Collaboration Patterns in Mixed Reality Environments for a New Emergency Training Center

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***Abstract*—Training actors from public safety agencies (PSA), e.g. emergency medical services, fire departments, police departments involves different technologies and communication and collaboration activities. New technologies promise better support, not only for training, but also for logging relevant information for future analysis and learning. However, choosing the right technologies, defining proper set-ups for the training activities, and identifying premises for long-term use of technical facilities is both difficult and time consuming. Applying earlier lessons from evaluating work in Virtual Environments (VEs) [1], our aim is to develop a better understanding of the impact of new technologies by identifying collaboration patterns influencing training. Collaboration is examined via social, technical, and task related interaction, distinguishable in the different phases of training, from starting an alarm to ending the emergency activities. Our main results illustrate the benefits of (1) building scenarios, and training whole activity chains for certain rescue or other emergency activities, (2) using simulations for better understanding physical places, the task, and (3) distinguishing technical, social and task focused characteristics for factors influencing emergency focused collaboration. Moreover, the results also contribute to understanding the benefits of considering specific simulation technologies when training for emergency and rescue activities.**

Keywords- mixed reality environments; shared virtual environments; simulations; collaboration; long-term; patterns; training; emergency

I. INTRODUCTION

Communication and cooperation between organizations engaged in public safety and emergency response is mostly regarded as self-evident. Public safety agencies (PSA) have to train regularly in order to be prepared [2]. However, they seldom train longer compound activities, coordinating specific activities, or whole activity chains from handling the alarm(s) to ending activities [3].

Even when the role of technologies in training is recognized, new technologies cannot easily replace older ones. As an example, it is not reasonable to believe that a new training center will be successful only by procuring new state-of-the art technologies but without investing in expertise in setting up, integrating and learning to use these technologies.

Taking telecommunication as an example, the multitude of communication units, for example two or three different radios, mobile phones at the hands of a public safety officer is an indication of a substantial lag in relation to the communications solutions available in public. As Philip Weiser points out: 'even in today's Internet-connected world, public safety agencies continue to rely on single-purpose technologies that do not provide economies of scale, network flexibility, or the broader functionalities routinely used by the military and private sector enterprises, p:548' [4]. Furthermore, new technologies are not necessarily easier to learn to handle than older ones [5]. They can usually be treated as new innovations with longer adaptation time, since they are often influencing everyday work patterns for many people [6]. When introducing a certain technology in emergency management and public safety, it is often evaluated and used separately. We can see this, amongst others, for GIS based technologies [7], patient simulators [8], more general learning facilities [9], environmental-, car-, decision support simulators [10] or specific technologies supporting communication [11].

Developing methods to examine and evaluate collaboration and communication during emergency situations seems to grow apart from methods evaluating the benefits of technologies. Additional efforts are needed to integrate the different results [12] and to determine the resources necessary to produce overall benefits [3].

This paper aims to contribute to better preparedness for, and more professional handling of emergency situations when planning and building a new emergency training center (ETC) in Skövde, a small city in the middle of Sweden. From current training practices, we understand that narratives and chains of activities need to be handled at such a center while there is simultaneously a need to understand how to determine the influence of (new) technologies.

This paper combines two ideas: developing scenarios for a future training center, designing and performing a pilot study that is naturalistic (see Figure 1) and using an evaluation method for collaboration in mixed reality environments [1]. It contributes to defining the usefulness of certain scenarios for developing new ETCs [13]. The focus is on collaboration for training emergency and rescuing activities.

II. MOTIVATIONS FOR NEW ETCS

Focusing on overall collaboration and openness allows us to take a perspective suitable for developing an ETC for

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future users and as yet undeveloped technologies, to contribute to robustness, and preparedness to handle changes and assure sustainability [13]. To permit gradual planning and training of changes is essential for launching new technologies in organizations in general [14]. Showing best practices and pointing to missing or possible redundant issues is important for practitioners [11, 15].

The complexity of planning for new technologies can be experienced as a deterrent factor at three different levels: 1) by experiencing insecurity when trying out the new technology together with the existing information and communication technologies, 2) uncertainty about choosing the most suitable equipment, and 3) lack of confidence in using it properly and having it updated with features that the digital communication allows [15]. By focusing only on a certain technology or a certain user group, or a specific emergency or risk situation, one can miss important features influencing the overall output. By focusing on central premises of collaboration, we contribute to understanding a whole that can be more than the sum of its parts.

The center proposed in this paper is an embryo for an emergency training center. Even though this paper reports on a pilot study, it has the much broader aim of discussing prerequisites and possibilities of an ETC. Many of the used technologies are not necessarily on the forefront of technological development or representative for training. In the jungle of new technologies today, one could easily add various other technologies for the set-up, or also compare with other technologies, with varying components or features, e.g. with different other projectors, interaction devices, tracking technologies for better logging, or using other simulations. Given the aim of determining overall impacts, a first step is therefore to set up some widely used technologies. Within the context of this paper and pilot study, the ambulance team has a central role. We will extend the training for other actors within PSAs in the next step.

III. BACKGROUND

A. Training centers

There are many organizations and associations that aim to support and ensure communication and collaboration in the Public Safety sector. One European example is the Forum for Public Safety Communication Europe, whose mission is to 'foster, by consensus building, excellence in the development and use of public safety communications and information management systems to improve the provision of public safety services and the safety of the citizens' [16]. The members of such associations also include communication and cooperation professionals helping actors from PSAs with both social and technical communication and collaboration issues. Examples include, social issues (e.g. assuring a well-functioning leadership), group work, help with communication that influences decisions, and communication with the government or public. They have specific interests in fostering development and use of technologies for public safety cooperation as well as in the benefit of communicating with the public. Much training is based on simulation [10] and there are a large number of ECTs already around us [13, 17]. These are often too narrow in their focus, i.e. focusing only on some training for one of the PSAs. To define a center that is cost effective, usable for everyday training situations, and adjustable (allowing integration of new technologies or new users) remains a current challenge [3].

B. Collaboration in mixed reality environments

Several communication modalities need to be used to communicate and collaborate effectively for training and learning: 1) face-to-face communication at the actual physical location, 2) verbal communication, e.g. receiving instructions from the emergency medical services or hospitals, 3) visual communications that support care, e.g. sending EKGs or pictures on patients or situations to the hospital for further analysis, or receiving pictures that facilitate decisions. It is also possible to use, for example, video conferences for cooperation during rescuing. Other technologies, such as VEs, augmented reality or simulators allow naturalistic support for specific training situations, while videos and networks of sensors allow logging and analyzing for e.g. learning purposes [15, 18].

Generally speaking, there are three parallel activities that an individual can do together with his/her partner in a training environment [19]. The first is to *solve a problem* and reach the goals of the training exercise (P), maintain *social interaction* with other involved people (S), and *handle technologies* (T). Disturbances in an activity, e.g. problems with handling a technical device may only be observable by one individual or part of the group, but may disturb the overall performance of the whole group [19]. In the same manner, social interaction problems, e.g. not being explicit on group leadership may result local misunderstanding, yet influence overall performance [2]. Since the three processes determine what an individual can do together with his/her partner or group in an environment once (s)he spends some time there, examining those processes is also an approach to exploring individual versus group experiences and effectiveness.

C. Training and learning

The results of the study point towards training needs that cover the whole chain of events from dispatching to the delivery of patients to the emergency department. Several activities within this process are already known but typically trained separately using simulations, e.g. patient care [10] or intensive rescue and care [20]. There are frameworks, methods, and technologies supporting rehabilitation and learning, for example for people with specific disabilities [21, 22]. Since it is essential for patient safety that the whole emergency chain works, people from PSA should be informed how to integrate these training situations in more overall training activities.

IV. STUDY DESIGN

With the aim of contributing to defining a new ETC where the focus is on training collaboration for better preparedness for handling emergency situations between PSA with help of advanced technologies, we 1) discuss how to examine collaboration in mixed reality environments and 2) present a pilot study for an ETC. Data is collected via qualitative observations [1] and the results examine this data in view of lessons from evaluating collaboration.

A. Collaboration patterns

There are three main stages of collaboration that are embedded in a "meta-collaboration" context. This context includes the interaction flow from acknowledging presence, navigating into a position, contributing to meta-planning, negotiation, contributing to the task at hand, and acknowledging utterances. After these stages, the flow begins again with acknowledging presence [19]. The temporal structure of the interactions can be divided into the beginning of the interaction, proper collaboration, and ending the collaboration [23]. This approach is applied and examined for comprehensive emergency management (CEM) and its four phases: mitigation, preparedness, response, and recovery [24]. While mitigation can be neglected for overall collaboration, it is essential to differentiate them for emergency training.

Since social interactions and technologies supporting them are considered to be of importance for this study, the potential success of mediated collaboration (see Table I.) is specifically in focus.

TABLE I. POTENTIAL SUCCESS OF SOCIAL BEHAVIORAL REPERTOIRE DURING TECHNOLOGY MEDIATED HUMAN-HUMAN INTERACTION. SCORES ARE FROM LOW FIDELITY (*) TO HIGH FIDELITY (*****), OR NOT AVAILABLE (-). (MODIFIED FROM TROMP [22])

Social Behavior	Real Life	Audio Comm.	Video Conf.	Media Spaces
Verbal com.	*****	****	***	**
Phatic communication	*****	****	****	****
Spatial Regulation	*****	-	*	*
Proxemic shifts	*****	-	-	-
Co-verbal behavior	*****	-	***	***
Turn-signal	*****	**	**	**
Peripheral Awareness	*****	-	*	**
Trust Building	*****	****	****	****
Reciprocity	*****	**	**	***
Indexicality	*****	**	**	***

By comparing certain characteristics of components of social behavior for real-life meetings with different types of mediated meetings (audio conferencing, video conferencing, media spaces, and virtual conferencing), Tromp obtained a list of benefits and drawbacks, depending on the technology, to support distance meetings. Besides the size of the group and how it is composed, the time spent together with the application plays an important role. Allowing time for learning, reflective restructuring, subjective time that the users experience, or objective time etc. influences the outcome. Additionally, the way in which groups interact socially, via distributed media or even through sharing the same interface, can matter in experiencing usefulness. Based on social interaction and its influences on technologies, and task Schroeder and his colleagues further developed a method for examining usability for collaboration [1]. They are arguing for the role of identifiable smaller parts of activities, called 'activity patterns' improving the usability – by means of improving the systems and features of the environment, and also by improving the users' awareness of their activities and settings.

If we consider that the future of mixed reality environments (MREs) will be shaped, broadly speaking, by three forces – technological improvements (including cost), user acceptance and diffusion, and competition with other similar technologies that have similar functionalities (videoconferencing, shared media spaces) – then the key to success may not be so much the study of how technical improvements can be made by using improved simulations or technologies, but rather a more systematic study of non-technical variables of how users interact with each other [1, 19]. The technical factors of these systems, moreover, are not in the first instance those at the high end – degree of immersiveness, realism, and quality of the network connection – but rather at the low end – communication and awareness of each other's actions [1]. Therefore, to put several people in an environment and expect them to perform activities by using technologies with good performance, the meaning of the activities – within the possible chain of activities – has to be studied first. To see how this can be improved, it is necessary to focus on the task and certainly on the available, required or possible competencies.

B. Towards developing an ETC

1) Pre studies:

One of the most important actors in emergence and public safety management are the emergency medical services (providing for instance an ambulance service). Having access to actual exercises for training and leaning in a pre-hospital context, this study chooses them as subjects. Before defining the pilot study, three different groups of at least two researchers observed training sessions for ambulance crews in actual conditions. These training sessions lasted for two full days for two scenarios. The scenarios were divided into five important activities from 1) getting the alarm and 2) driving to the accident place (the ambulance personnel had to practice driving an ambulance car in the city) to meeting the patient, 3) examining the patient and making decisions about help needed, 4) driving to the hospital and 5) handing over the patient. Debriefing sections followed all main activities. The instructors (and the external observers) used observation sheets with focused items throughout. Training days also included (in the beginning) lectures on decision-making, for example for understanding EKGs. An overall debriefing concluded the second day. The ambulance personal had to practice in small groups (two or three people in a group). Two of these five activities (driving the patient to the hospital and handing him over to the responsible at the emergency department were not practiced). It is worth noting that the different steps were decoupled and trained separately; hence the intersections and interactions between organizations and groups of personnel were not trained.

Based on the observation data and discussions with the training leaders, the pilot study was defined.

2) The pilot study

Using the simulator center at the University of Skövde, we designed a test for training a proposed concept for our future ETC, which includes several technical solutions as well as a proposed integration of the different activities into a chain of events with more realistic simulations. Choosing the task for training, determining the necessary spaces and places, choosing right equipment, and discussing technologies used was done in collaboration with the instructors and some practitioners from the PSAs.

The general purpose of the pilot study included: 1) allowing ambulance personnel to train *the whole chain of activities* for two separate scenarios that are usually included in their training, from getting the alarm to ending the activities, usually by handing the patients over to personnel at the emergency room, 2) *using simulation technologies* to maintain continuity and enhance realism, promoting naturalism in the flow of activities needed, and 3) allowing the performing of task and record activities.

The chosen scenarios are: a) a gas station attendee calls for an ambulance after a a truck driver complained of chest pains, and b) an ambulance is called as a result of trauma after a biker collided with a car.

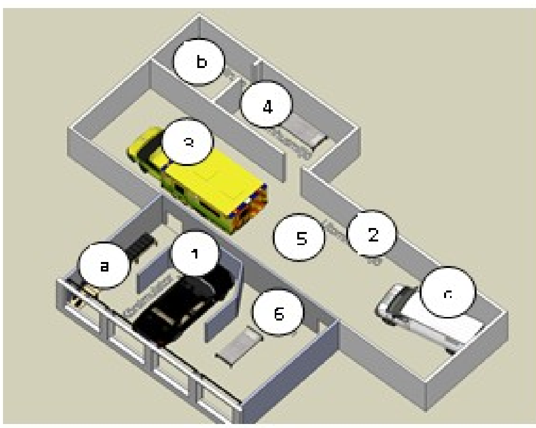

Figure 1.The used environment included 1) a simulator for a car with panoramic screens 2) simulating the accident environment using large projections 3) an ambulance with extra equipements 4) interior with patient simulator for the 'stroke' scenario 5) accident place 6) the interior for the emergency control room at the hospital and 7) coordinating simulations for a) environmental simulations and car and also connections with the ambulance b) patient simulator and communication technology around him/her and c) the external car.

The used equipment were: a Patient Simulator SimMan 3G, a real bed from the hospital, the driving simulator from the university used for dispatching and driving through realistic geographical environment, a standard equipped ambulance (VW T5 Profile) car, a real truck cab (used here as exterior props and observation and communication place), a real bicycle, projectors projecting realistic environment around the accident, computers, an audio system allowing audio simulation for the road environment in the traffic accident case, a 3x2 feet large projection surface projecting the scene of accident, miscellaneous equipment consisting of chairs and tables that were used as simple props, and three wireless cameras for recording the trials. The used environment and major equipment can be seen in Figure 1.

V. Results

Here we present the set up and observation results, data was collected via video and picture recording, observation of activities and a debriefing session after the performance.

A. Scenario 1: handling the 'chest pain' patient

After dispatching the units from SOS Alarm the ambulance personal used the driving simulator (see Figure 2). During this activity they got information about the actual alarm. After arriving at the place the team moved to the center place where supports (ambulance, truck, projection) visualized the action scene. The person who called for the ambulance presented the team to the patient and conventional treatment was initiated (the patient simulator was directed by an instructor from the control room).

Figure 2. Driving in the car simulator with the surrounding projection to the accident place.

This was followed by moving the patient to the ambulance with traditional equipment and additional communication and logging technologies continuing the treatment during transport.

One of the ambulance personnel drove the car while having the connection through a small screen with his partner helping the patient in the load part of the ambulance car. In the similar way the person helping the patient had video connection with the driver of the car.

Figure 3.Patient care in the ambulance car and handling over him at the cardiac ICU.

After arriving at the cardiac intensive care unit (ICU) the scenario ended with moving over the patient to a hospital bed end reporting his status (see Figure 3) The total time for the whole scenario, the chain of activities was approximately 29 minutes, divided in the following main activities: Preparatory activities (4 min); Driving to the place (6 min); Working at the place and loading the ‘patient’ (7.5 min); Driving to the cardiac ICU (5.5 min); Handling over the patient and reporting (6 min).

B. Scenario 2: handling the ‘trauma’ patient

After receiving the alarm, the units ‘drove’ to the scene of accident in the car simulator, similarly to the previous scenario. Upon arrival at the accident scene, a real place was projected on the wall and noise from a traffic jam was simulated. Several cars and people were on the way (ambulance, truck, passing people, projections) or visualized. The patient – through the patient simulator - was difficult to contact and almost immediately became unconscious.

After moving the patient simulator on the ambulance to the hospital, again similarly to the first scenario, the patient was transported to the emergency room. In this scenario, continuous contact with the hospital was needed both at the accident place and from within the ambulance (see Figure 4). The scenario ended with unloading the patient and reporting his state to the receiving team.

The total time for this whole scenario was 27 minutes, divided as follows: driving to the accident place (4 min); treatment at the accident place and moving the patient to the ambulance (9 min); care in the ambulance prior driving (4 min); driving to the hospital (7 min) and moving him over to the the emergency room (3 min).

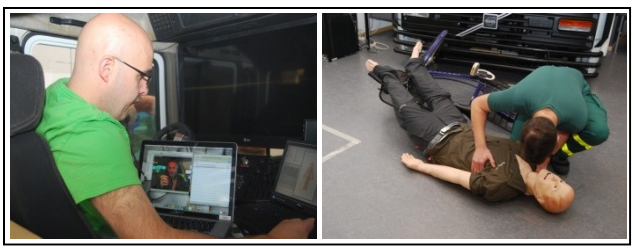

Figure 4. Steering communication from the lorry (behind the patient simulator) and examining the patient at the accident place.

VI. DISCUSSING OVERALL COLLABORATION

A. Examples from examining collaboration stages

For the pilot study, one and the same observer was able to follow the whole chain of activities and transitions between the main activities were smooth. Certain issues, not normally considered explicitly, could thus be trained, e.g. ‘step out from the ambulance and look for the right entrance to a house’, ‘carry some emergency equipment from the car through the entrance’, ‘actually lift the patient simulator from the ambulance stretcher to the hospital bed’. These transitional activities can be time-consuming and are usually not practiced. The benefit of our proposed approach is that this part of the scenario is actually enacted and logged as opposed to trainees simply having to explain to the instructor how they would have done it. This is of specific importance in all inter-organizational interactions as there is a major risk for loss of information.

Table II summarizes the flow for performing activities depending on the used technologies.

TABLE II. FLOW OF COLLABORATION USING TECHNOLOGIES – THE * INDICATES THE USEFULNESS OF THE FACTORS FROM TABLE I

Flow	Helping technologies*	Whole scenario
acknowledging presence,	Simulating places****, audio* and video**	****
navigating into a position,	Car simulator**, using the ambulance with logging**	**
contributing to meta-planning, overall comm.	Audio communication***, Communication with the patient simulator**	N/A (yet)
negotiation,	Face-to-face****, With the hospital**	N/A (yet)
contributing to the task at hand, co-work	Using Car Simulator**, Video***, Audio***, Patient simulator**	****
acknowledging utterances	Logging (this is not fully tested yet)	N/A - yes (Presumably)

B. Patterns: Problems, Social- and Technical interaction

The scenario in the emergency training tasks that needed to be performed can be considered successful for the pilot study. There were no task related problems (P) for the ambulance personnel to make decisions and act accordingly. However, this can, at least in part, simply be due to the fact that the tasks used two well-prepared individuals from the ambulance and the two most practiced scenarios from their re-occurring training.

The Social Interaction (S) was not considered to be as successful as task solving. Although face-to-face communication was successful, the subjects experienced problems during voice communication with the emergency medical services and the hospital. Communicating with the patient simulator also failed a few times. These failures tended to result only in 10-20 sec. occasional delays since other people replaced the broken line, e.g. by using other channels. However, a broken line can result in problems with handling the patient and reduced preparedness at the hospital, for example, and even short delays can influence the overall task performance (P).

Technical (T) disturbances accrued mainly with our patient simulator and the voice connections. This, of course, also influenced task solving and social interaction, too.

While the beginning and ending of the collaboration is nearly not observable for the pilot study for the pre studies all activities were separately tested and had several smaller beginnings and ends. The observer could examine the discussion and activities while the ambulance personnel drove to the location of the emergency. He could follow the same discussion (that was not interrupted in this case) on the way out from the car to the place, also during the main transition activities. Feedback from the experts from the ambulance unit revealed that the time spent on critical tasks (time on site) was well captured and perceived as realistic.

VII. CONCLUSIONS AND FURTHER WORK

The results contribute to understanding the benefits of using simulation and new technologies in following an entire training situation step-by-step. It is important to start beginning with the alarm, examining collaboration during driving to the accident place, taking care of the people involved, work together with other actors from the PSAs, until driving to the hospital and handing over the patient to the emergency room at the hospital. The importance of separating ongoing social, technical, and task related issues contributing to a better understanding of necessary flow between activities is identified. We can further conceptualize how social problems directly influence the introduction of technical systems, and conversely how technical problems cause social misunderstanding and delays – often unnecessarily. The results are examples that indicate the importance of combining research efforts in various interdisciplinary fields to achieve better roll-out and better understanding of the various facets of interoperability.

The results also pinpoint the need and role for further examining transition time slots to handle the resources under unfocused collaboration between the necessary collaboration activity patterns. The analysis of patterns in this study is not statistically significant and subjective in the sense that behavior is not directly measured but translated into the observer's categories. This also relies on the researcher possessing extensive knowledge on what the significant patterns are.

There are several ETCs and collaborative projects within emergency in Europe. To connect several simulator centers may contribute to better understanding work routines and requirements and through this to learning. We are going to set up distributed simulations (allowing simulations at geographically separate places) and investigate how people collaborate and learn from each other. There is a need to understand and apply the possibilities allowed by new technologies, e.g. simulating crowds [25], robots in rescuing [26], and so on. ETCs, whose use is not restricted to only academic users and people involved in emergency and rescuing activities, but open to any users with a need for distributed simulation for collaboration are needed. There is a need for training for groups with disabilities [21, 22]. However, to perform specific training, we first need to define basic conditions for a more general-purpose ETC. These issues can support further research on the social impact of launching and integrating new complex technologies in the activities at the ETCs.

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