Towards Shared Situational Awareness and Actionable Knowledge – An Enhanced, Human-Centered Paradigm for Public Health Information System Design

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Recommended Citation:

DOI: 10.2202/1547-7355.1727
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Abstract

Technology has exerted an increasingly dominant influence on the ways and means that objectives of informatics projects are pursued and has extended the capabilities of informatics systems in general. However, literature examining the importance of human links between situational awareness-related processes and decision-making capabilities remains relatively sparse. Substantial knowledge gaps exist in information system implementation between technology and public health surveillance. The purpose of this article is to present an enhanced conceptual framework, built upon innovative perspectives of a human-centered paradigm of implementation, to enable and enhance human-centric decision-making. To clarify this concept, we employ a case of situational awareness in the setting of a recent command post exercise in order to illustrate core concepts and practices. We divide the framework into methods, tools, and goals to broaden the context of discussion, and conclude with lessons learned from this field operation exercise. The present study could be of value to military commanders, policy leaders, and analysts across multiple disciplines, such as in the public health, counterinsurgency, and bioterrorism surveillance communities.

KEYWORDS: response, public health, informatics, human-centric decision-making
Introduction

Technology has exerted an increasingly dominant influence on the ways and means that objectives of informatics projects are pursued, and has extended the capabilities of informatics systems in general. However, literature examining the importance of human links between situational awareness-related processes and decision-making capabilities remains relatively sparse. Substantial knowledge gaps exist in information system implementation between technology and public health surveillance. The purpose of this article is to present an enhanced conceptual framework, built upon innovative perspectives of a human-centered paradigm of implementation, to enable and enhance human-centric decision-making. To clarify this concept, we employ a case of situational awareness in the setting of a recent command post exercise in order to illustrate core concepts and practices. We divide the framework into methods, tools, and goals to broaden the context of discussion, and conclude with lessons learned from this field operation exercise. The present study could be of value to military commanders, policy leaders, and analysts across multiple disciplines, such as in the public health, counterinsurgency, and bioterrorism surveillance communities.

The “Methods”

Military commanders and higher executives usually have access to a myriad of human and technical resources to support their missions. A commander’s staff can be viewed as a collection of cells or nodes with specific expertise, each of which may have specialized resource requirements and assets at its disposal. Achieving unity of effort is the ultimate task of command and control, making coordination of effort within such a staff both crucial and challenging.

One such challenge continues to be sharing and assimilating situational awareness within a command staff to support decision-making. A commander’s staff may be responsible for coordinating a vast array of supporting tasks across the full range of military operations and levels of command. The U.S. Joint Chiefs of Staff (2006) maintain that combined arms, joint, and coalition doctrine describes how to conduct missions simultaneously at tactical, operational, and strategic levels. Doctrine addressing these missions requires continual review and is frequently updated to reflect emerging capabilities and lessons learned. Unity of effort achieved through improved situational awareness in support of decision-makers needs to be a core component of such doctrinal analysis and revision.
The “Tools”

Situational awareness is defined by Endsley (2000) as "the perception of elements in the environment with a comprehension of their meaning and a projection of their status in the near future." Providing effective, integrated, and persistent situational awareness could substantially improve success of mission, unity of effort, and continuity of operations.

The rapid advancement of technology has enabled shared situational awareness including: Blue Force Tracks; Net-Centric Warfare; and other advancements within the various domains of the Global Information Grid. Communities of interest are developing the means to apply these technologies to synchronize and unify efforts in a common operational picture, and to support commanders at every level. In the Department of Defense (DoD), a community of interest has been defined by the DoD Chief Information Officer (2003) as a “collaborative group of users who must exchange information in pursuit of their shared goals, interests, missions, or business processes.” Shared situational awareness has immediate applicability within some fairly matured communities of interest: Chemical, Biological, Radiological, Nuclear (CBRN); Logistics; Intelligence; Medical; as well as non-military U.S. agencies and coalition partners. Communities of interest like these must share situational awareness to execute interdependent functions while overcoming barriers to interoperability such as “stove-piped”, or back-logged, information systems and processes. Riley et al. (2006) state that timely situational awareness must be shared between related communities of interest to provide unity of effort and to be of substantial benefit to the communities, the commander, and the mission. Information technology capabilities exponentially increase the amount of data available to commanders and their staffs in dynamic operational environments. Human-centric information management capabilities are required to enhance the products of information technology and translate them into useful and timely decision-support. The sharing of situational awareness among communities of interest, especially across the members of a command staff, poses the non-trivial challenge of producing a relevant, manageable, and useful set of information for timely decision support from a large amount of situational data.

Experimenting with “Methods” and “Tools”

Throughout the early part of the present decade, the DoD possessed almost no command and control system that integrated operationally-relevant medical information with other critical operational information to support timely and accurate decision-making. This shortcoming and the expressed needs of sharing medical situational awareness prompted the creation of the Medical Situational
Awareness in the Theater Advanced Concept Technology Demonstration (MSAT ACTD) in 2005.

Figure 1. MSAT Concept.

The central concept of MSAT (see figure 1) was the fusion of information from existing data streams within the medical domain (e.g., disease and non-battle injury, trauma, etc.) with data external to the medical domain (e.g., operational unit locations, CBRN threats, intelligence). Data fusion was envisioned to include geospatial mapping and algorithms or models, in order to produce medically-relevant, actionable knowledge to support decision-making by users at the tactical, operational, and strategic levels of warfare.

The lack of timely, actionable health information for operational decision-making in-theater delays effective interventions to neutralize health threats that cause otherwise preventable illnesses, injuries, and deaths. Although the requirements for medical situational awareness in support of major combat operations are rigorous, they are generally similar to the requirements for situational awareness of other combat service support communities of interest. However, in settings of complex humanitarian emergencies caused by natural disasters, such as tsunamis and hurricanes, strategic emergencies like an influenza pandemic, medical civil action programs, or even contemporary counterinsurgency (COIN) operations, the medical communities of interest are likely to assume a more prominent and complex operational role. For such missions, accurate and timely medical situational awareness is the foundation for achieving mission objectives and overall mission success. For those of us raised in the 20th century,
representation of information by “rows and columns”, arguably, was our greatest expectation. We need to move to a “cloud environment” where we visualize information in multiple dimensions.

The Demonstration

In its initial developmental phase, the MSAT ACTD focused on support for a Combined Joint Task Force (CJTF) to assess the military utility of medical situational awareness. U.S. Pacific Command, as the operational sponsor for the ACTD, selected Exercise Cobra Gold 06 (May 2006) as the venue for the operational test of this capability, and the staff of the CJTF Surgeon was the intended user. The MSAT prototype, the Medical Situational Enhancement (MSE), was developed for this specific exercise. The MSE operated within a coalition wide-area network which connected the combatant commander’s network in Hawaii with the CJTF network in Thailand during the Cobra Gold 06 command post exercise (CPX). The CPX scenario featured a simulated outbreak of avian (i.e., bird-derived) influenza in displaced persons during a peace enforcement operation in the fictitious mid-oceanic subcontinent of “Pacifica”. MSE capabilities included: a shared common operational picture with Blue Force Tracks; medical operations; medical surveillance; meteorological; unclassified medical intelligence; and tools related to pandemic influenza identification and response. The MSE prototype was found to possess military utility in support of the U.S. I Corps Surgeon (Ft. Lewis, WA), serving in the role of CJTF Deputy Surgeon. Detailed descriptions of that demonstration have been published elsewhere (see U.S. Army Medical Research and Materiel Command, 2007, and DeFraites and Chambers, 2007). Most importantly, this exercise validated the requirements for shared situational awareness. In preparation for support of Cobra Gold 06, medical situational awareness requirements were enhanced and added to those of the U.S. military’s global command and control system. In addition, the U.S. Joint Chiefs of Staff (2005) state that interoperability requirements for the CBRN and medical communities of interest were incorporated into joint warfighting doctrine. Following the successful operational test of the MSE prototype, the MSAT ACTD was transitioned to the Theater Medical Information Program (TMIP) to provide medical situational awareness and interoperability for TMIP’s portfolio of products.

Constructing the Human-Centric Decision-Making Framework

As we acquired experience during the development of the MSE and assessed the results of the exercise, we reviewed the original concept of medical situational awareness developed for the ACTD. Some potential MSAT users envisioned the
net-centric system as a decision-generating capability, rather than a decision-support capability, provided to the networked user and/or community of interest. We recognized the importance of continually reinforcing the user as the central focus of all net-enabled fusion of information technologies within the MSAT concept, specifically regarding situational awareness. The “user” might be a staff officer, an analyst, a consultant or advisor, or a commander. Users are at the core of situational understanding, and by extension, people are an indispensable element of decision support. The user must always be supported by networked information technology, not replaced by it.

We also realized that our concept should be extended to describe the relationships among situational awareness, situational understanding, actionable knowledge, and decision support. Finally, we recognized a need to establish a framework, including distinct spheres of tangible content, for visualization within the decision-making process. Figure 2 depicts the human-centric decision-making framework to illustrate the expanded concept. This framework is applicable to all human-centric decision-making, not just medical scenarios.

Figure 2. The Human-Centric Decision-Making Framework.
The proposed innovative framework comprises three domains or spheres: visualization; human; and information technology. First, the visualization sphere is driven by net-enabled fusion and includes situational awareness, situational understanding, decision support, and actionable knowledge processes. Second, the human sphere represents human-centric activities and the shared, tacit knowledge between individuals and communities. “Tacit” knowledge is defined by Nonaka (1994) as, “having a highly personal quality, that which is usually considered intuitive or instinctual – the ‘gut feeling’ – and thus usually difficult to formalize and communicate.” Analyses and collaborations are two examples of supported tacit knowledge. Lastly, the information technology sphere is composed of net-centric technologies and allows sharing of “explicit” knowledge. Explicit knowledge is defined by Nonaka as, “codified knowledge that is transmittable in formal, systematic language.” Explicit knowledge supports alerts and predictions.

Net-enabled fusion drives visualization and includes knowledge syntheses from the intersection of the human and information technology spheres. Knowledge synthesis may include functions such as organizational learning and adaptive systems. The decision-making framework includes capabilities to observe, assess, plan, and execute – all based on tacit knowledge. Decision-making framework capabilities align with specific visualization sphere processes: observe with situational awareness; assess with situational understanding; plan with decision support; and execute with actionable knowledge.

This perspective and framework has significant implications for military information management/information technology (IM/IT) operational and system architectures. Net-centric information systems must emphasize and enable human-centric decision support based on tacit knowledge, rather than, engaging in decision-making grounded solely on explicit knowledge. Both capabilities are necessary; however, the primary role of net-centric technologies should be to support human-centric decision-making.

**Actionable Knowledge and Situational Awareness**

Actionable knowledge is the culmination of situational awareness. The objective of decision support is to translate situational awareness and understanding into actionable knowledge. These are primarily human-centric activities. Figure 3 depicts the relationships between systems, services, and communities that serve to provide timely, actionable knowledge to a commander. There are two areas of emphasis within Figure 3. First is the human-centric orientation of net-centric capabilities. This is depicted by the human icons centered between alerts, analytics, and adaptive planning in order to enable human production and dissemination of actionable knowledge. Second is the hierarchical relationship of net-centric services providing a common operational picture that, in turn, supports actionable
knowledge. Higher order functions are more human-centric and are focused on tacit knowledge.

Figure 3. *The Actionable Knowledge Pyramid.*

Medical capabilities and force structure are examples of operational medical courses of action that surgeons must recommend and commanders must approve or redirect in-theater. Details include: distribution and location of medical assets; facilities; evacuation; special teams; and personnel. Commanders analyze and approve courses of action with inherent policy forecasts of disease and non-battle injury, wounded-in-action, medical days-of-supply, and adjustments for theater evacuation. Integrated, medical situational awareness and actionable knowledge permits analytic workflow in support of the military decision-making process. Figure 4 provides the model for integrating medical analytic decision support into a command staff workflow model which may be included within the military decision-making process in operational settings.
Relevant risk matrices are accessed via net-centric services to provide communities of interest the capability to aggregate vast volumes of indicator data/information. In the context of net-centric services, categorical thresholds may be set, reportable indicators required, and filters applied to establish analytic priorities and produce actionable knowledge. Prioritized indicators are also used to adjust the criteria to continually monitor aggregate indicators as a component of situational awareness.

**Applying the Human-Centric Decision-Making Framework**

The scenario used for the MSE demonstration at Cobra Gold 06 included the discovery of human-to-human transmission of avian influenza during humanitarian assistance operations. The spread of avian influenza from birds to man is a matter of considerable health concern. However, substantive evidence of person-to-person, avian influenza virus transmission represents a sentinel event signifying the
potential for broad and rapid spread (i.e., pandemic) of influenza in human populations around the world.

The MSE provided a rudimentary algorithm to enable primary health care providers to view and evaluate data from patients diagnosed with influenza-like illnesses for exposure history and evidence for potential human-to-human transmission of avian flu. When the evidence suggested a case of human-to-human avian influenza, specialized medical personnel were automatically alerted. Simultaneously, the scenario presented the staff with supporting evidence of influenza-like illnesses within the indigenous population as a whole. Laboratory, field, and surveillance tools produced threshold and reportable indicators to establish and track simulated human-to-human spread of avian influenza.

The medical use of a common operational picture enabled fusion of situational awareness and actionable knowledge from medical and non-medical communities of interest. Human-centric knowledge synthesis within the medical communities of interest provided the commander with the decision support capability for successful completion of the peace enforcement mission. The medical workflow required to respond to the human-to-human avian influenza outbreak and peace enforcement operation command and control processes to observe, assess, plan, and execute were fully integrated in the decision-making framework. These aspects of the scenario exemplify the structures and functions that are depicted in Figures 1-4.

With the global reach of adversaries, an emerging health threat may be a naturally-occurring disease or a CBRN event, and the consequence management alternatives may be equally far-ranging. Regardless of the nature of the health threat, across the range of military operations and other agencies of government, there are increasing requirements to achieve medical situational awareness, integrate with non-medical situational awareness, and produce actionable knowledge to support “observe, assess, plan, and execute” processes in an integrated decision-making framework. The capability to separate useful information from the overabundance of raw data and to focus human talent is dependent upon net-enabled fusion of communities, technologies, and appropriate algorithms and filters.

The integration of actionable knowledge into shared situational awareness within operational environments enables several key activities. For instance, military leaders have increased capability to match relevant information, tools, and expertise to operational requirements. Creating tacit knowledge from explicit knowledge and then combining tacit and explicit knowledge to produce actionable courses of action comprise only two parts of the human-centric decision-making framework. Analysts and knowledge managers have increased capability to capture lessons learned and translate tacit knowledge into explicit knowledge. Our field experiences with the MSAT prototype MSE were captured within the
human-centric decision-making framework and articulate the architectural integration of situational awareness and actionable knowledge.

Given the increased situational awareness and actionable knowledge achieved by using the MSE, the medical community of interest was able to integrate epidemiology within the commander’s military decision-making process at Cobra Gold 06. An optimal balance was achieved with automated systems providing explicit knowledge and medical experts sharing tacit knowledge. This optimal balance of bringing people and systems together produces a synergy analogous to massing forces. Combining the analytic capabilities (both the expertise and the tools) within the relevant operational environment at Cobra Gold 06 enabled the multi-community collaboration and multi-mission adaptation envisioned within situational awareness.

**The “Goals”**

In this article we have discussed shared medical situational awareness, but we employ the medical perspective merely as an example to demonstrate the benefits to be gained through the collaboration of diverse and networked communities of interest. The scope of application could certainly be extended. For instance, interdependent communities of interest other than those discussed above possess the agility to support commanders with fully interoperable staff processes and decision support in rapidly changing and novel situations. We believe that the most important aspect of this increased potential is the return to fundamental principles and unity of effort. “Methods” remain more people-oriented, while “Tools” have become more technology-oriented in high technology, complex systems. The “Goals” are uniquely human-centric over time.

Discussion of a revolution in military affairs has waned, in particular the “newness” of technology as a centerpiece of transformation. Barno (2006) maintains that global insurgencies and asymmetric vulnerabilities inherent in 4th Generation Warfare confound the benefits of net-centric operations in a network environment. High technologies, including information technology, or “information dominance”, should never be viewed as an automatic means to replace boots (or brains) on the ground, particularly in COIN operations. Technology is never an end in itself. Indeed, technology arguably represents a source of increased vulnerability and decreased resilience and adaptability in an asymmetric conflict. Resilient, adaptable, human-centric processes have advantages across the range of military operations and technologies.

The ongoing evolution of technology within the current environment requires a return to basics, not just for boots on the ground, but understanding the indispensable value of the human in analytic processes. Actionable knowledge must be focused on the decision-maker being enabled with the right information, in
the right situation, and at the right moment. Likewise, the production of actionable
knowledge must also be understood in a context of engaging the right communities
of interest, with the right situational awareness, in support of the right
decision-makers. Net-centric capabilities, with robust analytic tools and with
information fusion, are not relevant unless the right situational awareness is
presented to the right communities of interest in support of the right commanders.
This return to basics may be best appreciated as a neo-orthodox view that people
provide the best agility across the continuum of asymmetry with technologies
enabling human-centric networks. According to the Department of the Army Field
Manual (2006), keeping the human central in the loop at the tactical level has
certainly been re-emphasized in clear-hold-build COIN operations.

Our experience with medical situational awareness allowed us to understand that shared situational awareness must be derived from people collaborating across different communities of interest. Complex, interdependent, and fluid environments require human-to-human collaboration, empowered by the most appropriately-scaled systems. In fact, there is a convergence of business processes common to medical situational awareness and other communities of interest, such as CBRN, humanitarian assistance, and COIN operations. For example, COIN operations not only may benefit from medical situational awareness, but may also benefit directly from using the human-centric decision-making framework. Gompert (2007) states that global COIN strategies are particularly human-centric, and require networked information to integrate cognition and intuition for critical decision-making including reasoning and self-awareness.

Discussion: Collective “Goals” with Mutual “Methods” and “Tools”

There are many applications for shared business processes within a human-centric decision-making framework. Here, we employ current events to help conceptualize the proposed framework.

There are several valuable lessons learned from this field exercise. First, awareness of the medical situation (e.g., forces down, forces returnable to the front, forces being evacuated) is a force multiplier. In current austere operations, it is anticipated that the adversary will not have the “medical force multiplier” that we enjoy. This in and of itself could be exploited for our forces’ comfort, our adversaries’ dismay, and for public consumption. Second, a current case in point is the analog between disease vectors, such as mosquitoes that transmit malaria and other infections, and the vectors or carriers of global jihad. A counter-epidemic approach has been directly applied to counter-insurgencies. Strategic goals to “contain, protect, and remedy” in a model of “host, agent, environment, and vector” are best articulated within an epi-COIN model. Stares and Yacoubian (2006)
maintain that individuals, cells, and organizations are hosts. Islamist militant ideology is an agent. Conflict, political, economic, and social conditions are the environment. Mosques, madrassahs, the Internet, prisons, media, and social networks are vectors.

Several advantages of the human-centric decision-making framework warrant notice here. It enables the integration of situational awareness and actionable knowledge for many like-kind activities which are joined together in the same endeavor. The ability to share analytic processes and models within a common framework allows many higher-order synergies. The complexities inherent in globalization present new challenges with increasing interconnection of populations. To remain relevant, models and business processes must evolve in parallel with increased complexity in the environment. Mosquito control was one of the fundamental strategies to reduce disease – just drain the swamp. Ecological models later showed the need for wetlands preservation. The strategy to control or eradicate disease had to evolve beyond the single strategy of elimination of wetlands.

In summary, open and adaptive systems provide increased synergies, are more resilient, and reduce unanticipated consequences in complex environments. Since our asymmetric vulnerabilities increase as we become more interconnected by continually-increasing globalization, we must be sure that we also obtain the benefits of being more interconnected. Since the beginning of humanity, fighting disease has been the ultimate asymmetric conflict. In today’s environment, the collective advantages of a human-centric, decision-making framework in the continuing struggle to prevent and control diseases are extensible to other communities of interest with remarkably similar requirements. Situational awareness has rapidly progressed with technical innovation. Yet, in order for advancements in technology to remain relevant, rapid progress in how we work together must keep pace with the technologies that unite us.

References


