

# Making Action Visible in Time-critical Work

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## ABSTRACT

This paper presents descriptive accounts from an ethnographic study of time-critical work in the domain of emergency response and the operative work of fire crews. The verbal communication as part of such work creates difficulties in providing accountability of the fire crew's actions. The concept of work rhythms and temporal structures is used as an analytical framework. Design implications are presented suggesting that verbal communication should be made persistent, visible and accessible in order to support accountability. These design implications are discussed in relation to the fire crew's work practice.

## Author Keywords

Ethnography, time-critical work, emergency response

## ACM Classification Keywords

H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

## INTRODUCTION

In a range of professions, people experience periods of severe work intensity due to a work context where time-criticality and timing are key factors for success. This is typically the case in control room work such as traffic controlling [10, 3], emergency dispatch [16] and network troubleshooting [22]. For all these settings the notion of time-critical work captures a core aspect. Time and timing are important and failing to comply is often related to fatal consequences. In these settings it is not only important to make competent and timely actions but also to document the actions in order to coordinate the work and to provide accountability of the actions taken.

In such settings, computer-supported collaborative work (CSCW) applications have an important and central role by

providing shared visual representations to promote collaboration between distributed actors.

However, severe work intensity and time-criticality are not exclusive for control-room settings but also an unavoidable part in field-work settings of mobile professionals such as for service technicians [6], police patrols [14] and firemen [13]. In these non-office work settings collaboration is accomplished using other means than traditional CSCW-applications. Studies of people engaged in physical tasks and physical collaboration have shown that speech is the primary mean for coordination [7]. Verbal communication is beneficial for coordination but implies a distinct problem regarding accountability.

This paper reports from a study of time-critical work in the domain of emergency response, with a focus on emergency response work performed by firemen. In emergency response work, documentation of actions taken as part of an incident has become increasingly important but very problematic due to the absence of appropriate support. Traditionally, documentation has been an activity that primarily takes place after the physical emergency response operation has been completed and the fire crew is back at the fire station. This is about to rapidly change. There is now a strong movement in the emergency management community enforced partly by new *national accident prevention legislation* and partly by a general awareness that documentation of vital events and actions could provide insightful material for analysis and improvements of the work practice. Attempts have been made to explore the use of handheld devices for documentation of important actions during response work. The results of such efforts have been poor. Managing documentation activities during response work has conflicted with the physical work to handle the emergency.

The research question addressed in this paper is: "How can accountability be provided in a time-critical work practice where verbal communication is the primary mean for coordination?"

## RELATED WORK

There are several reasons to the unsuccessful attempts to provide information technology support for documentation as part of emergency response work. Not surprising, the problems are related to inadequate technology design in

relation to the pre-existing work practice. These problems will be discussed in relation to related work.

First, a major problem is the focus to provide information technology designed to fulfill the needs of a paper based practice. Studies of time-critical work have shown that textual information is not necessarily the obvious means by which people coordinate their work. Instead, for some work practices the primary means of coordination is speech [19, 22]. Studies of communication patterns in emergency response work support this view showing that ambiguous situations result in an increase of spoken communication [5]. User-centered studies of fire crew radio-communication [4] have shown the need for improvements regarding radio communication functionality.

Second, the aim of the documentation is understood to focus on capturing explicit decisions and important events as part of the work on the accident site. In emergency response work of fire crews, decisions are not explicit, but intertwined in the conversations and the situated actions. Firemen rarely reflect on several decision alternatives but rather use a single option strategy [11]. Sensemaking and not decision making is the issue that is central to the fire crew work in emergency response. Analysis of breakdowns in sense-making [20] and studies of how information technology can support fire crews in emergency response work [13] show how the effort to make sense is central in operative emergency response. Sensemaking as defined by Karl Weick is as an individual and collective process where “reality is an ongoing accomplishment that emerges from efforts to create order and make retrospective sense of what occurs.”[20]. This is contrasted to decision making where the question is *what shall we do*, whereas in sensemaking the question focuses on *what is going on*. A fundamental aspect in sensemaking is to understand that a person or a collective’s experiences of a situation are progressively clarified, and that this clarification works in reverse [21]. In emergency response, the situation which the fire crew responds to is many times unclear or ambiguous. In order to make sense, people must act since, from a sensemaking perspective, it is understood that action precedes understanding. People actively interact to create meaning by the enlargement of small cues and forming a structure to provide meaning. A fire crew cannot wait to respond or postpone their actions, even when the situation is equivocal. They must act even when the risks are severe, which was brutally evident in the 9/11 World-Trade Centre disaster.

Third, time-criticality and rapidly changing situations limit the ability and priority to type in information to provide documentation. The need to make physical actions takes precedence over what is understood as less important work. Further, studies of service technicians have shown how users struggle to align the mobile computers with the work situation at hand due to interaction issues. *Making place* [12] for IT has become an extraneous activity to adapt the situation to the abilities of the mobile technology. In other studies [6], embodied interaction has been adopted to guide

the design of mobile technology for service technicians in order to avoid such problems.

In the next section, work rhythms and the notion of temporal structures will be adopted as an analytical framework to illustrate aspects of time-critical emergency response work.

## **ANALYTICAL FRAMEWORK**

Time has gained renewed attention in organizational studies and in IS-research. Recent studies suggest that time provides a new and complementary lens [1] to the existing strategic design, political and cultural lenses used to explore how organizations function. They claim that a primary benefit of applying a temporal lens is that it allows us to explore not just processes and practices but the pace by which they move, the trajectory over time and what they align with.

Wanda Orlikowski and JoAnne Yates present the concept of temporal structuring to show how people experience time through the shared temporal structures they enact continuously in their everyday practice. People produce and reproduce a range of temporal structures which shape the temporal rhythm of their ongoing actions. Further, a practice-based perspective is applied that is suggested to overcome the traditional dichotomies that earlier researchers have used to discuss time, such as the dichotomy between subjective vs. objective conception of time [15].

From an IS-perspective, Madhu Reddy and Paul Dourish have made studies of temporal rhythms and information seeking in medical work [17]. They propose that information seeking should not be viewed as a separate task from other work activities. Instead they suggest that information seeking must be understood as an integrated activity in the everyday work of medical workers. By outlining large-scale and fine-grain temporal structures in the everyday work they illustrate how information seeking is a seamless and interwoven part of the everyday work and by that shape and is shaped by the work rhythms. This means that people create temporal structures as means to accomplish their work; project deadlines, meeting schedules and even lunch breaks can be seen as temporal structures. When people create temporal structures, they become also dependent on them. They shape their own work in relation to the temporal structure, such as working overtime to meet a deadline, or by re-scheduling a deadline.

In this paper, the concept of work rhythms and temporal structures will be adopted to give a contextual view of the rhythms and temporal structure in emergency response work. The concept of large-scale has been applied here to identify and present the large-scale rhythms of emergency response and related temporal structures.

## **METHOD AND RESEARCH SETTING**

This study is part of an action-research project [1] focusing on the design of information technology use in supporting emergency response work of fire crews in communal fire and rescue services. An extensive field study, started in 2002, has been conducted using an ethnographically inspired approach [9] with approximately 800 hours of participant observations. The observations have taken place as part of the fire crews' normal work shifts including 10-hour day shifts, 14-hour night shifts and 24 hour weekend shifts. In order to study emergency response work using a participant observation approach, also non-emergency work has been covered in this study. Emergencies are not easily scheduled which has resulted in an ongoing prolonged field study. On incidents, the author has been using the mandatory protective jacket, pants, boots and helmet.

The rich and large amount of material from the field study is used for providing a deep understanding of the work practice in order to inform the design of information technology use.

The data presented in this paper is from one incident but analyzed in relation to material of the entire study. The data consists of transcribed field notes written down during the response work as well as after an incident. Fire crew radio-communication on the incident location has been recorded using an mp3-player taped on the handheld radio. Radio-communication during transportation has been recorded via the vehicle communication-radio. The recordings have been transcribed and analyzed. Interviews have been made with fire crews for the purpose of capturing their reflections of recent incidents and their reflections on how they experience aspects of the time-critical work.

The setting reported of in this paper is operative emergency response work in communal fire and rescue services in Sweden. Fundamental characteristics of emergency response work is the uncertainty of what a fire crew will face on arrival to the accident location, the ambiguity resulting from incomplete or incorrect information from the alarm-caller, and the urgent actions that need to be done by the fire crew that are both unable to postpone and irrevocable when made. The physical work of emergency response is performed by fire crews. A fire crew consists of one fire crew commander (FCC) and four to six firemen. The fire crew commander takes the role as incident commander (IC) when the crew is dispatched to an emergency. When additional fire crews are dispatched to the same incident, a new commanding level is also dispatched and the role of incident command is switched to this new level. Incident dispatch is triggered by SOS-112 alarm-call and managed by command centre operators (CCO) located in a central command centre.

### **Retrospective documentation practice**

Prior to presenting the work rhythms and temporal structures in emergency response work, the current retrospective documentation practice will be outlined.

Documentation of emergency response work is a retrospective activity accomplished at the fire station after the emergency response operation. It is retrospective in the sense that the documentation outlined in an incident report is based on the reflections of a completed operation, based on the memories of the incident commander and brief notes scribbled down in note books, and in hindsight with the knowledge of the result of the operation. To a varied degree and depending on the organizational norms, some incident commanders make brief notes of important events and actions using pen and paper. Progressively and slowly, the documentation practice has evolved to include also specific time-stamped events generated and logged by the command center's computerized dispatch system. A range of time-stamped events have been added to the documentation and includes, time at the dispatch event, turn-out time, time at arrival, time at intervention and the time when the response work was completed. On the basis of all these time structures, lead-times are calculated. The incident documentation is performed using a computerized incident report software where the incident commander type-in the accounts and reflections of the incident. The incident documentation includes both qualitative (retrospective accounts) and quantitative information (time-stamped events). When completed, the documentation is submitted to the national Rescue Agency for statistical analysis.

## **RESULTS**

In this section results from participant observation of an actual incident are used, in combination with excerpts of transcribed radio communication from the same incident. In addition to this, also data from interviews with fire crew commanders and firemen is used to provide a rich illustration of the work practice.

In emergency response work, one can broadly speak of four sequential and distinct large scale rhythms. The initial rhythm is the mobilization rhythm where the fire crew receives the alarm and is dispatched to the accident location. The second rhythm is the intervention rhythm starting when the fire crew arrives to the accident site and starts their physical intervention. Following to this is the situational adjustment rhythm where the fire crew's initial work has had some effect on the emergency. In the following subsections aspects in these three large-scale rhythms will be outlined.

### **Mobilization**

The initial rhythm in emergency response work is caused by the triggering of an alarm. This rhythm has two major temporal structures; awakening and transportation, and is characterized by the sudden interruption of the ongoing activities and switch of attention to the preparations for the emergency response work that in short time will be accomplished.

“Station B. Major Alarm. Automatic fire-alarm at the Carl-Johan School, Admiral street seventeen.”

### *Awakening*

The distinct sound from the fire station alarm speakers creates an immediate interruption of the current ongoing activity. The fire crew experiences a sense of awakening where the sudden alarm is forcing them to switch focus, listen to the crackling sound when the operator's voice informs about the type of alarm and street address.

“When the alarm is sounded there is directly a sort of increased level of adrenaline or at least an awakening time where you wake up from your current activity, an interruption of what you do, and you are trying to listen to what the alarm is about.” (Fireman)

While the voice informs about the alarm, the firemen proceed rapidly to the protective gears and rescue vehicles in the ground-floor garage. On their way to the ground-floor the fire crew speaks rapidly in short sentences clarifying the address and the driving directions to the location.

IC: “did he say Admiral Street seventeen or seventy?”

Fireman: “seventeen...it is on the east-end of the admiral street”

The level of intensity in this activity is strongly related to the type of alarm and the time of day. If the alarm type is Automatic fire alarm in a nursing home in the middle of the day, then the alarm is understood as less critical compared to the same alarm three o'clock in the morning. The fire crew actions in the temporal structure of awakening are highly shaped by the 90 seconds turn-out time limit but they also shape this structure by adjusting their tempo in relation to type of alarm and time of day. In this initial moment the speed of actions and intensity of their conversations in the awakening temporal structure indicate the degree of seriousness that the fire crew assigns to a specific alarm.

### *Transportation*

The rescue vehicles leave the fire station and start the transportation towards the accident location. The incident commander contacts the command centre and confirms that they are on their way. The command centre operator informs the incident commander about what is known about the accident and what additional resources at this point in time have been dispatched. Often, the words of the command centre operator are hard to hear by the firemen sitting in the backseat. The incident commander repeats the information to the fire crew. During the transportation to the accident site, the fire crew is preparing for the potential situation on arrival. The conversation in the vehicle is dependent on how much the fire crew knows about the location and the resources available to make sense of the brief and sometimes incomplete information. Suddenly the command centre operator informs:

CCO: “We have received a call from the school and they say that there is a fire in a hall-way of

building C...you will get backup from station C and station D with rescue and ladder units”

IC: “That is acknowledged...did you say building C?”

CCO: “That is correct, over”

The information from the command centre operator is not just used to determine what has happened but also an indication of the scale and seriousness of the incident. A fireman explains:

“You try to listen to what is said to the IC over the radio, if there have been many calls about this incident. You know...you can hear the way the operator is talking to know if it is serious or not”

The time period of transportation provides the fire crew with a few minutes for preparation and making sense of what will face them upon arrival. A fire crew commander explains:

“Even if we do no physical work, we are still sitting in a rescue vehicle that is moving at high speed in the traffic. The guys are checking their stuff. The driver has the highest intensity due to the effort of driving fast to the accident site. So even if it could look as we are doing nothing, we are experiencing the opposite. Some of the guys might know the exact location and how the location looks and based on that you try to make a mental picture, what could be expected when we arrive, how we should deal with a certain issue that is specific for the accident location. So, even if it could be very quiet, that does not imply inactivity”

Incomplete or ambiguous information from the command centre can result in a significant effort for the fire crew to make sense of the situation, enroute to an accident location. Difficulties to make sense of the accident location result in intense conversations among the fire crew and pro-longed communication with the command centre [13]. What could have been perceived as non-productive time is by the fire crew used as an important time to prepare and make sense of the accident and location. The fire crew has shaped this temporal structure to become a resource in their preparations for the response work.

### **Intervention**

The fire crew shifts into a new rhythm when they arrive to the accident location. The characteristic of this rhythm is the shift from a state of preparing to a state of physical intervention in a set of parallel and coordinated activities. The visual impression of the accident situation and the way civilians act on the location contributes to the intensity of the intervention actions. Visual signs of emergency, such as thick black smoke-clouds, flames out of the window of a building or a severely crashed vehicle are triggering factors.

### *Window report*

The arrival is a critical moment where the individual as well as collective expectations, built up during the mobilization rhythm, either will be confirmed or rejected. The alignment of the built up expectations and the accident location's visual impressions are critical in order to establish a rapid intervention. As is illustrated in the excerpt below, a deviation between the expectations and the impressions on site could significantly delay the work.

“When you arrive, you get a confirmation on the things you've been thinking and not thinking of. If the situation is similar to what you expected then your thinking process fades, but it could also be the opposite, it does not make sense ... what the heck is this ... what should we do now? If this happens, then obviously it takes some time to know what to do.” (Fire crew commander)

Based on the snap-shot visual impression of the situation a verbal report, called window report, is provided by the fire crew commander, in the role of incident commander, by radio to the command centre operator. This report is very brief and the situation does not permit any discussions or follow-up questions, just a short confirmation from the command centre that the report has been received.

IC: (In vehicle F511):”G400... F511 arrived... we have a fire and there is heavy smoke from the hallway... I report back later”

CCO:”F511 that is acknowledged”

This report is the first verbal formulation to the command centre that explicitly is capturing what the situation is all about, based on the understanding of a rescue services professional on site. The window report is communicated using the radio allowing other fire crews enroute the accident location to take part of the information. There can be significant differences between what a non-professional has told in the 112-SOS call and what the commander reports upon arrival. The report is therefore, even if it is a snap-shot impression, a vital moment for how the subsequent actions on the accident site and the actions at the command center will be shaped. Based on the report, additional resources can be prepared for or directly dispatch by the command centre operator.

### *Situation assessment*

When the fire crew dismounts the vehicles, the commander starts a situation assessment and the firemen begin to deploy equipment according to a pre-planned routine that corresponds to the situation at hand. The situation assessment has the goal of providing fundamental understanding of the emergency in order to determine how to take control of the situation and minimize its consequences. A fire crew commander explains:

“When you arrive, you must try to understand the scale of the accident and not only from one side of

the building, you must look from several angles and that takes a time to accomplish. Because of this, we have a set of planned actions so that I do not need to tell the guys what to do but for them just to get things started. And by having them started I have also created some time for me to do the assessment. “

During the situation assessment task, the incident commander uses the fire crew open radio channel to inform about the situation that could require changes of the intervention tactics.

### *Rushed deployment*

While the commander is conducting the situation assessment the fire crew begins the physical intervention based on a set of coordinated activities, where each activity contributes to the progression of the intervention. The pace in this work is significant. The driver of the vehicle man the pump, the breathing apparatus team (BA-team) starts to lay fire hose and locate how to get close to the fire. In case of locked doors they apply the “break-in” kit to get access. The action of breaking-in is reported back, over radio, to the commander. When the BA-team is ready to move into the hallway, they call over the radio to the pump operator that set pressure on the fire hoses. The BA-teams' eagerness to start fire suppression as fast as possible put pressure on the pump operator to have finished the appropriate actions to provide water. The pump operator is experiencing a tight deadline. During these activities there is an intense communication over the fire crews' open radio channel, which provides awareness of the initiated work for the fire crew commander adding this to the situation assessment. A fire crew commander explains that rushed deployment and situation assessment is highly related:

”The orientation and assessment, well ... could be done by all of us. I have to be sharp and listen to what the other guys are saying, they see it from their perspective when they work. I have to take into account their impressions but it is then up to me to make the decision, everyone cannot make the decision...but I would be stupid if I do not listen to the guys, all this must be done in a very short time, you do not want to delay the response operation.”

What is shown here is how the rushed deployment and situation assessment is not really two distinct and separate activities, but two coordinated activities that are distributed over the fire crew but ultimately being the responsibility of the incident commander. The fire crew uses the open radio channel to communicate directly to one individual or part of the group while at the same time making the conversation available to the entire fire crew.

### *Status report*

The situation assessment is communicated in what is called a status report which is a verbal report with a specific

structure. The status report is used for updating the command centre of the ongoing work and to allow the operator to update and prepare the arriving units. The following excerpt is from a mobile phone conversation where the incident commander is providing a status report:

IC: "We have a fire here in the hall-way, we have initiated extinguishing. There are some cardboards and rubbish on fire and heavy smoke. I would like to have station C prepared to initiate search and rescue"

CCO: "that is understood"

The command centre operator calls over open radio channel to inform the fire crew in the vehicles from station D about the situation and the task that they should prepare for.

The status report has several purposes. It is used for providing a current view of the situation but also to provide information that is important for the arriving units. A fire crew commander explains:

"You try to provide the command centre with a report as fast as possible. That means that after you have retrieved a fair amount of adequate information, you want to share this knowledge with them, because they cannot see any of all this but still they must be able to provide the support I need. That is why it is important for me to deliver a picture so that they can be part of the game."

The status report is communicated over radio or mobile phone to the command centre. It provides information for the resources dispatched to the specific incident and information for possible re-allocation of available resources. The status report shapes the command center's alternatives to both assist the ongoing emergency and to provide resources for additional alarms. Allocation and re-allocation of resources are time-consuming and which makes status reporting important.

### **Situational adjustment**

When the actions of the fire crew have started to take effect, the emergency response operation is shifting into the third rhythm. The main characteristic of this rhythm is that of situational adjustment, meaning that the incident commander is planning ahead of the development of the emergency and is adjusting the actions of the fire crew according to foreseen and unforeseen events of the emergency. Additional resources arrive at the accident location, adding the need of updating the arriving fire crew commanders and higher ranking commanders of the situation. The ambition with situational adjustment is to control and force the emergency in a desired direction. The incident commander and the fire crew commanders are here working on different time scales. The fire crew commanders work close with their fire crews and are directly involved in the physical work whereas the incident commander has provided distance, both physically and

mentally, in relation to the emergency, and is focusing on keeping multiple alternatives open for any sudden changes of the progression of the response operation. This is illustrated in the following excerpt:

The unit from station C assigned to search and rescue has found additional floor plans that are filled with smoke. They report this to the newly arrived higher ranking commander that has taken over the role as incident commander. The incident commander immediately contacts the command centre over radio.

IC: "We have found additional smoke on level three and four. When will station D be here, over"

CCO: "wait a moment"

CCO: "They are arriving right now"

IC: "Good, I estimate that we will be here for the next hour, it will take some time to ventilate this building"

CCO: "that is confirmed"

### *Coordination in momentary meetings*

The incident commander and the fire crew commanders are coordinating their actions using a cyclic pattern consisting of short conversations in momentary meetings. There is a continuous flow of short face-to-face meetings and radio communication embedded in the physical work at the accident site. The occurrence of these meetings is accomplished by mutual adjustment. A higher ranking commander explains:

"These conversations happen when I need to check something or shortly discuss an issue. The meetings are accomplished in action when there is a need to talk to each other. If I see that Garry [fire crew commander] is occupied with work then I won't interrupt him. The same goes for him if he sees that I am in a discussion with property owners and a few policemen, then he will solve the issue without me."

The momentary meetings are used for coordination of actions and shaping of actions in the emergency response work. The actions are not always known in advance but are formulated as part of the work.

### *Periodic reporting*

Periodic reporting to the command centre is used both as a way of continuously updating them of the current situation and to highlight any potential needs of additional resources but also as a way of moving the task of documentation of important events away from the work on the accident site. As is shown in the following excerpt, the incident commander use the periodic reports as a way to let the command centre handle the documentation of the ongoing work. A fire crew commander explains:

“In general I rarely make any notes and instead I use the verbal reports to get something written down. I report to the command centre on what is happening...important events, so that they can add it to the protocol. And I do get disappointed if I see afterwards that they have missed certain things...but they have become better to make notes.”

The incident commander has shaped the cyclic temporal structure of periodic reporting to move documentation activity away from the physical work on the accident site.

IC: “G400, over”

CCO: “yes, over”

IC: “I have a representative from the school here, I will ask her to take contact with you to provide the contact info”

CCO: “do so, over”

When the emergency is under control, the time period between the verbal reports becomes longer. It is therefore not uncommon for the command centre to take contact with the incident commander to request an update.

### **Incident completion**

Eventually the work for the fire and rescue services is coming to an end on the incident location. This rhythm is characterized by the tasks of sending back units to the fire stations and to inform property owners of their responsibility for the premises. This rhythm consists of the following temporal structure.

#### *Demobilization of units*

Fire crews start to demobilize as soon as the work at the incident location comes near completion. The different fire crews are sent back to their fire stations and only a small number of firemen stay at the location. Demobilization of fire crews is a temporal structure that has significance for the command centre. From the moment of the first fire crew’s demobilization, the ability to handle the next incident is increasing. It is therefore important to gradually demobilize fire crews that are considered unnecessary at the location.

#### *Declaration of incident termination*

When the work of the fire crews has brought the emergency to end, then this is also the moment when the responsibility of the fire and rescue services comes to an end. This clock-time is important to document and to hand over the responsibility to the property owner in a clear and formal fashion. The following excerpt shows how the declaration of incident termination is accomplished by a phone call to the command centre.

IC: “Okay, we will now terminate the emergency response work ...the time is sixteen thirty-four

{16:34} and we hand-over the responsibility to the school representative.”

CCO: “that is understood”

The command center operator documents the clock-time in the incident management system along with a note that the emergency response work is completed. The property owner is from this moment formally responsible for any further actions and the associated costs to clean-up, rebuild and prevent people to enter the damaged area.

### **DESIGN IMPLICATIONS**

Based on the results from the study two high-level design implications have been proposed in order to answer the research question.

#### **Make verbal communication persistent**

Verbal communication has an important role for the involved actors in the accomplishment of emergency response, regardless if the actors are collocated or distributed. The verbal communication contains instances of both coordination tasks and sense making efforts. The command centre operator manually makes a few notes of what at the time was understood to be important information. It is not an exaggeration to claim that only a fraction of all the valuable information is covered by those notes.

The ephemeral aspects of verbal communication has formed a communication practice where significant amounts of information are repeated in order to transfer it between actors that are using different communication channels or communication devices. The verbal communication over radio or mobile phone is adapted to the time critical situation and consists of short sentences with a clear message.

The actions of the emergency response work are represented in the verbal communication. The actions are embedded in temporal structures which form the conversation and are thereby also represented in the communication. The work rhythm forms the conversations and makes aspects of the context of those actions visible in the conversation.

In order to provide accountability of the actor’s actions in emergency response work, the design implication here is that ephemeral verbal communication must be made persistent. Making it persistent would open up for possibilities to re-call and examine sequences or the entire communication. Transforming verbal communication from a state of ephemerality to persistence means in the most practical sense that the communication sequences are recorded, tagged (time and sender id ) and stored as audio-clips.

#### **Make verbal communication visible**

In initial phases of emergency response, situations are rarely fully understood. This means that emergencies are

unfolding and gradually clarified by the actions taken in the three work rhythms mobilization, intervention and situational adjustment. In the mobilization rhythm the fire crew is highly dependent on information from external actors. New information during the work has significant impact on the understanding of the situation and the actions that need to be taken. Commanders engaged in the response work must focus their coordination efforts ahead of the ongoing situation.

Making the verbal communication persistent to enforce accountability will also provide means to structure and make the communication visible and accessible as part of the emergency response work. In the process of making verbal communication persistent, added meta data will provide means of organizing the clips in a structure. The simplest structure would be based on the timestamp, or aligned to the command structure based on sender id. These structures would allow new ways to make visible the work structure as a resource for sensemaking [21] as part of the ongoing work. This means that the evolving collection of verbal communication sequences would correspond to and make visible the unfolding and gradually clarifying *picture* of the emergency.

## DISCUSSION

In this paper, accounts of time-critical work by fire crews in emergency response have been presented showing that verbal communication plays an important role in accomplishing such work.

The study shows that explicit documentation of actions, as part of the emergency response work, is limited. This situation presents significant problems for providing documentation for accountability purposes. Findings from the study suggest that verbal communication should be made persistent, visual and accessible for the actors in emergency response.

The design implications point in the direction of a dual use of the documentation; both for the *post-emergency* work and *ongoing response* work.

In *post-emergency* work, the use of the documentation is directed on investigating the cause of the accident and evaluating the emergency response operation. The persistent communication would here be seen as a structure of digital traces of the actions and used for detailed analysis. Further, in feedback sessions the involved fire crews will be able to access the same structure of digital traces to “replay” the response work, analyze detailed communication sequences and make sense of their actions in order to both legitimize and improve their work practice. The approach of meta-tagging the collected information will allow analysis based on a specific actor or set of actors and also focus the analysis on a particular point in time. In *ongoing response* work, the persistent communication could be visually presented in a structure representing the involved actors, relationships between the actors, the

communication intensity and the individual conversations. The structure would be accessible on the personal communication devices and used to provide cues and structure for sensemaking for the actors as part of their ongoing work.

However, making verbal communication persistent, visible and accessible would only provide minor value if the intended users have limited time to use such information. Emergency response work is time-critical and as presented in the field study characterized by temporal rhythms. The use of persistent verbal communication must therefore be aligned to these rhythms. Based on the findings from the field study, there exist occasions where such persistent verbal communication is valuable and where time is available.

One example of such an occasion is during transportation to the accident location. In current work practice, the fire crew is paying attention to the radio conversation, both to what is said and how it is said, in order to build expectations for the situation on arrival. A structure could here be valuable for units that are dispatched to an ongoing accident. Another occasion is found in the situation adjustment rhythm when the incident commander brief newly arrived resources. The documentation would here provide material for the conversation.

In relation to these occasions, there is also a potential use for fire crews and external actors that are stand-by for dispatch to the emergency to take part of the ongoing response work by having the access to the evolving documentation. Further research is required to explore how the use of the documentation can be used as part of the emergency response work practice. The next step is to develop a prototype and use it in field experiments with fire crews and incident commanders.

Providing documentation of the actions of emergency response work during the ongoing emergency will improve its value in post-emergency analysis. The argument for this is that documentation of actions should not become monitoring for post-emergency activity but a resource for sensemaking in the time-critical emergency response work. The structure of persistent verbal communication could become the shared visual representation of work for fire crews similar to what is found in successful implementations of CSCW-applications.

The suggested design implications address the major problems of emergency response documentation, outlined previously in this paper. First, the documentation is not dependent on manual paper based note-taking, but on natural spoken conversations. Secondly, by providing a structure for the ongoing work, the documentation could become a resource for the fire crew as part of their work practice where improved ability to make sense contributes to the result of such work. Third, in time-critical work the work rhythm and key temporal structures will be reflected in the communication and seamlessly collected and



structured. The time-critical aspect of emergency response work would not provide a problem for documenting the actions but instead become a triggering mechanism. The higher intensity in the work, the more communication will occur, which in turn will result in more traces of actions to capture and make visual in the structure.

The arguments put forward of making verbal communication persistent, visible and accessible for the actors in time-critical work, are partly confirmed by prior studies. There are two studies that from different perspectives confirm the design implications. First, a study by Rogers and Brignull, on technicians in distributed teamwork [18], shows that external representations of verbal communication reduce cognitive load and improve problem solving in dynamic situations. Second, the Whittaker and Amento study of network technicians have shown how persistent and visualized speech from a voicemail system improved the coordination of solving network failures [22].

Both these studies confirm the arguments but from other perspectives of time-critical work. In the first study, the objective was to reduce cognitive load in problem-solving situations. Whereas in the study presented in this paper the focus is not on the individual tasks and prioritization between tasks but on providing accountability and thereby improving sensemaking. In the second study the point of departure was the existing voice-messages, and an invalid work process and lacking system functionality to make use of these verbal messages for problem solving and coordination. This is in contrast to the situation reported in this paper where the actors have non-existing computerized support and the verbal communication is continuously evolving as part of the ongoing work.

Mobile phone and short-wave radio communication has been widely adopted in most work settings of society for a long time now. The use of such technologies have innovated the means by which we accomplish our professional and everyday activities. However, as this study shows the increase of verbal mediated communication presents also problems for organizations where time-criticality is a core issue.

## CONCLUSIONS

This paper presents descriptive accounts from an ethnographical field study of time-critical work in the setting of emergency response accomplished by fire crews.

Work rhythms and temporal structures of emergency response have been outlined showing that verbal communication is the primary mean for coordination in such work. Descriptive accounts have been presented that illustrates large scale rhythms and temporal structures of emergency response work, that both form and are formed by the work of the fire crew. The fire crew's actions are embedded in these temporal structures and represented in the verbal communication. The study shows that

documentation has a limited role for the fire crew in the ongoing emergency response work.

Implications for design have been presented to provide answers to the research question; *how can accountability be provided in a work practice where verbal communication is the primary mean for coordination?* Accountability can be supported by designing system functionality that makes the verbal communication *persistent, visible and accessible*.

Making verbal communication persistent to support accountability also offers improvements for coordination and sensemaking of the ongoing emergency. Access to the verbal communication would provide currently unavailable material for post-emergency analysis.

Much work is still needed to be done in exploring the relationship between the temporal structures and the actions of the fire crew and how this could provide new and innovative approaches to improve the quality of emergency response work. This will also establish a deeper understanding of how the work will be affected by new documentation requirements that in turn are dependent on new capabilities of information technology and the actor's use of such technology.

Implementation of systems that can make visible the actions in emergency response work is both a technically and socially challenging task. There is always a risk of ending up with systems that fail to comply with natural social behavior [8]. Seamless processing of verbal communication will form the way people accomplish their work. People will potentially adjust their actions and form new ways of interacting in relation to what traces will be collected, stored and used.

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