Identifying User Requirements for a CBRNE Management System: a Comparison of Data Analysis Methods

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ABSTRACT

The purpose of this paper was to identify an effective user-requirements data analysis method for informing the design of a Chemical, Biological, Radiological, Nuclear, and Explosive (CBRNE) management decision support system. Data were collected from a large simulation involving medical, police, hazmat/firefighters and subjected to three different kinds of analysis methods: Social Network Analysis, Content Analysis, and Observational Analysis. While all three methods yielded valuable information, the observational method was by far the best for the present purpose.

Keywords

Chemical, Biological, Radiological, Nuclear and Explosive events, Social Network Analysis, Content Analysis, Observational Method, User Requirements.

INTRODUCTION

Large-scale emergency situations involving mass casualties such as Chemical, Biological, Radiological, Nuclear or Explosive (CBRNE) disasters can unfortunately unfold very quickly anywhere in the world. Because the management of CBRNE attacks is far from a routine matter, it is difficult to generate suitable user requirements for software aiming to support the management of such events. Making sense of the large amounts of incoming information to the command post, especially in the early stages of managing a CBRNE event, is a huge challenge for the various agencies involved. Yet, the ability to interpret that information quickly and accurately is precisely the basis for making good decisions. As data cannot be obtained from real adverse events, large-scale simulations are occasionally conducted in which the first-responder agencies take active part. These simulations are typically driven by a fictitious, yet credible, scenario about an event that the responder teams are then tasked with managing. The data analyzed and reported in this paper were obtained from such a simulated event, described in more detail later.

In CBRNE events, the immediate area around the threat is called the hot zone, which is surrounded by the cold zone, a safe area where emergency crews and the command post are set up. When a CBRNE incident occurs, the emergency response team typically includes Emergency Medical Services (EMS), police and their teams (generalists, bomb technicians, identification officers), fire fighters and their specialized team of hazardous materials technicians (hazmat), and other first responders. Each agency has its own team leader who coordinates their operational responder team at the same time as coordinating actions with the other team leaders in the Command Post.

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To prepare first responders for CBRNE events, they undergo Simulation-Based Training (SBT) (Salas, Rosen, Held and Weissmuller, 2009). In Canada, such training is offered in special CBRNE training facilities in Ontario and Alberta. SBT provides structured learning experiences that are crucial to respond effectively to real CBRNE events. Fully-fledged scenario-driven field simulations may involve hundreds of people and include entire response teams as well as hired laypeople acting as casualties in the event.

A high level of Team Situation Awareness (TSA) in the command post is clearly important throughout such a dynamic simulation exercise. It can potentially enhance first responders' performance by minimizing the chances of potential breakdowns in communications that may result in additional adverse events (Gorman, Cooke and Winner, 2006; Son, Aziz and Pena-Mora, 2007). However, disasters that are characterized by highly unpredictable conditions often result in a delay between information acquisition and response in addition to differences between actual and perceived data (Son et al., 2007). A CBRNE event may, for example, require chemical decontamination to prevent further harm from the chemical exposure while also protecting health care providers (Liudvikas, 2008). Depending on wind and other meteorological conditions as well as on the amount of agent released, the dispersion dynamics of chemical agents rarely follow a 'straight line', since chemicals and gases may spread unpredictably. In the absence of effective information sharing, the severity, and types of disruption and damage are often unknown or underestimated early in the crisis. Thus, key challenges in disaster response include accurate assessment of an existing situation, collection of accurate and relevant data from the disaster scene and its analysis and transmission to the relevant personnel at the right time.

Studies of TSA tend to focus on either knowledge- or performance- based measures (Gorman et al., 2006; Yanco and Drury, 2004). Knowledge-based approaches rely on retrospective verbal protocols (Kuusela and Paul, 2000) which are marred by the unreliability of introspection and memory decay through the passage of time. Explicit performance-based measures probe individual team members' Situation Awareness (SA) by asking questions during randomly timed and spaced temporary 'freezes' of the exercise. While studies have shown that temporary freezes do not significantly affect performance (Endsley, 1990), the intrusiveness of this technique even during simulated emergency management scenes is a serious limitation (Endsley, 1995). Implicit performance measures focus on the assessment of task performance. In highly dynamic situations where there is often little time for reflection, action tends to guide perception and vice versa (Gorman et al., 2006). Performance on a given task may not make sense without considering the overall picture. Methodological limitations aside, it was not possible to apply any of the TSA methods in the simulation in which our data were collected. It is therefore unclear which of these methods may offer the best basis for identifying user requirements. By reporting the outcomes of three other data analysis methods, this paper aims to provide insight into the merits of each method specifically when seeking to derive user requirements for a decision support system to facilitate CBRNE event response management.

A prototype of this system was designed to record event data and it provides access to a suite of CBRNE event management software applications. It also has a feature that supplements communication within the command post, where it is often very busy and noisy, with multiple radios going simultaneously. The prototype will not replace radios. Rather, its purpose is to integrate communications and information during a CBRNE event, which also helps the various agencies to produce an incident report after the event.

The remainder of the paper is organized as follows. First, the data collection context is discussed, followed by a discussion of the way the event was re-constructed to yield a complete data file on the basis of which the data analyses could proceed. Next, the three data analysis methods are described, one at a time, in an effort to ascertain the merits of each for the purpose of generating user requirements for a management decision support system. To that effect, Social Network Analysis is discussed first in some detail. It is followed by a discussion of the particular content analysis employed, and finally, the observational method used is reported. The results are briefly discussed, and finally the limitations of the study are presented together with plans for future research.

DATA COLLECTION

In April 2009, a half-day CBRNE SBT exercise was conducted at a large indoor sports center in central Toronto, Canada. The simulated training event was just under three hours long. According to the scenario, an unidentified object had been thrown from a higher-level seat onto the lower section of the arena during a baseball game said to be ongoing at the time the response teams arrived on the scene. As in a real situation, a command post was set up to gather all of the necessary information and to manage the emergency response. A tent had been set up in the cold zone in advance because the early prototype of the CBRNE event management support system was also trialed in the exercise. Four laptop computers equipped with the prototype had been booted up for the command post team leaders. Once they arrived on the scene, they were provided with assessments of the situation from the first responders who were already inside the sports arena. The entire arena was designated as the hot zone. Communication between first responders and the command post continued throughout the entire SBT event via radio and face-to-face conversations. Finally, a one hour briefing session involving all participants in the exercise was conducted to provide feedback.

For the purpose of our part of the project, the main participants were the command post team leaders, composed of one hazardous materials (hazmat) expert, two Emergency Medical Service (EMS - paramedics) officers, one bomb technician and one identification expert, both part of the police force. Additional participants included all the responder teams working in the hot zone, the dispatch people at the base stations with whom other participants outside the CBRNE event were also interacting, and others who were in charge of the exercise. As the purpose of the present analysis was to generate user requirements for a CBRNE command post support system, five researchers each focused on different aspects of the event management. One researcher observed activities in the command post as a whole, while a second member always remained inside the hot zone. At all times during the exercise, the remaining three research team members observed the command post team leaders. One researcher observed the two EMSs, the second observed the hazmat expert, and the third observed the two police officers (bomb squad, identification officer). Each researcher was equipped with a video camera, an audio recorder, and a note pad enabling them to capture all of the activities of the command post team leaders as well as the activities inside the hot zone. The four laptop computers in the command post were assigned to each of the three participating agencies (EMS, hazmat, and police) as well as to the simulation leader who, in this case, was the bomb technician. Thus, the police force had two laptop computers at their disposal. Each command post team leader had their radio running at a specific, unique frequency and was also responsible for his responder team in the hot zone, whose radios were connected to their team leader's. Responders reported only to their own team leader. As much as possible, the researchers recorded these two-way radio conversations as well.

Before any of the analysis methods could be performed, all verbal interactions between command post members and their responder teams, both in person and via radio communication, were recorded. After the event, the video and audio recordings were transcribed ad verbatim and merged into a single file together with any notes taken, arranged in a minute-by-minute fashion as shown in Table 1. That way, the entire event was reconstructed. This transcript was the basis for the three analysis methods reported here. The transcript data file below made it easier to compare activities across all command post participants at any point in time during the exercise. Since multiple recording devices were being used simultaneously throughout the event, certain situations were captured on several records. This proved to be an advantage because one camera would sometimes miss what another one would catch more clearly; gaps in the transcript were therefore filled by consulting both records. All textual duplications between the video and audio recordings or between recordings made by different researchers were removed, leaving us with a complete and unique dataset. All the researchers viewed the recordings several times to identify and verify the identity of the senders and recipients of verbal communications. In order to focus the analyses, any conversations unrelated to the event management were removed from the transcript. All of these edits were done to ensure that the transcript was as accurate as possible to enable further data analyses to be performed. The goal of all of this was to identify all those instances in which communication in the command post could benefit from technological support.

Time	Source	EMS	Police	Hazmat
10:33	Video	SE's Radio: Right now we are looking at 2500 potential victims and that is a very small guesstimate. (SE quickly scribbling down message from radio) SE: Do we know what they are complaining of? SE's Radio: Itching, burning – nausea.		**File 141203 (8:10)** BH's Radio: Exercise, exercise, exercise – HazXXY responding. (pause)
10:34	Video	SE to NP: 10:31 MC… SE's Radio: A white powder substance like talcum powder – about 200 people – some are coughing – some are itching and sore eyes…	NP to radio: So you are gonna have to update me – so what we got, Mate?	BH's Radio: The section has been locked down, over.

Table 1. Format of the Transcript used for Data Analysis

Table 1 shows the time of observations in the leftmost column. The second column gives the original data source (video, audio, notes). Data obtained from each agency is in the three rightmost columns. Next, the data were entered into NVivo version 7.0 software for further analysis. NVivo facilitates qualitative data analysis by allowing digital coding of all the data in the data file. None of the formal analysis methods employed enabled the tracking of non-verbal behaviour. However attempts to identify and interpret instances of non-verbal behaviour revealed very few of these. The few that were found and that could be unambiguously interpreted were coded as verbal behaviours (ex. a thumbs up to signal that a message was received was coded as a confirmation). The three data analysis methods are discussed next, one at a time.

Social Network Analysis

Social Network Analysis (SNA) is gaining popularity for analyzing emergency response data. It was selected here because the team leaders in the command post fulfill different individual user roles that may require immediate access to different kinds of information and various levels of ability to broadcast messages. The SNA began with the construction of a communication network matrix, which shows the frequency of verbal communication between agency personnel. Then a connectivity graph was created, which displays the extent to which each agency member communicated with each of the others. The outcomes of the two analyses are then compared to show the kind of information each approach yielded.

Communication Network Matrix

In SNA, a 'social unit' is an entity that can be connected to another unit via some sort of interaction such as verbal communication. It allows researchers to describe the structure and pattern of the relationships between social units (Streeter and Gillespie, 1992) as these emerge via interactions. The social interaction considered here for SNA concerns the instances of verbal communication from the SBT transcript.

Centrality is a widely studied concept, measuring properties relating to the structural importance or prominence of a social unit in the network. *Sociometric status* is a centrality measure of how busy a social unit, *a*, is relative to the overall number of units in the network. Basically, all communications going to and coming from a social unit are added up and divided by the total number of social units in the network, excluding itself. Each unit has its own sociometric status, the average number of instances of communication made by each social unit. The total network is given by the square matrix *X* with *g* rows and columns, where *X(i,j)* denotes the number of instances of communication from unit '*j*' to unit '*i*'. The sociometric status is given by the following formula: $SS(a)=(X(a,1)+X(a,2)+\ldots+X(a,g)+ X(1,a)+X(2,a)+\ldots+X(g,a))/(g-1)$. This formula assumes $X(i,i)=0$. The sociometric status and connectivity of a social unit are correlated.

Table 2 shows the network matrix described above. It displays communication between listeners and speakers during the CBRNE SBT event. All of the communication instances are included. In Table 2, 'A' represents the hazardous materials expert, 'B' and 'C' represent the two emergency medical service officers, 'D' represents the bomb technician, and 'E' represents the identification expert. Additionally, 'Haz', 'EMS', and 'Pol' are in-person verbalizations made to and from team members in hazardous materials and the fire department, emergency medical service, and police officers respectively, who were not part of the command post.

	Speakers								
Listeners	A	B	C	D	E	Haz	EMS	Pol	Totals
A		16	18	45	13	13	0	4	109
B	35		24	28	8	0	13	4	112
C	31	21		31	5	4	7	2	101
D	55	21	28		29	0	2	11	146
E	31	11	15	44		0	0	0	101
Haz	9	0	4	0	0		0	0	13
EMS	1	15	11	5	0	0		0	32
Pol	2	3	2	22	1	0	0		30
Totals	164	87	102	175	56	17	22	21	644

Table 2. Frequencies of all Verbalizations, from Speakers to Listeners

The CBRNE SBT event observed has some directional interactions, meaning that a connection could exist between two social units, but that the communication was one-way (i.e. never received a direct response). However formulas from the literature only use bidirectional interactions. For the purpose of the SNA, directional interactions were treated as if there were bidirectional so that they could be included in the analysis.

The sociometric status was calculated for each social unit, using the communication frequencies in Table 2. The calculations for sociometric status are: SS(A)=(109+164)/7=39, SS(B)=(112+87)/7=28.43, SS(C)=(101+102)/7=29, SS(D)=(146+175)/7= 45.86, SS(E)=(101+56)/7=22.43, SS(Haz)=(13+17)/7=4.29, SS(EMS)=(32+22)/7=7.71, SS(Pol)=(30+21)/7=7.29. For example for C, listening frequency was 101 and speaking frequency was 102. These values were summed and divided by the number of possible people C could have been listening or speaking to, in this case, 7. This yielded a sociometric status for C of 29.

Connectivity Graph

Connectivity measures determine a social unit's direct connections to other units in the network (Meneely, Williams, Snipes and Osborne, 2008). To see how a social unit communicates with other units, several calculations need to be made. A unit is *disconnected* if it has no connections to other social units. The *degree* of a social unit is a primary connectivity metric that measures the number of connections on a social unit (Meneely et al., 2008). This measure shows how many people one person communicates with during an event. This is important to know when attempting to identify the most important people in a social network. The units that have the highest degrees are called *hubs*, and are the most connected. A social unit is a *key player* if its removal results in network fragmentation or significantly increases the path length between the remaining social units. Key players must be kept informed and updated at all times during a CBRNE event so that everyone in the network can have access to information.

The *geodesic distance*, sometimes referred to as the *degree of separation*, denotes the number of communication interactions that need to occur in order to connect two social units. The shortest, non-repeating path between two social units is called the *geodesic path*. The opposite of this is a network's *diameter*, which is the longest possible geodesic distance between two units via a series of neighbouring units (Meneely et al., 2008). This information is important because it depicts how information travels and how quickly that information can be passed off to others who need it. A low geodesic distance makes a social unit a convenient choice to relay messages, thus increasing its sociometric status.

The connectivity graph for this event is shown in Figure 1 (this graph does not use weights on edges). It shows which social units communicated with each other. Team leaders A and C communicated with all other people in the network and have a degree of 7. This makes them hubs because this is the highest possible degree in the network. Team leaders B and D have a degree of 6 because they never communicated to Haz. Person E and the group of Pol each have a degree of 5, the EMS group has a degree of 4, and Haz has a degree of 2.

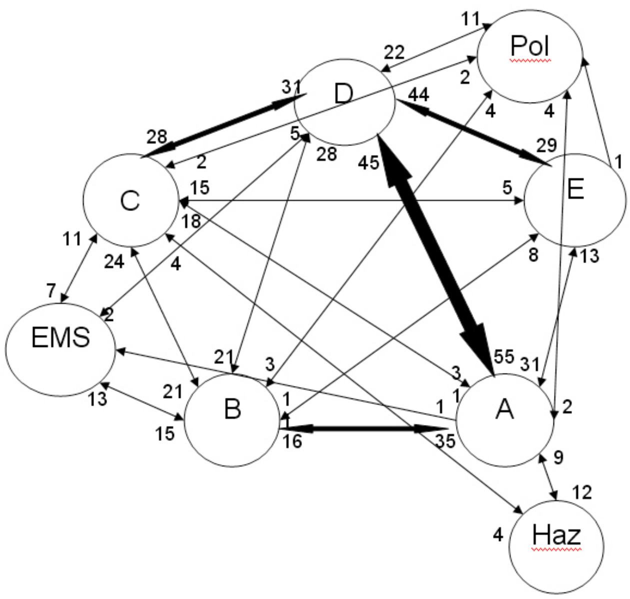

Figure 1. Connectivity graph and weighted SNA from the CBRNE SBT event, corresponding to speakers and listeners (A, B, C, D, E, Pol, EMS, Haz) and values (weights) from Table 2.

The entire graph is connected; there are no disconnected units. The deletion of any unit preserves graph connectivity, so there are no key players in this scenario. Therefore, this connectivity measure suggests that the management system should have the ability to create group notifications because all members in the command post are important. The geodesic distance from A and C to all other social units is 1, because they communicate directly to all the other units. They also provide an indirect link to any pair that does not communicate directly, so that the rest of the social units have a geodesic distance of 2. Since the maximal geodesic distance between any two units is 2, the diameter of the network is only 2. A low geodesic distance makes a social unit a convenient choice to relay messages. If the system keeps track of who has the shortest geodesic distance, it can let users know who to inform about events so that other can get informed rapidly as well.

Comparing the communication network matrix (weighted SNA) to the connectivity graph, two different interpretations of the data were possible. Team leader D has the highest sociometric status although it is not among the highest in connectivity because it is missing a connection to Haz. This suggests that both connectivity and sociometric status should be calculated when attempting to interpret the meaning of the interactions and generating an understanding of the users' needs. In the present case, the connectivity diagram suggested that the hazmat team leader, A, was central to the operation. However, the bomb technician, D, had the highest sociometric status. In fact, D was the event leader of the management team. Thus, if only the connectivity had been completed, this could have been misleading. Clearly, the event leader must be able to access all event information, which may not be the case for the other team leaders. The event leader's role still needs to be refined to determine exactly which information he needs in addition to that which everyone else needs.

The SNA revealed six user requirements. One that follows from the connectivity graph is that the system should know who in the command post needs to communicate what information with whom to ensure that the information reaches the intended individuals via the appropriate channels. It also suggests that a facility should be provided to enable individuals in the command post occasionally to engage in private one-on-one communications, or in communications with a subset of the management team. The geodesic distance metric suggests that the sender of a message should be able to select recipients and that the system should notify the recipient as to who else may need also to receive the message in the case of a geodesic distance of 2 because the message must travel.

Content Analysis

Since we had transcribed the entire simulation exercise, it made sense also to include a content analysis. Content analysis is a widely used research technique (Hsieh and Shannon, 2005). The nature of content could be manifest or latent. Manifest content is easily observable and objective (Rourke, Anderson, Garrison and Archer, 2001) and it is analyzed using Quantitative Content Analysis. Based on verbatim transcripts, it can measure the active participation of individuals by counting the number of times an individual spoke, the interaction of individuals based on the number of times one person communicated to another, and the frequency of use of particular words. Analysis of quantitative research data consists of three main steps. Assuming that the communications are already recorded in a text file format, in the first step, a protocol is created for identifying and categorizing the target variables. The second step involves researchers, also known as coders in this case, who apply these categories to the transcript. In the third step, the coders' data are then analyzed to describe the targeted variables and their relationships. This technique helps researchers extract meaning from event transcripts (Rourke et al., 2001).

Content could also be latent. Latent content is not directly observable and must be uncovered from transcripts. Examples include the use of humour which depends on context and cultural interpretation, critical thinking, judgment, initiative, and other cognitive dimensions (Rourke et al., 2001). Such data require a type of analysis known as Qualitative Content Analysis. Qualitative data analysis is often subjective. Similar to quantitative analysis, coders use a systematic classification process to discover themes in the data (Hsieh and Shannon, 2005). This systematic classification, also known as categorization, is used to subjectively interpret the meaning of the text content. The difference is that manifest content analysis has objective categorization of easily quantifiable properties, and latent content analysis requires the interpretation of data before categorization. Once the interpretation has been made and the data are coded, all codes are summed and tallies of categories are compared to infer meaning of the data.

Categories may be derived by induction or deduction. Inductive analysis gradually generates categories from transcripts. This process can be considered inclusive because categories are added so that all details in the data are kept. Deductive analysis starts with certain types of communicative behaviours and then sorts the transcript data into those categories. This process limits the number of categories so that the analysis is more focused. Deductive research is less common in qualitative research. Consequently, this article used the inductive method to identify relevant issues for the generation of user requirements. A unit of analysis that will be assigned to categories must be designated ahead of time. A single unit should convey a single item of information extracted from the content. A sentence, a paragraph, and a message are all objective units of analysis in transcripts. To apply the method, the researcher works systematically through sentences, paragraphs, and messages in the verbatim transcript to identify opportunities for improved performance that could be supported by interactive technology. The analysis part of the contextual design method aligns well with Rourke et al.'s (2001) description, and it is specifically applied when generating user requirements.

Latent Inductive Content Analysis

The transcript was analyzed using latent content analysis with inductive categorization. Two researchers independently coded each sentence from the transcript by speaker and type of communication, as types of communications emerged from the data. Some 18 categories of communication were identified before beginning the coding. However, as we progressed through the transcript, we found a need to add new categories, which rendered the exercise a little confusing because these also affected the original definitions and criteria for classifying verbalizations. Still, an inter-rater reliability of 91.5% was reached. In order to redefine the categories and increase the inter-rater reliability, the file was again scrutinized by the two researchers, who worked together and agreed on each statement. This iterative process resulting in a total of 14 unique categories was repeated several times by two coders, until an inter-rater reliability had reached 100%. Then, all codes were aggregated and transferred to NVivo to be tallied into a table as shown in Table 2. Finally, meaning was extrapolated from the category tallies.

The 14 categories included explanations, acknowledgments, questions, answers, confirmations, statements, suggestions, planning, updates, cross-checks, and others. All verbalizations from the transcript were coded as one of these communication types and further analysis was then done.

Table 3 clearly shows that questions were the dominant type of communication. Although there is not much evidence of briefings and of planning, some of this happened outside of the command post. In order to avoid being too intrusive, the researchers did not follow the team outside the command post. Many of the responder team briefings took place outside, so these were not on the transcripts. Therefore, the figures are correct with respect to what was observed in the command post where the support system would ultimately be placed, but the data are not entirely representative of what might have taken place outside.

	Speakers								
Category	A	B	C	D	E	Haz	EMS	Pol	Totals
Explanation	6	4	0	2	1	0	0	2	15
Acknowledgment	2	8	2	11	3	3	3	1	33
Question	17	22	12	23	18	2	9	9	112
Answer	13	16	17	33	2	1	5	3	90
Confirmation	11	11	6	15	11	3	0	5	62
Statement	13	12	22	23	9	0	1	2	82
Suggestion	13	0	4	3	2	0	0	1	23
Planning	1	0	0	5	0	0	0	0	6
Update	9	2	17	10	3	3	0	2	46
Order	6	7	1	11	2	0	0	1	28
Cross-check	8	1	0	2	1	0	1	0	13
Reminder	0	2	0	2	0	0	0	1	5
Briefing	0	0	0	2	0	0	0	0	2
Joke	0	1	1	3	2	0	0	0	7
Totals	99	86	82	145	54	12	19	27	524

Table 3. Inductive category totals from the CBRNE SBT event

Instances of open communication are evident from Table 2. For example, of the 112 questions, 90 were answered, leaving 22 questions that did not receive an answer. An example of an unanswered question came from the EMS team, asking the command post members what radio frequency they were on. This question was never answered, and the EMS leader never used his radio after that. This suggests that information may not always be flowing optimally, and that the management system should have the option to prompt for recipients' responses. In addition, even though only some of the statements, updates, cross-checks, plans, suggestions, and explanations required a confirmation or acknowledgement, their tallies (185) were almost double the sum of confirmations and acknowledgments (95) given during the event. A specific example of such an incident was right at the beginning of the event. There was confusion about the number of casualties, ranging from 20 to 2,500. With some of this information in mind, one of the EMS representatives ordered 2,000 decontamination suits without cross-checking this information with his team members. This example reveals a need for displaying a dynamically updatable summary of the main events and decisions taken, to ensure that everyone is on the same page. Another example of information that was not passed on involved the offending agent. One of the team leaders received a radio message identifying the agent. He assumed that everyone had heard it and did not pass on the message. This information was essential as the identity of the offending agent has implications for how to proceed with the decontamination of people in the hot zone, and hence with the management of the event. This example illustrates the need for a support system to summarize and allow for dynamic updates of important information that everyone needs to know immediately. In total, three user requirements were identified by this analysis method.

Observation Analysis

The observational method is a commonly used data analysis method because it shows what an individual actually does in a given situation. Once an observation has taken place, it is up to the researcher to interpret what they saw. Wherever possible, this is done in collaboration with the person or persons observed. In this case, it was not possible to take more of the participants' time after the event, as they were all on active duty. By the time the data had been processed sufficiently to allow interpretation, the limitations of retrospective verbal protocols noted earlier would have affected it anyway. The interpretation and assignment of meaning to the observation is the most important part of this method (Drury, 1995). Without meaning, nothing can be concluded. Thus, some level of understanding of the observed event is essential to acquiring important information from the event data, such as generating user requirements for a system intended to support team leaders in the command post managing a CBRNE event.

Information inaccessibility and communication breakdowns during the simulated event were identified first. Each such episode provided an opportunity for improvement that could be achieved with information technology. Overall, 43 issues were found using observational analysis. These were sorted into 5 categories, namely agency-specific issues (n = 10), communication issues (n = 13), information needs (n = 3), manipulation of content requirements (CRUD: Create, Read, Update, Delete) (n = 7), and personnel & equipment (n = 10) issues. An example of an agency-specific issue was that the police identification officer wanted to be able to reorganize and view exhibits by the time they had been found. For example, he wanted to store items together that belonged to a particular victim, such as a purse, driver's license, and a coat that may have been identified as belonging to the same person at different times. This suggested a need for an automatic time stamp to be added as an exhibit is entered into the database, as well as allowing the sorting and linking of exhibits by different criteria. The communication requirements included the need to create, update, and share action plans among the emergency response team. Information needs were requirements for the user to generate, send, and confirm receipt of documents during an incident. In addition to the need for standard word processing features, the manipulation of content category refers to the user requirements of selectively deleting material for individual reporting purposes, permitting format-free data entry, and the ability to enlarge fields in forms. User requirements related to personnel and equipment refer to the need to identify and locate response members, track location of equipment, see and share user roles, easily identify authorized personnel, enter changes to personnel on site, and update information about who was briefed when.

DISCUSSION

The three analysis methods yielded different information and different user requirements. The importance of each of the user requirements (must-haves (M), nice to have (N), and not important (NI)) was assessed separately by both the researchers and developers and it was found that the classification was identical. Taken together, however, the observational method was the fastest and easiest method to perform, and it ended up identifying the most user requirements (n = 43, consisting of 23 Ms, 18 Ns, and 2 NIs) and was thus the most useful method for the present purpose. Moreover, the observations were used as the basis of analysis for the other methods, adding to its importance. SNA took some time to code and tally frequencies of communication properly, and it was the second most productive method, revealing a total of six user requirements (4 Ms and 2 Ns), out of which only three (2 Ms and 1 N) were not already found in the observational method. The task of identifying user requirements from a tally of communications and numbers derived from equations was not intuitive. The content analysis used here was the least productive and only generated three user requirements (3 Ms), out of which two were additional to the user requirements found by the observational method. While it was relatively easy to perform, it took a long time to categorize data from the transcripts; then checking the coding took equally as long. Given that some of the user requirements found by both SNA and content analysis were important and were missed by the other methods, then they indeed were valuable and could be performed in future exercises as well. However, for a data analysis of this kind of event with the purpose of generating user requirements, if researchers have a limited time frame and can only do one, then the observational method is recommended. The observational method is the only method that enabled analysis of both content and sequence of verbal statements. The sequence is important because it gives the timeline of events and indicates if the right information (content) was available at the appropriate time. The user requirements from this analysis method are currently being used to design an advanced application prototype that will eventually result in an application supporting CBRNE response management.

Limitations of Study and Analysis Methods

It is important to mention some limitations noted during the analysis. For instance, it was found that during the SBT exercise, participants' communication alternated between considering the simulation as a real event and as a simulation. For example, at the very beginning when radio messages began to come in to the team leaders, there was considerable discussion about whether they were all on-scene yet, because in a real situation, the team leaders would not arrive simultaneously as they did here. Therefore, it was not always clear to the researchers if the participants were treating the situation as 'real' or as a 'simulation'. Comments and events were thus interpreted with this in mind and the user requirements were derived with caution. Moreover, some information might have been missed or may not have been obvious because the observed team was highly experienced and was accustomed to working together. It is reasonable to expect that a different exercise with a different team in another location would yield different results. It is therefore essential that additional observations be made as the development of the application proceeds.

The qualitative content analysis using inductive categories was the most time-consuming method. Creating and assigning categories while going through the event transcript took a very long time and it was repeated several times to ensure reliability. Despite the potential of this analysis method, other researchers also describe it as difficult and time-consuming. Almost none of these researchers have gone back to publish results using a second content analysis (Rourke et al., 2001).

In the SNA method, a slight discrepancy between the most connected and the most talkative individual was found that was not revealed by any of the other analysis methods. However, this could have been due to one of the shortcomings of SNA. The formulae preclude the ability to handle single verbalizations addressed to multiple recipients, such as broadcasts or announcements. Instances of these communications were treated as separate communications and were counted several times, depending on the number of listeners. For example, if person A communicated to persons B and C, this communication was counted twice: once as a communication from A to B and again as a communication from A to C, even though there was only one utterance. In addition, radio conversations were added to their respective teams since SNA does not account for different means of communications. A further limitation to SNA as applied here, is that the formulae from the literature only use bidirectional interactions. Since the current CBRNE SBT event had some unidirectional interactions which are indicative of communication breakdowns, it is clear that some potentially important user requirements may be missed if data were only analyzed by SNA. Also, the pure numbers of communication exchange yields no information as to the success of the response. Content must be analyzed as well. If these shortcomings could be addressed, the results of the SNA might have been different and may possibly have contributed differently to the identification of user requirements. These limitations to SNA suggest that the method is not the best suited for future user requirement acquisitions in CBRNE situations. However, as the team leaders in this command post were highly experienced, it is possible that a SNA could be more useful for analyzing communication in less experienced teams.

CONCLUSION AND FUTURE RESEARCH

The purpose of this paper was to assess the effectiveness of methods that help researchers determine user requirements when analyzing CBRNE event data. The focus on communication breakdowns proved to be effective for generating user requirements that are then interpreted to generate system requirements for a technological CBRNE management support system. To get a complete understanding of the event, both content and sequence analysis should be performed. The necessary data are apparently best obtained with the observational method.

When the transcript was refined, before the analyses took place, one half of the simulation time was not used because it was not related to event management or because it was an inactive period in the command post where no communication occurred. To avoid the additional work of unnecessarily transcribing information in future studies, data collection should be focused on capturing data from only the most active parts of the event. These typically take place in the early stages of an exercise during which the level of uncertainty and the amount of incoming, often contradictory, information is extremely high. It is unnecessary to capture the entire event, as the command post is busiest while the teams are still gaining an understanding of the nature and scope of the event as well as planning the response. After that, researchers should be vigilant and film unexpected events only. In this case, having one camera capture the entire command post from a birds-eye-view helped to put all of the other recordings together in a cohesive manner.

Although the Team Situation Awareness (TSA) method per se was not appropriate for this study, it is clear that smooth and accurate team performance does depend on a high level of TSA. Ideally, the researchers should have gone back for a post-exercise interview with the participants to assess each command post member's TSA. However, as stated earlier, this was not possible. In future studies, it would be interesting to explore more ways in which to assess TSA. A method that could predict when a breakdown is likely to happen would be a valuable asset to a researcher's toolbox.

It would be interesting to determine SNA results applied to individual communications and not to the whole event as was done here. A connectivity graph of an update, for example, would clearly state where and when the information got lost for that particular instance. Perhaps more information could have been extracted with such an implementation of SNA to the CBRNE event. Also, SNA could be combined with content analysis to examine both quantity and quality of communication breakdowns.

More studies with different teams need to be done to account for the effects of differences in expertise, personalities of command post team leaders, and for the diversity of CBRNE events. The comparison of the observational method, content analysis using inductive categorization, and SNA will hopefully aid future researchers by suggesting which of these methods is most useful for generating user requirements for management decision support systems. The user requirements obtained here will be applied and tested for usefulness on other CBRNE specialist teams. Further studies will examine the generalizability of these methods to other situations and other command posts.

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