Medical Surveillance for a Soldier Centered Battlespace Awareness

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ABSTRACT

Recent advances in sensor technologies have enabled a net centric view of the battlespace, substantially increasing situational awareness for the warfighter. However, this net centric awareness has yet to be extended to the status of the warfighters themselves. Medical technologies have progressed to the degree that portable, rugged and wireless designs can be conceived of that could give coalition commanders and medical personnel a view of the health and well being of their troops. This could give coalition forces a distinct advantage in both urban ops and more traditional force protection situations, allowing them to place the right resources in the best location well ahead of the usual indicators. These kinds of technologies would enable coalition commanders to make informed choices about when and where to send their troops, and how many may be prepared for the next mission. In the era of "just in time" force delivery – this capability will enable the best use of coalition forces in the events and actions that they are likely to face in the future. This paper will discuss the latest technologies under development that can be applied to the medical surveillance problem. In addition to technologies for the individual soldier, information delivery and display at the level of the commander and senior medical personnel will be discussed. As sensor presence on the battlefield increases, so does the need to manage and control the flow of information to enable the most effective decision making. It is only through the integration of the field based picture with the conditions and status of the warfighter that commanders will have a truly integrated vision of the battlespace.

1.0 INTRODUCTION

The NetCentric Battlespace is a pervasive and defining force in the current concept of Coalition operations. Technologists are increasingly focused on new sensors for the battlefield and innovative means of deploying them for the richest depiction of the battlespace in real-time. However, there is one aspect of the sensor

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enabled battlespace that has been largely ignored – the soldier centered battlespace. What is meant by "soldier-centered"? It is without question that our human assets are some of the most valuable that we have in the field. In the ever present reality of reduced manning, our warfighters have been asked to carry out more and more tasks – without much concern for the impact on their performance or moment to moment status. This is not to say that soldiers have lacked enhancements in their daily operations. Certainly protective gear has improved, soldiers have been provided with more sophisticated equipment to navigate in day and night, and warfighters have access to advanced communications tools from their remote field locations. However, the concept of the soldier centered battlespace centers around the notion that the soldier himself can be physically instrumented with sensors in order to give an accurate picture of their real-time status and readiness. These sensors would not provide information about the battlespace picture per se – however they would provide valuable information about the status of the human assets on the ground, therefore including them as a node in the networked operational picture.

2.0 STATUS MONITORING OF THE INDIVIDUAL SOLDIER

2.1 Medical Monitoring

2.1.1 Soldier-Based Assessment

Within the deployed environment there are several levels of surveillance that could be proposed. Some with a strictly medical assessment focus are already under consideration in large service sponsored efforts. These involve equipping the individual soldier with shirts or other clothing items that can communicate real-time information based on the integrity of the shirt and recordings from its embedded sensors. (see: http://www.gtwm.gatech.edu/ for details). These shirts can be equipped with a variety of sensors, including ECG (electrocardiogram), temperature, respiration rate, and a penetration monitor to detect wounds from ballistic objects on the torso of the soldier. These data are all collected and relayed to a status monitor that is worn by the individual soldier – which wirelessly communicates the real-time information to a remote medical unit. This is a significant advance for casualty care and the immediate deployment of these technologies to the battlefield would be of enormous value to both soldiers and those that manage casualties in the field. These sensor combinations would allow for rapid alerting and assessment of a soldier's wounds, and would accelerate their care and treatment – either in the field or at an advanced casualty care center.

The availability of soldier-worn sensors has also led to designs that utilize ultra low noise electronics for sensing and amplification of biological signals. One effort currently underway is developing a non-contact electrode that can work through everyday clothing – no special fabrics or fibers. These researchers have proposed that the electrical signals emanating from the skin are the major source of noise contamination in biological signals. Thus, they developed a novel non-contact sensor that detects the electric field emanating from the body, completely eliminating the contaminating signal from the skin. The first designs have detected ECG signals, but in addition to heart rate measures, they are now working on an EEG (electroencephalography) design that could be used to detect a variety of medically relevant signals without touching the operator at all. The sensor has been miniaturized, down to the size of a dime and able to be casually integrated into regular clothing items like t-shirts and helmets. The sensors are inexpensive and entirely passive, and work is underway to make the electrodes more sensitive to biological signals, wearable and wireless.

2.1.1 Novel Portable Assessment Tools

In addition to soldier-worn technologies, efforts are now underway to use the latest in optically based technologies for medical assessment in the field. Considerable effort has been made to protect our warfighters from head injury. However, closed head injuries are still a major concern in the dangerous work environments soldiers face when stationed at sea or in the battlefield. Even in non-military urban settings, acute head trauma is a leading cause of death and injury. The emergence of subdural/intracranial hematomas following blunt force head trauma can lead to life threatening complications including brain damage, disability and death particularly if the injury is not detected immediately after an event. An acute subdural hematoma (SDH) is a collection of rapidly clotting blood below the inner layer of the brain membrane (dura) but external to the brain. In operational or remote settings, immediate evaluation of these injuries following a closed head event is limited to the assessment tools at hand. Ships at sea and forward deployed hospitals are not equipped with technologies such as magnetic resonance imaging (MRI) and computer aided tomography (CAT) scans. These technologies are the standard tools for determining the presence of subdural hematomas – but their excessive size, lack of portability and cost prohibit their use in operational environments. Near infrared wavelengths of light can be used non-invasively to penetrate through the skull and detect/image blood beneath the skull surface and in the cortical layer of the brain. This affords combat casuality care medical teams an opportunity to "see" below the skull and make rapid assessments of patient status. Devices using near infrared spectroscopy have the advantage of being relatively inexpensive due to recent advances in near infrared sources and detectors. The development of imaging devices using near infrared spectroscopy will offer the military medical community an opportunity to detect subdural hematomas on site and should afford medical workers more time to make critical decisions about whether or not a patient needs to be evacuated from their current location.

2.2 Advanced Status Monitoring

In addition to purely medical monitoring, we now have the opportunity to begin incorporating more complex sensors into the baseline status monitoring systems described above. As discussed in the NATO RTO HFM-056/TG-008 Report on "Operator Functional State Assessment", there are a myriad of sensors now in development that can give an even more complete evaluation of real-time soldier status. In this context, soldier status does not just refer to the physical integrity of the warfighter, it refers to the cognitive or mental capacity of the warfighter as measured in the real-time operational environment. When we consider this broader definition of status – we can look at cognitive measures, such as workload, mental fatigue, stress, sleep deprivation and even begin to associate measures with concepts like situational awareness. Current investments in these technologies have contributed to revolution in this area and a significant paradigm shift with respect to the types of data that can be collected in real-time. Although not all of these tools are currently ready for operational deployment, the following table lists some of the sensors in use:

Actigraphy	Actigraphy
Blood Flow	
BP	Blood Pressure
Core Temp	Core Temperature
ECG (HR,HRV)	Electrocardiography
EDA	Electrodermal Activity
EEG	Electroencephalography
EMG	Electromyography
EOG/EyeMovement	Electrooculography
fMRI/imaging	Functional MRI
Hormonal	Hormonal
NIRS	Near-Infrared Spectroscopy
Oximetry	Oxygen Saturation
Respiration	Respiration Parameters

Table 1: Types of Physiological Monitoring Available

Of the measures listed in Table 1, not all are associated with a cognitive or mental state. However, all of these sensors have been evaluated to some degree for their usefulness in characterizing the warfighter's state. The author's of this paper recommend the NATO Report (RTO HFM-056/TG-008) for a complete evaluation and discussion of these sensors in primarily the aviation domain. Work is now underway to evaluate these measurements in the mobile environment and under increasingly hostile conditions. The eventual goal of this work is two fold. One aspect is the improvement of human performance through the assessment of soldier status in real-time. With this knowledge, information systems can be designed and modified in order to present information to the warfighter in the most beneficial and least stressful manner. In addition, a side goal of this work is the development of tools to be used in order to conduct 'fitness for duty' evaluations in real-time. This is part medical – but also part cognitive – as a warfighter may by physically ready for battle, but may not cognitively or mentally be in the zone. The hope is that preventative use of these technologies would reduce battlefield causalities, non-combat related mishaps, and other events that are due to mental fatigue. Circumstances in the field may necessitate soldiers to perform at sub-optimal levels; however, these technologies would give medical personnel the opportunity to exercise preventative care instead of triage.

3.0 MEDICAL SURVEILLANCE OF UNITS OF ACTION

The surveillance discussed in this paper thus far has centered around the individual solider and the assessment of his or her status in real-time. However, an even more powerful application of these tools could be used at the level of the medical officer or battalion commander to establish a real-time awareness of the health and status of their troops. This begins to approach the soldier centered battlespace awareness concept initially discussed. One could envision a whole range of status reporting – from a basic "green, yellow, red" readiness system that would be emitted by each soldier's personal status monitor giving a real-time picture of troop status - to even more complex and diagnostic data – particularly for medical officers – about the fatigue, stress, hydration status and physiological health of the troops. This type of information could give coalition forces a distinct advantage in the operational setting, allowing them to place the right human resources in the engagement at the right time. These kinds of technologies would also enable coalition commanders to make informed choices about when and where to send their troops, and how many may be prepared for the next mission. This is a notional concept at this time, but this type of capability should be considered as soldier-based measurements become part of the operational picture.

4.0 INFORMATION MANAGEMENT IN THE BATTLESPACE

Finally, we would be remiss without mentioning the impact that this additional information will have on workload in the field. Arguably, each additional node in the netcentric battlespace requires someone to receive process and interpret that information. Adding humans to this picture, through their assessed status is no different, and will require an information management solution for commanders and medical personnel to handle the flow of information. There is probably a great deal that can be learned from the civilian medical community, and the new emphasis on telemedicine. However, this field is expanding rapidly, and the development of new technologies for monitoring is likely to outpace the development of easy to use interfaces to fuse and analyze data to convert it to actionable format. Thus, these authors recommend that resources be invested in the human-computer interfaces that will collect this information – so that this approach does not become clouded by information overload rendering the data unusable in the field environment

[1] http://www.gtwm.gatech.edu/ Georgia Tech Wearable Motherboard™: The Intelligent Garment for the 21st Century

[2] Hancock, P. A., & Desmond, P. A. (2001). Stress, workload and fatigue. Mahwah, New Jersey: Lawrence Erlbaum Associates.

[3] RTO-TR-HFM-104 Operator Functional State Assessment : Technical Report has been prepared by the RTO Human Factors and Medicine Panel (HFM) Task Group HFM-056/TG-008 (2004) http://www.rta.nato.int/Rdp.asp?RDP=RTO-TR-HFM-104

[4] Wilson, G. F. (2002). An analysis of mental workload in pilots during flight using multiple psychophysiological measures. International Journal of Aviation Psychology, 12, 3-18.

[5] Combat Casualty Care http://www.foster-miller.com/projectexamples/t_bt_physiological_monitoring/Combat_Casualty_Care.htm

SYMPOSIA DISCUSSION - PAPER 13

Authors Name: Dr Schmorrow (US)

Discussor's Name: Col Cox (US)

Question:
Sensor data includes most, if not all, of the physiologic parameters used in polygraphs. This could be of potential value when needing to identify individuals communicating under duress, e.g., individual is at enemy gun point, but his comrades are unaware. Has such an applicant been considered? If so, what validity might you expect/predict? The application was not designed for that purpose, but multiple applications are possible using this type of sensor data. There is a problem of distinguishing between lie, deceit, or "simple" physical stress.

Author's Reply:
This technology will be able to detail levels of stress as well as associated bio markers of confusion and disorientation.

Authors Name: Dr Schmorrow (US)

Discussor's Name: Prof. Dr Garland (US)

Question:
1) What is the time-line for Sensors and algoriths for Medical Situation Awareness in theater?

   For:

   a. Personal status – normal situation

   b. Injured individual – assessment/monitoring

2) Is it reasonable to add these technologies in a 5 year time frame?

Author's reply:
1a) Personal status monitoring capability in fixed facilities will arrive in 3 to 5 years, in the field will arrive 7 to 10 years.

1b) Injured individuals. This capability will be demonstration as a portable low cost technology in 24 months.

2) Availability to medical facilities in a broader fashion will be available in 3 to 5 years.