MODELING HUMAN FACTORS INVOLVED IN CHEMICAL/BIOLOGICAL WARNING & REPORTING

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ABSTRACT

Chemical, Biological, Radiological, and Nuclear Warning & Reporting (CBRN W&R) is a key component of force protection. The task of CBRN W&R and CBRN defense is largely coordinated and executed by a CBRN Cell that interacts with a wide range of individuals, environmental queues, and sensors in order to collect, synthesize, and analyze data pertaining to a possible CBRN attack. The work presented here describes a qualitative model of operations in a CBRN Cell and the associated performance and decision making as well as a translation of the qualitative model into a quantitative Human Factors Agent (HFA). The software implementation of the HFA will assess situations, take actions, and make errors as would a human CBRN W&R officer.

INTRODUCTION

In order to create a model of CBRN W&R as it pertains to a CBRN Cell one must attempt to capture the procedures, response times, and mistakes the individuals operating within the Cell make during exercises and real-world situations. Individuals within a CBRN Cell are often inundated with messages from multiple sources via multiple communication devices and the challenges presented by this environment need to be captured and quantified in order to accurately represent the roll of the CBRN Cell.

The HFA is designed to take the place of a human-in-the-loop for testing and evaluation purposes. It is based on a qualitative model of human performance and factors within a CBRN Cell, developed through Cognitive Task Analysis (CTA). CTA techniques provide a set of tools for eliciting domain knowledge and key aspects of human performance and expertise within a given work environment. The HFA interfaces with the Joint Warning & Reporting Network (JWARN) as well as simulated communication devices (phone, fax, email, etc) for sending and receiving messages regarding the suspected CB event, carrying out the tasks of a CBRN Cell that are consistent with real-world practices.

BACKGROUND

Methods for conducting CTA have evolved from the study of Naturalistic Decision Making (NDM), a field of study pioneered at Klein Associates Division of ARA. Naturalistic Decision Making is the study of how people perform and make decisions under conditions of stress, time pressure, high consequences, and ambiguity[1]. A major objective of NDM is to understand the cognitive processes employed during task performance within the operational environment.

CTA comprises a series of techniques for knowledge elicitation and knowledge representation[2]. We have found that no single method works well in all cases – they must be combined and adapted to suit the needs of each domain. The methods that are most effective in each domain depend on the characteristics of the task, the characteristics of the operators, and the conditions under which they must perform the task. The CTA toolkit includes a number of different knowledge elicitation techniques that have evolved over the past two decades. For this project, our primary CTA have included a combination of incident-based techniques for both individuals and teams. These methods have been combined with naturalistic observation of the operator within his operational environment.

The HFA is based on a Bayesian Recognition Decision Model (BRDM)[3], a Bayesian implementation of the recognition-primed decision model[4] based primarily on models of episodic recognition memory[5,6]. Bayesian models of psychological processes offer principled approaches to understanding how evidence is used in various decision processes. These include decisions about episodic memory[5,7], semantic knowledge[6], perceptual judgment[8], and word recognition[9].

The challenges faced by the HFA include a low-incidence of actual CBRN events combined with a high-incidence of false alarms and incomplete data. The HFA must de able to discern real evidence of a CRBN attack from false alarms that could come from faulty sensors, panicked individuals, or a lack of pertinent data. The BRDM model fits the requirements of the HFA by accounting for sensor reliability, the likelihoods of certain CBRN events taking place (based on daily situational reports), and the likelihood that observed evidence of a CBRN attack can be present in the absence of a CBRN attack. In order to create the HFA, the BRDM is paired with a procedural component that looks for information to prove or falsify the existence of a CBRN attack via available resources and sensors.

The underlying BRDM equation that determines if datum *i* is evidence towards CBRN event *k* for the HFA is given by:

$$\lambda_{ik} = \frac{\hat{r}\times\hat{G}_{ik} + (1-\hat{r}\times\hat{F}_i)}{\hat{F}_i} \tag{1}$$

where:

- λ_{ik} denotes the likelihood ratio that evidence *i* pertains to CBRN event *k*,
- $\hat{r}$ is the HFA estimate of a sensor's reliability
- $\hat{G}_{ik}$ is the HFA estimate of the binomial probability of evidence *i* for CBRN event *k*,
- $\hat{F}_i$ is the HFA estimate of the likelihood that observed evidence *i* can be present in the absence of a CBRN attack.

The likelihood ratio of CBRN event *k* given all available evidence is given by:

$$\lambda_k = \frac{\hat{q}(k)}{1-\hat{q}(k)} \prod_i \lambda_{ik} \tag{2}$$

where $\hat{q}(k)$ is the likelihood of a particular CBRN attack (VX, anthrax, radiological, TIC, etc) given information from the daily situational report.

METHODS

The qualitative model of human performance is based on CTA techniques applied to operator interviews and exercise observations. We interviewed a total of 15 former and active CBRN W&R officers and Subject Matter Experts (SMEs) from the Army and Air Force and observed an exercise at Tyndall AFB's Silver Flag and the JWARN/JEM Multiservice Operational Test & Evaluation (MOT&E) at Ft. Hood. These interviews and observations gave us a firm understanding of the methods and techniques used by CBRN W&R officers and allowed us to compare what is actually done versus what should be done according to doctrine. In analyzing the data we've developed a comprehensive qualitative model that applies the factors effecting W&R tasks and performance to the future vision of the JWARN program.

Translation of the qualitative model to a quantitative model and to an intelligent software agent are accomplished by breaking the CBRN environment down into possible attack evidence, available resources (both human and mechanical/electronic), and preferred communication methods (with an eye towards future JWARN increments). Initial likelihoods of attacks and event evidence as well as perceived sensor reliability have been derived from the interview data. Those parameters will be refined in the coming year as we test the performance of the HFA against a human's performance using the Model Analysis & Verification ENvironment (MAVEN) [10], a testbed that simulates the players and injects that a CBRN Cell will deal with during an assumed CBRN attack. A small-portion of the proposed likelihoods and CBRN environment data is shown in Figure 1.

	Event	No Attack	Conventional	GB	VX	HD	Anthrax	Ricin	Radiological	TIC
	Event Likelihood	0.45	0.19	0.04	0.1	0.04	0.01	0.02	0.075	0.05
Evidence	Evidence Likelihood									
Attack Confirmation	0.25	0	1	1	1	1	1	1	1	0
Small explosion	0.3	0	1	1	1	1	1	1	1	1
M8	0.005	0	0	1	1	1	0	0	0	0
M256A1	0.005	0	0	1	1	1	0	0	0	0
Portal Shield	0.001	0	0	0	0	0	1	1	0	0
Persistent	0.005	0	0	0	1	1	0	0	0	1
Coughing	0.1	0	1	1	0	0	0	1	0	1
Miosis	0.005	0	0	1	1	1	0	0	0	1
Dead Fauna	0.2	0	1	1	1	1	1	1	1	1

FIGURE 1. Proposed likelihoods and possible present (1) or absent (0) evidence for a sampling of CBRN events and evidence.

DISCUSSION

A proposed qualitative model of CBRN W&R processes for an OCONUS airbase, the basis for our planned testing environment and scenarios, is presented in Figure 2. This model highlights the sensors and resources that the CBRN Cell interacts with, the modes of communication used by the CBRN Cell, and the reachback, evaluation, and synthesis process that the CBRN Cell employs. Most processes or tasks from Figure 2 have cognitive functions and errors associated with them that are further described below.

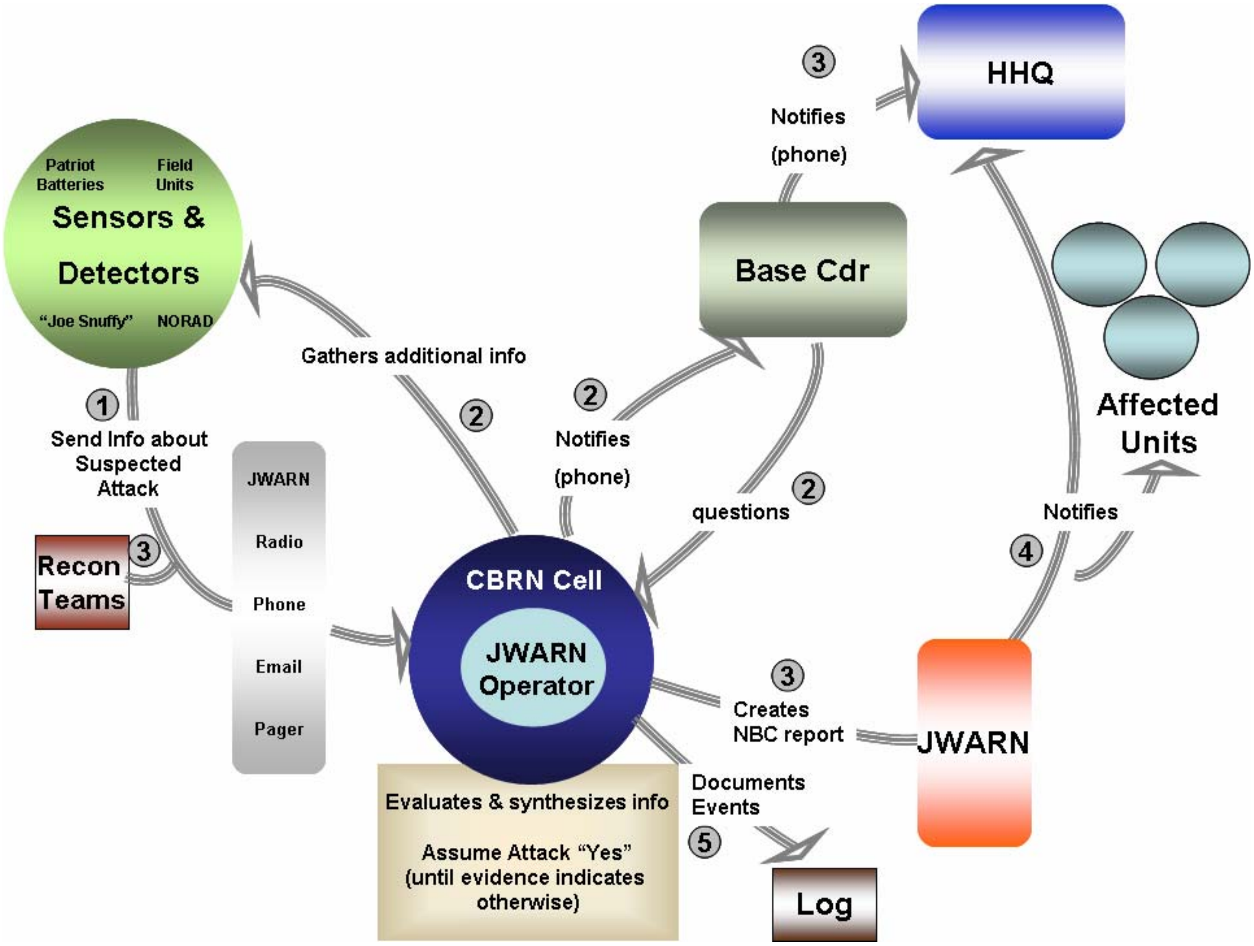

FIGURE 2. Proposed qualitative model of CBRN W&R processes.

Some of the cognitive tasks associated with the processes shown in Figure 2 include:

- Determining who needs to know important information and when they need to know it,
- Which questions should be asked and what information is needed,
- Eliciting information from panicked individuals,
- Determining the extent to which a report is consistent with the known threat and enemy capability,
- Determining the level of trust associated with the source of a report,
- Determining a reports consistency with other reports,
- Balancing keeping troops safe versus causing panic and wasting resources,
- Determining MOPP levels, decontamination areas, etc,
- Determining agent type and wind direction.

Some of the common errors associated with the processes shown in Figure 2 include:

- Not reaching back to primary sources for clarification of additional information,
- Over-reacting,
- Passing report on without assessing validity,

- Using wind direction incorrectly or misidentifying agent type.

Finally, some of the contextual factors under which the processes from Figure 2 are performed include:

- An awareness of high false alarm rates,
- An awareness of high risk,
- Fatigue,
- Location: CONUS or OCONUS,
- Time pressure,
- Environmental stressors (heat, noise, etc.).

CONCLUSION

The proposed HFA will capture most of the cognitive tasks, common errors, and contextual factors via the event and evidence likelihoods in conjunction with the procedural tasks and resource knowledge programmed into the source code. Results from the initial HFA have demonstrated synthesis of information from multiple sources and formation of hypotheses on the potential types of CBRN attacks and highlight the information required for a firm conclusion about the CBRN environment.

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