AI-Enabled Predictive Analytics to Enhance Force Health Protection, Readiness, and Resilience

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Emerging artificial intelligence (AI) technologies and systems can be used to enhance U.S. Army Infantry Soldier capabilities and capacity when operating for prolonged periods of time in austere and resource-limited environments. The Defense Health Agency Medical Research and Development Command (MRDC) is working on developing such systems to address readiness and lethality in conditions infantry unit personnel typically encounter, such as exposure to extreme environmental conditions, biological or chemical warfare, and infectious diseases, often coupled with conditions that allow for little to no sleep.

Military medicine efforts have combined AI-enabled personalized predictive analytics with commercial-off-the-shelf (COTS) wearable devices to develop solutions that can help individual Soldiers. The Department of War Biotechnology High Performance Computing Software Applications Institute (BHSAI) — part of the Defense Health Agency Medical Research and Development, MRDC at Fort Detrick, MD, — specializes in predictive analytics and integrates physical, computational, and life sciences to enhance force health protection, readiness, and resilience. With support from Henry M. Jackson Foundation research scientists and software developers, we created personalized predictive analytics tools that "learn" how service members respond to various stressors in order to optimize mental acuity despite sleep loss, reduce the risk of heat illness during high-tempo operations in hot and humid environments, and provide early warning of exposure to infectious threat agents. In addition, we developed predictive analytics tools that can increase the capability and capacity of combat medics to more efficiently treat trauma casualties.

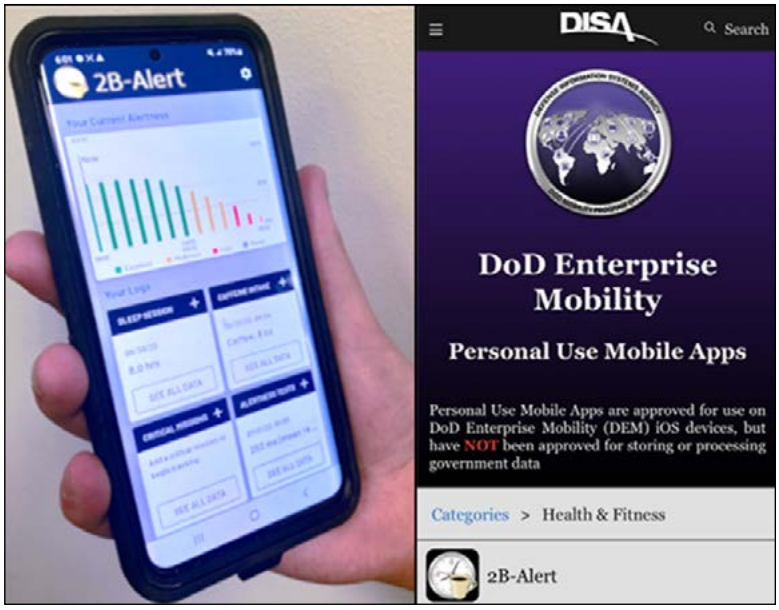
Predictive analytics uses data and mathematical models to forecast future outcomes. As such, the BHSAI-developed applications collect a service member's data using a wearable device or smartphone and process the data using AI and mechanistic models that generate personalized real-time predictions of a specific outcome. The apps either alert a Soldier of an impending problem or provide recommendations for how to improve a future outcome. For example, 2B-Alert enhances alertness and mental acuity when Soldiers cannot obtain enough sleep, 2B-Cool reduces the risk of an impending heat illness, and 2B-Healthy monitors health status. In the hands of warfighters, these tools will be invaluable to improve the probability of positive outcomes. Similarly, 2B-Treated analyzes vital-sign data from a cohort of trauma casualties and generates a plan to optimize resource utilization for those casualties. All of these tools are either currently ready for field use or are progressing through the different stages of development.

2B-Alert

The Department of War (DoW) recommends seven hours of sleep per night for optimal performance and readiness, yet about 40 percent of service members sleep less than five hours per night.[1] This lack of sleep can lead to poor performance, compromised missions, accidents, and most importantly, service member injury or even death. As a countermeasure, the Army offers one-size-fits-all caffeine guidance for when adequate sleep isn't possible; however, individuals vary in their response to sleep loss, making

Figure 1 — 2B-Alert Smartphone App

The 2B-Alert smartphone app allows users to input their data to obtain personalized alertness predictions and caffeine recommendations to minimize alertness impairment during specified time periods. The app is available in PUMA for government-issued iPhones under the Health & Fitness category.



the guidelines not optimal for everyone. Building on years of successful research in the sleep field, we used data collected from multiple sleep-deprivation studies conducted over the years at the Walter Reed Army Institute of Research (WRAIR) to develop an AI algorithm that personalizes alertness predictions and caffeine interventions so that an individual can reach peak alertness at their desired time using the least amount of caffeine necessary. The BHSAI first introduced the 2B-Alert web application,[2] and the smartphone app soon followed.[3] [4]Based on the success of the 2B-Alert technology, we continued to refine the tools by incorporating newly developed algorithms that extended the capability of the apps, allowing them to more efficiently identify safe and effective caffeine interventions and provide personalized caffeine recommendations in real time so that individuals could achieve a desired alertness level regardless of their vulnerability or resilience to sleep loss.[4] The 2B-Alert technology has been licensed to the private sector.

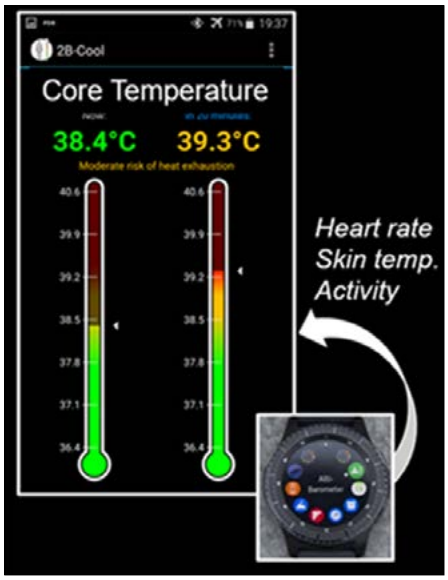


Figure 2 — 2B-Cool

Using vital-sign data collected by a smartwatch, 2B-Cool provides an early warning of a rising core body temperature with enough time to enable interventions and reduce the risk of an exertional heat illness.

To use 2B-Alert, individuals input their past sleep schedules and caffeine consumption as well as their desired future peak alertness periods into the app on their smartphone. In addition, they take a series of simple alertness tests on the smartphone so that the app can learn their individual responses to sleep deprivation and caffeine. Based on the user inputs, the 2B-Alert app automatically provides real-time personalized caffeine recommendations, including the time and dosage, to achieve the desired level of alertness during the specified peak alertness time periods (see Figure 1). Use of 2B-Alert to enhance alertness and mental acuity along with the personalized interventions to optimize the benefits of caffeine provide a 50 percent force multiplier. The 2B-Alert app has been approved by the Defense Information Systems Agency (DISA) and is now available in PUMA, the DoW app store (see Figure 1). Any DoW employee with a government-issued iPhone can download the app from PUMA under the Health & Fitness category, facilitating the self-management of alertness and cognitive performance.

2B-Cool

Environmental and exertional heat stress affects service members' performance and health. In fact, service members suffer 2,000 heat illnesses every year, including 500 heat strokes.[5] Although a rising core body temperature is the best physiological indicator of an impending risk of heat illness, measuring core body temperature in the field is challenging. However, wearable devices combined with machine-learning algorithms can continuously monitor core body temperature non-intrusively. We used data from an exertional heat-stress study performed at the University of Connecticut to prospectively validate 2B-Cool, a hardware/software system that automatically learns how individuals respond to heat stress based on their vital-sign data.[6] With 2B-Cool, users continuously wear a COTS smartwatch paired with a smartphone containing the BHSAI-developed software, where the watch wirelessly transmits the user's vital signs (heart rate, skin temperature, and activity) to the phone. Based on these three vital signs, 2B-Cool provides real-time personalized predictions of core body temperature, predictions of what the temperature will be 20 minutes into the future, and an early warning of a rising body core temperature, with 98-percent sensitivity (see Figure 2). This early warning of a rising core body temperature could indicate an impending heat illness with sufficient lead time (about 35 minutes) to enable proactive interventions and risk mitigation.

2B-Healthy

Early detection of exposure to pathogens from biological weapons or emerging infectious diseases is critical for maintaining force health protection and readiness. Wearable devices that continuously monitor vital signs combined with customized AI algorithms tuned to an individual can serve as powerful tools to provide an early indication of infection. In collaboration with the Walter Reed Army Institute of Research and the Naval Medical Research Center (NMRC) and using data collected during a NMRC-controlled human malaria infection study, we developed 2B-Healthy. This hardware/software system contains an AI-enabled infection-prediction algorithm capable of comparing an individual's baseline versus current vital signs to provide an early warning of infection.[7]

With 2B-Healthy, users wear a COTS smartwatch that continuously collects vital-sign data (heart rate and activity) and sends them to a smartphone containing the algorithm, which identifies aberrant heart-rate patterns and estimates in real time a probability of infection for that individual. 2B-Healthy was able to predict shigellosis infection with a 53-73 percent sensitivity and malaria infection with a 78 percent sensitivity. In fact, 2B-Healthy detected malaria infection more than six days before a positive blood-test confirmation.[7] The 2B-Healthy technology serves as a rapid, low-cost, and scalable approach to screen warfighters for abnormal physiological state, allowing for time-sensitive deployment of countermeasures for infectious disease, such as evacuation, quarantine, and treatment of infected service members. The 2B-Healthy application is progressing through the final stages of development.

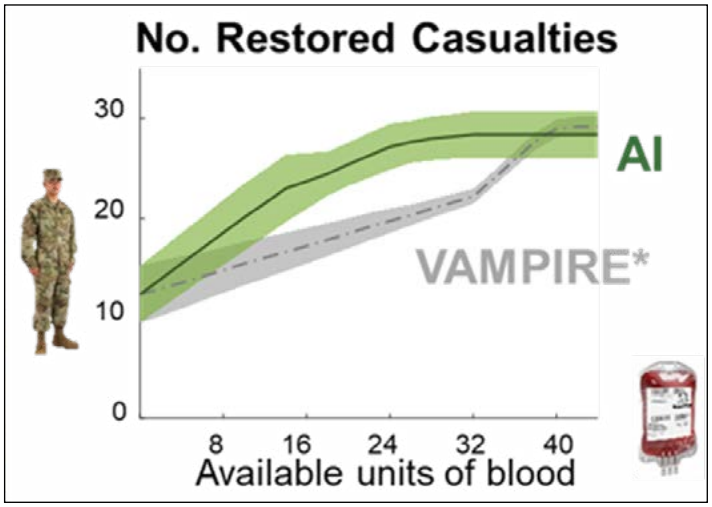
2B-Treated

With an anticipated increase in large-scale combat operations, medics will need to optimize resource utilization during mass-casualty events and prolonged casualty care. While the DoW has established practical guidelines for combat medics to identify and treat trauma casualties and provide fluid resuscitations (the Vampire Program), these guidelines are population based, only consider the current health state of the casualty, and are not designed for resource optimization in mass-casualty events.[7] To address this gap, we developed 2B-Treated, an AI algorithm that uses about 10 minutes of vital-sign data to prognosticate the outcome of each specific casualty 60 minutes into the future and identify the best treatment option that restores the largest number of casualties to a healthy state, thus optimizing resource utilization.[8] Combat medics input the casualties they are treating and the fluid resources they have available into the app, and 2B-Treated forecasts all treatment options and outcomes for the casualties and selects the one that maximizes the outcome/resource-utilization ratio. Based on preliminary computer simulations, compared to the Vampire Program, 2B-Treated restored up to 46 percent more casualties to healthy vital signs (Figure 3). The 2B-Treated application is progressing through further development and validation.

In conclusion, we have developed AI-enabled predictive analytics tools to assist combat medics and protect Infantry Soldiers. Combining expertise in AI, machine-learning algorithms, and mechanistic modelling with COTS smartwatches and smartphones, the BHSAI offers personalized optimal interventions for peak cognitive performance, heat illness risk reduction, detection of abnormal physiological states due to infectious diseases, and resource optimization in austere environments. These advanced AI solutions enhance individual as well as Force Resilience, Health Protection, and Readiness.

Figure 3 — 2B-Treated

This app optimizes resource utilization during mass-casualty events. *The Vampire Program recommends giving blood if heart rate is ≥100 beats/min or systolic blood pressure is ≤100 mmHg.



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Conflict of Interest Statement: Dr. Jaques Reifman received royalties for the licensing of 2B-Alert technologies to Distritec and 2B-Cool to Seaclaid LLC.

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