## REPORT DOCUMENTATION PAGE

*Form Approved*
*OMB No. 0704-0188*



**1. REPORT DATE** *(DD-MM-YYYY)*: November 2009

**2. REPORT TYPE**: Journal Article

**3. DATES COVERED** *(From - To)*:

**4. TITLE AND SUBTITLE**

Graphical User Interface for a Remote Medical Monitoring System: U.S. Army Medic Recommendations

**5a. CONTRACT NUMBER**

**5b. GRANT NUMBER**

**5c. PROGRAM ELEMENT NUMBER**

**6. AUTHOR(S)**

Sangeeta Kaushik, MD; William J. Tharion

**5d. PROJECT NUMBER**

**5e. TASK NUMBER**

**5f. WORK UNIT NUMBER**

**7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)**

Biophysical & Biomedical Modeling Division
U.S. Army Research Institute of Environmental Medicine
Kansas St.
Natick, MA 01760

**8. PERFORMING ORGANIZATION REPORT NUMBER**

M09-10

**9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)**

Same as #7 above.

**10. SPONSOR/MONITOR'S ACRONYM(S)**

**11. SPONSOR/MONITOR'S REPORT NUMBER(S)**

**12. DISTRIBUTION/AVAILABILITY STATEMENT**

Approved for Public Release; distribution is unlimited.

**13. SUPPLEMENTARY NOTES**

**14. ABSTRACT**

The U.S. Army is developing a far-forward medical monitoring system to provide medical information to medics and other medical personnel that are geographically removed from Soldiers they are monitoring. This system, termed the Warfighter Physiological Status Monitoring (WPSM), consists of a wearable sensor suite that allow remote health assessment of a Soldier.

**15. SUBJECT TERMS**

| 16. SECURITY CLASSIFICATION OF: | | | 17. LIMITATION OF ABSTRACT | 18. NUMBER OF PAGES | 19a. NAME OF RESPONSIBLE PERSON |
|---|---|---|---|---|---|
| a. REPORT | b. ABSTRACT | c. THIS PAGE | | | William J. Tharion |
| Unclassified | Unclassified | Unclassified | Unlimited | 6 | 19b. TELEPHONE NUMBER *(Include area code)* 508-233-5222 |

MILITARY MEDICINE, 174, 11:1190, 2009

# Graphical User Interface for a Remote Medical Monitoring System: U.S. Army Medic Recommendations

*Sangeeta Kaushik, MD*†; William J. Tharion, MS, MBA**

**ABSTRACT** We obtained recommendations for a graphical user interface (GUI) design for a new medical monitoring system. Data were obtained from 26 combat-experienced medics. Volunteers were briefed on the medical monitoring system. They then completed a questionnaire on background medical treatment experience, provided drawings on how and what information should be displayed on the GUI screens for use on a personal digital assistant, and participated in focus group sessions with four to seven medics per group to obtain group consensus on what information the GUI screens should contain. Detailed displays on seven screens provide the medical and situational awareness information medics need for triage decisions and for early processing of a casualty. The created GUI screens are a combination of object-based and text-based information using a color-coded system. Medics believed the information displayed with these GUI designs would improve treatment of casualties on the battlefield.

## INTRODUCTION

The U.S. Army is developing a far-forward medical monitoring system to provide medical information to medics and other medical personnel that are geographically removed from soldiers they are monitoring. This system, termed the Warfighter Physiological Status Monitoring (WPSM) system, consists of a wearable sensor suite that will allow remote health assessment of a soldier. The sensors currently provide: heart rate, respiration rate, skin temperature, body position, body motion, core temperature, fluid intake, and sleep status. In the future, there is a sensor that is currently in prototype form that assesses whether a soldier was hit by a ballistic projectile such as a bullet. Currently, far-forward battlefield medical information is communicated by limited voice radio, field medical cards, or verbal report. The WPSM system allows for evaluation of a soldier before, during, and immediately after injury. It is envisioned that WPSM data would be sent through a data radio network to a personal digital assistant (PDA) used by the medic. The information and the resulting medical response could greatly impact patient care and survival.

Previous research has examined the transmission of pre-hospital information to receiving facilities in an effort to improve patient condition and prognosis.[1,2] Organizing and tracking medical information using PDA-based systems for civilian mass casualty situations has been found to be acceptable and easy to use.[3] Developing a graphical user interface (GUI), which is often the medium humans use to interact with computers or machines, is a challenge. This challenge is only heightened when the information must be deciphered quickly in life-saving situations. Designers of computers and computer-based systems have found that a key barrier to user acceptance of the systems is the lack of user friendliness.[4]

The human-device interfaces on automated external defibrillators (AED) are designed to allow untrained individuals to perform defibrillation on individuals in cardiac arrest. Studies have shown that sixth grade children can use AEDs without prior teaching. The thoughtful design of the user interface was integral to the successful development and use of AEDs in community settings.[5] In another application, children have successfully helped design a computer display of the human body using cartoon pictures and symbols that are easy for children to understand. This display of the body helps children with cancer communicate their symptoms to health care professionals.[6,7] These designs were developed through an iterative process known as participatory design.[7] In general, participatory design implies that the participants developing the system are as similar as possible to those who will use the system in the future.[6,7] As recognized in many fields, and as recommended by Staggers and Kobus,[4] the design of GUIs "should include the use of human factors principles, and input from user-centered focus groups." Tan recommended the use of both graphics and text-based information, as there are advantages and disadvantages to each.[8] Furthermore, it has been demonstrated that the use of color graphics can greatly enhance cognitive and decisional effectiveness over the use of monochrome graphics.[8]

The purpose of this study was to identify an acceptable GUI for the WPSM system by gathering feedback from the end-user community, e.g., the line medic, on what information was needed and how that information should be displayed. The battlefield is a highly complex and chaotic environment. Yet, the issues facing the military medic are some of the same ones facing civilian police, firefighters, and civil support teams

*U.S. Army Research Institute of Environmental Medicine, Building 42, Kansas Street, Natick, MA 01760.

†Washington Hospital Center, Department of Emergency Medicine, 110 Irving Street, Washington, D.C. 20010.

Some information contained in this manuscript was previously published in a U.S. Army Research Institute of Environmental Medicine Technical Report no. T-07-04, 2006.

The views, opinions, and/or findings contained within this publication are those of the authors and should not be construed as an official U.S. Department of the Army position, policy, or decision unless so designated by other documentation.

This manuscript was received for review in April 2009. The revised manuscript was accepted for publication in August 2009.

that provide medical care in emergency situations. Remotely monitoring a patient wearing the WPSM system may take place without direct observation or contact with the patient. Furthermore, if an injury occurs, medical information may be collected throughout the entire treatment process. The WPSM system can also be used to monitor medical status of first responders wearing personal protective equipment in chemically or biologically contaminated environments.[9]

In this study, we asked medics what information was important and how should the information be displayed to help prioritize the injured or to identify the need for a diagnostic test or life saving intervention. Remote assessment of a patient should theoretically allow the medic to prepare for the most appropriate course of action upon arriving at the casualty. Having accurate, appropriate, and easy-to-understand medical information about a patient is very important. The study's goal was to develop a GUI for a remote physiological monitoring system that met medics' needs.

## METHODS

Twenty-six U.S. Army combat medics volunteered for this study, which was reviewed and approved by the Human Use Review and Scientific Review Committees at the U.S. Army Research Institute of Environmental Medicine (Natick, MA). Before any data were collected, participants were briefed on the study and were informed that participation was voluntary.

Volunteers completed a questionnaire used to ascertain their medical experience and attended a presentation on what the WPSM system is and how it functions. In addition, three GUI concept designs of how information could be displayed were presented. After the presentation, medics were asked to design their own GUI for the WPSM system on three 1/2 × 5 inch cards. They were instructed that each card should represent a screen that might be viewed on a PDA. They were told to orientate their drawings to either portrait or landscape depending on how they would want the information displayed on a PDA. They were given different color pens and told that, if they chose, they could use different colors to represent different meanings of information. Information on the frequency of occurrence of a particular characteristic was then tabulated. For example, the number of different screens their GUI was to have was recorded. Descriptive statistics of frequency of occurrence of particular designs as well as means and standard deviations were analyzed using SPSS 14.0 statistical software (SPSS, Inc., Chicago, IL).

Four focus group sessions with four to seven participants per group were held to allow medics to exchange ideas with one another and share those ideas with the investigators who served as moderators.[10] Drawings of GUI display screens were made upon poster boards when each group came to a consensus on the information that should be displayed on a particular screen.[11] Topics were introduced by the moderators and proceeded from general to more specific and followed previously published guidelines for focus groups.[12] The following general questions were discussed: (1) How many screens should there be? (2) How does a user navigate between screens? (3) How will a patient alert a medic? (4) How should troop location be represented? (5) How should medical status of a patient be represented? (6) How will treatment status be represented? (7) Should it be possible to enter information and, if so, how?

## RESULTS

All but one of the medics had combat experience, and some had several tours of duty. They primarily worked as front line medics stationed with mechanized or light infantry units. Medics were asked to report the top three injuries they observed in training and the top three they observed in combat. The following data represent the number of medics reporting a particular injury. The three main injuries seen during training were fractures (27%), upper respiratory illnesses (27%), and heat injuries (23%). The three main injuries seen in combat were ballistic wounds (68%), improvised explosive device (IED) shrapnel, and blast injuries (60%), and traumatic amputations (44%). Sixty-nine percent of medics reported that they would ideally want to know blood pressure and location of wounds. Fifty-eight percent of medics wanted all vital signs for treating injured soldiers. In triaging multiple casualties, medics stated they assess the severity and extent of injuries to life, limb, or eyesight. They used vital signs, anatomical location of the injury, severity of injury, and level of consciousness to make triage decisions.

The majority of individual GUI screens drawn by medics (89%) had some form of geolocation information built into a map. The average number of GUI screens the medic would tab through for specific information was approximately four with a maximum of seven screens. The majority of medics (70%) also wanted a name list screen that, when tapped, would go to an individual patient screen. In the name list screen, 44% of the medics wanted some vital medical information next to the name. The individual patient screen would have additional detailed medical information to include vital signs and a ballistic impact detection system (BIDS) alert function. The BIDS detects whether the body has been hit by a bullet or some other projectile. Eighty-nine percent of medics had, on one of their screens, an overall color-coded health status of the soldiers they were monitoring.

A composite of the most often cited ideas from the four focus groups, or unique ideas generated by one focus group, were incorporated into one set of seven screens. Figures 1–4 show the four most relevant patient assessment screens. Three screens not shown are (1) a squad status tracking screen that provides the commander the overall fighting strength of a squad given the number and nature of casualties sustained to that squad, (2) an electronic version of the U.S. Army Field Medical Card (DD Form 1380),[13] and (3) a medical reference section.[14]

Medics wanted the ability to input and update patient status. There was no consensus regarding the system coding an individual as dead with a black symbol based upon vital signs. Three of the four focus groups believed that designating a patient as dead should only be entered once the patient has been examined and pronounced dead, while one group felt that if the system was truly valid and reliable this would be important for triage and improves resource management. Codes that were agreed upon were a green square (patient is ok), a yellow triangle (patient's vital signs require attention), and a red circle (patient has vital signs that require immediate attention). If the red circle was flashing (designated in Figures 1 and 2 as a red sunburst) it means that patient status had changed from green or yellow to red. A blue diamond meant there was some issue with the WPSM system itself (e.g., low battery power).

The red-orange area of the map indicates enemy-occupied territory (Fig. 1). Across the top of each screen are tabs that can be used to navigate to another page. The two buttons near the upper left-hand corner of each screen are a lock/unlock button that locks the display screens. A password would have to be entered to unlock the displays if the lock button has been pushed. Tapping on that button would prompt the user to enter the password. Tapping on the light button would illuminate the screen to make it brighter so that it could be read in the dark. Battery strength is located near the top of the screen on the right-hand side. Medics recommended that their PDA vibrate or make an auditory alert if there were a change in medical status of the soldiers they were monitoring. In Figure 1, a summary of current local weather conditions would be displayed in the lower left of the screen. In the lower right of this map screen is located time and local geolocation information. Just above this information is a toggle switch where the user

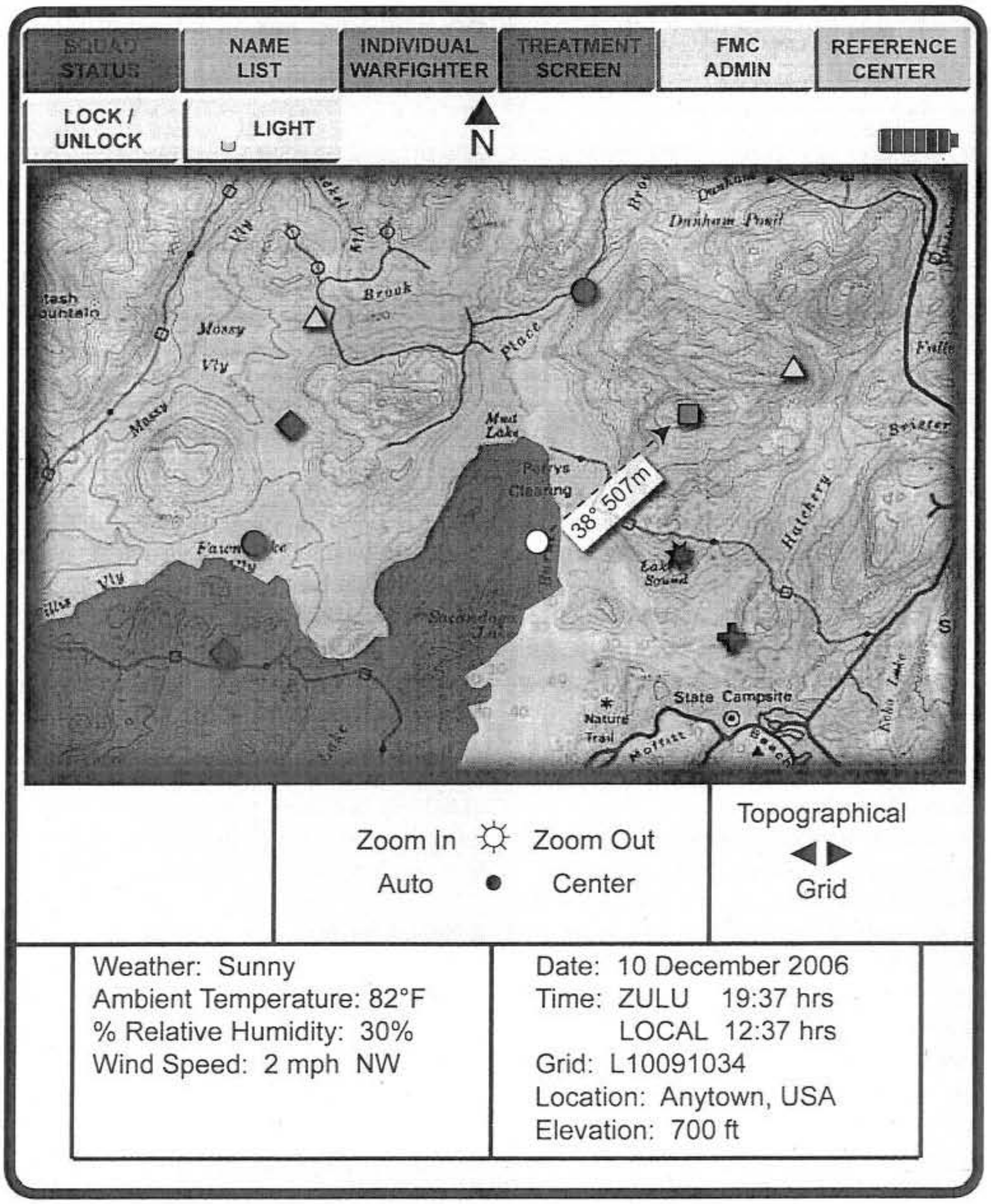


**FIGURE 1.** Map location of individual personnel, color-coded by medical severity. Medic symbol is a white circle. Direction and distance from the medic to interested personnel available by rolling PDA stylus over that individual. Red Cross symbol is the closest medical aid station or ambulance.

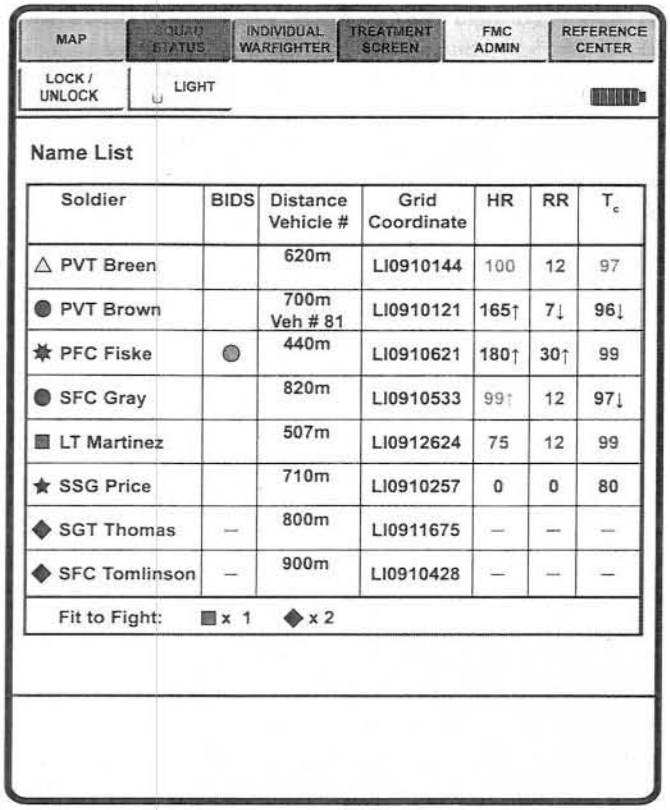


**FIGURE 2.** Name list display of personnel (names are fictitious). Sunburst symbol represents a blinking red circle, which indicates medical status change. Black star represents personnel pronounced dead by the medic.

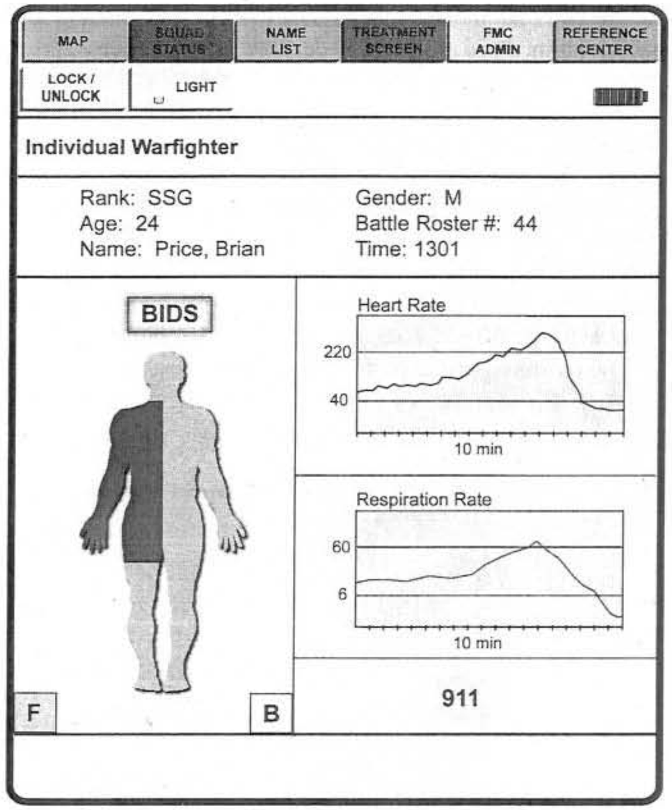


**FIGURE 3.** Individual physiological status (name is fictitious). Red represents likely ballistic impact. F shows frontal view of patient. Highlighted 911 indicates that injured soldier pushed "need help" button on his/her WPSM system.

would be able to change between a topographical map (shown in Figure 1) and a grid map. In the center of the map are two buttons that can be tapped to zoom in and zoom out and to auto-center the map after it has been moved. Tapping on the various boundaries of the map will pull the map in that direction. For example, tapping on the top of the map would pull the displayed map location to the north direction. The white circle represents the medic's location. Rolling the stylus over any of the soldiers would show the distance and direction of that soldier from the medic. The Red Cross symbol represents the nearest field hospital or aid station.

Figure 2 has arrows next to the vital sign measurements that indicate whether that vital sign is rising or falling. No arrow indicates a stable vital sign. The fit-to-fight at the bottom of this page is a summary of those soldiers that are not injured and can still be used for their designated job responsibilities.

Figure 3 is the individual patient screen. In the lower left are two buttons that allow the patient to be represented either in frontal view (F button clicked) or a back view (B button clicked). The red area on the representation of the human indicates the general area of the wound as indicated by the BIDS alert. On the right-hand side is a running 10-min history of heart rate and respiration rate. The 911 button is illuminated in this figure indicating the soldier alerted the medic that they needed medical help.

Figure 4 is the treatment screen. This screen allows the medic to input information. On the left-hand side is the location of the wounds. The default could be from the BIDS information but the medic could also tap on the figure to input that information themselves. They would then tap to indicate the type of evacuation they requested. For example, tapping the red button on evacuation status and the blue button under evacuation type would mean urgent evacuation by air. On the next level, near the bottom of the screen is a pull-down checklist of some common injuries and treatments that could be provided. Medics could enter notes near the bottom of the screen using their stylus pen. In addition, medics wanted the device to have a voice recorder for their comments.

## DISCUSSION

One of the goals of the WPSM medical monitoring system is to increase situational awareness and thereby reduce the time to respond to a critical event. On the battlefield and within the civilian trauma system, exsanguinations and central nervous system injuries are the two leading causes of death.[15] Uncontrolled hemorrhage is the main cause of death for almost 50% of combat fatalities and 70% of civilian trauma deaths.[15,16] The physiology of a trauma patient is dynamic and it is currently not available at point of injury but rather only once medics arrive on the scene. The WPSM system will

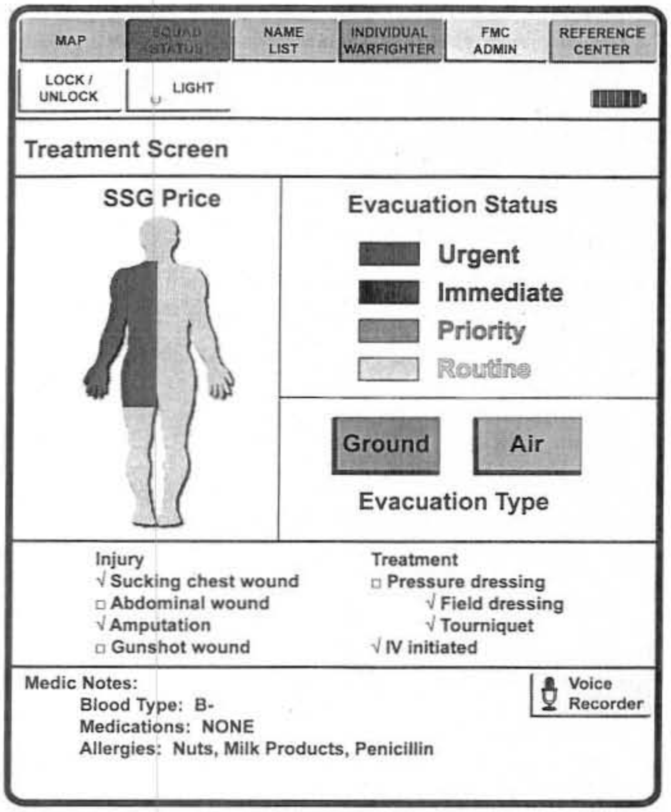


**FIGURE 4.** Medic input for treatment administered (name is fictitious).

allow medics to make rapid decisions regarding priority of care, more easily decide on the need for medical intervention, and ensure appropriate transfer to higher echelons of medical care.

A majority of medical monitoring systems use a "single-sensor-single-indicator" display resulting in the clinician having to gather and integrate multiple data points.[17] Approximately 67% to 90% of alarms generated in the intensive care unit, however, are noted to be erroneous.[18] The clinician must be an active part of deciding to act or not to act. Data from aviation, industrial accident research, and anesthesia show that approximately 80% of critical incidents are associated with human error.[19] However, according to the Joint Commission on Accreditation of Healthcare Organizations (JACHO)[20] poor interface design and lack of usability testing facilitates medical error. JACHO states that many adverse events in medicine are the result of poor interface design rather than human error, and that healthcare organizations should "expect and demand an optimized and tested user interface in the medical devices they purchase."[20]

The WPSM system has underlying algorithms that take raw data, process it, and present it graphically to the end user. α-Numeric displays require more mental processing time than when the information is presented graphically. Graphical object displays (e.g., use of a heart rate and respiration rate graphed over time in Figure 3) relate individual streams of data to create a multidimensional object. Anesthesiologists using the object display were faster and made fewer errors in determining the etiology of shock compared to those using a standard α-numeric display.[19] The GUIs designed by medics in this study make heavy use of graphic streaming displays, although α-numeric information is also present for those that want more detailed numerical information.

While medics see the value of the medical monitoring system with an easy-to-read GUI they do not view it as a replacement for their own clinical skills and judgment. Prior research has shown that on-site judgment by civilian emergency medical technicians (EMT) is superior to or equal to various scoring systems in identifying mortality or patients requiring operative intervention.[21] Holcomb and coworkers' research in a cohort of trauma patients showed the need for a life saving intervention could have been predicted on the basis of radial pulse character and the motor and verbal components of the Glasgow coma scale.[22] Hence, the decision-making capability of this medical monitoring system when the medic is on site is not as important as the medic's training and experience in correctly diagnosing the problem. However, when the medic has great distances to cover or has a mass casualty situation, the ability to rapidly assess and identify those with cryptic shock or in need of a focused and effective clinical intervention, the WPSM system may be seen as a way of providing better medical coverage to more soldiers for each individual medic. Hence, it becomes vitally important to provide an interface that the battlefield medic can readily use for dynamic clinical decision making, versus being faced with reams of data to process, integrate, and act upon.

Data gathering from point of injury, and interpretation of the data, are an important part of understanding trauma vital signs. Ambulatory vital signs may generate new and novel approaches to identifying cryptic shock, triage, or prioritizing evacuation status. The U.S. Army Institute of Surgical Research (USAISR) has done studies to suggest that the R-wave amplitude in lead II of an electrocardiograph correlates with central hypovolemia in human beings.[16] More research is needed to identify the acutely ill or injured soldier before deterioration. Also, greater technological or engineering investments may result in a refined sensor and critical data procurement. For instance, the ability to identify hypotension would be desirable given the fact it impacts mortality and identifies those needing operative intervention or intensive care.

This was a concept study using end-user recommendations regarding the display of medical information in austere environments. The next step would be to test the usability and end-user acceptance of these prototype screens in a combat training or chemical-biological training setting. The present study should be repeated in the civilian sector for assessment of needs and medical consistency. Further research needs to be done to see if a GUI system will truly enhance the medic's decision making process. Actual prototypes of these GUI screens need further testing to see whether they actually meet the medic's needs and performance expectations. For example, some screens recommended by the medics may present too much information to actually be viewed on a PDA-sized screen.

## CONCLUSIONS

The results from this study indicate an acceptance of the concept of physiological status monitoring technology for battlefield medic use. The medical status information sought by medics can be condensed into a limited number of screens. Geolocation and color-coded life signs status were rated as the most important information to display. However, the true potential of remote medical monitoring would be the ability to predict medical deterioration before the need for life saving interventions.

## ACKNOWLEDGMENTS

The authors thank Karen Speckman for help with data collection, Julio Gonzalez for graphics support, and Dr. Reed Hoyt for providing scientific guidance during the manuscript preparation. We are also very grateful to all the experienced medics who provided the information needed for this report. This study was funded by the U.S. Army Medical and Materiel Command, Fort Detrick, MD under the Army Technology Objective program entitled: Warfighter Physiological Status Monitoring–Initial Capability.

## REFERENCES


1. Hu P, Defouw G, Mackenzie C, et al: What is happening to the patient during pre-hospital trauma care? AMIA Annu Symp Proc 2006; 955.
2. Clemmensen P, Sejersten M, Sillesen M, Hampton D, Wagner GS, Loumann-Neilsen S: Diversion of ST-elevation myocardial infarction patients for primary angioplasty based on wireless prehospital 12-lead electrocardiographic transmission directly to the cardiologist's handheld computer: a progress report. J Electrocardiol 2005; 38(4, Suppl): 194–8.
3. Chang P, Hsu YS, Tseng YM, Sang YY, Hou IC, Kao WF: The development of intelligent, triage-based, mass gathering emergency medical service PDA support systems. J Nurs Res 2004; 12: 227–35.
4. Staggers N, Kobus D: Comparing response time, errors, and satisfaction between text-based and graphical user interfaces during nursing order tasks. J Am Med Inform Assoc 2007; 7: 164–76.
5. Caffrey SL, Willoughby PJ, Pepe PE, Becker LB: Public use of automated external defibrillators. N Engl J Med 2002; 347: 1242–7.
6. Ruland CM, Slaughter L, Starren J, Vatne TM, Moe EY: Children's contributions to designing a communication tool for children with cancer. Stud Health Technol Inform 2007; 129: 977–82.
7. Ruland CM, Starren J, Vatne TM: Participatory design with children in the development of a support system for patient-centered care in pediatric oncology. J Biomed Inform 2008; 41: 624–35.
8. Tan JKH: Health graphics: reconciling theory and practice in the 21st century. Medinfo 1995; 8: 796–800.
9. Buller MJ, Tharion WJ, Karis A, Santee W, Mullen S, Hoyt R: Real time physiological monitoring of encapsulated team members of the 1st Civil Support Team–Weapons of Mass Destruction (CST-WMD). USARIEM Technical Report T-08-01, Natick, MA, U.S. Army Research Institute of Environmental Medicine, 2007.
10. Fern E: The use of focus groups for idea generation: the effects of group size, acquaintaceship, and moderator on response quantity and quality. J Mark Res 1982; 19: 1–13.
11. Aaker DA, Day GS: Marketing Research, pp 124–126. New York, John Wiley and Sons, 1986.
12. McQuarrie EF, McIntrye SH: Focus groups and the development of new products by technologically driven companies: some guidelines. J Prod Innov Manage 1986; 2(March): 40–7.
13. Department of the Army. Medical Record Administration and Healthcare Documentation. Army Regulation 40-66, Washington, D.C., Headquarters, Department of the Army, June 17, 2008.
14. U.S. Special Operations Command: Special Operations Forces Medical Handbook. Tampa, FL, U.S. Special Forces Operations Command, 2001.
15. Sauaia A, Moore FA, Moore EE, et al: Epidemiology of trauma deaths: a reassessment. J Trauma 1995; 38: 185–93.
16. McManus JG, Convertino VA, Cooke WH, Ludwig DA, Holcomb JB: R-wave amplitude in lead II of an electrocardiograph correlates with central hypovolemia in human beings. Acad Emerg Med 2006; 13: 1003–10.
17. Wachter SB, Johnson K, Albert R, Syroid N, Drews F, Westenskow D: The evaluation of a pulmonary display to detect adverse respiratory events using high resolution human simulator. J Am Med Inform Assoc 2006; 13: 635–42.
18. Wachter SB, Markewitz B, Rose R, Westenskow D: Evaluation of a pulmonary graphical display in the medical intensive care unit: an observational study. J Biomed Inform 2005; 38: 239–43.
19. Blike GT, Surgenor SD, Whalen K: A graphical object display improves anesthesiologists' performance on a simulated diagnostic task. J Clin Monit Comput 1999; 15: 37–44.
20. Fairbanks RJ, Caplan S: Poor interface design and lack of usability testing facilitate medical error. Jt Comm J Qual Saf 2004; 30: 579–84.
21. Emerman CL, Shade B, Kubincanek J: A comparison of EMT judgment and prehospital trauma triage instruments. J Trauma 1991; 31: 1369–75.
22. Holcomb JB, Salinas J, McManus JM, Miller CC, Cooke WH, Convertino VA: Manual vital signs reliably predict need for life-saving interventions in trauma patients. J Trauma 2005; 59: 821–9.