic PTSD population makes up 20-30% of the PTSD population during the war years, i.e. periods of increasing PTSD, and comprises 30-45% of the PTSD population in the post-war period. This finding is derived simply from the empirical, long-term symptom dynamics outlined by Schnurr, et al. (2003) and Bonanno (2004) and does not include any assumptions about how civilian factors such as career and family impact symptomatology. This finding suggests that many more active cases may exist than indicated by an empirical study or screen, especially years after the war. In each year, a screen focused on current symptomatology would miss this significant percentage of the population, in addition to the false negative rate of the screen.

The PTSD trajectories of the population can also be described by individual servicemembers’ status over time since their first deployment. Figures 17 and 18 shows PTSD state by time since the first deployment. These figures suggest that PTSD rates among a cohort of servicemembers can be expected to rise through the first 5-6 years as the majority of delayed onset cases begin to express symptoms. In each period after the first deployment, only 60-65% of servicemembers with an active PTSD case will be observed with PTSD, and many of these may not have a formal PTSD diagnosis.
Figure 17. PTSD Population by years since the servicemember’s first deployment. Percentage is expressed with respect to the total number of OEF/OIF/OND servicemembers.

Figure 18. PTSD Population by Current State. Percentage is expressed with respect to servicemembers with an active case of PTSD in each indicated year since the servicemember’s first deployment.
4.3.5 Care-Seeking

Limited data is available on treatment duration, especially among the chronic PTSD population. Thus, this study is not able to capture overall usage. The care-seeking curves, then, represent inflows into the system. That is, they represent the lower bound number of servicemembers beginning an episode of care in that year. The episode of care may be fully completed within the year or may extend into subsequent years. Though many EBTs are designed to be conducted in an eight to twelve week program, many PTSD cases, especially those with other comorbid disorders such as substance abuse or depression, will remain in treatment for far longer.

Figures 19a and 19b show the number and percentage, respectively, of servicemembers entering a new episode of care in each period. The percentage of servicemembers beginning a new episode of care peaks at just above 3% in 2008-2009 as those returning from a period of high operational tempo begin to seek care. Though the percentage of servicemembers entering treatment declines around 2010, the number of servicemembers entering treatment continues to increase through 2014, as the operational tempo slows and thus new servicemembers are added to the model to cover continued OEF force requirements through this period. The increasing number of servicemembers beginning treatment may be expected to continue as deployments continue in the future (2015 and beyond; not captured in the current study). In particular, it should be noted that the percentage of servicemembers entering PTSD treatment in each year remains non-zero from 2020 through the end of the study. Many of these cases may remain in treatment for an extended period and that clinical resources may also be demanded for mental health concerns not studied here. The constant inflow suggests that levels in treatment may in fact increase as time progresses, especially in later years as increasing case complexity causes individuals to remain in treatment longer and clinical outflow rates to decline\(^\text{27}\).

Similarly, as noted above, a large percentage of the PTSD population remains symptomatic and observed through this period. Policies to increase awareness and generate treatment demand may increase treatment demand in the later years, even among those who may have already experienced an unsuccessful treatment program (see Policy Analysis below). Though not studied here, increased treatment demand may decrease the rate of treatment success if clinical resources are spread too thin, and similar may reduce the clinical capacity as some of these servicemembers may remain in treatment for an extended period. These systemic effects may cause significant,

\(^{27}\) This feature indicates the importance of future research on clinical outcomes and outflows over time.
adverse deviations from these “best-case” predictions.

As evidenced in Figures 16 and 18 earlier, a decreasing percentage of the PTSD population enters treatment in each period in the absence of policies to encourage care-seeking, even among individuals who never improve. Figure 20 shows the number and percentage of those with current PTSD symptoms in each period who have never received treatment to date. Over half of those with PTSD symptoms in each period through 2009 had never been treated. This figure declines to 40% by 2016 and remains above 30% through 2052 in the absence of policies to encourage treatment.
Figure 20. Number and percentage of currently symptomatic servicemembers who have never been treated to date.

Figure 21 shows the number of episodes of care initiated by each servicemember. This chart provides a minimum number of episodes of care per servicemember, as only one episode of care per year is counted. Though 50% of treated servicemembers only access care once, their limited care-seeking does not imply that treatment was successful. Of these, 25% will have recurrent PTSD symptoms within 5 years and 15-17% will be symptomatic in each period following their treatment episode. Symptoms may reoccur for three reasons: 1) because the treatment was unsuccessful, 2) because the treatment did not fully remit symptoms and the individual developed a new case of PTSD, or 3) because the individual subsequently redeployed and developed a new case of PTSD.

Servicemembers with only one episode of care may have not reentered treatment for a number of reasons. First, if they had a poor treatment experience their probability of treatment reentry is reduced (44% of single-treated population). Or, if they extend for a number of periods without symptom abatement and subsequent reobservation (typical of the Chronic, Unremitting PTSD type, 49% of those treated who have subsequent PTSD), they may become accustomed to their status quo symptoms and will not spontaneously choose to seek treatment again, absent of interventions or policies to encourage treatment by augmenting the care-seeking probability.
4.3.6 Delayed Care-seeking and Treatment

In many cases, those with PTSD may wait a considerable amount of time to be treated. They may do so either because they do not pursue treatment immediately following symptom onset or because clinical resources are unavailable to them for some time. In the latter case, they may wait for treatment and enter the clinic when resources become available or they may renege and no longer pursue treatment.

Figure 22 shows the number of years following PTSD onset that an individual waits before entering treatment. In the baseline case, with no clinical resource cap, this wait is fully attributable to delayed care-seeking. In this case, educational resources aimed at either 1) encouraging care-seeking in order to increase the initial probability of seeking care or 2) extending the amount of time for which an individual remains likely to seek care (i.e. reducing the decay parameter). Similarly, policies that encourage individuals to set mental health care appointments immediately upon entry into the VA system or a positive primary care screen may be particularly effective at reducing this wait time. Of particular note, with no clinical capacity constraint, 31% of the treated population (25% of the ever-PTSD population) pursues treatment in the first year of PTSD onset. Of those who ever have PTSD and do not pursue treatment in the first two years, 32% will never pursue treatment, absent interventions to promote recognition, diagnosis or care-seeking.
The post-deployment onset and care-seeking dynamics described by the model can help indicate how clinical demand will change over time for a particular deploying cohort. Following a period of enlistment, it is possible to describe the time distribution of servicemembers’ first episode of care, as well as the time distribution of all episodes of care initiated by servicemembers. Figure 23a shows the number of years after first deployment that an individual first enters treatment, and Figure 23b shows the number of years after first deployment of each episode of care. These figures demonstrate the time distribution of expected care-seeking activity among a cohort that begins their military service in a particular year. Especially since OEF is still ongoing, this chart may help predict the additional clinical resources necessary for each new cohort of servicemembers entering and deploying in the future. In particular, 59% of treated servicemembers do not receive their first treatment session until more than 5 years after their first deployment. This delay occurs for three primary reasons: 1) because the individual may be redeployed and develop PTSD as a result of a subsequent deployment, 2) as a result of delayed PTSD onset, and 3) as a result of delayed care-seeking, as discussed above. Treatment demand is particularly chronic, as demonstrated in Figure 23b. In particular, 26% of new episodes of care occur 20 years or more after the servicemember’s first deployment.
4.4 Alternative Model Results

Figures 24a and 24b demonstrate how PTSD prevalence and clinical demand differ with respect to the alternative model specifications outlined in Table 10. The baseline model represents the best-case values of parameters for which the empirical literature is uncertain. The alternative models demonstrate how model results differ as parameter values deviate from these empirical
limits in practice. More details on the outcomes under alternative model specifications are available in Appendix C.

In particular, realistic, constrained treatment assumptions have a significant, adverse effect on PTSD prevalence. These assumptions reflect the realities posed by largely non-EBT treatment in clinic and resource constraints that decrease treatment quality and increase dropout. Currently symptomatic rates double under poor treatment conditions and remain elevated throughout the length of the study. Lower observation rates caused by lack of education about mental health conditions or stigma marginally worsen long-term PTSD rates as compared to the considerable effect of constrained treatment. Though outcomes are worse in the constrained treatment models, treatment entrance rates remain consistently below the baseline rates.

![Percent Currently PTSD by Alternative Model](image)

*Figure 24a. The currently symptomatic rate with respect to alternate model specifications. Alternative model specifications represent specific changes in parameter values at the beginning of the study that reflect uncertainty in parameter values in practice.*
Sensitivity analysis was conducted with respect to the observation and treatment parameters. Little is known empirically about many of these factors. Many have not yet been studied to date, such as the time dynamics of observation or care-seeking probability, assumed herein to decay geometrically. Other parameters have been reported in the empirical literature, but are a) highly particular to the culture or time period that they describe and b) conflated with other, related factors that are not studied in this model. The sensitivity analysis indicates the extent to which model results may be expected to differ as a result of deviations from the assumed parameter values. Therefore, the sensitivity analysis may indicate important policy implications, as many mental health care policies are inherently designed to alter these parameters.

The sensitivity analysis plots the currently symptomatic and currently entering treatment rates with respect to time across a range of plausible current state parameter values (Table 11). Univariate analyses are conducted to understand how each individual parameter affects the servicemember population to first order. However, many parameters may be closely related and a change in one parameter may cause a concurrent change in other parameters, leading to complex systemic effects (see Discussion section). For each parameter, the model is run multiple times.
using values within the plausible range and holding all other parameters constant at the best-case, baseline value.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Baseline Value</th>
<th>Plausible Current Range</th>
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<td>Observation Decay</td>
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<td>Unknown. $\beta_{obs} \in [0,1]$</td>
</tr>
<tr>
<td>$\beta_{obs} = \frac{P(I_{obs}(t+1))}{P(I_{obs}(t))}$</td>
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<td></td>
</tr>
<tr>
<td>P(Observation)</td>
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<td>0.5-0.9</td>
</tr>
<tr>
<td>P(Care-Seeking)</td>
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<td>0.2-0.8</td>
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<td>Treatment Decay</td>
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</tr>
<tr>
<td>$\beta_{cs} = \frac{P(I_{cs}(t+1))}{P(I_{cs}(t))}$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P(Treatment Dropout)</td>
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<tr>
<td>Treatment Efficacy</td>
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<tr>
<td>P(PTSD Recurs Post-Treatment)</td>
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<td>Unknown. $P(Recur) \in [0,1]$</td>
</tr>
</tbody>
</table>

Table 11. Plausible ranges of observation and treatment parameters based on empirical studies.

4.5.1 Observation Parameters

There are two primary observation parameters that impact whether or not a servicemember recognizes current symptoms as indicative of PTSD in a given period. $P(\text{Observation})$ is the baseline probability of positively recognizing new symptoms. Observation Decay, $\beta_{obs}$, is a measure of how persistent the observation probability is over consecutive symptomatic periods.

$P(\text{Observation})$ has been documented in one empirical study as 0.78 among anonymous survey responders, but the value in practice for the purposes of care-seeking may be lower (Hoge, et al., 2004). The decay in observation probability, $\beta_{obs}$, is equal to the ratio of the probability of observation in $t+1$ to the probability of observation in $t$ if the servicemember is symptomatic in both periods. The period on period observation probability is thus assumed to decay geometrically, though the time dynamics of symptom recognition have not been studied empirically. Thus, neither this functional form nor possible parameter values is known.

Figures 25a and 25b present the Currently Symptomatic rate over time for a range of observation probability values. These figures suggest that the baseline probability of observation alone does not have a significant effect on PTSD rate or long-term clinical usage so long as this probability is above 0.4. That is, if each individual servicemember has at least a 40% chance of recognizing new symptoms as indicative of PTSD, long-term population outcomes are nearly as good (7.5% of population symptomatic in each period) as if every servicemember recognized
PTSD symptoms with near certainty (6.3% symptomatic in each period).

![Percent Currently PTSD by Year, pObservation](image)

**Figure 25a.** Sensitivity of the annual Currently Symptomatic rate to the probability of positively recognizing symptoms as indicative of PTSD.

![Percent Currently in Treatment by Year, pObservation](image)

**Figure 25b.** Sensitivity of the annual Entering Treatment rate to the probability of positively recognizing symptoms as indicative of PTSD.

Similarly PTSD outcomes are relatively robust to the decay in observation probability from period to period. Figure 26 shows the percentage of servicemembers currently symptomatic in each year for a range of values of the observation decay parameter. If the probability of PTSD observation from one period to the next remains above one half the prior period probability (decay parameter equal to 0.5), all else equal, PTSD rates are likely to stay constant near 6.3%. If the probability from one period to the next decays to less than half the prior period value, the long-
term PTSD rate is expected to be in the 7.2%-8.2% range. Observation probability decay does not have a marked impact on treatment entrance rates.

![Percent Currently PTSD by Year, obsDecay](image)

**Figure 26.** Sensitivity of the annual Currently Symptomatic rate to the period on period persistence in observation probability. The “obsDecay” variable is defined as the ratio of observation probability in $t+1$ to the observation probability in $t$.

### 4.5.2 Care-Seeking and Treatment Parameters

In contrast, care-seeking and treatment efficacy parameters have a pronounced effect on PTSD rates and clinical usage. Under the baseline assumptions, the probability of seeking care has the most significant effect on long term PTSD prevalence and clinical usage. Figure 27a shows the percentage of servicemembers currently symptomatic in each year with respect to a range of care-seeking probability values. With a 0.40 (baseline) conditional probability of care-seeking, peak current symptomatology is 12% near the end of the war, and the long term rate is 6.4%. Figure 27b shows the percentage of servicemembers entering treatment in each year for a range of care-seeking probability values. In the baseline model, care-seeking peaks at 3.2% of the population. However, the probability of care-seeking in practice is uncertain and highly dependent on cultural and logistical factors. A deviation of 20 percentage points in care-seeking probability from the baseline has a significant effect on PTSD prevalence and peak care-seeking. At a care-seeking probability of 0.60, peak symptomatology is 10.8% of the population and 3.8% in the long term, but peak clinical entrance per period is 4.7%. At a care-seeking probability of 0.20, peak care-seeking is only 2.1% of the population, however the current symptomatology rate peaks at 14.3% and remains as high as 10.7% over the long term. With no care-seeking whatsoever, the currently
symptomatic rate remains as high as 15.9%, slightly less than the peak rate of 17.0% due to spontaneous symptom remission.

Figure 27a. Sensitivity of the annual Currently Symptomatic rate to the baseline probability of seeking care conditional on symptom recognition.

Figure 27b. Sensitivity of the annual care-seeking rate to the baseline probability of seeking care conditional on symptom recognition.

Unlike observation probability decay, the time dynamics of care-seeking probability matter significantly for long term currently symptomatic rates. This difference may occur because successful treatment often occurs after multiple episodes of care. If treatment fails, the individual
returns to the Observed state, but the care-seeking probability continues to decay\textsuperscript{28}. In the event of unsuccessful treatment, a lower period to period care-seeking probability ratio has a drastic effect on the individual’s willingness to seek repeated episodes of care and ultimately receive successful treatment.

Figure 28 shows the currently symptomatic rate over time for a range of treatment decay values. If the period to period care-seeking probability ratio is 1 (that is, the probability of seeking care does not decay at all from one period to the next), the long-term currently symptomatic rate decreases to 1.3\%, as most individuals with PTSD continue to seek treatment until they are eventually treated successfully\textsuperscript{29}. However, even at a ratio of 0.6, the long term currently symptomatic rate remains as high as 8.6\%. As with observation probability, the time dynamics of care-seeking rates are unknown and highly depending on cultural and political factors (see Discussion).

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{fig28}
\caption{Sensitivity of the annual Currently Symptomatic rate to the period on period persistence in care-seeking probability. \textit{treatmentsDecay} is defined as the ratio of care-seeking probability in \textit{t+1} to the care-seeking probability in \textit{t}.}
\end{figure}

Finally, long term outcomes are also highly dependent on the quality of treatment. Treatment quality is characterized by both the treatment efficacy measure, or how likely treatment

\textsuperscript{28} It actually may decrease by more than the period on period rate if the individual has a poor care experience.
\textsuperscript{29} However, this efficacy is only possible if clinics are able to sustain peak entrance rates as high as 4.3\% of the population.
is to abate symptoms, and the probability of PTSD recurrence following treatment, or how likely the individual is to re-develop a new case of PTSD after successful treatment.

Treatment efficacy is highly variable in practice and depends significantly on the quality and appropriateness of the treatment modality used, clinician expertise, and clinical resources to schedule sessions and follow-up as frequently as is clinically prescribed. Treatment efficacy has been tested in depth for many modalities through randomized controlled trials and empirical studies among VA patients. However, the plausible range for treatment effectiveness in practice, 0.20-0.60 as measured empirically, corresponds to a wide range of possible model outcomes in terms of PTSD prevalence (clinical usage is roughly constant within this range at 3.0-3.5%).

Figure 29 shows the currently symptomatic rate for a range of treatment efficacy rates. At 20% treatment efficacy, a plausible value for non-evidence based treatment under clinical constraints, the peak PTSD rate persists through 2019 and reached 14.2%, while the long term rate is as high as 10.9%. At 60% treatment efficacy, a value consistent with RCT studies of EBTs as designed, PTSD rates peak at 12.4% and decline to 6.0% in the long term. With additional research, it may be possible to develop more efficacious treatments.

Figure 29. Sensitivity of the annual Currently Symptomatic rate to Treatment Efficacy, defined as the probability of successful treatment conditional on treatment completion.

With respect to the probability of PTSD recurrence following treatment, current PTSD rates are also highly variable (Figure 30). Little is known empirically about the rates of PTSD recurrence following successful treatment, however it is dependent on a number of factors
including treatment modality. The RAND (2008) study uses values in the 0.25-0.55 range, but notes that these values are uncertain. At 0.6 probability of PTSD recurrence, peak PTSD rates reach 13.2% and the long term prevalence is as high as 8.5%.

![Figure 30. Sensitivity of the annual Currently Symptomatic rate to the probability of future PTSD recurrence following successful treatment.](image)

It is important to note that a number of informal interventions, such as yoga or therapy animals, may have high efficacy rates, abating PTSD symptoms with high probability, but also high PTSD recurrence probability. These types of treatments should be studied separately within this model framework in the future, because four parameter values for these types of interventions are highly different from the other model assumptions. First, treatment efficacy has been shown empirically and anecdotally to be very high. At the same time, these gains have been shown to end shortly after the intervention is removed, as the individual reverts back to a symptomatic state with high probability. However, these are low barrier, highly accessible programs, such that the probability of care-seeking and the year on year ratio of care-seeking probability are both high.

The probability of dropout has an effect on current PTSD complementary to the probability of treatment. That is, dropout acts effectively as an immediate transition out of the treatment state without symptom abatement, and thus has a similar effect to the complement of the probability of entering treatment on the individual level. However, in practice, the plausible range of treatment dropout probability is wider than the probability of care-seeking, especially if episodes of care that do not provide the minimally adequate number of sessions are included, and dropout probability may depend on treatment modality and clinical resources, thus the sensitivity analysis is of
particular interest. Figure 31 shows the sensitivity of the currently symptomatic rate to the treatment dropout probability. The probability of dropout may range from 0.25 to 0.75 depending on the criteria for dropout, clinical resources available and choice of treatment modality. With respect to probability of dropout, clinical demand changes little. However, currently symptomatic rates are highly sensitive to dropout. Currently symptomatic rates are as high as 15.1% at the peak and 12.3% at a dropout rate of 0.80, the high end of the plausible range.

![Figure 31. Sensitivity of the annual Currently Symptomatic rate to the probability of treatment dropout.](image)

It should be noted once more that the baseline model is highly optimistic, providing the best-case values of each parameter based on current empirical findings. Because the sensitivity analysis is univariate, it tends to indicate the best case results given a deviation of each individual parameter from the baseline estimate. Parameter values in practice may differ considerably from the baseline assumptions and may be highly localized by clinic or culture. A deviation in any one parameter may also induce changes in other parameters due to complex interactions among parameters. Appendix C provides the same univariate sensitivity analysis run on the Constrained Treatment and Constrained Treatment, Realistic Observation alternate models for comparison.
4.6 Policy Analysis

Finally, policy analysis was conducted to demonstrate how the effects of targeted changes from the status quo on PTSD prevalence and clinical usage can be predicted. For the purposes of this study, policies are described as a targeted change in one or more parameters at some time during the course of the model. Policy analysis differs from sensitivity analysis in two ways. First, policies are implemented mid-course, i.e. they are not static properties of the system, but rather are introduced in response to the PTSD burden in some period after the start of the study. Second, policies may affect multiple parameters simultaneously to achieve a targeted effect. The model can be used to predict the effect of various policies at different times on the metrics of interest and help identify why certain policies may be more or less effective than intended. Framing policy interventions in terms of their model-predicted outcomes also allows for possible benefits to be compared across policies that span different aspects of the mental health care system.

Three different policies are presented here to demonstrate how temporal effects and the magnitude of change in various policies impact prevalence and clinical usage outcomes. Different types of policies may take different amounts of time and investment to realize a change in the desired parameter, and this model provides one way by which to compare these policies. The efficacy of any policy action both within the model and in practice should be determined by comparing the result of the policy with model-predicted no-intervention values. A simple before/after event study on a policy action may not take into account the temporal dynamics that would occur under the status quo in the absence of the policy.

The sample policies studied here are listed in Table 12. Each policy represents a change in a set of parameter values. The change in parameter value can either be temporary or permanent. For example, a one-time screen would cause a temporary change that augments the observation probability to the screen’s true positive rate in the year of the screen and resets it to the status quo incident-based observation probability thereafter. An educational program that augments the incident-based observation probability by teaching servicemembers about PTSD warning signs

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30 Policy interventions should also be assessed by relevant qualitative metrics that the model may not be equipped to address. In particular, the groups of servicemembers/veterans that stand to benefit from each type of intervention have different characteristics, and there may be non-quantifiable reasons to implement a particular policy beyond its direct effect on prevalence rates. These tradeoffs must ultimately be weighed by the policymakers responsible for fund allocation.
would cause a permanent change in the observation probability.

A policy may affect multiple parameters at a time. Parameters may change at different times depending on the type of policy implemented, timing of the policy decision, or the cost or time necessarily to develop and implement the change.

<table>
<thead>
<tr>
<th>Policy Name</th>
<th>Year of Change</th>
<th>Details</th>
<th>Relative Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Care-Seeking Education</td>
<td>2016</td>
<td>Causes P(Care-Seeking) to increase to 0.6 permanently.</td>
<td>$</td>
</tr>
<tr>
<td>Treatment Research</td>
<td>2020</td>
<td>Causes Treatment Efficacy to increase to 0.75 and the probability of PTSD Recurrence to decrease to 0.1 permanently</td>
<td>$$$</td>
</tr>
<tr>
<td>Clinical Follow-up</td>
<td>2016</td>
<td>Causes P(Dropout) to decrease to 0.15 and the probability of follow-on care-seeking to increase to 0.85 permanently</td>
<td>$</td>
</tr>
<tr>
<td>All of the Above</td>
<td>As above.</td>
<td>All of the above policies are implemented at their respective times.</td>
<td>$$$$</td>
</tr>
</tbody>
</table>

Table 12. Sample policy alternatives, specified in terms of the parameter changes and relative costs they comprise.

The Care-Seeking Education policy represents investment in an education program among servicemembers and veterans with a possible mental health concern that encourages care seeking. The education program would result in a permanent change in the probability of care-seeking conditional on PTSD recognition by mitigating the stigma or professional concerns surrounding care-seeking and emphasizing and legitimizing the potential benefits from treatment. As servicemembers and veterans internalize the information and pass it along to fellow servicemembers, the probability of care-seeking for any single servicemember in any period increases permanently. This program is relatively inexpensive as it requires only the development and dissemination of educational materials.

The Treatment Research policy represents investment in a research program to improve available treatment modalities. Though such a decision may be taken in 2016, the time to develop, test and disseminate the treatment improvements to clinicians delays the change in parameter values to 2020. The hypothetical new treatment improves both treatment efficacy and the probability of PTSD recurrence post-treatment considerably, but at high research cost.

The Clinical Follow-up policy represents investment of clinical resources in improving
follow-up with PTSD patients. As a result of the increased attention to each patient outside the clinical session, the probability of treatment dropout decreases considerably and the probability of care-seeking for follow-on sessions increases permanently among the treated population. This policy may be considerably costly if follow-up is to occur without adversely impacting the clinic’s capacity to accommodate new patients, and it may require hiring new mental health clinicians with military PTSD training.

Figures 32a and 32b show the currently symptomatic rate and treatment demand rate across the policy alternatives specified in Table 12. In particular, treatment education was most effective by far at mitigating PTSD symptoms. However, this effect relies on the infinite treatment capacity specified in the baseline model, as demand for treatment spikes to 7% of the population in the year of policy implementation. It is important to note that in practice, such a spike could result in poor treatment outcomes because of overtaxed clinical resources and/or a low care-seeking probability in the future among servicemembers and veterans who are turned away or receive substandard treatment. Otherwise, treatment entrance rates are largely similar across policies. The Clinical Follow-up policy is slightly more effective than the Treatment Research policy, following the intuition that successful treatment is likely to occur eventually so long as clinicians are able to spend enough time and follow up indefinitely with patients as necessary to achieve a successful outcome. The assumption of independence in treatment success rates from one episode of care to the next is central to this particular result, but may not reflect actual treatment success rates among complex PTSD cases. Further empirical research is necessary in this area to describe how treatment success rates change among chronic patients.
Figure 32a. The currently symptomatic rate with respect to four different policy alternatives. Policies represent specific changes in parameter values (outlined in Table 5) beginning in the indicated year. Currently symptomatic rates are identical to the baseline model rate until the year in which the policy change is implemented.

Figure 32b. The entering treatment rate with respect to four different policy alternatives. Policies represent specific changes in parameter values (outlined in Table 5) beginning in the indicated year. Treatment entrance rates are identical to the baseline model rate until the year in which the policy change is implemented.

Policy alternatives represent deviations from the baseline parameter values in the indicated year of implementation. Policy outcomes may be sensitive to other parameter values within the model. The effects of these policy changes with respect to the alternate model specifications are presented in Appendix C.
Chapter 5
Discussion and Policy Implications

This thesis presents a novel systems framework and stochastic model that captures the long-term dynamics of PTSD prevalence and clinical usage. The current study applies recent empirical observations of PTSD prevalence, recognition, care-seeking and treatment to predict long-term trends in prevalence and clinical demand and elucidate hidden challenges for policymakers. Results indicate that even with state-of-the-art treatments and optimistic assumptions regarding PTSD recognition and care-seeking behavior, the PTSD burden of the current wars will be chronic and substantial on both the individual and population levels. The model incorporates certain necessary simplifying assumptions but offers avenues for future research that could help further explain the long-term effects of combat-related PTSD. This chapter summarizes the key findings from the current study, presents their implications for researchers and policymakers, and discusses the limitations and future work motivated by this approach.

5.1 Key Findings

The current study shows that PTSD is prevalent, chronic, and difficult to treat. Even with the best treatments available today and optimistic assumptions about observation and care-seeking, long-term prevalence remains high for the decades following the war, though PTSD rates gradually decrease over the post-war decades. The model representing best-case parameter values was selected as the baseline in order to describe the limitations of the current state. However, the set of parameters describing the current state may deviate from the best-case in different ways across communities, regions or clinics. In many communities, the constrained models presented in Appendix C may be more representative of the current state than the best-case baseline model. When assumptions about recognition, care-seeking and treatment quality are relaxed to the lower levels frequently observed in practice, prevalence rates remain elevated and do not improve with time after the war period.
5.1.1 PTSD Prevalence

The study presents three measures of PTSD prevalence in each year: Currently Symptomatic PTSD, Active PTSD Cases, and Lifetime PTSD. Each metric represents a different, complementary view of the PTSD prevalence at a given time; no one measure fully describes the policy challenges posed by the PTSD burden.

The ever-PTSD rate describes the percentage of the servicemember population expected to experience PTSD at any point in their lives. The baseline model predicts that 29% of servicemembers deployed under OEF/OIF through 2014 will experience PTSD at some point in their lives through 2065. This finding is consistent with early prevalence estimates, current VA health records, and long-term prevalence rates among Vietnam War veterans.

The Currently Symptomatic rate describes the percentage of the servicemember population that expresses full PTSD symptoms in each period. The Currently Symptomatic rate corresponds to those who would screen positive on a diagnostic test for PTSD, as most screening tools ask respondents to assess their symptoms at the time of the test. Of active PTSD cases, only 55-80% are symptomatic in any year in the post-war period. Over the long run, 6-8% of all servicemembers are expected to display symptomatology in any period. This figure may be as high as 14-15% under constrained treatment and observation assumptions (Appendix C).

The Active Case rate describes the percentage of the servicemember population that has a probable case of PTSD in each period, though they may temporarily exhibit less than full symptomatology in that period. The percentage of the population with an active case of PTSD declines gradually from 16% in 2020 to 11% through the end of the study. Under more realistic, constrained treatment and observation assumptions, the Active Case rate is persistent in time at as high as 20-23% (Appendix C).

5.1.2 PTSD Recognition

Servicemembers and veterans with probable PTSD may not realize that they have a mental health concern. In the baseline model, as many as 1.4% of the population (11% of symptomatic PTSD cases) may be symptomatic and unobserved in any period, meaning that the individual expresses full PTSD symptoms in the period but does not recognize that their symptoms are representative of a mental health concern. In the Constrained Treatment and Realistic Observation model, a constant 33-35% of symptomatic PTSD cases (22-25% of all active PTSD cases) are
unobserved in each period.

Asymptomatic active cases and unobserved symptomatic cases present two main challenges for both clinical and command decisionmakers. First, the finding that asymptomatic and unobserved symptomatic cases represent as many as half of the active PTSD cases in a given period suggests that the observed prevalence from empirical studies or population surveys may comprise only the tip of the iceberg that is the PTSD burden. The high level of unknown or temporarily asymptomatic PTSD cases and the uncertainty of this ratio from period to period (ranging from 37-49% of all PTSD cases in a given period in the baseline model; 54-61% in the constrained model) complicates decisionmakers’ ability to plan effectively. On the clinical side, the high level of unobserved or asymptomatic PTSD in any period poses the threat of unanticipated clinical demand spikes from period to period according to changes in symptomatology or observation that complicate clinical resource allocation. Among command leaders, such period to period changes could cause unanticipated personnel shortfalls that threaten operational readiness for current or future conflicts. Second, the high level of asymptomatic active cases in any period creates challenges for clinicians, empirical researchers and other decisionmakers to accurately track PTSD cases as symptoms remit. Specifically, in practice it is difficult to determine when a case of PTSD has remitted permanently versus when symptoms have remitted temporarily. Model results indicate that through both spontaneous remission and remission through treatment channels, a considerable percentage of those whose symptoms remit from one period to another do so only temporarily. Longitudinal measures of PTSD such as the Active Case measure, as well as continued follow-up after surveys and treatment, could improve the accuracy of prevalence metrics and the ability of such decisionmakers to ensure continued care for servicemembers and veterans with PTSD.

5.1.3 Care-Seeking and Treatment

The links between clinical need and care-seeking are complex. In general, the majority of those who ever experience PTSD—and a considerable portion of the population—will seek care at least once over their lifetime. As many as 80% of those who ever experience PTSD (23% of the population) will pursue PTSD-related health care at least once in their lives. However, in any given period, a considerable portion of those who stand to benefit from clinical care are unlikely to have ever received treatment. In 2020, 36% of those currently symptomatic will not have ever had an
episode of care to date. This figure remains as high as 28% through the end of the study.

Even for those who undergo care, the majority of such treatments are unsuccessful, and many servicemembers and veterans are unlikely to pursue subsequent episodes of care. In reality, an individual will likely need multiple episodes of care to fully remit PTSD symptoms over their lives. Half of servicemembers pursue treatment only once, however 39.4% of these cases are unsuccessful. Of those who ever receive treatment, 70% will eventually receive successful treatment. However, only 59% of the ever-treated population will eventually receive successful treatment that permanently remits their symptoms. Again, these figures reflect use of the best, evidence-based psychotherapeutic treatments currently available. Under realistic treatment constraints, outcomes are far more chronic (see Appendix C).

Table 13 summarizes the key findings by domain for the baseline model and each of the alternative model specifications.

<table>
<thead>
<tr>
<th>Domain</th>
<th>Metric</th>
<th>Baseline Model</th>
<th>Constrained Treatment Model</th>
<th>Constrained Treatment and Realistic Observation Model</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Long-term Currently Symptomatic Rate</td>
<td>6-8%</td>
<td>13-15%</td>
<td>14-15%</td>
</tr>
<tr>
<td></td>
<td>(% of servicemember population)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prevalence</td>
<td>Long-term Active Case Rate</td>
<td>11-16%</td>
<td>19-21%</td>
<td>21-23%</td>
</tr>
<tr>
<td></td>
<td>(% of servicemember population)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Long-term Ever-PTSD Rate</td>
<td>29%</td>
<td>29%</td>
<td>29%</td>
</tr>
<tr>
<td></td>
<td>(% of servicemember population)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Recognition</td>
<td>Peak Unobserved PTSD rate</td>
<td>11%</td>
<td>12%</td>
<td>39%</td>
</tr>
<tr>
<td></td>
<td>(% of currently symptomatic population)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Long-term Unobserved PTSD rate</td>
<td>4.5%</td>
<td>3%</td>
<td>35%</td>
</tr>
<tr>
<td></td>
<td>(% of currently symptomatic population)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Treatment</td>
<td>Long-Term Ever-Treated rate</td>
<td>80%; 23%</td>
<td>63%; 18%</td>
<td>48%; 14%</td>
</tr>
<tr>
<td></td>
<td>(% of ever-PTSD population; % of servicemember population)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Successfully treated and permanently remitted</td>
<td>59%</td>
<td>21%</td>
<td>21%</td>
</tr>
</tbody>
</table>

Table 13. Key findings by domain for the baseline and alternate model specifications.
5.2 Implications for Research and Policy

Model results and the sensitivity and policy analyses conducted in Chapter 4 motivate a series of key conclusions surrounding PTSD prevalence and clinical usage that could have useful implications for future policy and research. These conclusions largely fall into three categories: implications for PTSD prevalence, observation and treatment (summarized in Table 14).

5.2.1 Implications for PTSD Prevalence

Care-seeking factors have the greatest effect on long-term PTSD prevalence.

The baseline model sensitivity analysis indicates that the parameters governing care-seeking have the greatest individual effect on long-term PTSD prevalence rates, holding all other parameters constant. The care-seeking parameters with the largest effect on prevalence are the probability of seeking care, the decay in care-seeking probability, and the probability of treatment dropout. However, the empirical literature has shown that these variables also feature the greatest range in parameter uncertainty and heterogeneity across units and veteran communities.

The uncertainty in these parameter values propagates to considerable uncertainty in the outcome metrics of interest. At the upper and lower bounds of the plausible current state ranges for each parameter, the long-term currently symptomatic rate differs by approximately 5 percentage points, nearly doubling the percentage of servicemembers currently symptomatic at the end of the study. Differences in care-seeking from one unit or community to another are thus likely to have an important effect on the outcomes of their members. Put another way, this finding suggests that the care-seeking features of an individual’s unit or community—the extent to which those around them encourage care-seeking and follow up on its outcome—impact the likelihood that the individual will remain symptomatic over the long term as compared to an individual in another unit or community with different care-seeking features.

Therefore, research to better understand the factors underlying care-seeking and dropout probabilities across units is likely to have the greatest predictive power in terms of long-term outcomes. The high degree of baseline model sensitivity to these parameters suggests that policies to improve care-seeking would improve long-term prevalence. This implication is supported by the effectiveness of the Care-Seeking demonstration policy analyzed in Chapter 4, though more
sophisticated analysis is needed to predict the effects of an actual, detailed policy proposal.

These implications are particular to the best-case, baseline model and under different model conditions, changes in parameter values may have different results. For example, under the Constrained Treatment and Realistic Observation model, sensitivity analysis indicates that long term prevalence is far more resistant to improvements in single parameter values than under the baseline model (Appendix C). Under Constrained Treatment and Realistic Observation, no one parameter alone has a significant effect on outcomes. Thus under multiple mental health system constraints, there is no single, “silver bullet” parameter that can be improved to ameliorate the PTSD burden. For policies to be effective in reducing the PTSD burden, they must represent a concerted, multi-dimensional approach across the mental health system to jointly improve the factors that mitigate PTSD.

*PTSD Recognition does not directly have a significant impact long-term PTSD prevalence.*

To be sure, PTSD recognition is a necessary condition for treatment entrance. Many individuals with PTSD symptoms do not recognize them as indicative of possible PTSD, even anonymously. Thus regular observation and screening programs are necessary to identify such cases and enable those individuals to seek care. However, model results indicate that the two observation parameters, the base probability of observation in the first period of symptomatology and the decay in observation probability with time since onset, have a relatively low direct effect on long-term PTSD rates relative to care-seeking and treatment parameters. Specifically, baseline model results suggest that above a threshold value of 40% base observation rate, an increase in observation probability does not significantly improve population outcomes.

The baseline model rate of 78% PTSD observation is based on a 2004 survey, early in the current wars and before large scale DoD/VA initiatives to promote PTSD recognition. Since then these initiatives and increasing education regarding military mental health concerns are likely to have improved recognition even further. Widespread screening and education programs such as these are likely to help *individual servicemembers* who may not otherwise be aware of military mental health concerns. Without such programs, the model indicates that a non-negligible percentage of the PTSD population remains unobserved and does not have access to care, especially under the Constrained Treatment and Realistic Observation model specifications. However, such programs are unlikely to offer a significant, direct impact on *long-term prevalence.*
Model results indicate that the principal bottlenecks in addressing the PTSD burden involve care-seeking and treatment, downstream of observation, as indicated in the prior conclusion.

In terms of long-term prevalence, screening and education programs are likely most effective in their ability to legitimize PTSD-related mental health concerns, shape unit and local culture accordingly, and encourage servicemembers to seek care. It is important that recognition and screening programs be designed as much as possible to encourage care-seeking and reduce stigma, because as pure observation devices, this study’s results indicate that they are not likely to significantly impact long-term prevalence.

The model assumes that observation and care-seeking probabilities are independent across servicemembers, such that an increase in observation probability does not impact the probability of care-seeking conditional on observation. However, unit or local culture is known to play an important role in increasing a servicemember’s willingness to disclose symptoms and encouraging both processes (Bickman & Kelley, 2009; Pietrzak, et al., 2009). A unit or local veteran culture that promotes well-designed screening and observation efforts is also likely to promote care-seeking and follow-up, increasing the positive effect of recognition and screening programs through their indirect effect on care-seeking probability.

*Event studies should be conducted for policy analysis, and should consider the natural population dynamics of the system.*

Outcome data are increasingly being collected and analyzed to understand the impact of the various policies that are implemented to address the PTSD burden. This step is essential to understanding the structure of the PTSD burden and the effectiveness of policy design for military mental health. These data largely assess the short-term, local effect of the intended policy. For example, a program evaluation of the PDHRA assesses the program’s ability to generate informative screens and refer positive respondents to clinic (Bickman & Kelley, 2009). Such studies are essential to verify that the policy works as designed.

However, such studies typically do not capture the effects of the policy on broad metrics of long-term interest, such as long-term prevalence or clinical demand. Thus additional policy analysis should be conducted in order to validate that the program as designed in fact has the intended effect on the mental health system writ large. For example, the PDHRA program evaluation is simply unable to track the servicemembers evaluated under the program and assess
its impact on long-term outcomes. This type of analysis to improve understanding of how the military mental health care system works and how the various factors outlined in this study jointly impact long-term prevalence.

Similarly, for such studies to be instructive, they should consider the natural dynamics of the system. The current study indicates that, especially during the war period, population symptomatology and care-seeking dynamics are complex. Thus, these natural dynamics should be considered when assessing the effect of any policy in order to determine the extent to which a change in outcome metric (for example, currently symptomatic rates or clinical demand) can be attributed to the policy change as compared with the natural dynamics of the system under the status quo.

5.2.2 Implications for PTSD Recognition

**PTSD screens should be conducted over an extended period of time in order to mitigate classification error due to symptom fluctuation.**

Screening and other types of surveys to determine PTSD prevalence should be conducted regularly and over an extended period of time in order to mitigate the possibility of prevalence underestimation and missed cases due to symptom fluctuation. Longitudinal empirical studies have shown that a substantial percentage of active PTSD cases may express subthreshold or asymptomatic PTSD as much as 75% of the time (Schnurr, et al., 2003; Bonanno, 2004).

This model indicates two main implications of symptom fluctuation for screening. On the population level, the high percentage of asymptomatic active PTSD cases in any period suggests that any single screen is likely to underestimate the true PTSD rate. On the individual level, any single screen may be less likely than expected to positively identify an active case of PTSD. The model results indicate that a screen has a significant (20-45%) chance of being assessed when an individual with an active PTSD case is asymptomatic, and in addition, the screening instrument itself has an intrinsic false negative rate. A false negative screen during a period of relative asymptomatology could have an adverse effect on individual care-seeking behavior. If an individual is cleared as a false negative in a primary care screen or PDHA/PDHRA without a
formal clinician interview\textsuperscript{31}, they may be discouraged in the future from seeking care and thus bear the burden of future symptoms because they do not expect to have PTSD.

\textit{Prevalence rates depend considerably on symptomatology time dynamics and thus should be cited with caution.}

Individual symptomatology may change considerably from period to period depending on the individual’s PTSD trajectory. Model results indicate that at any given time 20-45\% of Active PTSD cases may not express symptoms. Further, the model shows that population prevalence changes dramatically during the war period as delayed PTSD cases gradually set on\textsuperscript{32}. These results suggest that empirical prevalence estimates should be expected to vary with respect to the timing of the assessment.

A surprising result of the present study is that the model results support highly disparate empirical prevalence estimates among the same model-generated population\textsuperscript{33}. This phenomenon occurs because using this model, it is possible to control for the complex time dynamics of symptomatology by matching as closely as possible the empirical sample population’s composition with respect to deployment cohort and year of analysis. This result suggests that a considerable component of an empirical prevalence estimate can be explained by the time dynamics of symptomatology and that a prevalence estimate is not simply a static, inherent measure of the population.

Thus to the extent possible, empirical results should be cited with caution, as they reflect a population's currently symptomatic rate, which may change drastically from period to period as delayed PTSD cases set on or individuals’ symptoms fluctuate. PTSD prevalence rates are highly politicized and represent an integral factor in resource allocation decisions (Fisher, 2014). The present model results suggest that any single empirical prevalence rate provides a necessary but incomplete snapshot of the PTSD burden among a particular cohort at a fixed point in time.

\textsuperscript{31} While a clinician interview is a main component of the PDHRA, Bickman & Kelley (2009) indicate that clinical questioning typically only addresses those items that the servicemember self-reported on the PDHRA. Thus in an asymptomatic period, the clinical interview component of the PDHRA may not capture additional information about PTSD risk.

\textsuperscript{32} Milliken and colleagues (2007) study this phenomenon empirically. As discussed in Chapter 4, model results are consistent with both their early (PDHA) and delayed (PDHRA) prevalence estimates.

\textsuperscript{33} For example, model results are consistent with the 6.2\% current prevalence among Active Duty Army PDHA respondents in 2004-2005 (1.6\% Error) as well as the reported 31.5\% ever-PTSD rate reported among VA care-seeking veterans through 2015 (15.2\% Error).
Therefore decisions based on prevalence should be made with extreme caution, and it can be assumed based on these model results that a given prevalence estimate is likely to understate the actual PTSD rate in the population.

This result highlights the importance of further research to develop methods to control for the time since trauma in determining and comparing empirical PTSD rates. As noted by Schnurr, et al. (2003) and Bonanno (2004) the relationship between time since trauma and symptomatology is complex and non-linear; thus methods to control empirical PTSD rates for symptom dynamics should reflect this temporal complexity.

5.2.3 Implications for Treatment

More likely than not, an episode of care will be unsuccessful, therefore continued treatment follow-up is essential.

A number of factors combine to limit the effectiveness of even the best treatment modalities in practice. This study considered the effect of dropout, treatment efficacy and the probability of PTSD recurrence following successful treatment. With these factors combined, baseline model results indicate that only 34% of episodes of care are successful. Further, of successfully treated cases, at least one in four is expected to recur. While little is known empirically about the probability of recurrence after treatment, the model is highly sensitive to this parameter. Model results indicate that long-term prevalence varies within a 3 percentage point range with respect to the plausible range of post-treatment recurrence probability (25-55%) reported by Tanielian & Jaycox (2008). The current model did not consider the effect of other factors that could impact treatment efficacy such as time since trauma or onset, resource constraints, clinician skill and patient alliance, nor PTSD case complexity. These factors are likely to decrease the actual probability of permanently successful treatment even further.

Under the baseline model assumptions, half of the treated population does not pursue more than one episode of care, even if their treatment was unsuccessful or their PTSD case later recurred. Due to the low likelihood of successful treatment completion and permanence, treatment most likely will not be successful in permanently abating a patient’s symptoms.

Policies to encourage treatment follow-up are paramount, because it should be assumed that even the best treatments will not succeed in permanently mitigating symptoms. In the policy
analysis, a Treatment Follow-up policy that reduced the probability of dropout and increased the probability of treatment re-entry after an individual’s first episode of care was as effective as a policy to invest in research of new treatment modalities. Emphasis could be also added on treatment follow-up as part of care-seeking education programs, encouraging servicemembers and veterans to pursue regular and frequent follow-on care.

Peacetime measures to encourage care-seeking could help mitigate clinical capacity constraints.

Historically, mental health concerns achieve cyclical political importance and public attention during war periods, and tend to fade in priority after the war (Solomon, 1995). These factors may decrease individuals’ willingness or ability to seek care during peacetime until a future conflict or war draws newfound attention and acceptance to military mental health issues.

The current model demonstrates that a significant percentage of the PTSD population has observed symptomatology but does not seek treatment in any particular period. However, in periods where mental health issues are called to the forefront and the probability of care-seeking increases, a sudden increase in demand for PTSD care of as much as 4 percent of the total veteran population may overwhelm mental health clinics. Those servicemembers and veterans bearing persistent symptomatology without seeking care may be driven concurrently to seek care by newfound attention to military mental health issues during a future conflict or war. For example, contemporaneous news articles during the Gulf War describe the spike in traumatic response among Vietnam veterans, triggered by media reports of Gulf War violence; similarly attention to the mental health concerns faced by Vietnam veterans have spiked during the current wars (Peterson, 1991).

However, these spikes in attention can cause poorer treatment by spreading clinical resources too thin among both veterans of prior wars and newly returning veterans. Model results suggest that even in periods of low clinical demand, a considerable portion (6-7% under the baseline model) of the full servicemember/veteran population has an active, observed PTSD case. To the extent possible, countercyclical measures to encourage care-seeking in periods of low clinical demand could help smooth clinical usage.
Table 14 summarizes the above implications for policy and research by domain.

<table>
<thead>
<tr>
<th>Domain</th>
<th>Policy Implications</th>
<th>Research Implications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prevalence</td>
<td>1) Care-seeking factors have the greatest effect on prevalence.</td>
<td>1) Status quo population dynamics should be considered in policy event studies.</td>
</tr>
<tr>
<td></td>
<td>2) PTSD Recognition policies impact prevalence indirectly.</td>
<td></td>
</tr>
<tr>
<td>Recognition</td>
<td>1) PTSD screens should be conducted over an extended window.</td>
<td>1) Prevalence studies should control for symptom time dynamics.</td>
</tr>
<tr>
<td></td>
<td>2) Prevalence rates are highly time dependent and should be cited with caution.</td>
<td></td>
</tr>
<tr>
<td>Treatment</td>
<td>1) Care follow-up has a significant effect on long-term outcomes.</td>
<td>1) Empirical research could elucidate long-term, post-treatment trajectories</td>
</tr>
<tr>
<td></td>
<td>2) Outreach to encourage acyclical care-seeking could help avoid demand spikes.</td>
<td></td>
</tr>
</tbody>
</table>

Table 14. Implications of the current study for policy and research.

5.3 Future Work

The model developed for this study necessarily incorporates certain assumptions that may limit the applicability of its results in practice. The results presented in this study indicate a number of avenues for future research that could improve our understanding of PTSD as a complex, systemic issue and our ability to apply such knowledge to improve policy.

PTSD Onset

Little is currently known about the psychological mechanisms underlying PTSD Onset. The mechanism underlying the current model is based on population studies and does not replicate the individual factors that render servicemembers more or less susceptible to PTSD.

Atkinson, Guetz and Wein (2009) developed the most sophisticated model of PTSD onset
to date, and it may be illustrative to combine such an onset model with the trajectory model developed in the present study. Such an approach should further explore the complex relationships among combat stress, PTSD onset and trajectory. The effects of repeated trauma have not yet been studied thoroughly in the theoretical or empirical psychological literature, and this relationship may be especially complex for those who deploy multiple times (Reger, et al., 2009). Compared to the Atkinson, Guetz, and Wein model, the model presented in this study incorporates a wider range of combat stressors known to cause PTSD, many of which are not easily quantifiable (Fontana & Rosenheck, 1998). Thus it is particularly difficult to understand the extent to which a particular stressor might have a traumatic effect on a given individual at a given time and apply this mechanism within a modeling framework.

Similarly, the issue of psychological resilience is too complex to address in the present study, and it not clear how the multidimensional factors that comprise resilience may change with time and training or interact with combat trauma. Resilience is neither defined nor quantified consistently across studies and should not necessarily be regarded as a fully protective state that can be achieved through training (Almedom & Glandon, 2007). While it is important to invest in research and training programs to improve prevention, too little is known about PTSD onset to rely extensively on resilience training for PTSD prevention. Further, because it is difficult to measure, command decisions based on resilience may be faulty, and the most seemingly resilient servicemembers may be placed into unexpectedly traumatic situations\(^\text{34}\). Finally, multiple deployers face an increased risk of PTSD even though they are arguably more prepared to enter combat because they have already experienced and successfully endured the psychological stress of combat trauma.

Resilience is also not studied here because this model replicates deployments occurring through 2014. Therefore, resilience training is not a viable policy option for those servicemembers who have already deployed and developed PTSD. In future work, resilience could be incorporated in the model by altering the probability of PTSD conditional on exposure level.

\(^{34}\) In *The Good Soldiers* (2010), David Finkel provides vivid accounts of such situations, in which outward perceptions of resilience belie unexpected traumatic reactions.
Long Term Dynamics

The model is particularly conservative in terms of delayed onset estimates, because the PTSD onset rates are based on the latest large scale surveys conducted among Vietnam veterans in the late 1980s and early 1990s, approximately 25 years after the war’s end. In particular, little is known about the probability of PTSD onset or recurrence late in life. Psychological theory and anecdotal evidence support the possibility that major late life events (e.g. retirement, death of loved ones) could enable PTSD in those who were otherwise healthy (so called Late Onset Stress Symptomatology, or LOSS; Ehlers & Clark, 2000; King et al., 2007; Macleod, 1994; c.f. Folman, 2008). The model does not address LOSS or late-life PTSD onset because sufficient empirical data are currently unavailable. Therefore, the model may underestimate long-term rates, because model assumptions and structure are based primarily on twenty year trajectories (Schnurr, et al., 2003; Koenen, et al., 2003; Solomon & Mikulincer, 2006). Future work should elucidate the risk factors and dynamics underlying late-life onset, as well as the long-term dynamics of treatment, and the late-life probability of recurrence among those whose PTSD remits.

Similarly, little is known about the dynamics of observation and care-seeking probability, and yet the model identifies these temporal factors (i.e. the probability decay parameters) as a significant determinant of PTSD prevalence dynamics. Empirical work to characterize the factors affecting PTSD observation and care-seeking probability over time as well as to describe its functional form and measure these parameters could help improve model predictions and indicate policy options.

Future Deployments

The model does not speculate regarding drawdown strategies and thus the analysis reflects the effect of only those deployments occurring through 2014. The model therefore provides a lower bound level of PTSD prevalence and clinical usage because the traumatic effect of future deployments to the ongoing OEF conflict are not considered. The number of servicemembers with PTSD and in clinic in each period will increase with new deployments, and the percentage of servicemembers may also increase depending on both the extent to which current servicemembers are redeployed in the future (and thus face an increased risk of PTSD) as well as the deployment duration and relative intensity of future combat.
Parameter Optimization

This study demonstrates how mathematical modeling can be used to assess and validate different empirical prevalence estimates (e.g. the current-PTSD rate, ever-PTSD rate or treatment entrance rate) in an apple-to-apples comparison by creating a representative cohort. Though model results are generally consistent with a number of disparate prevalence estimates, the parameters underlying the model were derived from a small number of basic assumptions based on long-term Vietnam veteran data, in order to elucidate the time and system dynamics of PTSD trajectory. Model parameters could be optimized relative to a broader sample of empirical results to help elucidate the maximum likelihood parameters describing PTSD risk.

The model results correspond most closely with strict criteria for PTSD. This criterion provides a lower bound on the percentage of servicemembers who are affected by PTSD symptomatology, and does not address the burden caused by subthreshold PTSD. It may be useful to replicate the model approach using looser, screening criteria for PTSD in order to determine a broader measure of full and subclinical PTSD prevalence as a result of the current conflicts.

Similarly, parameters may depend considerably on geographic and cultural factors. The baseline model presented in this study represents the national-level best-case values for each relevant parameter. In practice, individuals are governed by a set of local conditions with heterogeneous parameter specifications from one military base or veteran community to another. The current study presents the best-case model in order to provide a general, lower-bound result. However, future studies might simulate the local dynamics, as well as the change in local conditions that occurs for each individual at the time of discharge or change of military base.

Informal Interventions

Informal interventions are an important component of the response to PTSD. Many servicemembers and veterans benefit from a wide array of informal interventions outside the clinic to manage their symptoms. These interventions have not been studied empirically in sufficient detail, and thus they are not included in this study. However, informal interventions could also be simulated within the model, and a clinical decision support tool to choose between formal treatments and informal interventions could be incorporated into this model. This tool would help understand the important effect that informal interventions could have on individual symptom management and population PTSD prevalence.
Treatment Duration

Little is known about the distribution of treatment duration, nor about the effect of treatment duration on clinical outcomes. However, the distribution is likely highly complex. Treatment duration may easily range from the 10 week recommended duration of EBTs including PE and CPT to the indefinite chronic treatment undergone by patients with the most complex cases.

The model assumes that all treatments are completed within the year in which treatment was entered and that treatment outcomes take effect in the following model year. This assumption is simplistic, but it is consistent with the recommended, 10 week EBT duration and avoids imposing an arbitrary treatment duration distribution that could affect model results. The one-year treatment assumption has the advantage that intuitively, a period in which an individual is In Treatment thus represents the period of treatment entrance, if not necessarily its completion. Therefore, while an individual may in practice remain in treatment indefinitely, the model is able to capture the flow into the clinic in each year. In practice, an individual in treatment is immediately free to re-enter a new episode of care in subsequent years, though they may be actively enrolled in an ongoing treatment program. The flexibility to enter a new treatment program even while currently enrolled is consistent with the model’s one period treatment assumption.

Information about the distribution of treatment duration and the probability of successful treatment, dropout, and treatment re-entrance conditional on duration would enable the model to predict actual usage levels, and not just treatment program entrance. This feature would improve usage estimates and allow for a more nuanced treatment of clinical capacity constraints and their effect on treatment entrance.

Parameter Interaction Effects

In the current model, all parameters are independent, such that a change in one parameter value has no effect on the value of the other parameters. In reality, PTSD trajectory, care-seeking, and treatment are closely linked and interactions between parameters could have substantial unexpected consequences.

For example, an increase in the probability of treatment, could cause clinical resources to be constrained as more individuals seek treatment at one time, thus resulting in poorer treatment and thus a lower probability of treatment success for each individual. Treatment quality declines
may subsequently decrease the clinical capacity, as individuals are expected to stay longer in treatment before improving and thus claim resources that could be directed to new cases. The treatment quality declines could also increase the probability of dropout, as patients perceive treatment to be ineffective.

Thus, while the current model presents the first order effects of each parameter, future work could consider the interactive effects of single parameter changes on other parameters across the PTSD care system.

5.4 Conclusions

The current study presents a novel long-term, dynamic model of PTSD prevalence and clinical usage. This model demonstrates how empirically observed rates of PTSD onset, care-seeking and treatment efficacy impact PTSD population prevalence over time and how uncertainty in these factors propagate to uncertainty in prevalence and clinical usage. The model also provides a framework for testing policies to mitigate the PTSD burden \(a\ priori\), which may help policymakers make decisions regarding the complex system of PTSD symptomatology, symptom recognition and care-seeking.

This research frames the PTSD burden as a complex system. It incorporates the patterns of symptom dynamics that naturally occur among individuals with PTSD and various decisional factors from across the mental health system. The model predicts the joint effect of these psychological and social factors on the macro level outcomes, such as PTSD prevalence and clinical usage, that are ultimately of primary interest to policymakers, servicemembers and veterans, and the general public. The systems approach provides a unique view of military mental health policy analysis that may elucidate new policy solutions, though there may be qualitative reasons to prioritize certain outcomes or options in practice that a quantitative systems approach cannot capture.

Though this study specifically addresses OEF/OIF combat-related PTSD, the systems approach presented here may be generalized to other populations and mental health concerns. In particular, systems analyses of conditions such as substance abuse, depression and anxiety, as well as Vietnam and Gulf War-related PTSD, could complement the present study to provide a more complete picture of DoD and VA mental health workload.
The model indicates that improvements in one or more parameters according to the local outcome metrics used to evaluate that intervention may not necessarily have a significant impact on long-term, macro level outcomes such as PTSD prevalence and clinical usage. Little work has been done to date framing military mental health as a complex system. This study suggests that this avenue of research may offer surprising and beneficial insight that could improve how researchers and policymakers understand and provide for the long-term mental wellness of servicemembers and veterans.

The model provides the basis for future work to further elaborate such systemic complexities from both an empirical and modeling standpoint. Further information about the long-term time dynamics of PTSD symptoms, recognition, and care-seeking as well as the interaction of social factors across the military mental health system will help improve prediction in this area and policy decisionmaking to mitigate the issue. The psychological and social factors underlying PTSD are dynamic and complex; the use of mathematical modeling is a relatively new strategy to address them and could help trauma researchers and policymakers better understand the structure and dynamics of this disease burden.
Appendix A

State Indicator and Transition Definitions

State Indicators

The indicator variables are defined as follows.

Symptomatic

In a given period, an individual may either express Post-traumatic Stress Symptoms (PTSS) or be asymptomatic for PTSD. Servicemember $i$ is considered Symptomatic for PTSD in period $t$ ($I_i^{Symp.}(t) = 1$) if they exhibit sufficient PTSS in $t$ to be clinically diagnosable with PTSD\[35\].

An individual with a chronic PTSD case may not express symptoms in all periods. Symptomatology may fluctuate from period to period and they may experience subclinical or asymptomatic periods even without permanent remission. For example, an individual with chronic, intermittent PTSD only experiences symptoms approximately 25% of the time, and asymptomatic periods may occur as a result of positive life events unrelated to the trauma.

During asymptomatic periods, the Symptomatic indicator is false ($I_i^{Symp.}(t) = 0$), even if the servicemember indeed has an underlying PTSD case. This specification is chosen because empirical studies and prevalence surveys typically test current symptomatology at the time of the survey. Therefore in asymptomatic periods, such an individual would test negative for PTSD in empirical surveys. With this specification, the Currently PTSD rates generated by the model are directly comparable to empirical results.

Policies that directly impact Symptomatology include changes in deployment rules that increase or decrease servicemembers’ exposure to trauma as well as resiliency training that decreases the probability of PTSD conditional on a level of combat exposure.

\[35\] In practice, an individual may also express Subclinical PTSD. Subclinical PTSD cases are considered asymptomatic in the current study.
Observed

Though the individual may be Symptomatic in $t$, they may not recognize these symptoms as indicative of a possible mental health problem. The Observed indicator takes a value of *true* in period $t$ ($I^{Obs}_i(t) = 1$) if the individual has PTSD symptoms in $t$ ($I^{Symp}_i(t) = 1$) and accurately recognizes those symptoms as indicative of a possible mental health problem. If the individual does not have PTSD symptoms in $t$ ($I^{Symp}_i(t) = 0$) or does not recognize those symptoms as indicative of a possible mental health problem, then the Observed indicator takes a value of *false* ($I^{Obs}_i(t) = 0$) in $t$.

PTSD recognition depends first on education and awareness regarding military mental health, such that the individual has a basic understanding of traumatic psychological sequelae and recognizes that their symptoms may comprise a disordered traumatic response. PTSD recognition also depends on acceptance of military mental health issues, such that the individual is willing to identify their symptoms as PTSD-related in order to proceed with a possible formal diagnosis. The observation indicator in the Longitudinal Model thus represents the minimum threshold for recognition of a possible mental health case and the first step toward treatment.

PTSD recognition may occur through two mechanisms. First, an individual may experience incident-based recognition, in which they experience PTSD symptoms (for example, a hypervigilant episode in a crowded, public space) and accurately recognize the experience as a disordered traumatic response. Incident-based recognition may occur in any period that the individual experiences symptoms, and its probability depends on the level of awareness of military mental health issues that they, their family and their colleagues have, as well as the level of cultural acceptance of such issues in their community. Second, recognition may occur through a screen, in which a local or national policy encourages or requires the individual to undergo a diagnostic test for probable PTSD. Screen-based recognition occurs sporadically according to the current screening policy and may particularly occur around key life events like return from deployment, discharge, or VA intake. The probability of screen-based recognition depends on the individual’s symptomatology at the time of the screen, the screening instrument’s sensitivity, and the willingness of the individual to provide accurate responses.\(^{36}\)

Both incident- and screen-based recognition may lead to formal PTSD diagnosis. Formal

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\(^{36}\) A symptomatic individual may choose to lie on the diagnostic test if they believe a positive screen will entail burdensome bureaucratic or logistical requirements or adverse professional consequences.
diagnosis is not addressed in the present study but is often a requisite step for access to certain formal treatments. Many who recognize their symptoms as indicative of probable PTSD may not pursue formal diagnosis for the same reasons they do not pursue formal treatment: fear of stigma and adverse professional consequences, logistical challenges in finding a clinician who can provide a diagnosis. The formally diagnosed population is thus a subset of the ever-observed population. That is, not all of those who recognize their symptoms as indicative of probable PTSD are formally diagnosed, but all who are formally diagnosed have at some point (through incident- or screen-based recognition) recognized their symptoms as indicative of probable PTSD. Also, individuals with a formal PTSD diagnosis at $t$ may be asymptomatic in $t$ if they have a chronic, intermittent case and retain the diagnosis. Thus, for the purposes of the present study, diagnosis is considered to be a component of care-seeking behavior and treatment instead of an observation mechanism.

The Longitudinal Model assumes that false positive observations do not occur; that is, an individual who is Not Symptomatic at $t$ cannot be observed with PTSD in that period. False positives are excluded for two reasons. False positive rates for screens could be determined by the specificity of the screening tool used. However, these cases may in fact have benefits for the individual or for the system. False positive PTSD screens or perceived malingering may indicate subclinical PTSD, for which the individual may still benefit from treatment or general therapy. Or, these cases may indicate other, related disorders for which the individual may require treatment. Care-seeking after a false positive diagnosis provides benefits, as the individual is able to obtain accurate diagnosis information and may gain earlier indication of other disorders than without the PTSD false positive. Second, on the model time scale (annual time steps over 60 years), the clinical resources necessary to address false positives, as clinicians would identify non-PTSD cases within the first few intake sessions.

Policies that directly impact Observation include educational programs that increase awareness about military mental health issues among servicemembers and screening programs that implement diagnostic tests at various times.

Entering Treatment

The Entering Treatment indicator takes a value of true for servicemember $i$ at time $t$ ($t_{i}^{treat}(t) = 1$) if the servicemember has observed PTSS in $t$ ($t_{i}^{obs}(t) = 1$) and initiated an episode of care at a mental health clinic in $t$. If the individual has not observed PTSS in
Entering treatment depends on both the individual’s decision to seek care and the availability of clinical resources to provide treatment. The servicemember initiates an episode of care in $t$ if they choose to seek care in $t$ ($I_i^{CS}(t) = 1$) and clinical resources are available to them in $t$ ($I_i^{Available}(t) = 1$). The probability of care-seeking is determined from empirical studies described below. Clinical availability is determined by specifying a Treatment Capacity, $TC(t)$, the maximum number of new cases the clinical system is able to accept in $t$. Treatment is available to servicemember $i$ if the maximum number of new treatment cases in $t$ has not yet been reached among the first $i-1$ servicemembers.

$$I_i^{Available}(t) = \begin{cases} 
1 & \text{if } \sum_{j=1}^{i-1} I_j^{CS}(t) < TC(t) \\
0 & \text{o/w}
\end{cases}$$

Because of limited data on the amount of time chronic cases remain in treatment, the model assumes that treatment is completed within one year. Many chronic cases may remain in treatment programs for years or even indefinitely, so this assumption is highly conservative. Many factors both within and outside the scope of the Longitudinal Model may impact treatment length, including the case complexity, comorbidities, and logistical constraints that delay appointment sessions. However, little is currently known about the distribution of treatment duration, nor about how treatment duration impacts the probability of treatment success.

The lower bound, one period estimate on treatment duration is consistent with both prescribed treatment durations for the manualized treatment modalities simulated in the present study and prior modeling research. The primary Evidence-Based Treatments (EBTs) for PTSD, Prolonged Exposure (PE) and Cognitive Processing Therapy (CPT), currently being disseminated throughout the VA system, are expected to last 8-12 weekly sessions (VA, 2010). The only other known modeling effort that attempts to capture treatment duration is the RAND model, which assumes an 80% probability of continuing treatment from one quarterly period to the next (Tanielian & Jaycox, 2008). Thus the expected duration of treatment in that model is given by the inverse of the treatment continuation probability, or 1.25 years. Both precedents are consistent with the one year, deterministic treatment duration in the current study.
Beyond the first year of an episode of care, an individual is considered Symptomatic/Observed. This specification is made because the treatment success probability used in the present study is based on efficacy studies assessed within months after the treatment. Those in long term care would appear to be symptomatic at the end of those studies, and data on their ultimate treatment outcomes is unavailable. Thus, in the current study, these servicemembers are considered Symptomatic/Observed after the first year of an episode of care, though they may continue using clinical resources indefinitely within the same episode of care. Instead of assuming an arbitrary treatment duration distribution and generating inaccurate clinical usage findings, it is more informative to discuss the number of servicemembers entering treatment in a period, instead of the number that are using treatment resources in a period.

The number of servicemembers with \(I_i^{Treat}(t) = 1\) should be thought of as the minimum number of new episodes of care that clinics should be able to support in \(t\), in addition to any chronic cases continuing care from \(t-1\). The distribution of treatment lengths is highly dependent on the individual characteristics, case complexity, and comorbidities of the patient and the treatment modality being used. Therefore, the model can be thought of as a tool to predict new cases in clinic. Once in clinic, the model assumes that clinical staff use their expertise to judge how long to expect patients to remain in treatment and allocate resources among existing cases and the model-identified new cases accordingly.

The Longitudinal Model assumes that unnecessary treatment does not occur; that is, an individual who is Not Symptomatic at \(t\) cannot enter treatment for PTSD in that period. This assumption is chosen because it is difficult to determine what constitutes unnecessary treatment, whether or not it is pursued maliciously, and what ancillary, preventive benefits may result from such treatment. Intentionally feigning PTSD, or malingering, is a contentious issue. However, leading trauma researchers agree that its actual frequency is unknown and that many important, non-malicious factors may explain the effects currently being interpreted as malingering behavior (Marx, et al. 2012). Further, any malingering activity that may occur would tend to burden the disability compensation system, with limited impact and even a possible decrease in clinical resource use (ibid.). Additionally, many of those who pursue treatment without a PTSD diagnosis, especially those who do so unintentionally, may in fact have subclinical PTSD cases or another, related disorders or could benefit from general counseling. Thus, the magnitude and directionality of the impact of “unnecessary” treatment is not well known and should be addressed in further
research.

Policies that impact Treatment include those that address care-seeking, such as educational campaigns to reduce care-seeking stigma or increase awareness of available programs and those that address treatment availability, such as hiring of new clinicians, implementation of group therapy programs, or changes in the geographic distribution of clinics and programs.

**State Transitions**
The descriptions of possible state transitions are as follows:

*From the Asymptomatic State:*

- **Asymptomatic, Not in Treatment:** \( S = [0,0,0] \)
- **Symptomatic, Not Observed, Not in Treatment:** \( S = [1,0,0] \)
- **Symptomatic, Observed, Not in Treatment:** \( S = [1,1,0] \)
- **Entering Treatment:** \( S = [1,1,1] \)

*Asymptomatic to Symptomatic/Unobserved:* An individual may transition from the asymptomatic state to the symptomatic/unobserved state as a result of three factors:

1) Fluctuating Symptoms. The individual may experience a transient fluctuation in symptoms that exceeds the threshold for subclinical or probable PTSD. These symptoms may occur in an otherwise healthy individual, driven by other life events but temporary in nature. Temporary symptom fluctuation among otherwise healthy individuals does not necessarily constitute a diagnosable traumatic disorder (Mol et al., 2005). Or, an individual with chronic PTSD may also experience intermittent asymptomatic periods, which may cause fluctuation between the asymptomatic and symptomatic states but in fact constitute a long-term disorder (Schnurr, et al. 2003).
2) A Change in Life Events or Resilience. The individual may experience a permanent change in symptoms that constitutes a disordered response to an existing trauma. This delayed onset PTSD may occur because a life event causes the individual to appraise the prior traumatic experience in a new, adverse manner (Ehlers & Clark, 2000).

3) An Increase in Traumatic Exposure. The individual may experience a permanent change in symptoms as a result of a new traumatic exposure, such as a redeployment. Though the individual had previously been exposed to trauma, the increase in exposure may trigger a traumatic response.

Asymptomatic to Symptomatic/Observed: An individual may transition from the Asymptomatic state to the Symptomatic/Observed state as a result of two factors:

1) Immediate, Incident-Based Observation. The individual may immediately recognize their symptoms as indicative of probable PTSD. This recognition may occur if the symptomatic episode is particularly vivid (e.g. nightmares about the trauma, a hypervigilant episode in a crowded setting) and the individual is sufficiently educated about PTSD to recognize the symptoms as a possible mental health concern.

2) A False Positive Screen or Recognition Event. The individual may be observed as a possible PTSD case due to a false positive screen or may self-identify even though they do not have PTSD. This may occur if the individual in fact has a related disorder (e.g. Depression, General Anxiety Disorder) and conflates the symptoms with PTSD, or if the individual has temporary symptoms driven by life events that are not closely tied to the trauma or are not long-lasting.

In the present study, Transition 1 (Immediate Observation) occurs indirectly. The individual transitions temporarily from Asymptomatic to Symptomatic/Unobserved and then transitions from Symptomatic/Unobserved to Symptomatic/Observed within the same period.

Transition 2 (False Positive) can be captured in the Longitudinal Model but is ignored for the purposes of this analysis. A false positive is not included because the individual would quickly be identified by clinicians as a non-PTSD case upon seeking care. In addition, the directionality of the impact of a false positive on the system is not clear. On the one hand, these individuals may
not need care for PTSD. On the other hand, such cases may self-identify because they suffer from related symptoms or subclinical PTSD and thus could still benefit from similar treatment at the same facility.

Asymptomatic to In Treatment: An individual may transition from the asymptomatic state directly to the in treatment state as a result of two factors:

1) A False Positive Screen. As above, the individual may directly enter PTSD treatment as a result of a false positive screen.

2) Malingering. Individuals without probable PTSD (PCL < 40) may also directly enter PTSD treatment as a result of intentional malingering behavior. The individual may demand clinical resources because they seek a PTSD diagnosis to gain disability compensation for which they do not qualify. However, this behavior may also reflect subclinical PTSD, a related disorder (e.g. depression, anxiety), or a malingering disorder for which the individual may benefit from other forms of treatment.

Similarly, these transitions can be captured in the Longitudinal Model but are ignored for the purposes of this analysis.

From the Asymptomatic state, the two transitions of interest are: remaining Asymptomatic and becoming Symptomatic/Unobserved. The other two transitions consume negligible clinical resources on the model time scale and could indicate clinical needs for other, related disorders that are outside the scope of the present study.

From the Symptomatic/Unobserved State:
Symptomatic/Unobserved to Asymptomatic: An individual may transition from the Symptomatic/Unobserved state to the Asymptomatic state as a result of two factors:

1) Symptom Fluctuation. As above, an individual may experience temporary symptom fluctuation that causes them not to exhibit symptoms from one period to another. This transient symptom abatement may occur as a correction for anomalous symptoms, i.e. those that occur temporarily as a result of life events and do not constitute a trauma disorder. Symptoms may also abate from one period to another among chronic, intermittent PTSD cases who occasionally experience periods without symptoms (e.g. chronic, intermittent PTSD cases experience symptoms only 25% of the time on average (Schnurr, et al., 2003)).

2) A change in Life Events or Resilience. As above, a life event or change in resilience can also cause a permanent change from a PTSD to a healthy status. Spontaneous remission of symptoms may occur without treatment. Schnurr, et al. (2003) characterize 24% of cases as remitting, and they do so after an average of 8 years.

Symptomatic/Unobserved to Symptomatic/Unobserved: An individual remains in the symptomatic, unobserved state if their symptoms do not naturally remit and they do not recognize their PTSS (through either a screen or symptomatic episode) during the period.

Symptomatic/Unobserved to Symptomatic/Observed: An individual may transition from the unobserved state to the observed as a result of two factors:

1) A Positive Screen. The individual may undergo a regular screen as a result of a change in life status (e.g. discharge) or a new military or VA policy. A screen includes any regular diagnostic tool that is administered in order to determine possible PTSD status. This may include the PTSD-related questions on the Post-Deployment Health Assessment, issued to all returning servicemembers at one month after deployment, or the PTSD screen required for all new VA primary care patients.

2) A Symptomatic Episode. The individual may experience a symptomatic episode as a consequence of their subclinical or possible PTSD. A symptomatic episode constitutes an observation of PTSD if the individual recognizes that the episode is potentially indicative of PTSD. Hoge, et al. (2004) indicate that 78-83% of American active duty
servicemembers screening positive for a PTSD, depression or anxiety “acknowledged a problem” in an anonymous survey.

*From the Symptomatic/Observed State:*

*Symptomatic/Observed to Asymptomatic:* As in the Unobserved state, an individual can transition from the Observed state to the Asymptomatic state as a result of either temporary Symptom Fluctuation or a permanent, positive response to a Life Event or Change in Resilience.

*Symptomatic/Observed to In Treatment:* An individual may transition to the Treatment state if they enter a formal treatment program (e.g. at a VA clinic) or pursue informal interventions (e.g. a support group session, yoga, or therapy dog program). To do so, the individual must choose to pursue care and the treatment resource must be available (i.e. there must be a facility nearby with an appropriate program and the facility must have the resources available to conduct the treatment program). For the purposes of the model, these factors (care-seeking behavior and availability) are considered independent, though in reality, actual or perceived unavailability of treatment may negatively impact the individual’s willingness to pursue care. For example, perceived unavailability may decrease an individual’s care-seeking behavior if the individual perceives that the VA system is backlogged or that their care-seeking will negatively impact another veteran’s ability to get necessary care.

*Symptomatic/Observed to Symptomatic/Observed:* An individual remains in the Observed state if their PTSS do not remit and they do not choose (or is logistically unable) to pursue care.
From the Treatment State:

In Treatment to Asymptomatic: An individual may transition from the Treatment state to the Asymptomatic state if treatment is successful. For the purposes of the model, treatment is considered successful if the individual completes the prescribed program and the treatment has the effect of reducing the individual’s symptom level below the threshold for PTSD diagnosis. The effect may or may not be persistent, and the model is run under various scenarios to test its sensitivity to the duration of treatment effect after the period of intervention.

In Treatment to Symptomatic/Observed: An individual may transition from the treatment state to the observed state as a result of three factors:

1) Drop Out. The treatment is considered unsuccessful if the individual drops out of treatment before completion. The individual may do so because they no longer believe the treatment to be worthwhile or for logistical reasons, e.g. after a move or discharge causes the individual to change clinics.

2) Unsuccessful Treatment. The treatment may also be unsuccessful if it is not effective in reducing symptoms for that individual. This may occur if the individual has a highly complex or chronic PTSD case, if the therapeutic alliance is not strong, or the wrong treatment is chosen for the individual.

The persistence of treatment outcome also depends on the type of treatment. A primary outcome of Cognitive and Behavioral Therapy is a learned set of coping mechanisms and strategies, which in concept are retained and applied by the individual indefinitely. In contrast, yoga is considered effective at mitigating PTSD symptoms, but these gains typically do not last once the individual discontinues the practice (Libby et al, 2012).
3) Chronic Treatment. If treatment takes longer than one period, the individual transitions to the Symptomatic/Observed state within the model, but may in practice continue therapy indefinitely. It is also possible in practice for an individual in chronic treatment to begin a separate treatment program concurrently or directly after a multi-period, unsuccessful episode of care. In this case, the model would capture the subsequent treatment program as a new transition from Symptomatic/Observed to In Treatment.

*In Treatment to In Treatment*: Certain individuals, particularly those with a chronic or complex PTSD case, may remain in treatment long-term. Also, those in informal intervention programs (e.g. yoga or group therapy) may regularly pursue these interventions indefinitely. For the purposes of this analysis, treatment is conducted instantaneously within one year.
Appendix B
Longitudinal Model Algorithm

Upon entrance into the model, each servicemember begins in the Asymptomatic state. The model increments annually for all servicemembers with a series of processes that occur depending on the current deployment and health states of each individual servicemember. The model lasts for 50 years after the last year of deployment (2014), and all servicemembers live for the full length of the study.

For each year, \( t \), the model follows the following algorithm:

**Check Deployment:**

For each quarter in year \( t \), \( q \in [tQ1, tQ4] \), the model checks the Deployment Schedule to determine if a force is to be deployed in \( q \). The Deployment Schedule specifies the required force sizes, \( \{\hat{N}_o(s)(q)\} \), by service and operational theater for all quarters of conflict.

If at least one force is scheduled to deploy in \( q \) (\( \hat{N}_o(s)(q) > 0 \)), the model runs the Deployment module for all service-theater pairs for which a deployment in \( q \) is scheduled. Otherwise, the model continues to the Symptomatology module.

**Deployment Module**

1. **Choose Deploying Cohort:**

   The model checks \( Q_o^s(q) \), the Available Cohort Queue, at time \( q \) for service \( s \) and theater \( o \). If \( \|Q_o^s(q)\| > 0 \), the first element of \( Q_o^s(q) \) is chosen as the deploying cohort \( c \). If \( Q_o^s(t) = \emptyset \), a new cohort is created and chosen as the deploying cohort \( c \).
2. Choose Deploying Servicemembers:

The model then checks whether cohort $c$ has enough available servicemembers, $\bar{N}_c(q)$, to fulfill the force requirement.

If $\bar{N}_c(q) \leq \bar{N}_o^s(q)$, then all $\bar{N}_c(q)$ available $s$ servicemembers in $c$ deploy to theater $o$ in $q$. Additionally $\bar{N}_o^s(q) - \bar{N}_c(q)$ new $s$ servicemembers are attached to cohort $c$ and deploy to theater $o$ in $q$.

If $\bar{N}_c(q) > \bar{N}_o^s(q)$, then $\bar{N}_o^s(q)$ of the $\bar{N}_c(q)$ servicemembers in $c$ are chosen at random. These $\bar{N}_o^s(q)$ servicemembers deploy to theater $o$ in quarter $q$. The rest of the servicemembers in $c$ remain attached to $c$ but do not deploy in $q$.

3. Determine Cohort Next Available Date:

The model checks the Deployment Schedule for the deployment length, $l_s(q)$, and Boots on Ground/Dwell ratio, $BD_s(q)$, corresponding to service $s$ at quarter $q$. The model then calculates the cohort’s Next Available Date, $A(c)$:

$$A(c) = q + l_s(q) + BD_s(q) \cdot l_s(q)$$

Cohort $c$ is added to the end of the Available Cohort Queue for service $s$ and operational theater $o$ in quarter $A(c)$.

4. Deploy Servicemembers:

The model calculates the current quarter’s combat exposure adjustment factors. The duration adjustment factor for the service $s$ is equal to $\frac{4l_s(q)}{3}$ and the severity adjustment factor for theater $o$ is equal to $\frac{\overline{C}^o(q)}{\overline{C}^{Iraq}_{2007}}$. After all deployments for year $t$ are completed, the model continues by running the Symptomatology module below.

For each deploying servicemember $i$:

4.1. Draw Combat Exposure

The model draws a raw combat exposure score, $c_{raw} \in [0,30]$, is drawn according to the historical 2007 Iraq distribution.

The model then calculates the combat exposure score for servicemember $i$ in quarter $q$: 
\[ c_i^o(q) = c_{raw} \times \frac{\bar{c}_o(q)}{\bar{c}_{Iraq}(2007)} \times \frac{4l_8(q)}{3} \]

4.2. Bin Combat Exposure

The model bins exposure level, \( X \), based on \( ce_i^o(q) \) according to the following cutoffs:

\[
X = \begin{cases} 
  \text{Low} & c_i^o(q) \leq 8 \\
  \text{Medium} & c_i^o(q) \leq 21 \\
  \text{High} & c_i^o(q) > 21 
\end{cases}
\]

4.3. Determine PTSD Probability

The model determines the PTSD probability conditional on exposure level.

\[
P(PTSD) = \begin{cases} 
  0.07 & X = \text{Low} \\
  0.211 & X = \text{Med.} \\
  0.44 & X = \text{High} 
\end{cases}
\]

4.4. Draw Expected PTSD

The model determines whether servicemember \( i \) will have Expected PTSD. The model draws a random number \( r^* \in [0,1] \).

If \( r^* < P(PTSD) \), servicemember \( i \) has Expected PTSD as a result of the deployment. The model runs the PTSD Onset Module for servicemember \( i \).

Otherwise, servicemember \( i \) does not have Expected PTSD as a result of this deployment. The model continues by assessing the next deploying servicemember.

4.5. PTSD Onset and Trajectory Module

4.5.1 Draw PTSD Onset Year

If servicemember \( i \) has Expected PTSD as a result of this deployment, the model determines the PTSD Onset Year and PTSD Trajectory.

PTSD Onset Year, \( Y \), is drawn as a multinomial random variable according to the following probability mass function:
\[ P(Y = y) = \begin{cases} 0.314 & y = 0 \\ 0.305 & y = 1 \\ 0.318 & y \in [2,5] \\ \frac{4}{4} = 1 & y \in [6, r] \end{cases} \]

where \( r \) is the number of years remaining in the model.

PTSD Onset occurs in model year \( t+y \).

### 4.5.2 Draw PTSD Trajectory

PTSD Trajectory, \( T \), is drawn as a discrete random variable according to the following probability mass function\(^{38}\):

\[ P(T = \tau) = \begin{cases} 0.18 & \tau = Rem. \\ \frac{9}{9} \times I(y < 6) & \tau = CI \\ 0.24 & \tau = CI \\ \frac{9}{9} \times I(y < 6) & \tau = CU \\ 0.48 & \tau = CU \\ I(y \geq 6) & \tau = DO \end{cases} \]

where \( y \) is the number of years to PTSD Onset; \( Rem. \) signifies the Remitting cluster; \( CI \) the Chronic, Intermittent cluster; \( CU \) the Chronic, Unremitting cluster; and \( DO \) the Delayed Onset cluster.

PTSD Remittance and PTSD Recurrence probabilities are set according to the PTSD Trajectory. The model continues to assess the next deploying servicemember.

### Symptomatology Module

The Symptomatology module is run for all servicemembers existing in the model to date.

For each servicemember \( i \):

1. Did the Individual Undergo Treatment Last Period?

If the individual was In Treatment in \( t-1 \), assess Treatment Outcome. If the individual was not In Treatment in \( t-1 \), continue to assess State Transitions.

\(^{38}\) The PTSD Trajectory is set to Delayed Onset with probability 1 if the Onset Year is 6 years or more from deployment. If Onset Year is less than 6 years from deployment, PTSD Trajectory is chosen randomly from among the Remitting, Chronic, Intermittent, and Chronic, Unremitting types. For each of these three types, the model must use the conditional probability of that cluster given Early Onset PTSD. Thus, the empirical rate of each cluster must be normalized by the empirical rate of Early Onset PTSD, equal to 1 minus the empirical rate of the Delayed Onset cluster, \((1-0.1)=0.9\).
2. Treatment Outcome:

2.1. Did the individual drop out of treatment?

The model determines whether servicemember \( i \) Dropped Out of treatment. The model draws a random number \( r^* \in [0,1] \) and compares it to \( P(Dropout) \), the probability of drop out.

If \( r^* \leq P(Dropout) \), servicemember \( i \) dropped out of treatment. Treatment is considered Unsuccessful and servicemember \( i \) transitions to the Symptomatic/Observed state. The model continues to assess State Transitions.

If \( r^* > P(Dropout) \), servicemember \( i \) remained in treatment for the full duration of the program. The model then determines if treatment was successful.

2.2. Was the full treatment program successful?

The model determines whether the treatment program begun in \( t-1 \) was successful. The model draws a random number \( r^* \in [0,1] \) and compares it to \( TE \), the Treatment Efficacy for the type of treatment program offered to servicemember \( i \) in \( t-1 \).

If \( r^* \leq TE \), treatment is considered Successful. The servicemember transitions to the Asymptomatic state. The model then determines whether the individual will Relapse.

If \( r^* > TE \), treatment is considered Unsuccessful. The servicemember transitions to the Symptomatic/Unobserved state. The model then determines whether the individual had a Positive or Negative Experience.

2.3. Will the individual relapse?

The model determines whether the individual’s PTSD case will relapse following this treatment episode. The model draws a random number \( r^* \in [0,1] \) and compares it to \( RPE \), the probability of PTSD relapse post-treatment.

If \( r^* \leq RPE \), servicemember \( i \) will relapse following this treatment. Servicemember \( i \) has Expected PTSD and the model runs the PTSD Onset module to determine Onset Year and PTSD Trajectory for the new PTSD case.

If \( r^* > RPE \), servicemember \( i \) will not relapse following this treatment. \( P(Recur) \), the probability of PTSD symptom recurrence, is set to zero for servicemember \( i \).
2.4. Did the Individual have a Positive Treatment Experience?

The model determines whether the individual had a positive or negative treatment experience. If the treatment experience was negative, the servicemember’s future probability of care-seeking is decreased by $\beta_{FutureCare}$. The model draws a random number $r^* \in [0,1]$ and compares it to $P(NE)$, the probability of a negative care experience.

If $r^* \leq P(NE)$, the treatment experience is considered Negative. The probability of Care-Seeking for servicemember $i$ is set to $\beta_{FutureCare} \times P(CS)$. The model continues to assess State Transitions.

If $r^* > P(NE)$, the treatment experience is considered Positive. The probability of Care-Seeking for servicemember $i$ remains constant. The model continues to assess State Transitions.

3. State Transitions:
The model assesses possible transitions depending on the state in which servicemember $i$ begins period $t$.

3.1 Transitions from the Healthy State:

3.1.1. PTSD Onset (To Symptomatic/Unobserved):

If servicemember $i$ is in the Asymptomatic state and has Expected PTSD from a prior deployment or post-treatment relapse, the model checks whether PTSD Onset is set to occur in the current period.

If Onset is set to occur in $t$, servicemember $i$ transitions to the Symptomatic/Unobserved state. The model advances to assess further transitions from the Symptomatic/Unobserved state in $t$.

If PTSD Onset is not set to occur in the current period, the servicemember remains in the Healthy state and advances to the next period.

3.1.2. Symptom Fluctuation (To Symptomatic/Unobserved):

If the servicemember is in the Asymptomatic state and has experienced prior PTSD, the model determines whether PTSD symptoms will recur in the current period. The model draws a random number $r^* \in [0,1]$ and compares it to $P(Recur)$, the probability of PTSD symptom recurrence.
If \( r^* \leq P(Recur) \), servicemember \( i \) will experience PTSD symptoms in the current period. Servicemember \( i \) transitions to the Symptomatic/Unobserved state. The model advances to assess further transitions from the Symptomatic/Unobserved state in \( t \).

If \( r^* > P(Recur) \), servicemember \( i \) will not experience PTSD symptoms in the current period. Servicemember \( i \) remains in the Healthy state and advances to the next period.

### 3.2 Transitions from the Symptomatic/Unobserved State:

#### 3.2.1. Permanent Remittance or Symptom Fluctuation (To Asymptomatic):

If servicemember \( i \) is in the Symptomatic/Unobserved state (either because they were Symptomatic/Unobserved in the prior period or transitioned from the Asymptomatic state during the current period), PTSD symptoms may remit temporarily or permanently\(^{39}\). The model draws a random number \( r^* \in [0,1] \) and compares it to \( P(Remit) \), the probability of PTSD symptom remittance.

If \( r^* \leq P(Remit) \), servicemember \( i \) will not experience PTSD symptoms in the current period. Servicemember \( i \) transitions to the Asymptomatic state and advances to the next period.

If \( r^* > P(Remit) \), servicemember \( i \) will continue to experience PTSD symptoms in the current period. The model then assesses whether symptom observation will occur in \( t \).

#### 3.2.2. Screening or Episodic Observation (To Symptomatic/Observed)

If the servicemember remains Symptomatic in \( t \), symptom observation may occur. First, the model checks whether a screening event is scheduled for the individual during this period. If so, the probability of observation in \( t \), \( P(I_{Obs}(t)) \), is set to the screening instrument sensitivity. Otherwise, the probability of observation is updated to reflect the likelihood of episode-based observation given the number of periods since onset, \( s \): \( P(I_{Obs}(t)) = \beta^s \cdot P(I_{Obs}(t)) \).

The model draws a random number \( r^* \in [0,1] \) and compares it to \( P(I_{Obs}(t)) \).

If \( r^* \leq P(I_{Obs}(t)) \), servicemember \( i \) recognizes their PTSD symptoms in \( t \). Servicemember \( i \) transitions to the Symptomatic/Observed state. The model then assesses whether \( i \) will enter treatment in \( t \).

If \( r^* > P(I_{Obs}(t)) \), servicemember \( i \) does not recognize their PTSD symptoms in \( t \). Servicemember \( i \) remains in the Symptomatic/Unobserved state and advances to the next period.

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\(^{39}\) Temporary and permanent remittance occurs through the same mechanism. The remittance is permanent if the servicemember’s probability of recurrence, \( P(Recur) \), is equal to zero.
3.3. Transitions from Symptomatic/Observed

3.3.1. Permanent Remittance or Symptom Fluctuation (To Asymptomatic)

If the servicemember is in the Symptomatic/Observed state because they were Symptomatic/Observed in the prior period, PTSD remittance may occur through the same mechanism as the Symptomatic/Unobserved-Asymptomatic process. If PTSD remits, the servicemember transitions to the Asymptomatic state and advances to the next period. This transition may be permanent or temporary, depending on the servicemember’s probability of PTSD recurrence.

3.3.2. Care-Seeking and Treatment Available (To Treatment)

If the servicemember is in the Symptomatic/Observed state (either because they were Symptomatic/Observed in the prior period or transitioned from the Symptomatic/Unobserved state during the current period), they may choose to seek care. The probability of care-seeking, \( P(I_{CS}(t)) \), is updated to reflect the likelihood of care-seeking given the number of periods since observation, \( r: P(I_{CS}(t)) = \beta_{Care}^r \times P(I_{CS}) \).

The model draws a random number \( r^* \in [0,1] \) and compares it to \( P(I_{CS}(t)) \).

If \( r^* \leq P(I_{CS}(t)) \), servicemember \( i \) enters treatment \( t \). Servicemember \( i \) transitions to the Entering Treatment state if clinical resources are available and advances to the next period. The effects of treatment are applied in the next period. If clinical resources are not available, servicemember \( i \) remains in the Symptomatic/Observed state and advances to the next period.

If \( r^* > P(I_{CS}(t)) \), servicemember \( i \) does not enter treatment in \( t \). Servicemember \( i \) remains in the Symptomatic/Observed state and advances to the next period.

Discharge Module

Finally, in each year, the Discharge module is run for each servicemember to determine their future military status.

For each servicemember \( i \):

If servicemember \( i \) is currently Veteran, the model advances to the next period.

If servicemember \( i \) is currently Active, the model determines whether they will discharge from the service. The model draws a random number \( r^* \in [0,1] \) and compares it to \( cr \), the service continuation rate.

If \( r^* \leq cr \), servicemember \( i \) remains Active and advances to the next period.
Servicemember $i$ remains eligible for future deployments.

If $r^* > cr$, servicemember $i$ discharges from the service in $t$. Servicemember $i$ is set to Veteran status in $t$ and is no longer eligible for deployment.
Appendix C
Alternative Model Results

The figures below present outcome metrics for the alternative models.

Constrained Treatment Model

Outcome Metrics
Sensitivity Analysis

With respect to Observation Probability:
With respect to Decay in Observation Probability:

With respect to Treatment Probability:
With respect to Decay in Treatment Probability:

With respect to Treatment Efficacy:
With respect to Probability of Recurrence following Treatment:

Constrained Treatment and Realistic Observation

Outcome Metrics
**Sensitivity Analysis**

With respect to Observation Probability:

With respect to Decay in Observation Probability:
With respect to Treatment Probability:

With respect to Decay in Treatment Probability:
With respect to Treatment Efficacy:

With respect to Probability of Recurrence following Treatment:
Policy Analysis

[Graphs showing the percent currently PTSD by policy alternative and the percent currently in treatment by policy alternative.]
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