Model-Based Policy Analysis to Mitigate Post-Traumatic Stress Disorder

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Abstract:
A wide range of modeling methods have been used to inform health policies. In this chapter, we describe the use of three models for understanding the complexities of post-traumatic stress disorder (PTSD), a major mental disorder. The models are: 1) a qualitative model describing the social and psychological complexities of PTSD treatment; 2) a system dynamics model of a population of PTSD patients in the military and the Department of Veterans Affairs (VA); and 3) a Monte Carlo simulation model of PTSD prevalence and clinical demand over time among the OEF/OIF population. These models have two characteristics in common. First, they take systems approaches. In all models, we set a large boundary and look at the whole system, incorporating both military personnel and veterans. Second, our models are informed by a wide range of qualitative and quantitative data. Model I is rooted in qualitative data, and models II and III are calibrated to several data sources. These models are used to analyze the effect of different policy alternatives, such as more screening, more resiliency, and better recruitment procedures, on PTSD prevalence. They also provide analysis of healthcare costs in the military and the VA for each policy. Overall, the developed models offer examples of modeling techniques that can utilize a wide range of data sources and inform policy makers in developing programs for mitigating PTSD.

1. Introduction

Policy informatics refers to the use of information technologies, data analysis, computational modeling, and simulation techniques to address complex public policy problems Johnston and Desouza (2015). The goal is to utilize multiple and extensive data sources and computational methods to inform policy makers and to help improve the design and implementation of policies (Johnston & Desouza, 2015; Kim, MacDonald, & Andersen, 2013). A broad definition of policy informatics includes data-driven system dynamics models and other mathematical models developed to study complex systems (Johnston & Desouza, 2015). Example applications include studies of social welfare (Zagonel, Rohrbaugh, Richardson, & Andersen, 2004), environment and energy (Sterman, 2014), education systems (Ghaffarzadegan et al., 2014), and healthcare systems (Fallah-Fini, Rahmandad, Huang, Bures, & Glass, 2014; Teytelman & Larson, 2013; Wittenborn, Rahmandad, Rick, & Hosseinichimeh, 2016). Specifically, in the domain of health care, growing attention has been paid to developing models that can capture population health and prevalence of chronic health conditions or infectious disease and be used as platforms to test policy alternatives (Finkelstein, Larson, Nigmatulina, & Teytelman, 2015; Homer & Hirsch, 2006; Milstein, Homer, Briss, Burton, & Pechacek, 2011).

In this chapter, we focus on the application of simulation-based models in a specific mental health policy context, the problem of post-traumatic stress disorder among military personnel and veterans. The materials in this chapter are based on the outputs of modeling different aspects of PTSD in the Post-Traumatic Stress Innovation project that was conducted at the Massachusetts Institute of Technology from 2012 to 2015. Here, we provide brief information about PTSD and the results of the three models. Overall, these models provide examples of how modeling techniques that utilize a wide range of qualitative and quantitative data sources can help analyze a major health issue and inform policy makers.

2. What is PTSD?

Post-traumatic stress disorder is a mental illness that can occur after experiencing a traumatic event, such as combat, family violence, sexual assault, a terrorist attack, or serious injury (US Department of Veterans Affairs, 2016a). Individuals with PTSD continue to experience the psychological effects of trauma, including symptoms of re-experiencing, avoidance of similar stimuli, negative cognition and mood, and increased physical arousal, long after being removed to a safe environment (SOLOMON, AVIGALSNIR, & ROSENBERG, 2015). PTSD is also highly comorbid with other psychological effects or mental illnesses that can occur following trauma, including depression (Campbell et al., 2007; Ginzburg, Ein-Dor, & Solomon, 2010), substance abuse (Breslau, Davis, & Schultz, 2003; McFall, Mackay, & Donovan, 1992), guilt and shame (Hendin & Haas, 1991; Henning & Frueh, 1997), and suicidality (Jakupcak et al., 2009).

PTSD is becoming a serious public health challenge. About eight million people in the United States suffer from PTSD(US Department of Veterans Affairs, 2016b). The illness is more common among military personnel and Veterans, especially those deployed to combat zones. It is estimated that 11% to 20% of US military personnel who served in Iraq or Afghanistan have diagnosed or undiagnosed PTSD (US Department of Veterans Affairs, 2016b).

The military PTSD burden incorporates not only the medical challenge of treatment, but also social dimensions that interact with cultural and logistical aspects of the military system. In 2007, the Department of Defense Task Force on Mental Health outlined four goals for improving mental health care, incorporating both medical and non-medical factors: a culture of support for psychological health; a full continuum of excellent care in both peacetime and wartime; sufficient and appropriate resources allocated to prevention, early intervention, and treatment; and visible and empowered leaders at all levels to advocate, monitor, plan, coordinate and integrate prevention, early intervention, and treatment. Though this effort is an important step in normalizing care-seeking and improving access to mental health services, cultural factors such as stigma and fear of professional repercussions still prevent many individuals from seeking the care they need (Ghaffarzadegan & Larson, 2015; Phelan, 2005; Vogt, 2011).

Moreover, the tools and techniques used for screening and diagnosis are mainly based on self-reported surveys. In order to diagnose PTSD, individuals usually answer a survey consisting of 17 questions, referred to as a post-traumatic checklist (Hoge, Riviere, Wilk, Herrell, & Weathers, 2014). Each question receives a score of 1 to 5, with a possible total of 17 to 85. While there is not a precise cutoff value, generally people with numbers above 40 or 50 are considered to have PTSD symptoms and are sent for interviews and diagnosis with mental health professionals. Since this is a self-reported survey, it is not difficult to hide symptoms and manipulate responses. This adds to the uncertainties and difficulties of PTSD diagnosis.

3. Our project

Mathematical models are well-known to the Department of Defense (DoD). The very birth of operations research, which relies heavily on mathematical models, was DoD-driven during World War II. Among the products of this work were efficient linear programming algorithms to improve wartime logistics; the theory of optimal search, which proved invaluable to U.S. efforts in the North Atlantic to find and destroy enemy submarines; and optimal location theory, which proved most useful for placement of radar stations in Britain to detect incoming enemy aircraft.

However, models of human health and behavior and interventions to improve them were less well-developed at that time. The subsequent seven decades have seen a lot of good work in this area, focused less on hardware-dominated tactical operations and more on human systems. Epidemiology is now a mature field involving many different types of mathematical models of behavior-influenced disease progression and control. In the case of PTSD, mathematical modeling is a relatively new field, and there are just a handful of papers addressing the topic.

The goal of the innovation project has been to incorporate work based on both qualitative and quantitative modeling as a way to capture the potential benefits of a multidisciplinary examination of the burden of PTSD and how it might be addressed in the military health system going forward. Our mathematical modeling work takes a "system" perspective, embedding servicemembers in the military system and then structuring various PTSD-focused models around that, with the type of structure depending on the decisions and policies to be guided and influenced by the model. From the system point of view, we seek first to frame the problem to understand the overlapping and intertwined subsystems – formal and informal, positive and negative – that influence the treatment of PTSD. Then, from an aggregate level, we seek to project PTSD treatment workloads of the DoD and the VA over the coming years and even decades.

Mathematical models come in many varieties: deterministic or probabilistic; equation-based, algorithm-based, or simulation-based; optimizing or descriptive; and so on. Our approach is simulation-based and descriptive in response to the complexity of PTSD. Simulations also come in a number of varieties: Monte Carlo (probabilistic) simulation, system dynamics, and even micro rule-based, so-called agent-based simulations. Our work utilizes system dynamics and Monte Carlo simulations.

Simulation models have a wide variety of uses. Among others, they support *"what-if" analysis and workload projections*. A simulation model of a PTSD treatment system can project the multi-year consequences of PTSD workloads and costs under a wide variety of "what-if" scenarios, ranging from those largely outside the control of the PTSD system, such as the intensity of engagements in future wars, to those under the control of the PTSD system, such as the deployment of additional resources and the use of new evidence-based treatments. This can inform projections of budgets and needs for professional manpower and facilities.

Another use is to *improve the understanding of a system*. Sometimes, a model's primary use is problem framing, through which decision makers and other stakeholders – such as PTSD-afflicted servicemembers and veterans, their families, friends, and personal support organizations – can learn from model development and structure about the shared importance of the many intertwined stakeholders in helping to ameliorate the symptoms of PTSD. From a DoD perspective, such a framing model can justify the allocation of government resources to family, friends, and supporting organizations outside the DoD, as these are also seen as critical in a comprehensive treatment program.

We should clarify that no models perfectly depict reality; and they are used to describe reality as best as they can. As George Box and Norman Draper famously wrote, "[A]ll models are wrong, but some are useful."[1] Also, complex models do not necessarily imply greater or even equal usefulness as compared to simpler models. Here a quote often attributed to Albert Einstein is appropriate: "Everything should be made as simple as possible, but not simpler." We have tried to follow these two propositions in our three developed models, which we describe next.

4. Three PTSD models

Model I: a conceptual system model of PTSD

With what we refer to as Model I (developed as part of the innovation project), Ghaffarzadegan and Larson (2015) developed a qualitative representation of the system, seeking to answer a basic question: What are the interrelations among psychological, sociological, and medical factors in PTSD treatment? The main inputs for the model were published articles and reports about PTSD in the military and the Department of Veterans Affairs. With this model, the researchers uncovered several root causes that contribute to the complexity of treating PTSD.

The main outcome of the study was a model to present an overall picture of the system. The model demonstrates how military personnel with PTSD are situated in a complex web of partially overlapping structures, some formal, such as those operated by the Department of Defense (and later, the VA), and some informal, such as those provided by family and friends.

The model represents PTSD treatment as influenced by medical, personal, and social factors. This creates multi-layer dynamics. The individual layer concerns how personal decisions and willingness to seek care affect treatment. Patients should first seek care, and in an ideal situation, we would expect willingness to seek care to result in PTSD treatment and mitigation of symptoms. In the family and friends layer, others may provide social support and help in treatment. In addition, family and friends may encourage patients to seek care. However, there is a limit to people's tolerance, and patients start losing the support of their close friends and family members as their illness progresses and they show more symptoms, affecting the lives of those around them. At a more macro societal level, patient behaviors attract media attention and influence public perceptions of living with patients with PTSD. This creates a social stigma and exclusion of PTSD patients from society. Patients lose their social support and become unsuccessful in treatment. All of this ultimately feeds back to the individual layer and affects treatment and willingness to seek care.

Beyond evaluating various causal aspects of the complexity of PTSD treatment, Model I points to five major vicious cycles. In this context, a vicious cycle is a feedback loop that, over time, creates cascading negative influences on PTSD sufferers and exacerbates their mental health situation. As time passes, these cycles (presented below, also represented as reinforcing (R) loops in Figure 1) make PTSD less likely to be treated.

- R1 - cascading illness and medical complexity
- R2 - cascading illness and isolation from family and friends
- R3 - stigma and social exclusion
- R4 - self-fulfilling prophecy
- R5 - the malingerer stigma[2]

Let us briefly review feedback loop R1—see Ghaffarzadegan and Larson (2015) for the description of other loops. If patients do not actively seek care, the illness progresses over time

[1] Box and Draper (1987)

[2] Additional information about these cycles can be found in Ghaffarzadegan and Larson (2015).

and their medical condition worsens. Studies indicate that some patients with PTSD also develop other psychiatric disorders (Najavits et al., 2009). Increasing complications render medical interventions progressively less effective. Patients' responses in the form of drug abuse can further complicate health conditions. The entire process ends up in a cascading pattern that eventually converts mild medical illnesses into chronic and life-threatening conditions.

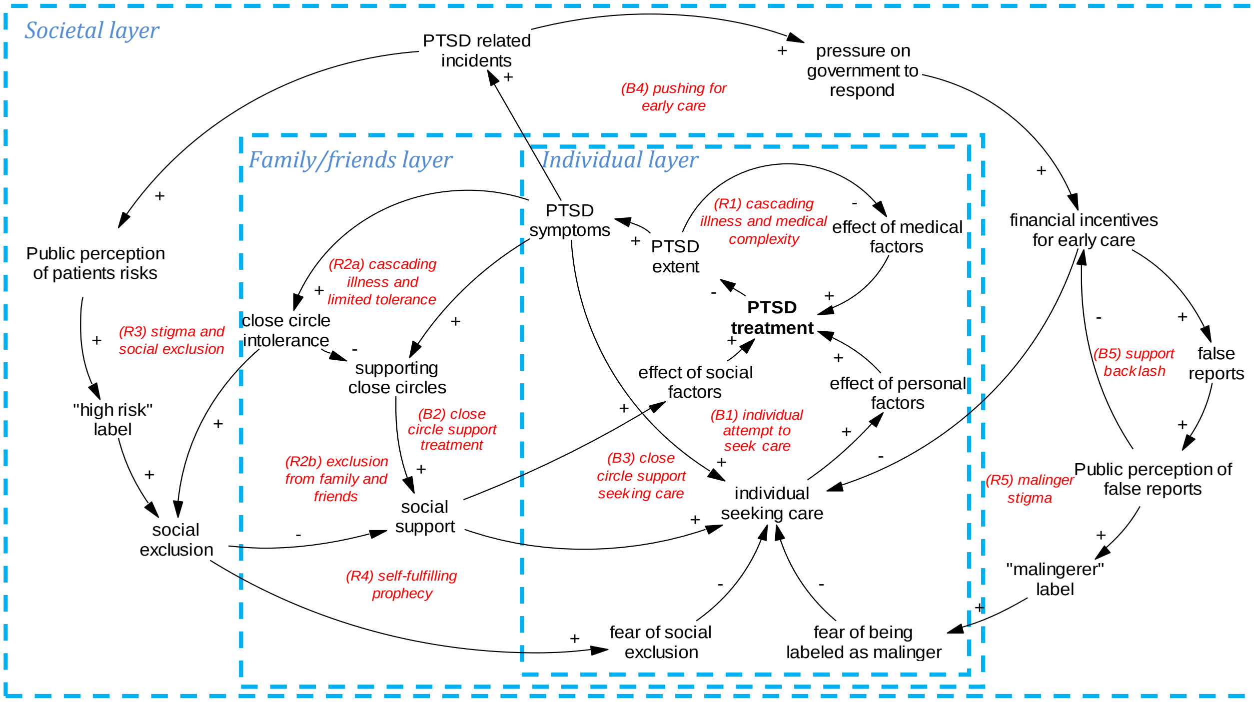

Figure 1. A conceptual model of PTSD treatment
Adopted from Ghaffarzadegan and Larson (2015)

Overcoming vicious cycles is very difficult, requiring policies and patience over the long term. Without early interventions, these cycles result in a downward spiral into depression, family discord and possible divorce, substance abuse, joblessness, homelessness, and even suicidal ideation or action.

Like a snowball that gets bigger and bigger as it rolls downhill, vicious cycles are difficult to stop as they gain momentum. This analysis points to the need to prevent these situations from developing, potentially even from the beginning. Two conceivable policy steps are early effective screening and resiliency-related interventions (e.g., better recruitment procedures and resiliency-related training), where attention should be paid to military personnel and their families.

Model I was a first step in framing the problem and understanding interconnections and complexities surrounding military personnel with PTSD. In the next stages, we needed models that helped quantify these effects and compare and contrast the effects of improving resiliency and early treatment. Such quantitative models should include uncertainty in diagnosis, individual health, access to care, and military personnel readiness. The models should also help compare PTSD prevalence and healthcare system costs under different policies and scenarios.

In response to these requirements, two additional models were developed for the project: a system dynamics model of PTSD prevalence and a Monte Carlo simulation model.

Model II: a population-level system dynamics model of PTSD

With Model II, we moved toward quantifying the effects of different interventions on PTSD prevalence, asking these basic questions: What are the trends in the population of PTSD patients among military personnel and veterans in the postwar period? What policies can help mitigate the effects of PTSD? What are the healthcare cost implications of these policies?

To answer these questions, Ghaffarzadegan, Ebrahimvandi, and Jalali (2015) developed a system dynamics simulation model of the PTSD population with a broad boundary, where the model incorporates both military personnel and veterans. It encompasses veterans of pre-2000 wars and more recent wars in Iraq and Afghanistan, and can track cases over the entire lives of patients. The overall structure of the model is developed in a way that simply—while as precisely as possible—presents the flow of individuals in the military and post-military and across different stages of developing the illness, diagnosis and treatment. In other words, our simple model captures the core mechanisms of a complex system. The model's equations are fully documented—along with the coding and time series—for further development and assessment (see the supplementary materials in Ghaffarzadegan et al. (2015) for more detail).

Structurally, Model II depicts the flow of people from recruitment into the military, from the military to the post-military stage, and from the post-military stage to death. Figure 2 presents the stock and flow structure of the model, where a stock represents accumulation in the system and a flow is the rate at which the stock is changing. Let us briefly discuss these stocks and flows.

Flow (1) presents the recruitment of individuals, the majority healthy, who enter the 'Healthy Military members' stock; however, a small percentage might already have a history of PTSD and enter the 'Ill-Undiagnosed Military members' stock. As a result of traumatic events, healthy people in the service may develop the illness (Flow (2)) and move to the 'Ill-Undiagnosed Military members' stock. These undiagnosed individuals are either diagnosed with PTSD during their service and moved to the 'Ill-Diagnosed Military members' stock (Flow (3)), or separated from the military with unknown illness (Flow 6). Moreover, if 'Ill-Diagnosed Military members' are successfully treated (Flow (4)), they are moved to the 'Healthy Military members' stock.

A similar diagnostic process also exists for veterans, where individuals in the 'Ill-Undiagnosed Veterans' stock are diagnosed with PTSD (Flow (8)) and moved to the 'Ill-Diagnosed Veterans' stock—these two stocks are fed by Flows (6) and (7), respectively. The last stock is 'Healthy Veterans,' which includes healthy individuals separated from the military (Flow (5)) and the successfully treated veterans (Flow (9)). It should be noted that all stocks in Figure 2 have an outflow of death—the death rates are different for each stock, e.g., the death rate of healthy military members and that of healthy veterans are not the same. The death outflows are shown in grey.

For the sake of presentation, Figure 2 contains a simplified version of the model and only illustrates the stock-and-flow structure. See Ghaffarzadegan et al. (2015) for more detail on the causal relationships among the variables that are key components of any system dynamics model. The model also incorporates the chances of deployment, experiencing trauma, and developing PTSD given that trauma. In the model, individuals do not necessarily reveal PTSD symptoms immediately; the diagnosis may be delayed, in some cases occurring after separation from the military. It should be also noted that since the model includes two subsystems, military and post-military, it helps estimate PTSD-related healthcare costs for both the DoD and the VA.

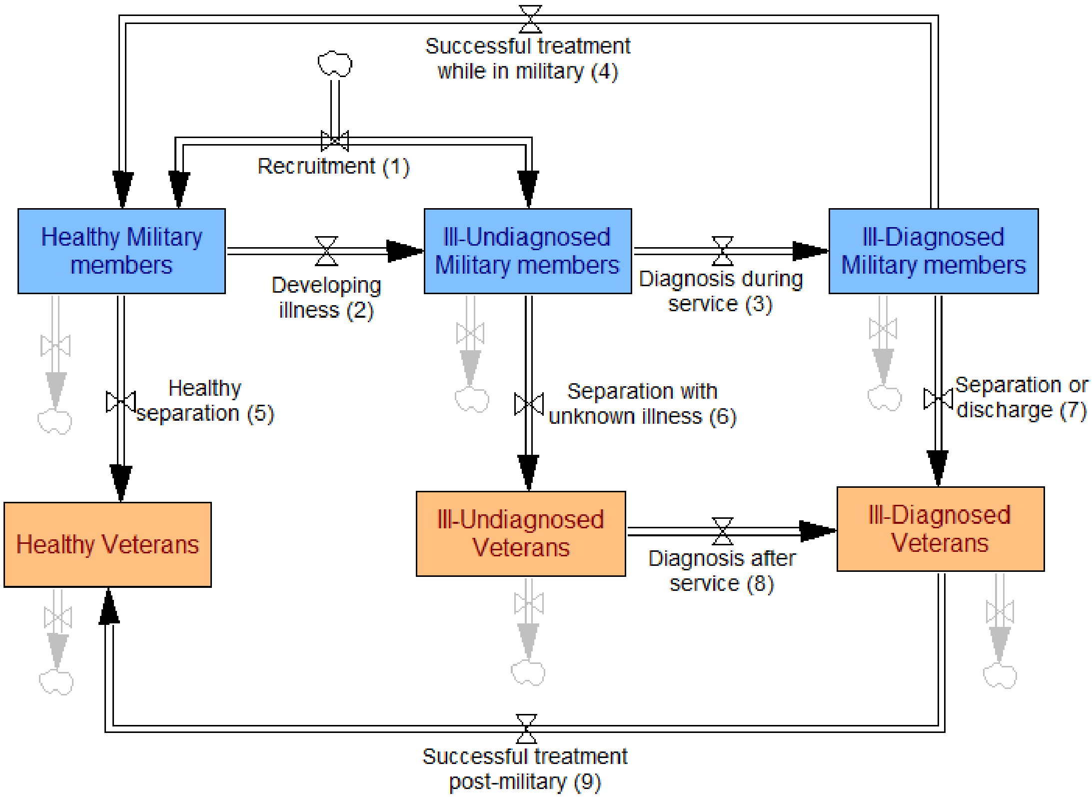

Figure 2. A simplified version of Model II representing stocks and flows in the system
The blue boxes ('stocks') represent the military subsystem, and the orange stocks represent the post-military subsystem. Variables (1) through (9) are the main 'flows' in the system. All stocks in the model have an outflow (shown in grey) which represents death. For the sake of simplicity in this presentation, causal relationships among the model variables are not illustrated (see Ghaffarzadegan et al. (2015) for more detail).

The model uses a variety of data sources. The structure is informed by previous work by the researchers in the literature, other published articles and reports. The model parameters and time series (2000 to 2014) come from the DoD, the Institute of Medicine, and the VA. We ran the model for the period 2000 to 2025, where 2000 to 2014 was used for model validation and examination of the model's fidelity in replicating the historical data. Then, the model forecasts the period 2015 to 2025. To create scenarios for forecasts, U.S. involvement in wars and the intensity of future wars (in comparison to "Operation Iraqi Freedom" - OIF) were used as inputs. The outputs are PTSD prevalence, number of PTSD cases diagnosed and undiagnosed in both the military and the VA, and PTSD-related healthcare costs. Figure 3 is an example of one of the outcomes for Model II.

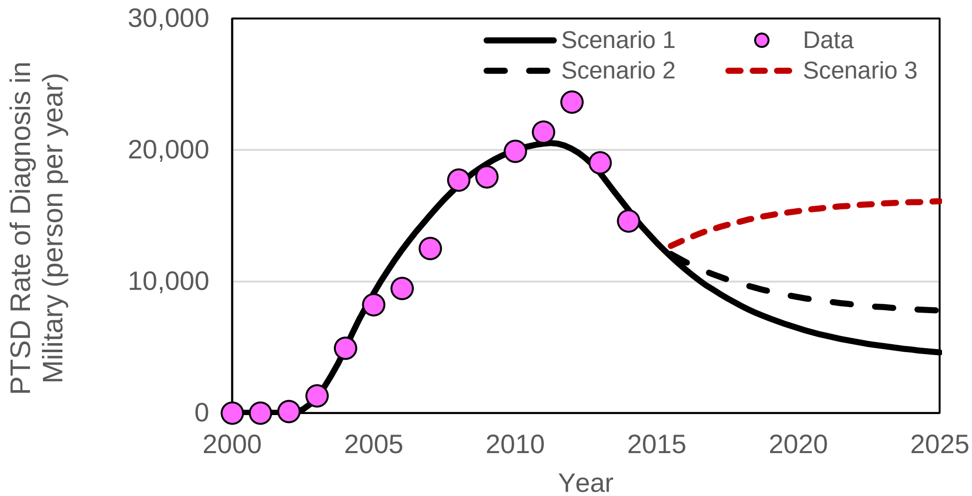

Figure 3. PTSD diagnosis rate in the military [new cases per year].
Note: The model fits the available historical data for 2000 to 2014 and predicts the trends for 2015 to 2025 for three scenarios: Scenario 1: Minimum deployment to intense/combat zones (1% of military personnel); Scenario 2: 2% deployment to intense/combat zones; and Scenario 3: 5% deployment to intense/combat zones. Adopted from Ghaffarzadegan and Larson (2015).

In an article based on Model II, Ghaffarzadegan et al. (2015) analyze four policies aimed at improving resiliency, screening, treatment, and a combination of the three. Users can test different combinations of these policy measures under different scenarios for future wars, and examine PTSD prevalence and costs as outputs. The model yielded four major results:

1. The model predicted that the population of patients and system costs will be very sensitive to U.S. involvement in future wars, and that screening and treatment policy interventions will have marginal effects in comparison. In fact, more screening increase healthcare costs by increasing demand for health services.

2. In a very optimistic scenario, Model II estimated that PTSD prevalence among veterans in 2025 will be 10%. Figure 3 includes undiagnosed cases of PTSD.

3. Effective policies for war and postwar periods are potentially different. During a war, resiliency-related policies are the most effective in decreasing PTSD; however, in a postwar period, there is no silver bullet for overcoming the problem of PTSD. This is consistent with what was argued in Model I regarding the difficulty of controlling the vicious cycles of PTSD.

4. It takes a long time, on the order of 40 years, to overcome the psychiatric consequences of a war. This is also consistent with the data on Vietnam War-era PTSD patients.

Ghaffarzadegan et al. (2015) also provide detailed discussions about healthcare costs for the DoD and the VA related to PTSD (limited to direct healthcare costs). In reality, there are also social costs associated with PTSD, but these were not considered in the analysis. In an optimistic scenario (about 1% to 2% deployment to intense/combat zones in the next ten years), the model's predictions of PTSD healthcare costs for the military in 2025 range from $130 to $160 million (in 2012 dollars). With greater involvement in future wars (about 5% deployment to intense/combat zones), the costs potentially increase to \$260 million. For the VA, the cost estimates are one order higher, with average estimates of \$2.9 to \$3.2 billion (in 2012 dollars). With greater involvement in future wars (5% deployment to intense/combat zones), this cost can also increase to \$3.6 billion.

Beyond prevalence and cost estimates, Model II stresses that PTSD is a multi-organizational problem. A systematic approach to PTSD needs to consider the military and post-military stages together, since an effective policy in one stage may create problems for the other. The models should also look at long-term dynamics, considering delays between developing PTSD and showing symptoms. The analysis also shows that a focus on resiliency and decreasing the chances of developing PTSD is potentially one of the most effective policies, which is consistent with Model I's suggestions.

Model II can work as a "flight simulator" and provide a framework for policy experiments. Installation of the simulation software is not needed. It can be tried online at https://forio.com/simulate/jalali/ptsd-simulation. Figure 4 provides a snapshot of the online presentation of the model.

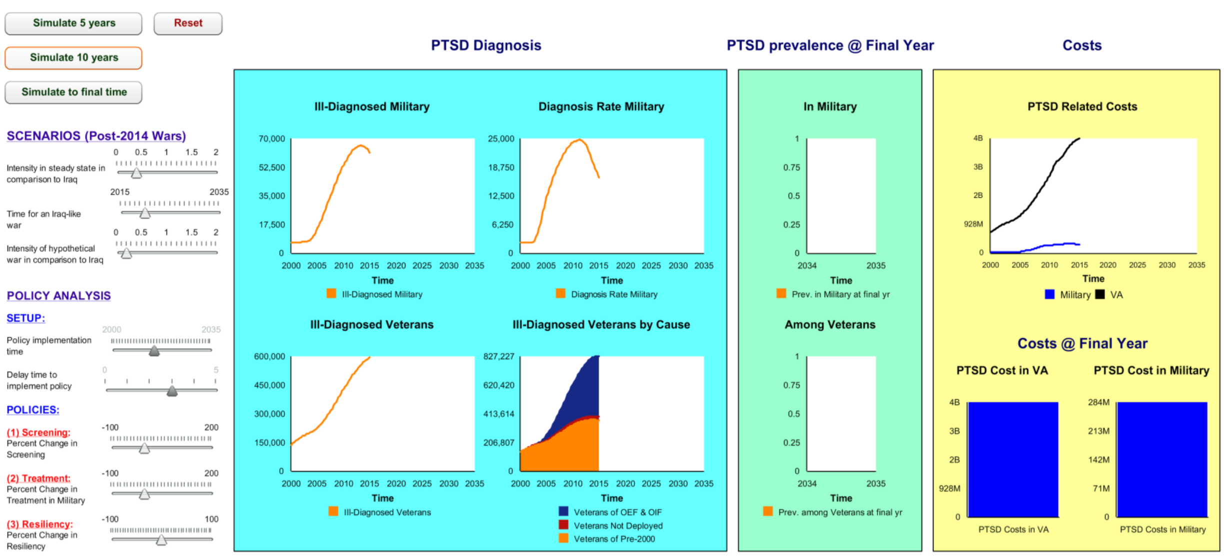

Figure 4. Snapshot of the online presentation of Model II, available at:
https://forio.com/simulate/jalali/ptsd-simulation

Model III: a Monte Carlo simulation model of PTSD

Fingerhut (2015) developed the third of the three models as part of the innovation project, using a Monte Carlo simulation approach to predict PTSD prevalence and clinical demand by individuals over five decades following "Operation Enduring Freedom" (OEF), the war in Afghanistan, and OIF, and the population over the period 2003 to 2064. This approach creates representative service members who replicate the deployment schedule, PTSD risk, care-seeking behavior, and treatment of actual service members from the two conflicts. After randomly assigning each virtual service member's deployment and trauma exposure, as well as possible PTSD onset, recognition, and treatment events over the period of study, the study aggregates each individual's simulated history to determine population level statistics and trends. This study also provides a series of sample policies designed to replicate possible decisions a policy maker could implement to affect the PTSD burden.

The model uses empirically observed distributions of parameters from across the mental health care system (traumatic exposure, onset, recognition, care-seeking, and treatment) within a relatively simple structure to estimate the time dynamics of a series of individual and population parameters. This approach enables policy makers to understand what each of these observed factors – as well as potential changes in their values – means in terms of macro-level parameters of interest (such as population prevalence and clinical usage). This approach also enables researchers to understand how certain unobservable values may change over time and motivate dynamic observation of these factors within a population of interest.

Model III manipulates a time-series form of input, and is thus able to provide time-series output. That output takes the form of prevalence estimates from the population perspective, that is, each point in calendar time provides a snapshot of what a real-world population prevalence estimate would look like, given changes over time in deployment, combat, and other similar factors.

The model predicts a peak rate of active-case PTSD of nearly 200,000 by 2016 (17% of the population deployed to date), declining to 150,000 by 2025 (15% of the population). These predictions reflect best-case assumptions about PTSD recognition, care-seeking, and treatment efficacy that represent the most optimistic rates for these factors observed in recent empirical studies. The model predicts a long-term, active-case PTSD rate of 19% to 23% under assumptions that reflect realistic limitations of these factors. This model further predicts that 29% of OEF/OIF combat veterans will experience PTSD at some point in their lives (Figure 5).

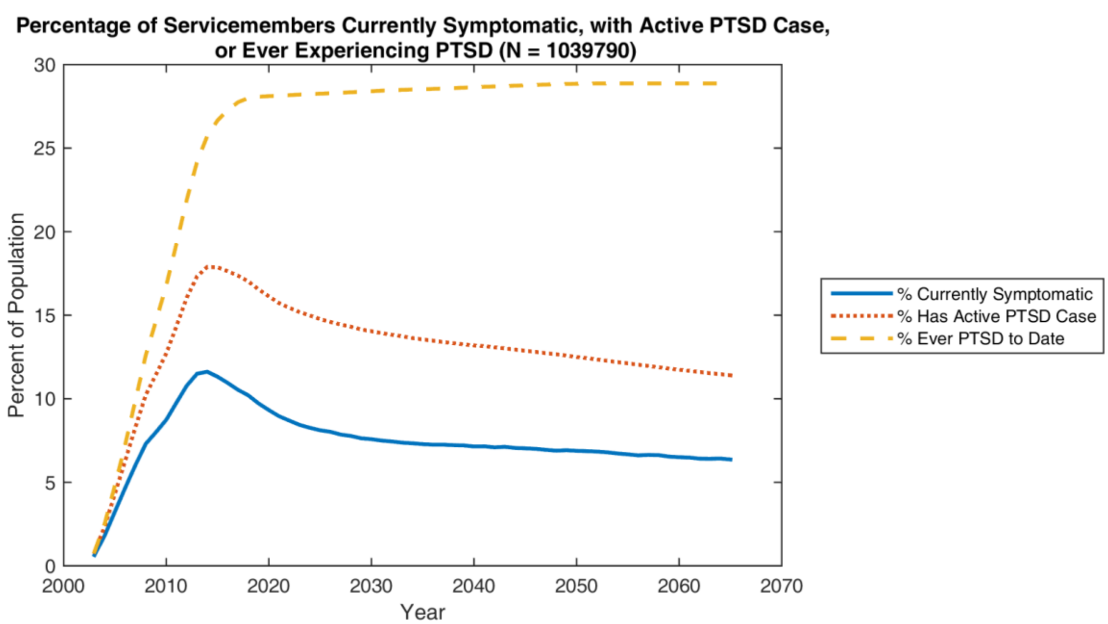

Figure 5. Baseline (best-case) model predicted percent of servicemembers with currently symptomatic or active case PTSD in each year and servicemembers who have ever experienced PTSD through the indicated year end. Percentage denominator is equal to the number of servicemembers who have ever been deployed through the indicated year.

In terms of care-seeking and treatment, under best-case care-seeking assumptions, Model III predicts that 80% of the ever-PTSD population (23% of the full OEF/OIF population) will seek treatment at some point in their lives. Under realistic recognition, care-seeking, and treatment assumptions, 48% to 63% of the ever-PTSD population (14% to 18% of the OEF/OIF population) are expected to seek treatment. Under best-case model assumptions, clinical demand peaks at 3% of the OEF/OIF population per year in 2010, decreasing to 0.5% of the OEF/OIF population in 2025. Under best-treatment efficacy assumptions (including the most effective treatments currently available and low rates of treatment dropout and PTSD recurrence), 59% of the ever-treated population is expected to remit PTSD symptoms successfully and permanently.

5. Discussion and conclusions

The three models specific to the innovation project are initial efforts to depict (in a system context) our knowledge about PTSD treatment system structures. The models embed the all-important psychological and social processes, both formal and informal, underlying the PTSD burden in the populations studied. They provide a good first look at the implications of various policies and managerial actions for future PTSD prevalence, clinical demand, and cost. For those interested in additional details, each model is fully developed in separate refereed published papers and/or technical reports, as cited in this chapter's footnotes and in the references.

The models discussed in this chapter are different from many studies of PTSD in two major respects. First, they take a system approach. Most previous models of mental health in the military or the VA have a very narrow perspective on the problem and focus on either the military or the VA. A narrow focus on one organization (e.g., the military) "shifts the burden" to the other organization (e.g., the VA). Furthermore, most past models take a snapshot of the problem and focus on solving "today's issues." Second, the models presented here were informed by a wide range of qualitative and quantitative data. Model I is rooted in qualitative data, and models II and III are calibrated with several data sources.

Going forward, two key questions remain. First, *How might these models be used*? Our suggestion is to view the models as living entities, evolving and improving over time as new knowledge becomes available. This will require professionals in the DoD to take ownership of the models and have timely access to all kinds of model-related information as it becomes available.

Second, *What is the anticipated take-away*? It ranges from administrative aspects such as multi-year projected budget levels that may constrain system resources to new scientific knowledge about the efficacy of new treatments for PTSD. Within the models, budget constraints may appear only indirectly in terms of total numbers of professionals and facilities available for PTSD treatment. Putting new scientific knowledge to work will require going into the details of the models, feedback loops, flow parameters, response delays, and so on, and updating them to be compatible with the new scientific results. New science will, in turn, affect budgets and facilities, up or down. Perhaps a new treatment protocol would be very costly, but demonstrates a very high chance of lifetime cessation of PTSD symptoms after, say, two years of such treatment. A protocol of that sort, if discovered, would be expensive in the short term and very cost-effective in the long term. All this shows how scientific knowledge of treatment effects can cause major changes in the DoD resource-intensive system model.

One final thought: Our observation, not only for the DoD but also for the VA and virtually all large service systems (including research universities), is that everyone is so dedicated to their work that on a day-to-day basis they often only "see" the immediate vicinity of their own workplaces. Improvements – some may call them “optimizations” – tend to be local, that is, focused only on that small part of the total system in which a group of professionals works. One major value of system models is that they show clearly how everything affects everything else. They demonstrate clearly the hazards of local optimization, showing how even attractive local changes have the potential to be detrimental to the total system. In that sense, then, system models provide an integrated, unifying framework for key decision makers throughout the system to discuss their problems intelligently and dispassionately. This attribute may be one of the major arguments in favor of system models.

Acknowledgments
This article is based upon MIT work supported, in part, by the Office of the Assistant Secretary of Defense for Health Affairs, under Award No. W81XWH-12-0016. The US Army Medical Research Acquisition Activity, 820 Chandler Street, Fort Detrick MD 21702-5014, is the awarding and administering acquisition office. Opinions, interpretations, conclusions and recommendations are those of the authors and are not necessarily endorsed by the Department of Defense, MIT, or Virginia Tech.

References:

Box, G. E., & Draper, N. R. (1987). *Empirical model-building and response surfaces* (Vol. 424): Wiley New York.

Breslau, N., Davis, G. C., & Schultz, L. R. (2003). Posttraumatic stress disorder and the incidence of nicotine, alcohol, and other drug disorders in persons who have experienced trauma. *Archives of general psychiatry, 60*(3), 289-294.

Campbell, D. G., Felker, B. L., Liu, C.-F., Yano, E. M., Kirchner, J. E., Chan, D., . . . Chaney, E. F. (2007). Prevalence of depression–PTSD comorbidity: Implications for clinical practice guidelines and primary care-based interventions. *Journal of General Internal Medicine, 22*(6), 711-718.

Fallah-Fini, S., Rahmandad, H., Huang, T. T.-K., Bures, R. M., & Glass, T. A. (2014). Modeling US adult obesity trends: a system dynamics model for estimating energy imbalance gap. *American journal of public health, 104*(7), 1230-1239.

Fingerhut, H. (2015). *A Simulation Model to Predict Long-Term Posttraumatic Stress Disorder Prevalence Following Operation Iraqi Freedom and Operation Enduring Freedom.* (Masters), Massachusetts Institute of Technology, MIT Technology and Policy Program.

Finkelstein, S. N., Larson, R. C., Nigmatulina, K., & Teytelman, A. (2015). Engineering Effective Responses to Influenza Outbreaks. *Service Science, 7*(2), 119-131.

Ghaffarzadegan, N., Ebrahimvandi, A., & Jalali, M. S. (2015). A Simulation-Based Analysis of PTSD Prevalence among the US Military Personnel and Veterans in 2025. *Under Review (Millbank Quarterly)*, 1-11.

Ghaffarzadegan, N., & Larson, R. (2015). Posttraumatic Stress Disorder: Five Vicious Cycles that Inhibit Effective Treatment. *US Army Medical Department journal*(4-15), 8-13.

Ginzburg, K., Ein-Dor, T., & Solomon, Z. (2010). Comorbidity of posttraumatic stress disorder, anxiety and depression: a 20-year longitudinal study of war veterans. *Journal of affective disorders, 123*(1), 249-257.

Hendin, H., & Haas, A. P. (1991). Suicide and guilt as manifestations of PTSD. *American Journal of Psychiatry, 148*(5), 586-591.

Henning, K. R., & Frueh, B. C. (1997). Combat guilt and its relationship to PTSD symptoms. *Journal of clinical psychology, 53*(8), 801-808.

Hoge, C. W., Riviere, L. A., Wilk, J. E., Herrell, R. K., & Weathers, F. W. (2014). The prevalence of post-traumatic stress disorder (PTSD) in US combat soldiers: a head-to-head comparison of DSM-5 versus DSM-IV-TR symptom criteria with the PTSD checklist. *The Lancet Psychiatry, 1*(4), 269-277.

Homer, J. B., & Hirsch, G. B. (2006). System dynamics modeling for public health: background and opportunities. *American journal of public health, 96*(3), 452-458.

Jakupcak, M., Cook, J., Imel, Z., Fontana, A., Rosenheck, R., & McFall, M. (2009). Posttraumatic stress disorder as a risk factor for suicidal ideation in Iraq and Afghanistan war veterans. *Journal of traumatic stress, 22*(4), 303-306.

Johnston, E. W., & Desouza, K. C. (2015). *Governance in the information Era: Theory and practice of policy informatics*: Routledge.

Kim, H., MacDonald, R. H., & Andersen, D. F. (2013). Simulation and Managerial Decision Making: A Double ‐ Loop Learning Framework. *Public Administration Review, 73*(2), 291-300.

McFall, M. E., Mackay, P. W., & Donovan, D. M. (1992). Combat-related posttraumatic stress disorder and severity of substance abuse in Vietnam veterans. *Journal of studies on alcohol, 53*(4), 357-363.

Milstein, B., Homer, J., Briss, P., Burton, D., & Pechacek, T. (2011). Why behavioral and environmental interventions are needed to improve health at lower cost. *Health Affairs, 30*(5), 823-832.

Najavits, L. M., Ryngala, D., Back, S. E., Bolton, E., Mueser, K. T., & Brady, K. T. (2009). Treatment of PTSD and comorbid disorders. *Effective treatments for PTSD: Practice guidelines from the International Society for Traumatic Stress studies*, 508-535.

Phelan, J. C. (2005). Geneticization of deviant behavior and consequences for stigma: the case of mental illness. *Journal of Health and Social Behavior, 46*(4), 307-322.

SOLOMON, Z., AVIGALSNIR, H. F., & ROSENBERG, M. (2015). Long-Term Trajectories and Recovery from PTSD. *Long-Term Outcomes in Psychopathology Research: Rethinking the Scientific Agenda*, 187.

Sterman, J. (2014). Interactive web ‐ based simulations for strategy and sustainability: The MIT Sloan LearningEdge management flight simulators, Part I. *System Dynamics Review, 30*(1-2), 89-121.

Teytelman, A., & Larson, R. C. (2013). Multiregional Dynamic Vaccine Allocation During an Influenza Epidemic. *Service Science, 5*(3), 197-215.

US Department of Veterans Affairs. (2016a). PTSD: National Center for PTSD. Retrieved from http://www.ptsd.va.gov/professional/PTSD-overview/index.asp

US Department of Veterans Affairs. (2016b). How Common is PTSD? Retrieved from http://www.ptsd.va.gov/public/PTSD-overview/basics/how-common-is-ptsd.asp

Vogt, D. (2011). Mental health-related beliefs as a barrier to service use for military personnel and veterans: a review. *Psychiatric Services*.

Wittenborn, A., Rahmandad, H., Rick, J., & Hosseinichimeh, N. (2016). Depression as a systemic syndrome: mapping the feedback loops of major depressive disorder. *Psychological medicine, 46*(03), 551-562.

Zagonel, A. A., Rohrbaugh, J., Richardson, G. P., & Andersen, D. F. (2004). Using simulation models to address" what if" questions about welfare reform. *Journal of Policy Analysis and Management, 23*(4), 890-901.