Communication Interface for Virtual Training of Crisis Management

Jan Rudinsky
University of Iceland
Dunhaga 5, 107 Reykjavik
Iceland
janr@hi.is

Ebba Thora Hvannberg
University of Iceland
Dunhaga 5, 107 Reykjavik
Iceland
ebba@hi.is

ABSTRACT

Since crisis management training requires extensive resources, a computer-simulated environment where communication plays a crucial role, can be an effective and efficient way to complement real-life training. With the aim of designing a simplified communication interface for a training simulator, this paper analyzes the complex communication network of crisis management, based on observations of a real-life, large-scale exercise of emergency services. Three research objectives were pursued to reach this goal. The results show that a selection of the most useful communication metaphors suggests that face-to-face and radio should be provided in a virtual environment. Consolidation of the communication groups highlights two groups, namely, the first responders and commanders. And, the analysis of the communication flow identifies different roles and the information flow between and within the groups. With this approach we aim to provide a single, multi-role interface that will be easily scalable and reconfigurable, while saving implementation costs.

Keywords

Communication, crisis management, training, virtual environment, interface.

INTRODUCTION

Previous research (Rudinsky and Hvannberg, 2011a, 2011b, 2012) has shown that the communication and data flow between roles during crisis management is paramount and plays a crucial role in coordination through all levels. Therefore, a complex communication network to facilitate the command and control between commanders and first responders must be deployed to drive an operation into successful recovery of a normal situation. Training this coordination and communication is prerequisite to this success.

While real-life training of crisis management requires extensive resources, a computer-simulated environment can be effective and efficient to complement life training. A simulated environment offers to save preparation time and resources and provides the advantage of testing hypothetical situations without causing disruption in a community. Presenting users with a virtual scene and allowing them to interact, permits responders to crisis to train collaborative activities. As a part of this collaboration, inevitably, trainees need to communicate verbally. To provide a realistic training environment for crisis management personnel a simulated environment needs to replicate the complex communication network in and provide different interfaces for many roles. This task is complex due to two reasons. The first is the number of roles covering first responders and lower-level commanders at the scene and higher-level commanders at remote operation centers. The second is the number of channels connecting them. Some research has already been conducted to meet these requirements supported by previous knowledge of communication in online multiplayer games (Rudinsky and Hvannberg, 2011b). For example, a communication prototype including communication between two roles has been designed based on the findings of online games research and the requirements of crisis personnel (Rudinsky and Hvannberg, 2012).

Motivated by this problem, we aimed at finding out if a communication interface could be simplified as a single, unified interface for all, i.e. multi-role. Using data from a large real life exercise, we wanted to analyze the complex communication network of crisis management and suggest how it could be simplified in a training simulator. Thus, rather than collecting communication requirements per role and designing corresponding interfaces, we hypothesized that we could consolidate the roles and their communication functions. If successful, there will be several advantages to this approach. With less implementation cost, it is expected to provide a single, multi-role interface that easily will be scalable and reconfigurable, offer better suitability for learning and save time and resources that would otherwise be necessary to replicate the real setup.

Three research objectives were pursued to reach this goal. For each of them one or two further research questions were stated:

RO1: Find the **selection of the most useful communication metaphors** that would determine basic interface features.

- Would a single communication metaphor (e.g. face-to-face or telecommunication) be sufficient for all?

RO2: **Analyze the communication groups** in the complex communication structure to find out if the groups' size can be reduced or group members can be predefined.

- What groups are involved in the communication hierarchy?
- Can there be a single group with a set of characteristics that represent them all?

RO3: **Analyze the communication flow** between roles within and across the borders of the groups to identify the differences between roles' use of communication channels (i.e. communication flow).

- What roles represent a group?
- What is the common communication flow represented by consecutive and simultaneous use of channels between roles within and across the borders of the groups?

After analysing the above research objectives, we will examine its implication on the user interface design of a training simulator.

RELATED WORK

A number of case studies have analyzed the information flow in current verbal communication-based crisis management from different perspectives including decision making (Smith and Dowell, 2000), content (Real and Dixon, 2007), communication problems (van de Ven, van Rijk, Essens and Frinking, 2008; Bharosa, Lee and Janssen, 2010; Manoj and Baker, 2007) and information services (Schooley, Marich and Horan, 2007). Ethnographical field studies have focused on the design implications of communication and training systems for emergency responders. One such investigation of novice and experienced fire emergency responders (Toups and Kerne, 2007) resulted in characteristics of firefighting practice relevant to the design of fire emergency response education systems (Toups, Kerne, Hamilton and Shahzad, 2011). A similar field study of the work of fire fighting incident commanders (Jiang, Chen, Hong, Wang, Takayama and Landay, 2004) found specific interaction patterns including spontaneous and opportunistic communication and resulted in the design and development of a system supporting tacit communication between firefighters. Compared to these studies of fire-fighting practice, our study is different in three aspects. Its focus is set on major incidents; it extends across many emergency services and includes all command levels.

The work extends to the Computer-Supported Cooperative Work (CSCW) area studying the work of people in groups and organizations that is supported by computers. The interaction between individuals during cooperative activity is described by a 2 x 2 CSCW matrix (Johansen, 1988) with 2 columns representing time, i.e. synchronous and asynchronous and 2 rows representing space, i.e. collocated and distant. The communication needed for crisis management as discussed in this paper focuses on synchronous communication, both collocated and distant.

Using virtual simulation for training may need to consider the influence of new technology on coordination and communication. The theory of communications grounding (Clark and Brennan, 1991) introduced characteristics of different media and described their influence on information delivery and understanding. An evaluation of these media characteristics in a field study of communication in the oil-drilling industry (Bayerl and Lauche, 2010) showed, when the use of traditional media (phone, email, mail, audio-conferencing and planning systems) was compared to new information and communication technology capabilities (video-conferencing, data screens and desktop sharing), that the new media did not have a radical impact on team coordination, but rather resulted in modification and adaptation of existing routines. A different study (Owens, Mitchell, Khazanchi and Zigurs, 2011) focused on the use of metaverses ("a visual, three-dimensional environment") and the influence on virtual team projects and outcomes. The empirical investigation of communication and interaction of project teams in a Virtual World (VW) setting examined the relation of communication, interaction, technology capabilities, behaviors, and outcomes. The results showed that VWs are different than traditional collaboration technologies. For example, to build a shared understanding there is reduced reliance on traditional textual or verbal communication, but, instead, more reliance on the ability to see and touch objects.

In addition to advanced technologies for communication, there are improvements in technologies to implement how the content is decided. Thus, some studies have analyzed the problems of communication in the simulated environments and proposed solutions based on artificial intelligence. For example, one study finds that the training skills, such as communication and team coordination, are inadequately addressed by simulation and suggests “specific approaches that extend the reach of simulation, employing interactive synthetic teammates, in directions that directly address unmet training needs” (Bell and Santarelli, 2009). Another system for communication and decision making training in emergency situations has used autonomous agents for simulating and explaining human behavior (Dörner, Grimm and Seiler 2000).

A different strand of work on how to implement simulators can be found in an ongoing standardization work of 4C (Command, Control, Cooperation and Coordination) systems. The work aims to define and develop generic information systems for training of emergency services including the formal specification of crisis management language (Gustavsson, Nero, Wemmergård, Turnitsa, Korhonen, Sjöquist, Evertsson and Garcia, 2008). Such a language is meant to be readable by both human and machine and allow instructors to define scenarios of command and control, e.g. for a simulator. The work performed as a part of the research reported in this paper could be input to this standardization.

Verbal communication in virtual environments has been further explored by the design of speech-based player interaction in multiplayer online games (Wadley, Gibbs and Benda, 2005). They have suggested a mobile phone, a landline phone and a proximity chat metaphor for player-to-player voice interaction. These metaphors were implemented in a field trial (Gibbs, Wadley and Benda, 2006) demonstrating the necessary basis for the training of crisis management in VE. Furthermore, based on empirical data gathered during site visits to three end-user partners at as many locations (Rudinsky and Hvannberg, 2011a), three voice communication metaphors have been implemented in a prototype. The metaphors reflect the communication spaces used in training and in a real crisis event and consist of radio, telephone and face-to-face (F2F) conversation.

DATA COLLECTION

Observing an exercise of crisis management training is an effective method for studying the work of responders and commanders. A complex exercise is a live action role play, which is a multi-agency, large-scale training exercise wherein people accomplish tasks in a real-life environment and are supervised and evaluated by training managers. Data set to address the objectives and research questions of this paper was collected during a live exercise and provided observations of different roles represented by individuals, their organizational structure (i.e. groups of individuals) and the communication channels they used within groups (“peer-to-peer”) and across the group borders. The data were collected at a real-life, large-scale exercise of emergency services simulating a plane crash at an international airport. The exercise involved 250 participants from multiple emergency services including airport and local fire fighters, emergency medical services, police, search and rescue services, Red Cross, and airline and airport services. The main objective of the exercise was to take care of approximately 60 casualties, played by volunteers, within a three-hour interval spanning from the alert phase until declaring the exercise over.

Nine researchers made observations of the real-life exercise. They were individually placed at different predefined locations. Researchers collected data according to a written protocol and recorded important events of rescue, response and command Additional information on the exercise context and its artifacts was collected by taking photographs. All data records (558 records) were stored in an online database and classified according to the place of origin, i.e. location, and type of activity, e.g. command & control and registration & counting.

RESULTS

The data collected during the exercise are described in further detail below and analyzed by induction in three phases, each addressing one research objective and providing answers to the research questions.

Data Classification in Relation to Locations

The data were collected at five locations during the exercise. Figure 1 plots the relation between the locations, classification of data and the number of collected records. The majority of the data records represent command and coordination collected at an Emergency Operations Command centre (EOC), an On-Scene Command centre (OSC) and a Casualty Assembly Point (CAP), followed by the medical and triage data observed at the accident site and CAP, and the transportation data that were recorded at the Rendezvous Point (RVP).

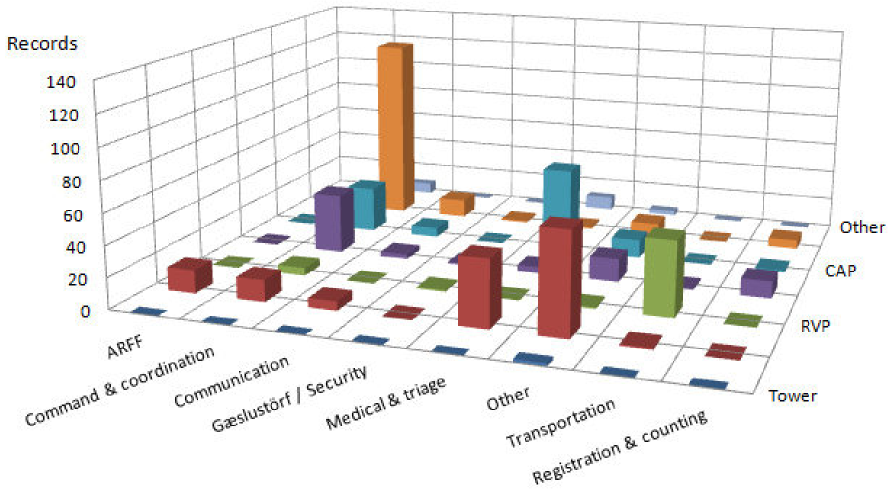

Figure 1. Number of data records at each location and for each data classification.

Primary Communication Channels

The first objective was to identify the most commonly used communication channel(s) necessary to facilitate crisis management training. The analysis of the total data set of 558 records was carried out in two steps. First, data records related to communication between exercise participants were selected giving 202 (36%) records. Then, each record was decomposed into pairs representing a training role and the communication channel used for verbal (e.g. a commander speaking face-to-face) and non-verbal (e.g. a responder pointing) communication producing 349 pairs.

Quantitative analysis of the verbal communication pairs determined 31 unique roles engaged in communication via four major communication channels: face-to-face (FTF), radio, mobile phone and landline. The results show a significant role of FTF (82%). It clearly pre-dominates the radio communication, which is the second most common channel (15%). Finally, the results show the minimal role of mobile phones (2%) or landlines (1%) in the verbal communication during crisis management.

Dividing the data per observation location of the exercise area confirms that there are no significant differences between them with respect to the communication metaphors (Fig. 2). FTF dominates all locations, followed by radio, while the use of mobile and landline is quite rare. At three locations (EOC, OSC and Accident scene), FTF is used in more than three quarter of cases and at one (CAP) in more than half the cases. The landline was only used at EOC, but in addition to EOC, landline was only available at OSC. An exception was the double rate of observed radio communication at CAP, which we think is because an observer was located nearby an exercise participant using two radio devices, where others normally used only a single device.

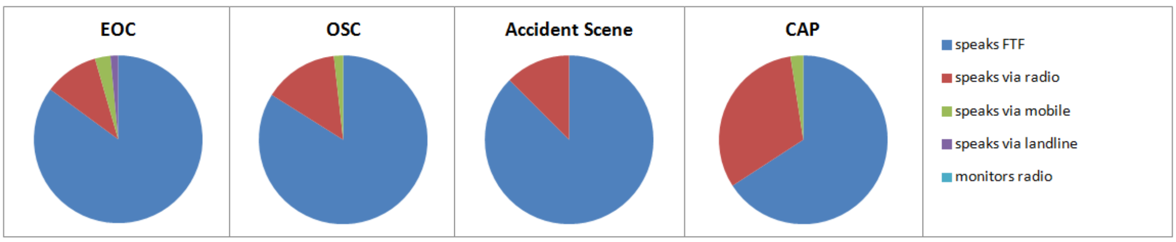

Figure 2. Communication channel use per location

As the data suggest FTF and radio are important communication channels during crisis management training and should be provided in a form of communication metaphors in a virtual environment. According to this data, the use of a mobile phone and a landline seems to be insignificant and, therefore, may or may not be supported in the VE, although a mobile phone may be offered for training purposes as will be discussed later.

Communication Groups Consolidation

An analysis of groups that constitute the complex communication structure was carried out to achieve the second objective, but the purpose of this objective was to reduce the number of groups or to find out if group members could be predefined to simplify the communication interface. A group identifies a number of collocated people, who move around exercise locations and engage in communication while involved in a joint effort. The communication within and between groups was observed and photographs taken at and around the five exercise locations. Analysis of the photographs revealed many groups, which were then compared and consolidated according to these characteristics: persons' locations, size of groups, roles, persons' mobility, and the type of communication used. Table 1 shows an example of the groups' consolidation at the RVP.

Sub-location	Size of groups	Roles	Mobility	Communication
Meeting point	one group of three officers and people waiting in cars	First responders	Officers move around the location	can engage in FTF, monitor radio
Gate	one group of five officers and people arriving in cars	First responders	Officers move around the location	can engage in FTF, monitor radio

Table 1. Example of consolidation of groups at one area Communication activity of the sources represented by number of observations

The groups' consolidation shows that most locations, where casualties are treated, and the RVP are characterized by the presence of many groups of first responders. These groups work collocated and they can speak FTF (e.g. call for help). The groups present at the scene, CAP or RVP, move between many locations and, therefore, they are stationary only temporarily at these locations. Therefore, all participants can engage in FTF at any time. Some of them are also equipped with a radio device and they monitor the conversation on the channel, but not all of them speak via the radio. Coordinators, who represent the lowest level of command, were observed stationary at their posts (e.g. scene or CAP). They engaged in FTF conversations and reported or received information via radio. Higher-level commanders were observed stationary in a command centre (e.g. OSC or EOC) with the single exception of a commander visiting a scene due to lack of information. Majority of commanders (80-90%) were monitoring radio communication or observing a computer screen and reporting important information FTF.

As a result of the consolidation the groups can be simplified into two groups. A generic **first responder group** would include two to four persons who move between several locations (RVP-Scene-CAP). People in this group would speak FTF, some would monitor radio and they might speak via the radio. FTF communication would be within and between groups. FTF conversation or the use of radio may occur while moving. A generic **commander group** would be around ten stationary persons, who receive and send information via radio or computer and engage in FTF discussions. The information flow within these groups is show in Figure 3. where a radio channel is the means of distant communication, FTF is communication between group members and carrier is a representation of persons joining or leaving a group. A lower-level command has to have a visual overview of the location, while a high-level command does not require it. In the lower-level command there is a specific role of an on-scene coordinator with mixed characteristics. A coordinator works individually or may be supported by one assistant. Some move around their location (e.g. Medical Coordinator (MC) at CAP), while others are stationary in a command vehicle (e.g. Rescue Coordinator (RC) at the scene). Coordinators engage in FTF as well as in radio communication.

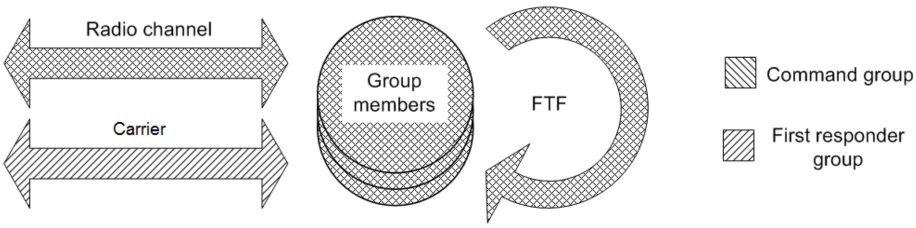

Figure 3. Communication flow in the first responder and commander groups

Based on the characteristics of the two groups we can determine whether groups' members should be predefined or can change during an exercise. First responders and low-level commanders on the scene communicate in dynamic groups, where communication counterparts can change with time, i.e. the communication groups can have predefined members only temporarily. Commanders operate in predefined groups with established counterparts, i.e. the groups can be predefined for the duration of the whole exercise.

These findings determine the requirements of FTF communication. People in groups of two or more persons engage in FTF within the group. Additionally, groups that move between locations or are present at a location where people that come and go engage in FTF with other groups.

Information flow between and within groups

As described in the previous section, consolidation of the groups has identified two types of groups, the first-responder and the commander groups. This section and the next describe the flow of information between roles within and across the borders of these groups. It addresses the third research objective, i.e. identification of different roles within groups and their communication flow. As in the previous two objectives, the purpose is to see whether this analysis can lead to a simplification of the user interface. To understand the flow, the roles were analysed in two command groups and then in two first responder groups. After the main roles had been identified, we identified consecutive and simultaneous channel use. An example of consecutive channel use is when one trainee talks on a radio and then turns to a teammate and speaks face to face. Another example is when a trainee talks on one radio channel and then switches to another one. An example of simultaneous communication channels is when a trainee monitors one channel while speaking in another.

When carrying out the analysis of communication flow in the commander groups, a few factors emerged allowing us to identify commonalities and differences across the command centres, OSC and EOC. The factors were a stimulus or a trigger of communication, a response to the stimulus, and status meetings. In both command centres exceptions to normal communication could be observed.

In the EOC, a majority of the FTF communication triggers came from outside the command centre. The triggers were radio messages and a majority of them represented progress reporting. While some observations did not cite the means of communication as the trigger, the data clearly implied an update from another location that could be reached via radio or a computer. As opposed to the EOC, in the OSC the communication trigger was most often the OSC commander (Fig. 4).

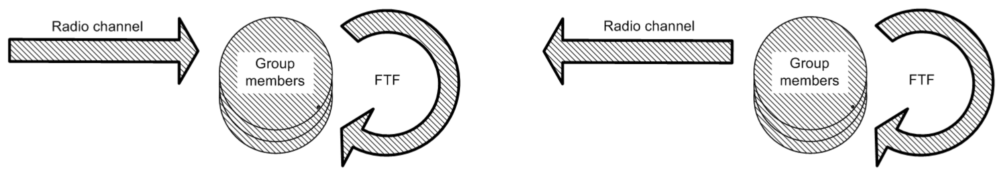

Figure 4. Communication triggers originate outside the EOC (left) or start locally in the OSC (right).

Looking at how command centers responded to triggers, we noticed that in the EOC important messages were announced to all commanders followed by decision making by two or more commanders. This shows one example of consecutive communication activities, i.e. receiving information on radio (the trigger) and talking FTF (announcement). The process did include inquiries about information from other locations. In the case of progress reporting, a message was relayed to other locations and in the case of an information request an answer was sent back to the source of request outside the command centre. In the OSC, the commander started the flow by asking commanders FTF within the centre or tasking them to obtain information from a source outside the centre. The conversations included decision making in several cases.

An important communication activity in a command centre was a status meeting, where each commander reported progress. During the status meeting, the EOC commander required additional information during FTF discussion. As in the EOC, status meetings were held several times during the exercise in the OSC and involved reporting and decision making. An observer in the OSC was active in asking commanders questions following an action in the centre. In both centres, the status meetings were triggered by regular time intervals.

In a few cases, we noted exceptions to the normal flow of information as described above. One was when a person left a command centre (EOC) and entered another one (OSC) to deliver a message in person, which had not been successfully delivered via radio. The content of the message was to request information and resources. Another exception was when commanders in the OSC moved to a new station within the centre. Finally, although most of the communication was via radio or FTF, a person in the EOC and an instructor in the OSC used a mobile phone for training purposes.

Above, we saw examples of consecutive communication, but now we will discuss simultaneous ones. The outcome of the first research objective was that all exercise participants were involved in FTF conversations and many of them used radio. Out of the 31 unique roles identified, 20 were equipped with a radio device and 14 were observed to speak via radio at least once. The implication is that half of the roles may simultaneously use two channels, which demands an analysis of the need to support simultaneous speaking and listening of the channels in the simulator. Speaking via radio occurs across the commander (6 roles) and first responder/coordinator groups (8 roles). Theoretically, when a person is speaking via radio, others would be able to hear the conversation. However, the data do not indicate any need to follow radio conversation by others (e.g. to raise a question). Also, when a person is speaking FTF it is not simultaneously delivered via radio. In fact, the data confirm that when a person needs to deliver information discussed FTF to a distant party via radio, he or she asks another person to do it (command group) or does it him/herself (coordinators). Therefore, we conclude that speaking via both channels simultaneously is not required.

On the receiving side of the radio communication, observations showed that listening occurred in both groups, i.e. commander and first responder. Contrary to speaking there were several examples where a commander listening to a radio channel reacted to FTF discussion. Examples include: "ARFF commander announces the amount of fuel on board the plane to EOC commander. A resources manager asks if dangerous goods are present. Negative answer received.", and another one is: "EOC commander concludes that the transport capacity is not enough to transport all red casualties. She asks a resource manager for more resources. A radio operator informs that OSC has not requested for resources, only to move existing resources closer." Therefore, receiving communication on FTF and radio channel should be simultaneous. In another case simultaneous communication has been avoided in the OSC, i.e. when a commander from EOC asked for information via radio and OSC replied that they were busy in a FTF meeting and would reply later.

The conclusion of this analysis is that with respect to communication flow the command centres have many similarities. There are similarities in how the centres respond to triggers and have status meetings. The use of mobile phones is similar. The main differences are how communication activities are triggered, i.e. outside the centre via radio in the case of EOC but inside the centre in the case of OSC. The explanation can possibly be found in OSC assessing the situation based on information received by looking through the windows or through the operation databases. In both centres there is a need to have some flexibility in physical mobility, either within or between centres. While there are a number of examples of consecutive communication, simultaneous communication of speaking is avoided, but not listening. There are two types of communication roles. Everyone can speak FTF and everyone can monitor and speak on the radio, albeit on different channels. The second type of communication roles are those who can observe and provide information to computer systems. There is a need to allow exceptions to rules of communication.

The consequences of the above consolidation for the user interface design are the requirements to include the following communication patterns. First, consecutive communication, e.g. radio, FTF, radio: radio on one channel followed by radio on another channel. Second, a broadcast of FTF is needed. Third, the user interface needs to include a computer as a source or a sink of information. We conclude that although the triggers of communication are different in EOC and OSC and it is an interesting pattern to observe, this need not affect the user interface since both centres receive information from outside.

Mobile phones seem not needed in the simulator, at least not in the simpler training versions. It is important to include in the user interface the ability of a trainee to enter and exit a commander group, which will affect the scope of who they can talk to FTF. The trainees in the OSC centre were able to move within the centre, but we conclude that this need not be implemented in the user interface, since the OSC is so small that this motion will not affect who the trainee can talk to. We conclude from the above analysis that it would be beneficial to have two communication roles, one speaking FTF and having access to radio and the second one having all these capabilities and accessing information systems.

Next, we turn to describe the flow of communication in the first responder groups. We analysed the data from CAP and the Scene, but information from RVP was not so dense. Three factors emerged from the analysis, i.e. arrival of a trainee on the scene, communication between groups within the super group (CAP, Scene or RVP) and reporting results external to the group. As in the case of the commander group several exceptions to normal operations were observed.

In all cases, CAP, Scene and RVP, trainees needed to report to someone upon arrival on the scene. In the case of CAP, transport personnel reported to the MC or medical personnel, in the case of the Scene, arriving resources, e.g. rescue or medical personnel, first met FTF with the responsible person, either a doctor or an RC, and in the case of RVP it was a police officer.

During work at CAP and the Scene trainees interacted with casualties, their own teams or with other teams within the super-group. At the CAP, the Medical Coordinator (MC), regularly was seen discussing the casualty status FTF and making plans mainly with her assistant and in several cases a doctor, a triage team leader or medical personnel. Medical personnel at CAP sometimes talked to casualties, reported to the MC's assistant and waited for orders from the MC. At the Scene, the resources engaged in FTF interaction with other teams and some of them monitored radio.

The third factor which emerged was how trainees responded to situations or reported them. At CAP, the MC reported the casualty count to a different group via radio or she tasked the medical and transport personnel either by walking to them or via radio to prepare for casualty transport. No such pattern was observed at the Scene.

Several exceptions to normal flow or means of communication occurred. At the CAP, the MC used a mobile phone because a recipient did not answer the radio call. Another exception was at the Scene, when a radio request was unsuccessful, a person tried to speak FTF to others. The result of this communication was unsuccessful since the person did not receive sufficient information.

The conclusion of the analysis of CAP and Scene is that they are very similar with respect to communication flow. In both cases, there are sequences of communication, e.g. FTF followed by radio. Groups are mobile within the location, into and out of the location, and results of work trigger tasking a group member or reporting results to outside the location. Surprisingly, with respect to communication, only one role is needed, i.e. all can speak FTF, monitor and initiate conversation on the radio. The difference lies in the diverse channels they use and the type of information they will provide and receive.

Using this information to determine the impact on the user interface design of the training simulator, we conclude that in the first responder group similar patterns were observed as in the commander group. The exception is that in the first responder groups there is no need to equip the roles with computers. The members of the first responder groups need to be mobile between groups within the location which will affect with whom they can talk FTF. Whereas this is a norm in the first responder group, it is an exception in the commander group. In both groups, members need to use the metaphors consecutively and simultaneously. The summary of the group members with respect to communications and user interface features are provided in Table 2.

Feature \ Group	First responder group	Commander group
Face-to-face	Yes	Yes
Radio	Yes	Yes
Mobile phone	In exceptional cases	In exceptional cases
Computer as a source/sink	No	Yes
Mobility of members	Yes	Only in exceptional cases
Consecutive use	Yes	Yes
Simultaneous use	Yes	Yes

Table 2. Overview of results of Roles and Information Flow between Groups

DISCUSSION AND CONCLUSION

In this paper, we have reported on research which has aimed at investigating if a simplified communication interface can be designed for a training simulator for crisis management. To investigate the three research objectives stated in the introduction, data from a real life exercise has been analysed. Although the answer to the overall question, namely, if the communication interface can be simplified as a single, unified interface for all, was negative, the results show that considerable simplification can be achieved. That majority of people were involved in FTF (82%) and only 15% were via radio shows that the personnel involved in crisis management training cannot be expected to share a single communication channel. Mobile phone and landline use (2%, resp. 1%) was quite rare. Therefore, at least two communication metaphors representing FTF and telecommunication should be provided.

Turning to the second objective of the research we asked what groups were involved in the communication hierarchy. We concluded that two groups were involved, a first responders group and a commanders group. A generic **first responder group** would have two to four persons who move between several locations (RVP-Scene-CAP). People in this group would speak FTF and some monitor radio. They would be able to speak via the radio. An FTF communication would be within the group but also between the groups. The FTF conversation or the use of radio might occur while moving. A generic **commander group** would be around ten stationary persons, who would receive information via a radio or a computer and engage in FTF discussions. The lower-level command needs to have a visual overview of the location, while high-level command does not require it.

Furthermore, when asking if these groups could be predefined we found that first responders and low-level commanders communicate in dynamic groups where communication counterparts change with time, i.e. the communication groups can have predefined members, but only temporarily. A high-level command operates in predefined groups with established counterparts, i.e. the groups can be predefined for the duration of the whole exercise.

From the communication perspective, a command structure shows general features. The structure can be simplified as two layers connected by a transition layer. The lower level, represented by first responders, shows high frequency of FTF communication with occasional use of radio. Similar features can be identified in the higher level of command structure, represented by commanders. However, the difference between the layers lies in persons' mobility that is more frequent on the lower level. The transition layer, between first responders and commanders, is represented by coordinators. Although, similarly to the first responders, they are present at the accident scene and they can move around a location their mobility rate is rather low. Also, the more frequent use of the radio by coordinators seems to create an information bridge between the lower and higher level of command.

Using the data from a large real life exercise, we analyzed the complex communication network of crisis management and suggested how it could be simplified in a training simulator. Rather than collecting communication requirements per role and designing corresponding interfaces, we consolidated the roles and their communication functions, thus saving time and resources that would otherwise be necessary to replicate the real setup. The findings can help in further designing of a single, multi-role interface that is easily scalable, reconfigurable and offer better suitability for learning.

As we have stated in the beginning of the paper, only a few studies have investigated communication modalities and flow during crisis management. We compared our results to others (Toups et al., 2007), who identified radio and face-to-face as essential communication modalities for fire emergency response real-time information flow. With our results we can extend this finding to all emergency services involved in crisis management including emergency medical, police, and search and rescue. In addition to this detailed study that ends at the "incident commander" level of the command structure, our research has identified the communication flow of the higher level command during the analysis of two command centers. We should point out that as opposed to the other study we analyzed the command structure including many emergency services. And, that would be at the coordinators' and commanders' level.

To conclude, we state some limitations of this study. Possible limitations of the data collection method could be that observers easily can perceive the communication of people they are located close to, but the intelligibility of the speech lowers with the distance from a speaker or with the number of parallel conversations, observers clearly can identify a speaker, but may not always identify all listeners, observers can recognize the use of telecommunications (e.g. radio) for sending a message, although receiving can be clearly identified only when handheld devices are used and not when ear-plugs are worn. A second limitation is that the data cover only one large-scale exercise. However, from experience from several other sites (Rudinsky and Hvannberg, 2011a), we conclude that division of the roles under observation among first responder and command groups concur with other emergency systems at those sites. Observations may be limited by the number of observers and the distance from observed participants. Observers were located within a short distance from the exercise participants and they were mostly able to see and hear the participants. However, the number of exercise participants was several-times higher than the number of observers and conditions on the scene were not always safe and, therefore, only a sample of all the communication examples was collected. On the other hand, exercise duration of several hours made it possible to observe most of the roles and collect a solid sample of communication records.

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