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Resolving Safety-Critical Incidents in a Rally Control Center

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Control centers in large-scale events entail heterogeneous combinations of off-the-shelf and proprietary systems built into ordinary rooms, and in this respect they place themselves in an interesting contrast to more permanent control rooms with custom-made systems and a large number of operational procedures. In this article we ask how it is possible for a control center that is seemingly so "ad hoc" in nature to achieve a remarkable safety level in the face of many safety-critical incidents. We present analyses of data collected in two FIA World Rally Championships events. The results highlight three aspects of the workers' practices: (a) the practice of making use of redundancy in technologically mediated representations, (b) the practice of updating the intersubjective understanding of the incident status through verbal coordination, and (c) the practice of reacting immediately to emergency messages even without a comprehensive view of the situation, and gradually iterating one's hypothesis to correct the action. This type of collaborative setting imposes special demands to support the practices of absorbing, translating, and manipulating incoming information.

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CONTENTS

1. INTRODUCTION

With about 300,000 spectators, Neste Oil Rally Finland is one of the largest annual events in the Nordic region. At their top speeds, the rally cars travel on narrow gravel roads at up to 210 km/hr (130 miles/hr) with spectators watching them from designated roadside areas. The rally organization needs to take considerable precautions to ensure the safety of drivers, staff members, and spectators. The conditions under which the control center of this rally has to operate are challenging. The rally control center (RCC) work has characteristics of emergency dispatch work and of management of safety and security in large-scale events. Medical emergencies are bound to occur, and one of the responsibilities of the RCC is to address those incidents by sending emergency vehicles to appropriate locations, halt the rally if necessary, and generally maintain safety by whatever means necessary. When preliminary information about an emergency is received, workers in the RCC engage in a process of finding out the relevant "who," "what," and "where" of the situation: Maps are read, calls are made, questions are posed, laptops are consulted, and so on.

Most of the research on control centers thus far has focused on contexts that are furnished with custom-made proprietary systems and managed according to procedures honed through years of continuous work. The workers have cooperated with each other for a long time, and new workers have to go through extensive training or an internship period. Good examples of these environments are nuclear power plant control rooms, underground transit line control rooms, and air traffic

control centers (see, e.g., Heath & Luff, 2000, pp. 88–124; Mackay, 1999; Mumaw, Roth, Vicente, & Burns, 2000). Less instrumented and regulated environments have not been addressed to the same extent.

Temporary control centers, such as the RCC, are interesting in that, although they face high operational demands, they do not have the luxury of supervisory control systems but have to resort on ad hoc, non-tailor-made technologies. Only some of the technologies in use are purpose-built to meet the specific requirements of rally management. Practically all information from the rally course that reaches the RCC is technologically mediated and oftentimes ambiguous or incomplete. At times, the regional emergency center (REC) receives a phone call from a spectator and delivers this information to the RCC. In other cases, the information arrives through the hosting rally organization's own channels. Sometimes, pieces of information from different sources contradict each other. It is then the RCC's duty to make sense of and act upon the messages. In doing this, the RCC must achieve balance between potentially contradictory obligations: ensuring that the schedule of the rally is met while guaranteeing the spectators' and drivers' safety.

This article studies the question of how it is possible that a control center like this can achieve a remarkable safety level. After all, Neste Rally has managed rather well: It was elected "Rally of the Year" by the international World Rally Championships organization in 1998, 2002, 2003, and 2004. The goal is to explain how the RCC operates, utilizing it as a case for understanding collaborative sensemaking. We carried out multivideo observations of the control center in two years: 2004 and 2008. We report on three classes of practices that explain the control center's operational performance. First, the tools employed in the RCC produce a state of representational redundancy that enables presentation of the same information in different ways, allowing for flexibility in resolving the incident and communicating with the outside collaborators. Second, verbal outlouds, or quick shouts of information, by members of the team are necessary for updating a state of intersubjectivity and coordinating work. This supports error-checking and correction in collaborative sensemaking when prescribed procedures do not exist. This is different from communication patterns presented in previous literature (e.g., Heath & Luff, 2000) that consist of small, indexical gestures and overhearing other workers' verbal communication. Third, due to the high risks, when making sense of situations and deliberating the responses, collaborative sensemaking focuses on immediate identification of and response to the worst plausible case of events at the accident location. The RCC then gradually refines this hypothesis and takes the corrective action. Delays in additional information cause this to evoke a distinctive style of sensemaking that is qualitatively different from contexts in which the object of action can be better interacted with: Here, decisions are made "on the fly" without waiting for a comprehensive view of the situation. The present study contributes to the research on sensemaking (e.g., Klein, Moon, & Hoffman, 2006a, 2006b; Russell, Stefik, Pirolli, & Card, 1983; Weick, 1995; Wilson, 1999) by detailing practices through which sensemaking is achieved in collaborative efforts—in this case, use of multiple representational tools, articulations, and anticipation of outcomes of events.

Given the particular nature of the RCC (temporality, the heterogeneity of emergency situations to tackle, and personnel available), the findings are best applied to control centers where anticipating the nature of upcoming emergencies is difficult and that are not operated on the basis of full training in a set of standard operating procedures and hierarchical command structures. In particular, they can be applied to control centers that have to tackle very heterogeneous emergency situations while having only a few joint training sessions among their members and no dedicated heavyweight technologies for supporting the task. The practices and strategies observed may not necessarily be optimal in terms of efficiency, but they seem to robustly solve the problems at hand.

2. RELATED WORK

Resolving time-critical incidents such as spectators' medical emergencies or drivers' car crashes depends on the RCC team members' success in making sense of available information. Sensemaking occurs in the face of ambiguous situation or confusion and is a process that may include innovative and nonobvious courses of action (Foreman-Wernet, 2003). As Weick (1995, p. 14) put it, in sensemaking an individual invents what is to be interpreted. Sensemaking can also be considered as the process in which situation awareness is achieved (Klein et al., 2006a).

Collaborative sensemaking is related to the concept of situation awareness in human factors research. Situation awareness encompasses the perception of relevant objects and events in the environment, the synthesis of observations and the comprehension of their significance from the standpoint of task goals, and the ability to apply this knowledge to predict future situations (Endsley, 1995b). It can be measured by examining responses to in-situ tasks presented to team members (Endsley, 1995a). When investigated on a team level, situation awareness has been described as "what is a shared understanding of a situation among team members a particular point in time" (Salas, Prince, Baker, & Shrestha, 1995, p. 131). Another definition sees team situation awareness as an aggregated measure of team members' independent awareness states (Endsley, 1995b). The scope of each individual's situation awareness is determined by that person's responsibilities in the team. Furthermore, it is assumed that members' task responsibilities are understood by the other members through organized bodies of knowledge called shared mental models. These shared models of the object of work and the patterns of acting enable members to anticipate each other's actions and perform functions from a common frame of reference (Cannon-Bowers, Salas, & Converse, 1993; Stout, Cannon-Bowers, Salas, & Milanovich, 1999). Shared mental models can be used to explain expert performance. Experts appear to better recognize important information in different representational formats and to generate richer mental models of the problem space than novices do. This helps experts to formulate courses of action that better take into account the sequence and timing of events (Serfaty, MacMillan, Entin, & Entin, 1997). Good teams also strive to form realistic situation assessments that are understood by all team members (Zsambok, 1993).

Previous research has identified many features that efficient teams employ in their task management and communication (for condensed summaries, see Boiney, 2005; Zsambok, 1993). For instance, in comparative studies it has been found that members of successful teams provide information in advance, without explicit requests to do so (Stout et al., 1999). In addition, it was found in firefighting command that teams that communicate by using fixed pathways of information tend to perform better than those that can freely adjust the number of parallel information channels (Artman, 1999). However, it was also found that having two fixed parallel pathways may be better than just one in the sense that this seems to spark creative solutions for information management.

In addition, a number of studies exist that have drawn from ethnography, ethnomethodology, and conversation analysis to explore the interactional organization of the ways in which tools and technologies are used in work and collaboration (for a review, see Heath & Luff, 2000). From studies of this type, aspects of practices that are beneficial for successful collaborative sensemaking can be identified.

In a study of a London Underground line control room it was found that workers collaborate with each other only rarely with explicit utterances. In contrast, workers monitor each other and make their activities visible by talking out loud seemingly "to oneself" and with gestures and glances directed toward the tools used (Heath & Luff, 2000, pp. 88–124). Similarly, constant reciprocal monitoring has been identified in air traffic control (Harper & Hughes, 1993; Mackay, 1999) and dispatch centers (Whalen & Zimmerman, 2005). In a study of an emergency department in a hospital, it was found that situation and activity awareness played an important role in sensemaking and was maintained in social interaction. Group members often shared information about situational issues, such as the status of beds, incoming patients, and resource availability, and about execution of collaborative tasks (Paul, Reddy, & de Flitch, 2008).

Another supportive practice is active anticipation of problems. In another study of the London Underground, it was examined how overcrowding is identified and managed in the operations room (Heath, Luff, & Svensson, 2002). In contrast to what conventional thinking might suggest, the problem was not solved simply by identifying crowd densities by means of general monitoring. Instead, overcrowding was actively anticipated and prepared for on the basis of comparison of crowd densities in foyers and on platforms in conjunction with train schedules.

A third element revealed by previous work is flexibility in the use of artifacts. In air traffic control, paper flight strips are used to indicate information about individual aircrafts. At a center studied by Hughes, Randall, and Shapiro (1992, 1993), the team consisted of two controllers, two assistants, and a sector chief. The strips were flexibly annotated by the assistants, who thus made sure that the controller had all necessary recourses at hand for making sense of the overall flight traffic flow. Flexibility in artifact use has been observed also in firefighting work during drills of reconnaissance missions. Firefighters drew ad hoc maps to visualize areas and communicate their knowledge. The key sensemaking activity was related to understanding of dimensions and volumes of building interiors (Dyrks, Denef, & Ramirez, 2008).

As, by definition, sensemaking takes place amid ambiguous situations (Foreman-Wernet, 2003), the concept of sensemaking shifts the focus from routines to uncommon situations in which active problem solving is needed. The quality of such work is then dependent on the interpretations that those involved are able to make of data and on how they direct their further actions to receive feedback about their inferences. In the RCC study described here, a deliberate decision was made to focus in the analysis on the safety-critical, demanding, and unexpected incidents that occurred during the rally.

3. THE SETTING

Neste Oil Rally Finland is one of the 15 rally competitions (in 2008) comprising the World Rally Championships (WRC) tour. The rally lasts 4 days in early August in the regions surrounding the city of Jyväskylä, in central Finland. About 100 cars participate, either with self-financed drivers or as competitors in teams of big car manufacturers. The rally route is, in total, about 340 km long and consists of 24 competition sections called *special stages*, each one lasting approximately five hr from the passage of the first signal car to the final safety car opening the road again for public traffic. Geographically, the rally spans an area of 80 × 80 kilometers. Tens of thousands of spectators are lined up at each stage to watch the cars.

Organizing the rally involves a lot of planning. The competition follows a detailed schedule that specifies starting times and the estimated duration of the special stages with a precision of minutes. The special stage routes and their safety arrangements, such as the locations of spectator areas and the numbers of personnel along the special stage, are planned months beforehand. Much of the time, more than one special stage is under way, because the first cars may start the next special stage before the last ones have reached the finish line of the previous stage. Competition in each special stage is carried out with a strict schedule and precautions. The road is closed to public traffic three hours before the actual starting time. After this, the arrangements are inspected multiple times from a helicopter and by car. About half an hour before the start, the so-called 0-cars are dispatched to carry out the final check. These cars drive at almost full rally speed, and this serves as a sign for the spectators that the first competitor is soon on the way and that everybody should stay in the designated spectating areas. Once everything is ready and accepted by a WRC representative, and an "OK" signal is given to the RCC, the RCC gives permission for the special stage to start. From then on, cars are sent off at regular intervals. After all cars have crossed the finish line, the arrangements are dismantled and the special stage's area is reopened to public traffic.

During the competition, the RCC's main routine task is to monitor the preparations and arrangements of special stages, including giving permissions to start and close the stages and seeing that emergency vehicles arrive at the correct posts and to sort out any discrepancies related to these activities. The RCC also works in collaboration with the WRC's nearby control room, which manages competition-related

issues such as timekeeping and jury decisions. For example, the RCC informs the WRC control room whenever competitors have to drop out of the race.

3.1. Goals and Constraints

The RCC is responsible for two interrelated tasks: keeping the rally on schedule and ensuring that safety precautions are maintained according to rigorous standards. Taking care of safety is the RCC's primary goal, but at the same time, the RCC tries to keep the competition in progress as smoothly as possible, without unnecessary breaks. This is important for providing a satisfying rally experience for the spectators, a smooth and fair race for the competitors, and media visibility for the advertisers.

Sometimes ensuring safety while attempting not to deviate from the schedule poses challenges. In addition, the RCC team must cope with uncertain, incomplete, and mediated information. The size of the event renders it unreasonable to cover the area with video cameras or other sensors. Also, it is only possible to place safety personnel in selected spots along the route. Safety at a typical-length 15 km special stage is ensured with two ambulances, an ambulance helicopter, a first-aid team, a physician, and a police unit. In addition, the rally has three so-called satellite ambulances, which do not have designated guarding posts at the special stages but can roam freely in the area and serve as replacement units if needed. The rally staff can also ask for help from all civil emergency units at surrounding hospitals. However, on many occasions, the first person reaching the scene of an incident is not a member of the rally organization but a spectator who calls 112 (the emergency number equivalent to 911) and talks with the REC, which then passes the information to the RCC. Often spectators are unable to report the exact location of the incident or in other ways cannot describe the situation in the level of detail required by the REC or the RCC. Gradually the information becomes more and more complete, but often it is not possible to wait for accurate information before a decision is made on whether to halt the race at that stage.

To sum up, activity in the RCC is characterized by a particular form of sense-making that is carried out concerning conditions with great risks and fragmented information. When accidents occur, the RCC has to form a conception of the type and location of the incident. If there is a chance that the competitors or spectators are in danger, the RCC must decide whether it is necessary to bring the race to a halt in order to get the emergency vehicles to the scene. Further, the RCC must find out which emergency vehicles are available and the way in which they should be directed to the target. If the race is halted at a certain special stage, the rally cars also have to be directed to the next special stage—either to drive past the accident scene at reduced speed or, if necessary, to take a detour.

3.2. Organization

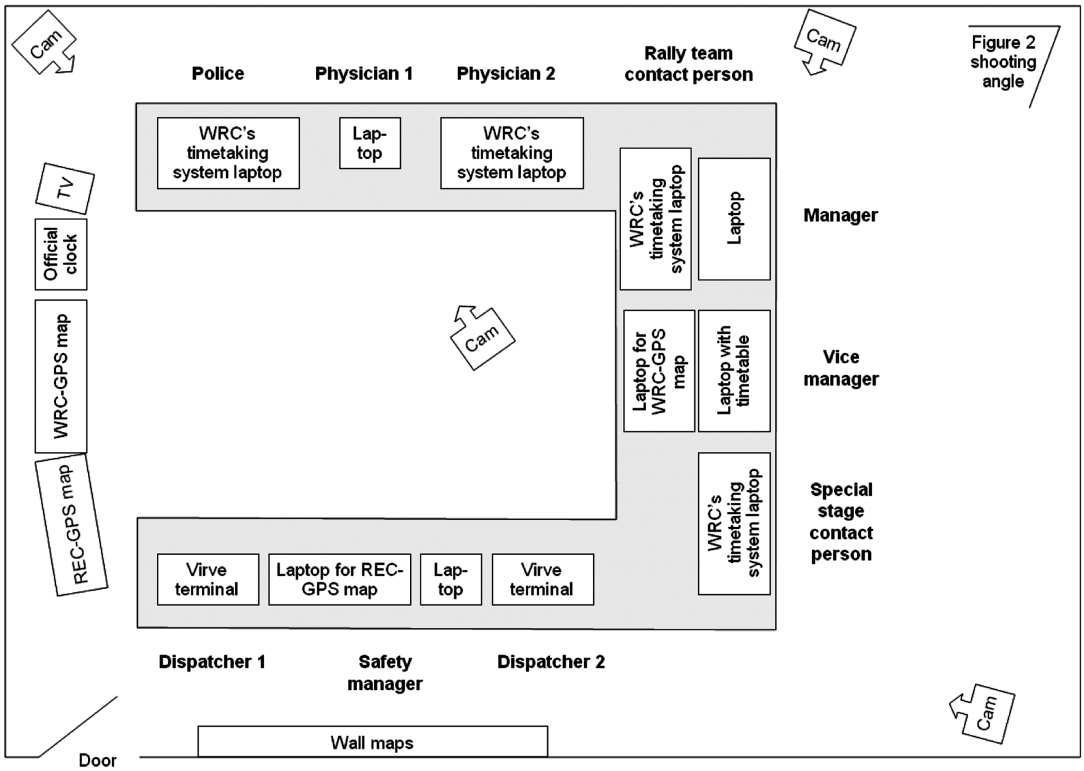
The RCC personnel comprise a manager and a vice-manager, one or two medical doctors, up to four dispatchers who work two or three at a time, a policeman, and

contact persons. Their competence stems from their regular occupations as emergency center dispatchers, physicians, and so on; their accumulated experience as personnel in the RCC over the years; and their experience of rallies. Some of these people have worked at smaller rallies, in other teams of the Neste Rally organization, and even as rally drivers. Therefore they possess knowledge of how the rally organization works and what the demands are in managing a rally. Also, many team members have a thorough understanding of the geographical setting because they reside in the area. The team's seating order and the locations of tools can be seen in the RCC room floor plan in Figure 1. A photograph of the room is provided in Figure 2.

Most of the RCC personnel are volunteers who have been willing to dedicate their time and provide expertise in their occupation for the benefit of the rally. However, the manager and vice-manager are paid professionals with the association that is responsible for organizing the rally every year.

During the rally, the responsibilities of the team members are assigned as follows. When resolving emergencies and other unexpected incidents, the rally managers have the responsibility to decide whether to cancel or halt the competition at a special stage. The actual rescue operations are managed by a physician and a rescue operations manager, who also acted as a dispatcher. Their division of work is based on the distinction of whether the emergency situation could escalate to become a more

FIGURE 1. The floor plan of the control center of Neste Oil Rally Finland in 2008.



Note. **WRC = World Rally Championships; GPS = global positioning system; REC = regional emergency center.**

FIGURE 2. A picture from the rally control center in 2008. (Figure available in color online.)

Note. **The shooting angle for this figure is indicated with a "V" symbol in Figure 1.**

serious accident on account of other competitors at the track. However, despite these official roles, in practice the hierarchy in the RCC is flat and such formal responsibilities are hardly noticeable.

The dispatchers handle the communications to the organization in the field and to external partners (such as the REC) in emergency situations. Together, the physicians and the dispatchers decide where the emergency vehicles should be located so that they are readily available if an accident should take place.

Usually two contact persons are present in the RCC. One communicates with rally teams and the WRC control room, handling issues such as how and when the damaged rally cars can be brought in for servicing, and which cars have been forced to drop out of the competition. The other conducts routine communications with the special stage workers. They also have much general knowledge regarding rallies and the geographical setting of the rally course. The policemen do not take part in managing the incidents but act as contact persons facing the local police forces.

Although the first and the fourth day of the rally are quite short, on the second and the third day of the rally the RCC personnel work long hours. The first special stages are driven early in the morning, starting at about 7 o'clock. Work in the RCC has to be continued until the last cars have arrived at the service park late in the evening. To handle the workload and fatigue, the manning of the RCC follows a freeform rotation, and some of the personnel work in shifts. However, at all times at least five team members are present in the control room to take care of the key responsibilities.

The collaboration in the RCC is affected by the temporary nature of the organization. That the personnel do not normally work together affects the development of procedures and common practices. The RCC team is a combination of people with different occupations and ways of working. For the most part, the common

ways of working in the RCC have developed gradually and informally over the years and have not been written down in the form of standard operating procedures. For instance, the safety manual lists the preparations and equipment required at each stage by each member of the organization and the RCC but does not contain step-by-step descriptions of procedures to commence upon receipt of news of an accident. The team members are, however, quite familiar with the common practices, because the composition of the team has changed little over the years.

3.3. Technological Environment

The RCC uses many tools for collaborative sensemaking and for managing and monitoring the progress of the rally arrangements. With respect to its relationship to the outside world, the RCC is, in fact, almost a 100% technology-mediated environment. Virtually all information entering and leaving the room is electronic communication. In principle, the RCC would not have to be present at the event—it could be physically anywhere, provided that it can retain its real-time communications.

In addition to being mediated, the RCC exhibits a peculiar mix of different types of external representations. The room is *not* fully furnished with such proprietary and custom-designed controls and monitors as are emblematic of modern control centers in power plants (Mumaw et al., 2000), air traffic control (Mackay, 1999), and underground line control (Heath & Luff, 2000, pp. 88–124). Instead, most of the artifacts are cheap, lightweight, and general-purpose, such as printed maps, booklets, and handwritten log sheets. The only proprietary information system is a large display to show global positioning system (GPS-) based data on the last known position of rally cars, which is provided by the WRC host organization. The RCC also borrows two systems from the Finnish authorities: the VIRVE system for efficient and reliable radio communication and a GPS-based system indicating emergency vehicles' locations. The following paragraphs describe the most important tools.

Communication Tools. In most cases, information arrives in the RCC through VIRVE, managed by the dispatchers. This is the official digital network of the authorities—a closed, secure radio network dedicated to communication among different official bodies in Finland.[1] It is used in the rally with special permission because of the potential need to be in touch with various public authorities. Therefore, rally staff who need to communicate with the RCC have a VIRVE handset and dedicated communication groups for talking. The VIRVE system is organized into push-to-talk groups in which it is easy to get confused as to who is addressing whom unless the parties clearly communicate this information in their openings and closings. Therefore, the addressee must always start her turn by stating (a) whom she is addressing and (b) whom she is herself. She then waits for the party she is addressing to respond with his name. Only then does she proceed to deliver the

[1]For more information on VIRVE, see http://en.wikipedia.org/wiki/VIRVE.

information. The party she has addressed then repeats the message in an abbreviated form. An example of this turntaking pattern is provided the following excerpt.

Excerpt 1: A typical exchange within VIRVE between a pilot and a dispatcher.

Pilot (at helicopter):	**rcc**, **heco.**
Dispatcher (at RCC):	**heco**, **rcc.**
Pilot:	**we're on the ground now, around the copter, and will leave for urria at around a quarter to eleven.**
Dispatcher:	**heco on the ground and quarter to eleven to urria rcc.**

Upon receiving a message, the dispatcher enters it in a log and timestamps it. A simple sheet of paper and a pen are used for this purpose. Later the log will be rewritten in electronic form via computer. The dispatchers' VIRVE communications are shared aloud in the RCC room over loudspeakers (see Figure 1).

In some cases, members of the team also communicate with cell phones. This is especially true for the rally managers and contact persons. Phone numbers for the RCC are widely shared among the rally organization, media companies, rally teams, and so on.

Manuals. In the normal course of action in the RCC, much of the monitoring of the event follows plans presented in various manuals. The biggest of these is the safety manual, which is a meticulously prepared 230-page book with dedicated pages for each special stage and recommended spectating area. It shows the map of each stage, the guarding posts of the various emergency response units, phone numbers for different representatives, and so on. Other important manuals are the so-called road book, which has a drawing of each crossroads the rally cars cross during the rally, and the directional signing manual, which also can be used to refer to individual crossroads. Some of the information in the manuals is replicated elsewhere in the RCC. For instance, the rally schedule is also available in electronic form from one of the laptops in the room.

Map Representations. As Figure 2 shows, two types of map representations are visible on the walls: traditional, large paper wall maps and GPS-supported electronic maps. Two paper wall maps provide an overview of the region and its road network. One of these is also used to keep track of the locations of different emergency response units, such as ambulances and the ambulance helicopter, and thus provides a more dynamic representation of the static information given in the safety plan manual. Little tags referring to each unit are attached to the map with pins and moved on the map accordingly when their predefined guarding posts change according to the rally schedule. The other wall map indicates suitable landing places for the helicopters. The location of the maps right behind the dispatchers' desks is a common meeting point during incident resolution.

One of the GPS maps (the WRC-GPS map) is provided by the WRC for the purpose of monitoring the rally cars, whereas the other (the REC-GPS map), provided

by the REC, indicates the locations of the emergency vehicles. The two maps are able to provide this information almost in real time. These maps are highly visible to all team members in the RCC and can also be viewed via laptops. The WRC-GPS map displays each car with a color that indicates whether the car is driving in the rally, driving to move to the next special stage or the service area, having a problem, or halted without an emergency involved. The change of color is partly automatic and partly signaled directly by the driver. The colors and the locations are not fully trustworthy, as the drivers occasionally forget to update their status and the map may not be in operation all the time. The cars shown in the WRC-GPS map are not directly connected to the GPS satellites; this is handled via an airplane flying above the rally region. Because the plane must sometimes refuel on the ground, the map is not always available for use. The WRC-GPS map provides fairly rough location data for the rally cars and includes only a small quantity of geographical data in addition to the marked rally routes. Thus, the WRC-GPS map is used mostly for monitoring the overall situation and to a lesser extent in incident resolution. The REC-GPS map, by contrast, is more sophisticated, presenting the exact road network. It is a relatively new tool and was not in use during the 2004 rally.

Other maps are used also, including normal foldable hand maps that can be easily carried around the room. The most important additional maps, however, can be found in the safety plan and the road book. Most of the time, the dispatchers keep their safety plans open to the page showing the map of the main special stage that is currently under way.

Shakedown. Before the actual rally starts, the reliability of the technology and the communication protocols between the RCC and the special stages is always tested in a realistic setting. This takes place the day before the actual rally, in a mock competition called a shakedown. From a spectator and media perspective, this is a relaxed media event in the city center and its surroundings, in which the competitors follow a short route. For the rally organization, however, the shakedown is a realistic test case for the next day's first rally stages, which means that all actions are carried out according to the full protocol. This verifies that the tools used are functioning properly.

4. DATA COLLECTION AND METHODS OF ANALYSIS

Observations of the work in the RCC were carried out at a 2004 Neste Rally event and a Neste Oil Rally event in 2008. The data were collected with passive video camera recording, from selected positions in the room, focusing especially on the activities at the dispatcher desks. In 2004, this was handled by one researcher with a camera with an internal microphone. In 2008, two researchers operated four cameras (see Figure 1), with an attempt to capture the activity in the whole room. During both visits, notes with timestamps were written continuously in order to gather a log of

the activities. As an outcome, 22 and 44 hr of activity were shot in 2004 and 2008, respectively.

The supplementary material included hundreds of photographs taken in the RCC and at other sites of the rally, as well as freeform interviews with key persons in the RCC during their break hours. In addition, in 2004, the researcher also joined one of the safety car drivers for half a day to learn about the safety arrangements at the rally track from the perspective of a representative of the organization. Spectators have been studied in the same rally event in 2004, 2005, and 2006 (Jacucci, Oulasvirta, Ilmonen, Evans, & Salovaara, 2007; Jacucci, Oulasvirta, & Salovaara, 2007; Salovaara et al., 2006).

The analysis presented in this article is based primarily on interaction analysis (Jordan & Henderson, 1995) of video-recorded episodes of safety-critical incident resolution in the RCC. Interaction analysis is a qualitative research method for analyzing sequentially ordered verbal and embodied interaction on a detailed level. It has roots in conversation analysis (e.g., Sacks, 1992), which is a microsociological research approach that utilizes detailed transcriptions of speech for its primary data. In interaction analysis, the emphasis is not only on conversation but also on people's movements, manipulation of artifacts, and other nonverbal actions. The main goal is to analyze and identify the building blocks on the basis of which people maintain and engage in successful cooperation, social interaction, and mutual understanding.

The video footage obtained from the RCC first was sampled with the written field notes as an index; then the candidate episodes were reviewed more closely. By "episode" we mean an uninterrupted clip of video footage that starts with the reception of news about a safety-critical incident (most commonly an accident or a medical emergency situation) and continues to its final closure, such as news that the patient has been brought to a hospital. Of all the video footage, those episodes were selected that included an element of ambiguity concerning the exact location or the nature of, or access to, the event, due to either lacking or conflicting information. The incidents in the episodes were potentially severe for the competitors or spectators and thus required relatively rapid decision making. Resolving the incidents also required active cooperation among the RCC team members and with external parties. This two-pass sampling strategy provided us with six episodes for detailed interaction analysis (see Figure 3).

These episodes were transcribed in different levels of fidelity, with an increased level of detail around the events that seemed relevant for sensemaking. The analysis of these transcriptions was qualitative and data driven, with inspiration from distributed cognition research (see, e.g., Hutchins, 1995) in the analysis of tool use. The goal was to identify practices with which the RCC made sense of situations.

5. FINDINGS

In this section of the article, we present three important perspectives on group sensemaking in the RCC: the use of representationally redundant technologies, the

FIGURE 3. The duration, year, and content of the rally incidents analyzed.

Episode	Duration	Year	Content
1	18 min	2004	A spectator had broken his wrist at a special stage, and finding out the exact location required cross-checking against many information sources.
2	30 min	2004	A co-driver had injured his back in a collision of a rally car with a large rock. Dispatching of more rally cars was terminated, and an ambulance was urgently directed to the location.
3	59 min	2004	When the rally was just about to start, a spectator had a heart attack in a location that was very hard to access and to leave. Bringing an ambulance to the patient created a threat of delaying the whole competition considerably.
4	46 min	2004	A fully loaded tourist bus had driven off the road in an unknown location close to one of the special stages. A serious civil accident was feared; therefore, many ambulances were dispatched.
5	53 min	2008	A rally car had crashed in the middle of a special stage. Dispatching of further rally cars was terminated. The electronic wall map for rally cars (i.e., the WRC-GPS map) was not in operation during this episode.
6	15 min	2008	A rally car had driven off the road. Making sense of the location and the gravity of the situation required cross-checking.

Note. WRC = World Rally Championships; GPS = global positioning system.

construction of coherent situation awareness through different social coordination patterns, and strategies adopted for managing high risks and ambiguity. Respectively, they provide a picture of the RCC's work from technological, interactional, and strategic viewpoints in the case of emergencies.

5.1. Representational Redundancy

As previously noted, most of the tools and technologies in the RCC are general-purpose and lightweight: paper maps, printed manuals and plans, cell phones, laptops, and so on. Larger and more expensive tools include two separate GPS-based systems, presenting position data for rally cars and emergency vehicles, and the VIRVE communication system. Maps are presented in several forms: electronically with the two large shared screens (also viewable with laptops), as shared paper wall maps, and in printed books and plans. This implies a significant amount of *redundancy in external representations* in the room. In resolution of an incident, the same information can be represented in several externalizations in several places (Cabitza, Sarini, Simone, & Telaro, 2005). For instance, the location of an accident can be represented in a handwritten note in a log, as a spot on a map, and with reference to a page and box number in the road book.

Representational redundancy is advantageous because it provides flexibility for choosing the most suitable tool for the situation. Next we describe two ways of making use of representational redundancy: its support for coping with the need to translate pieces of information into a manageable form that can then be used for sensemaking about incidents and the support for communicating the decisions in a way that is understandable as commands for external partners such as emergency vehicles.

Inferring Information Sources

During incident resolution, the RCC takes in information from a variety of sources, including the REC (which spectators may call in case of an emergency), managers of the rally stages, various emergency response vehicles and safety cars, and the GPS systems that provide information in an automated manner. Each of these sources is able to provide information about the incident in a different way, referring to the factual state of affairs with different concepts or figures, accuracy, and trustworthiness. Thus, at times, the information requires further manipulation by reformulation, specification, or double-checking. For example, an ambiguous message about location from the central emergency center may have to be reformulated by looking at a map so that the information can be further used for guiding emergency units. This kind of "translation work" is necessary for integrating the information into the RCC's overall picture of the situation.

In general, the RCC's aim is to gather precise information from a trusted source, or make a nice "fix" through combining information from different sources, in order to be able to use maps for further problem solving. Figure 4 provides a chronological summary of one of the episodes analyzed and exemplifies the translation work involved in ongoing successful management of incidents. In Phase 1, a rough location is learned. In Phases 3 and 5, further perception of the same location is constructed, with the use of different tools. Gradually, the understanding of the location becomes more specific and is transformed further, into practical directions to the location (Phase 6). Thus, we see how the information transforms by being expressed in some of the many tools to represent locations used in the RCC. In all cases, and in synthesis of the representations to form a holistic picture, translations are enabled by different representational tools that allow rapid intake of information from external partners.

Most commonly, the information is integrated by means of a paper map—either the wall map or a page in the safety plan—which allows bringing the current locations of emergency response units and the general road network into coordination with each other.

Translating Information for External Partners

In a similar manner to making sense of the incoming information and representing it via a suitable representational medium in the RCC, the outgoing commands to the remote partners need to be presented in a format that is usable to these.

FIGURE 4. Translations of incident location and accessibility information, using different representational artifacts.

Phase	Time	Source	Information	Reaction in the RCC
1	0 min (12:30)	Regional emergency center delivering the news provided in a phone call from a spectator	"Some kind of patient at the special stage, 3 km from the start"	Starting double-checking of the news with the special stage manager. Starting finding out of how the spectators are probably positioned in the 3 km area.
2	4 min	Contact person with local knowledge in the RCC	"There is an officially recommended spectating area at 3 km"	—
3	5 min	Special stage manager at the track	"Directional signing manual, page 2, box 18"	A comment within the RCC that this information is hard to interpret since the manual has not been designed for use in the RCC.
4	5 min	Special stage manager at the track	"3.14 km from the start"	Replying back by asking the manager whether he knows what has happened.
5	6 min	Physician in the RCC consulting the wall map	"It is at leg 5 of that special stage"	—
6	6 min	Special stage manager at the track	"Only accessible by driving along the rally track, leaving from the start"	Order to the manager and two ambulances positioned at the start: ambulances to drive to the 3.14 km spot, pick up the patient, and leave the rally track at safety point 1 at 13 km.

Note. RCC = rally control center.

Thus, the goal is to see the situation from the point of view of a unit that does not possess the same perspective on the circumstances as the RCC does.

In talking to a partner in the field about locations, the RCC often uses very generally understandable descriptions that the partner can understand by looking at any regular road map of the area. Alternatively, a medium shared by the RCC and some external partners such as safety cars is the road book, which unambiguously names every crossroads at every road with rally driving. It can be used when one wishes to refer to a specific location at the rally track. For example, in one of the episodes it was very important to get an ambulance carrying a patient off the rally track at the earliest possible point. To ensure that the ambulance did not miss this exit, the dispatcher, following the vice-manager's commands, gave instructions to a safety

car accompanying the ambulance. The road book was used in this communication between the RCC and the safety car, as seen in Excerpt 2.

Excerpt 2 (2004/Episode 3): The vice-manager gives instructions to a safety car. The dispatcher delivers the instructions, using a road book.

Dispatcher:	**can we soon let the zero zero** [a safety car driving before the first competitor] **onto the track?**
Vice-manager:	**zero zero to the track, carefully.**
Dispatcher:	**yeah?**
Vice-manager:	**then they do so that, they drive, do you have the road book? ok here.** ((flips through pages))
Dispatcher (to VIRVE):	**zero zero go carefully, rcc.**
Vice-manager:	**zero zero carefully, until pena** [driver of another safety car that here has been asked to drive with the ambulance] **says the track is clear, then faster, and**
=>	**drive so that they exit the special stage at box 8. page 88, box 8. zero zero exits there. pena drives the whole track to the finish, one zero drives to the finish.**

Delivering this information required new translation with the purpose of giving clear instructions to an external partner. With different representational tools available, this communication is facilitated, because translations of location-related information from one tool to another can be carried out swiftly.

In conclusion, the RCC benefits from the use of multiple representations and from their redundant characteristics. The RCC needs to reformulate the incoming messages and adapt to the information processing characteristics of the external partners. Performing the necessary reformulations is part of its overall sensemaking process.

5.2. Construction of Shared Situation Awareness

Achieving situation awareness concerning incidents is a constant requisite for successful and timely decision making. The managers, physician, and rescue operations manager are responsible for making major decisions, but given that the RCC has a very flat hierarchy, there are few restrictions to how the other team members can enter the decision making. In practice, the process of interpreting a situation is a joint effort.

In more permanent control centers, where procedures are honed in years of continuous work, mere peripheral attention and subtle communication may be enough to maintain cooperation and shared situation awareness (Heath & Luff, 2000, pp. 88–124; Mackay, 1999). In contrast, the work in the RCC seems to require communication that rests on explications and negotiation: Many questions, answers, requests, suggestions, and verbal inferences are uttered. This emphasizes the importance of the auditory environment.

Coordinative Articulations

The multiplicity of information sources is one of the reasons the RCC team members need to communicate with each other explicitly. Information is communicated in the RCC in parallel through many, different means, most prominently through VIRVE channels. Normally each dispatcher manages communication in two to five channels. In addition to VIRVE, members of the RCC team may communicate over landline or cell phones. The use of many technologies enables flexible and efficient absorption of incoming information from many sources, adaptive workload-balancing, and double-checking of interpretations, but it can also lead to situations in which different members of the RCC team base their work on different perceptions of the situation. For example, the RCC worker who happens to note from the GPS map that a car has stopped on the rally track has to deliver the news to others, as not all may be monitoring the situation with full attention. Different social interaction patterns for sharing notions and avoiding differing perceptions can be identified.

First, the dispatchers in particular use *outlouds* in the RCC. Outlouds are quick shouts of work-related information that usually are not directed to any specific person, and thus no responses or answers are waited for. Making an outloud instead of specifically addressing a colleague is economical in that colleagues do not have to interrupt their tasks to deliver a response (Heath, Jirotka, Luff, & Hindmarsh, 1993). Outlouds aid in creating general awareness of emergency situations. A common moment in which outlouds could be observed was when news of general relevance was received from VIRVE. The radio talk protocol for repeating the messages received could also serve occasionally as an outloud. The following excerpt provides an example of an outloud.

Excerpt 3 (2008/Episode 5): An outloud. Dispatcher 2 overhears communication between REC and dispatcher 1, and repeats the message as an outloud.

	REC:	((requests attention from the RCC via VIRVE))
	Dispatcher 1:	**REC RCC hears you.**
	REC:	**in about the middle of ss14** [special stage 14] **a car has driven off. the driver is out of the car in a confused state. we are figuring out the location.**
=>	Dispatcher 2:	((speaks in a clearly articulated manner)) **IN THE MIDDLE OF AN SS, CAR IS OUT AND DRIVER OUTSIDE IN A CONFUSED STATE.**

Second, short *checkups* are used when someone needs to make sure that he or she has received or correctly made sense of what to do next. Although they are addressed to a certain person, they are similar to outlouds in causing only a little disturbance for that person. This is because they are interactions of minimal temporal duration and, in the best case, can be answered in one word. The following excerpt presents an example of a short checkup.

Excerpt 4 (2004/Episode 1): A checkup between two dispatchers.

Dispatcher 1: **and they will go onto the track to pick up the patient?**
Dispatcher 2: **yeah.**

Third, *summaries* are used as restatements of the current interpretations and can be addressed either to the RCC team members or to external partners in VIRVE. They serve the purpose of making sure that all who are present perceive the situation in a similar manner. They are different from outlouds and checkups in that they are more time-consuming and require more attention from the receivers of the information. Nevertheless, they are efficient, because they synthesize a certain situation in a few relevant sentences. Moreover, producing a synthesis and verbalizing it can clarify the status of a situation to the speaker himself or herself as well. The following transcript is an example of a summary.

Excerpt 5 (2004/Episode 3): A dispatcher provides a situational summary for the physician about the location of ambulances.

=> Dispatcher: **they now have längelmäki's first-aid unit at the start. it had also been dispatched.**
Physician: **they have that one as well?**
=> Dispatcher: **it's already there. and orivesi's ambulance is approaching. so we already have an fia[2] -approved manning there. let's just settle our satellites there once they are there.**

These methods for maintaining coherence and coordination—outlouds, checkups, and summaries—are all efficient practices for distributing awareness among the RCC team members. To achieve shared situation-awareness, those in the RCC do not just pose and respond to questions, make decisions, and deliver them to external partners. Rather, the team members create and distribute the awareness in a self-initiated manner by uttering their understanding (with outlouds) and comparing it with others' (with checkups) and by ensuring that the others have understood the situation as a whole (with summaries).

Management of Work Practices

In some cases, proactive distribution of information is not the only means of facilitating good collaboration. For instance, collaborative work can face situations in which the problem-solving and inference strategies employed by the team members are not optimal, whether because of a workload imbalance, the choice of problem-solving strategy, or the choice of what information is delivered to others. To avoid this, the RCC team members may engage in suggestions concerning how to speed up, or ensure better quality in, sensemaking. Two patterns of action were observed.

[2]Fédération Internationale de l'Automobile (International Automobile Federation).

First, team members apply *load coordination* when they can easily divide their tasks across parallel trajectories of action. Most commonly, this was seen in management of VIRVE communication, as in the following excerpt.

Excerpt 6 (2004/Episode 3): Load coordination.

=> Dispatcher 1: **i'm not listening to anything other than this ss12 right now.**
=> Dispatcher 2: **and i don't listen to anything other than neste rally. we have to freeze other things for a while.**

Another pattern illuminates more of the organization of the work process as a whole. Sometimes a person may notice that a certain task in figuring out a situation could be carried out in a different and improved way. This can involve the use of different representational media, or the conceptualization of a piece of information. Then *suggestions about better sensemaking methods* are aired. In the following excerpt, we can see suggestions as to how the situation should be understood by using a map and with a verbalization that follows a common terminology.

Excerpt 7 (2004/Episode 2): Two suggestions about better sensemaking methods. The physician asks a contact person to share his knowledge of an accident location by using a more suitable representational medium (the road book), and a dispatcher suggests a way to talk about a route to that location unambiguously (by referring to a predefined safety point).

	Dispatcher:	((shouts across the room)) **WHERE'S OUNINPOHJA'S GOAL about ten kilometers?**
	Contact person:	**to ouninpohja's goal ten kilometers. it is here** ((walks to a wall map)) **here's that place; it's where they drove last year.**
=>	Physician:	((at dispatcher's desk)) **come here to show it in the book.**
=>	Dispatcher:	**I GUESS IT'S PROBABLY SOME INTERMEDIATE SAFETY POINT that's best to use** [for ambulance access].
	Physician:	((at dispatcher's desk, pointing at a point on a map))
	Contact person:	((arrives at dispatcher's desk, pointing also at a point on the map)) **it's here.**

Load coordinations and suggestions differ from the outlouds, checkups, and summaries mostly at the level of how these interactions affect the RCC work. Whereas outlouds, checkups, and summaries are about the distribution of information among the people in the RCC, load coordinations and suggestions are interactions in which the work process is affected as a whole, at least temporarily.

The interaction patterns just presented further indicate that the overall sensemaking process is heavily dependent on the proactive and self-initiated coordination work. This may be at least partly a result of the ill-defined nature of the problems faced by the RCC. In difficult cases such as accidents, the information is often revealed in piecemeal fashion and is redefined in light of new incoming information. As a result, resolution processes cannot be decomposed into simple subtasks entailing simpler, less coordinated sensemaking tasks. Thus, the effortful and well-articulated negotiation characterizes much of the joint sensemaking processes in the RCC.

5.3. Management of High Risks and Delayed Feedback

As already noted, the actual circumstances of each situation can be revealed to the RCC in "little by little" fashion. The initial information on which to base sensemaking may not be precise enough, it may not have been received from a fully reliable source (it may be from a spectator who has delivered false details in the heat of the moment), or the external partners cannot provide it immediately upon request. In addition, the pieces of information may be in slight contradiction with each other. A spectator might be able to report only that an accident has occurred "closer to the finish than the start," whereas a helicopter pilot may tell a different story.

In addition to all of this incompleteness and ambiguity, the RCC has to deal with the possible risk of the situations. In determining which actions are necessary, ensuring spectator and driver safety is of the greatest concern. High risks are involved, and wrong decisions can have grave consequences. On the other hand, safe choices are sometimes hard to find. For example, contrary to what could be expected, dispatching an ambulance helicopter is not always the best way to reach a location. This is a highly forested region of Finland, and open spaces for landing are not available everywhere. Therefore, it is often best to use an ambulance car instead and face the challenge of congested side roads and the closed rally track.

As already implied, besides high risk, another factor is that immediate feedback cannot be received about the chosen courses of action. In most observed cases, the precise status of the situation was learned only when the first unit had arrived at the location and had time to provide a report from the scene. In this, RCC work departs from many assumptions and models of sensemaking. For example, this work cannot be fully described with Klein et al.'s (2006b) model portraying sensemaking as a test–reframe loop in which feedback to one's action is always available for reframing the subsequent perception of the situation. In the RCC, this loop is broken by delays, meaning that the incident's resolution can be described as *nonlinear* sensemaking. That is, decisions need to be made and instructions delivered even before information collection is finished. The RCC has two practices to handle this challenge.

Anticipating the Worst Plausible Situation

As previously stated, the two most important goals of the RCC are keeping the rally going and ensuring safety. This means that if the news is about only a small incident in which people do not require immediate medical care and the situation is unlikely to escalate, the resolution is based on the idea of causing minimal impact on the rally schedule. Then the RCC has more freedom to choose how to handle the incident. The smooth progress of the rally schedule is prioritized.

However, if there is a chance of serious injuries, the worst plausible outcome is considered and the situation is handled on that basis. In this case, the RCC starts to communicate with external partners immediately without waiting for a comprehensive or accurate view of the situation. This can sometimes result in sending more units than actually needed. In one episode, a tourist bus had driven off the road and

10 emergency units had soon been dispatched to a place even before knowing the exact location. Similarly, the following excerpt illustrates anticipation of the worst plausible outcome from a situation in which the RCC had just received news from the REC that a rally car had crashed at a special stage. In the discussion between RCC team members it was explicitly remarked that the situation was ambiguous and yet the idea of sending an ambulance helicopter was evoked.

Excerpt 8 (2008/Episode 5): Discussion about dispatching a helicopter between the vice-manager, a dispatcher, and the physician. The RCC has, 20 s before, received news that a rally car has crashed. Although the situation is not clear and has not been confirmed, the ambulance helicopter is asked to prepare itself.

	Vice-manager:	**is there, you know, do they need help out there?**
=>	Physician:	**don't know yet.**
=>	Dispatcher:	**we don't know. this news is from the spectator side. they say there's a driver acting strange out there, so-**
	Vice-manager:	**should we start waking up that helicopter?**
=>	Physician:	**we have no clue where it is right now.**
	Vice-manager:	**yeah, but if it just flew a bit closer-**
	Manager:	**yeah, they could kind of heat up that thing a bit.**
	Physician:	((points at the wall map)) **hey, but the ambu heco is just right next to them.**
	Vice-manager:	**so they could go and have a look.** ((30 seconds later, the helicopter is contacted by the dispatcher))

One can infer that in nonlinear sensemaking, when the actual need for help is not known, the RCC creates not one but many interpretations of possible states of emergency. These states might require different types and numbers of emergency units at the location. Then the potentially most serious scenario is chosen, and actions are decided upon by working back from that possibility to the resources one has at hand to prevent it from happening. Such anticipation relies on each person's expertise and knowledge of what the rally is about as an event, and how the different parts of the event interact with each other.

Delegating Sensemaking to External Partners

In addition to anticipating the worst plausible situation, another strategy for dealing with risks and the lack of feedback is to rely on external partners in making sense of the situations. This also explains why the RCC makes decisions in a nonlinear manner by dispatching units even if the situation is uncertain. The units are used as sources of information. In some incidents, as many as two helicopters (the safety inspection helicopter and the ambulance helicopter) were used to respond to the situation and to gather better information. In one incident, the relieving news about a minor accident was received directly from the co-driver of the crashed car. He understood that the helicopter had been dispatched to the location to gather initial information and gave a thumbs-up as a sign to the helicopter that he and the driver

were fine. Thus, there are active agents beyond the limits of the walls of the RCC room that aid in the overall sensemaking process: Even the drivers themselves can be actively involved.

Similarly, in addition to dispatching emergency vehicles, the RCC can attempt to get in touch with the volunteers at the rally track. In such cases, the manager of the special stage was contacted and asked to pass a question on via the VHF radio channel of the volunteers. However, even more information sources could be creatively considered. The information sources were not limited to the members of the rally organization or the Finnish authorities. In the following excerpt, the RCC vice-manager tries to "make up" who would best know whether a crashed car is blocking the rally track. As one of the solutions considered, he remarked that the co-driver of the crashed car itself could be asked to provide the information.

Excerpt 9 (2008/Episode 5): The manager, vice-manager, and contact person talk about contacting external partners.

	Manager:	**is the road open?**
	Contact person:	**we do not know yet.**
	Vice-manager:	**isn't there a sequence manager [in long special stages, manager of a part of the stage] or anyone?**
	Manager:	**yeah, sequence manager or someone to the phone there at the start.**
=>	Vice-manager:	**or then that co-driver.**
	Manager:	**yeah.**

We can now see that, to understand the overall sensemaking process in the RCC, it has to be borne in mind that the RCC is part of a larger system, which includes the rally organization, emergency units, competitors, the audience, and others. To conclude, contrary to what common sense might suggest, the work in the RCC is not simply about figuring out relevant facts of emergency situations and responding to them. Rather, it includes two types of anticipation and imagination: about what the situation could be like in the worst-case scenario and about who could provide further information.

6. DISCUSSION

Most previous work involving control centers has looked at settings furnished with permanent installations of proprietary supervisory control systems and costly instrumentation. Such systems have been used to provide visualizations of the physical structure of the target process (e.g., process diagrams), trend graphs, or other time-related information, as well as alarms (Riera & Debernard, 2004). Study of such control centers has pointed out that the construction of shared situation awareness can be supported by (a) communication (both verbal and nonverbal); (b) shared displays, papers, and notification mechanisms (including means using auditory and

tactile modalities); and (c) the shared environment itself (visual, auditory, and tactile cues, such as sounds and vibrations, that the team members can directly perceive in the environment; Endsley, Bolté, & Jones, 2003). We found that, although all three elements of support just listed are found also in the RCC, they exist in a form that creates a demand for investment of considerable effort from team members to find workarounds and adopt shared practices.

We found that redundancy in information tools and contents allows RCC team members to choose the tool most convenient for the situation at hand. Admittedly, previous work has highlighted the same issue. Maintenance of shared situation awareness, flexible adoption of coordination strategies, cooperation via a shared information space, and alternation between perspectives have been considered important design goals for control center support (Jasek & Jones, 2001; for technological suggestions, see, e.g., Billman & Bier, 2007; MacIntyre et al., 2001). In addition, tools should support the basic mechanisms of collaboration: explicit communication, implicit communication, coordination of actions, planning, monitoring, assisting others, and protection of one's own work (Luczak, Müchfelder, & Schmidt, 2003). Representing the same information via different tools can help a control center member entertain alternative viewpoints on the situation and form a richer interpretation and using multiple tools rather than just one can be a deliberate strategy. Our findings indicate a distinctive characteristic of this particular category of control rooms: the notion of *representationally influenced resolution pathways*. By this we mean that the overall process of sensemaking is in part determined by the way in which the information is presented in different external representations. This reflects the "representational effect" discussed by Zhang and Norman (1994), who studied the relationship between representations of a problem and emerging problem-solving strategies. They found that how the problem is represented influences the kind of solution strategy adopted. Depending on how the task was represented, the study subjects found different solutions to a mathematical puzzle. Although that research was mostly individual oriented, the same appears to hold in the collaborative sensemaking context of the RCC: External representations such as maps influence inference of acquired information and its communication outwards to external partners. Among the tasks of the RCC staff is to use this "representational influence" in a way that benefits the external partners: Representations that are understandable by them should be used. Given this viewpoint, it is not sufficient to consider, for example, how finely joint situation awareness can be acquired with customized shared visualization systems—the awareness also has to be communicated outward. Naturally, this might not be an issue in some cases in which communication is limited to only a few external partners who have standard operation procedures with which to respond to emergencies reported by the control center. However, it *is* an issue in a case such as the RCC, where almost anything can happen in a vast geographical area and there are myriad relevant external partners with which the center may communicate. Representational redundancy is a benefit in such a case. Our findings are consistent with Artman's (1999) notion of the usefulness of having parallel information pathways in providing opportunities for creative solutions. In summary, in line with the work

of Cabitza et al. (2005), it can be emphasized that technologies serve as organizing elements in opportunistic use of representational resources: When a certain task needs to be accomplished, the member of the team concerned is likely to grab the tool that seems to most conveniently afford the necessary information or its manipulation.

The second point that the findings highlight is how shared situation awareness is achieved through well-articulated communication and coordination work, both of which increase coherence in understanding of the ongoing situation among the members of the RCC team. Without such practices, some team members could miss important information, leading to confusion in the collaborative sensemaking process. Combining our findings with those of others, we begin to gain a fuller picture of social interaction in control centers. In a study of London Underground line control, one strong finding was that explicit utterances were rarely made and peripheral monitoring was often sufficient (Heath & Luff, 2000, pp. 88–124). However, in dispatch centers (Whalen & Zimmerman, 2005) and air traffic control (Mackay, 1999), casual talk and chatting fostered peripheral monitoring and the work itself included conversation. Our study emphasizes that team members actively coordinate work and distribute their perspective with explicit utterances. Thus, there is a continuum of control centers between subtler and more explicit social interaction. Because the RCC is an example of a control center that includes experts in different fields, has multiple information sources, has a flat hierarchy and faces challenging and ambiguous situations, these factors may exert influence such that more explicit social interaction occurs. In particular, an additional reason might be the temporality of the RCC: Because the RCC staff members do not work together on a regular basis and therefore do not have precise knowledge of each other's ways of communicating, they cannot rely on identification of implicit utterances and gestures. This is food for thought for anyone planning a control center and trying to judge how much explicit interaction between staff members will be required. This might be relevant, for example, in determining how to position staff members physically: Is it beneficial for them to be able to point out external representations with subtle gestures, or is it only necessary that they can access each other in face-to-face interaction? Should the personnel be situated side-by-side (which could foster gestural pointing out) or face-to-face (which could be suitable for negotiations)?

There is always a trade-off, when one is broadcasting new information, between enhancing the shared understanding and creating cognitive overload (Boiney, 2005). Thus, explicit communication may be useful or disturbing, and our finding on its usefulness cannot be generalized to all work contexts. Reciprocal communication might not be useful in control centers saturated with auditory information—for example, where bleeping alarms and ringing phones have to be addressed very frequently. It is also questionable whether the explicit communication is optimal as a solution for a control center team. Actually, the practice of employing well-articulated explications may, in fact, be a result of absence of a properly shared understanding of the resolution procedure (Cannon-Bowers et al., 1993; Stout et al., 1999). Implicit communication and peripheral monitoring could be more economical and efficient,

but more long-term mutual work experience might be needed for achieving this. An alternative explanation as to why the RCC achieves such a high performance level is that the collegial atmosphere in the center (which might be a result of the fact that most workers in the RCC are off-duty safety professionals who have volunteered for this task) may decrease power struggles and thus may improve the flow of information during the peak moments. Similarly, it may be that the workers achieve high performance levels because they know that full effort is required for just 4 days, after which one can rest.

The third point highlighted by the study is that, roughly speaking, the decisions in the RCC during ambiguous incidents reflect the RCC team's joint understanding of the worst plausible outcome of the incident. This anticipation of the worst is a resolution to the challenges in making sense with the help of only impartial and untimely information on the actual status of the incident, which still requires the RCC to respond immediately to the news received. Due to nonlinear sensemaking (described in previous section), the outcome of the incident can never be fully anticipated before it has been fully resolved. Such anticipatory sensemaking is dependent on the staff's expertise in estimating the interdependencies between the schedule and the migrating spectators, closed roads, traffic jams, and distances between emergency units and incident locations. This is in line with the definition of situation awareness that emphasizes the understanding of the current situation and its projection to future states (Endsley, 1995b). In addition, these findings are similar to those on anticipation of overcrowding in the London Underground (Heath et al., 2002). There, too, anticipation required combining information about several factors: Crowd densities in foyers and on platforms were considered in conjunction with train schedules. Thus, it is illustrated how control center work requires comprehensive consideration of the situation at hand. In addition, in the London Underground, making sense of overcrowding was dependent not only on the staff working in the control room but also on personnel positioned throughout the subway station in locations where problems are likely to emerge. The control room workers relied on their colleagues' abilities to identify problems. Similarly, RCC team members delegate tasks to external partners to find out what is going on. This is consistent with the concept of sensemaking, as it includes individuals making sense of the world in a dialogical manner by being in contact with others (see, e.g., Foreman-Wernet, 2003). An additional point in relation to which the concept of sensemaking converges with our findings is the RCC team members' way of creatively invent whom to contact in order to find relevant information. Both of these notions, dialogue and inventing ways to find information, emphasize how the RCC team members literally *made* sense of the world. There is point in highlighting that sensemaking includes inventing and discovery (Weick, 1995, pp. 13–14) also in such cases as a control center.

To conclude, this article has described work in a control center that has the responsibility of managing safety-critical, hard-to-predict, and massively geographically distributed activity with the help of completely technologically mediated information channels. The control center work provides viewpoints to social uses of heterogeneous representational technologies, social interaction, and management of risks.

NOTES

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