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Abstract. The performance of teams, with different levels of domain- and crisis management experience, managing unexpected and escalating situations was observed by using a mid-fidelity ship-bridge simulation and analysed by applying the central concepts of joint activity coordination (Klein et al., 2005) as well as Woods' (2002) theory building on data overload. The coordination strategies used by the teams were evaluated by applying coordination process indicators and the concept of control. The paper discusses how different aspects of team coordination in unexpected and escalating situations, e.g. that teams that maintain a high level of control in escalating situations avoid or minimise the effects of data overload by using explicit and agreed-upon goals rather than sharing as much incoming information as possible. The results presented in this paper shows the benefits of applying a broad set of theoretical concepts to illuminate the actual demands that escalating situations pose on people's data processing capacities and processes. It also provides guidance on successful performance of teams in such situations and thus support for development of successful strategies for management of them.

Introduction

Recent crises (e.g. the Tsunami disaster, Hurricane Katrina, the BP disaster in the Mexican Gulf) have demonstrated the severe threat of escalation on organisational resilience, i.e. the ability of an organisation to detect, prevent and prepare for and if necessary handle and recover from disruptive challenges. Reviewing the central concepts of joint activity coordination (Klein, Feltovich, Bradshaw and Woods, 2005) as well as Woods' (2002) theory building on data overload, we evaluate the performance of teams, with different experience of the domain as well as of crisis management, simulating unexpected and escalating situations.

Escalation and data overload

An escalating situation is one where an initial irregularity develops into a continually deteriorating situation and starts affecting other areas in an accelerating tempo, with consequences that are difficult to overview and impossible to predict (Woods & Patterson, 2003). The current of events in an escalating situation quickly unveils any deficiencies in the structures of the organisations involved in managing it, e.g. problems associated with institutional preparation, organisational design or cross-organisational communication. Timely and accurate organisational responses to the increasing magnitude and variety of problems as well as the higher tempo of the process are essential to be able to maintain organisational resilience and manage the escalation.

Unexpected and escalating situations can create a range of cognitive and coordinative demands in several domains, such as aviation (Dekker et. al., 2008), healthcare (exemplified, but not made explicit in DeVita et al., 2006; Figueireido, Tsatsaris & Mignon, 2007), and civilian crisis management at national, regional as well as local levels (Bergström, Dahlström & Petersen, 2008). As the tempo of the process rises and becomes more (if not entirely) event-driven, there is more to consider, communicate and coordinate, i.e. more data to process, distribute and act upon (Woods, Patterson & Roth, 2002). Goals can diversify and compete more steeply. Woods and Patterson (2003) characterises escalating situations by making the following points:

- There is a cascade of effects in the monitored process
- Demands for cognitive activity increase as the problem cascades
- Demands for coordination increase as the problem cascades
- The cascade and escalation is a dynamic process

In terms of data processing the effects of the escalation is dual. With the escalation follows an increased amount of data to process. On the one hand having greater access to data is beneficial in principle, but on the other the flood of data challenges the ability to find what is informative and meaningful in the data flow. Woods et al. (2002) refer to this as *the data availability paradox.* According to Woods et al. the problem of data overload can take three forms:

- A clutter problem where there is too much data available
- A workload bottleneck where there is too much to do in the time available
- A problem in finding the significance of data when it is not known a priori what data from a large data field will be informative

Most traditional strategies to cope with the data overload problem fails, according to Woods et al., because of their inability to address the context sensitivity problem; that "meaning depends on relationships among data and relationships between data and the goals and expectations of observers" (p. 30).

Team performance, coordination and control

A simple definition of a team is a "collective that [is] composed of two or more individuals who (a) interact, (b) are interdependent, and (c) share some common goal(s) or objective(s)" (Ilgen, 1999, p.129). According to Salas (2008) team performance is defined by both, its *internal process* and teamwork *outcomes.* Based on the approach of joint cognitive activity, the internal process is articulated through the team members' activities to coordinate and control multiple tasks and resources towards the system's goals (Woods & Hollnagel, 2006). Studies have shown that team outcomes depend mostly on the internal process, but also on the environment in which the work is carried out, the resources available, and the work constraints (Wilson et al., 2003). According to Hollnagel (1998) and Hollnagel and Woods (2005) studies of cognitive features of work should investigate cognition as a situated and distributed phenomena. These authors suggest that teams are cognitive systems, where coordination and control are the primary features responsible for their performance. In this study, we take coordination and control as primary means of performance analysis during escalating situations.

Coordination is a goal-oriented and articulated function of the system artefacts (Amalberti, 1996; Woods & Hollnagel, 2006). By means of coordination, multiple agents synchronize, integrate and apply order to the working situation, minimizing losses and maximizing efficiency (Rousseau, Aubé, Savoi, 2006; Salas, Bruke, Cannon-Bowers, 2000). Coordination requires a common and pre-established script for team members, but also some degree of adaptation. The pre-established script is part of a common and shared interpretation of the working situation used by the team members to anticipate and react to each member's action (Klein, 2001).

Klein et al. (2005) have identified three primary requirements for successful coordination in joint activities: *interpredictability, common ground, and directability*. According to Klein et al. *interpredictability* refers to the ability to predict the actions of other parties involved in the joint activity, including aspects as making the own action predictable to others and share estimations of time and skills needed to perform a certain action. The second requirement for successful coordination, *common ground,* is defined by Klein et al. as: "the *pertinent* mutual knowledge, mutual beliefs and mutual assumptions that support interdependent actions in some joint activity" (p.8). Klein et al. points out that *common ground* is "not a state of having the same knowledge, data and goals. Rather, common ground refers to a *process* of communicating, testing, updating, tailoring, and repairing mutual understanding" (p. 8). *Directability* will here be referred to as the ability to adapt the process to the dynamic environment of an unexpected and escalating situation. Klein et al. agrees with Christoffersen and Woods (2002) in stating that *directability* is a central aspect of team resilience, but also emphasises *directability* as central to the interdependence of actions in the joint activity. Klein et al. (2005) labels the carrying out of these requirements as a *choreography*, stating that: "the choreography for carrying out these requirements involves coordinating a series of phases, and it is accomplished through employing various forms of signaling and the use of coordination devices, all of which incur coordination costs."

To analyze the outcome of a specific coordination strategy in escalating situations we will use the concept of *control.* According to cybernetics, control is a process involving a sequence of behaviors that lead a system toward its goals (Woltjer, 2009). Cognitive systems theory has adopted a cybernetics approach to define control by its circularities of feedback and feedforward. This approach combines, the cybernetic notion of regulation (Ashby, 1959; Woltjer, 2009), the Perceptual Cycle of Neisser (1976) and Hutchins' ideas of distributed cognition (1995a, 1995b), to provide a functionalist approach of control. In this sense, control 'happens' during the interaction of multiple agents, is goal-oriented and influenced by the context in which the situated activity occurs. The system's feedback and feedforward loops are essential functions of control circularities (Hollnagel, 2002). The first refers to information provided by salient aspects of the situation, while the second represents anticipations of the current situation. Feedback and feedforward determine the way representations are produced and, consequently, the way actions are taken.

According to Comfort (2007), control in disaster environments "means the capacity to focus on the critical tasks that will bring the incident to a non-destructive, nonescalating state" (p. 195). This definition is normative, consequently our interest lies in understanding how different coordination processes affect control. Hollnagel and Woods (2005) distinguish between four *control modes*. In the *scrambled* mode the choice of the next action is random, a trial-and-error type of performance. "This is typically the case when situation assessment is deficient or paralysed" (p. 147). The second control mode described by Hollnagel and Woods is the *opportunistic* in which "planning or anticipation is limited, perhaps because the situation is not clearly understood or because time is limited. An action may be tried if it is associated with the desired outcome, but without considering whether the conditions for carrying it out are met" (p. 147). In the third control mode, the *tactical,* control is established by adhering to prescriptive rules and procedures. The final control mode as described by Hollnagel and Woods is the *strategic* mode characterized by a longer time horizon and the management process looking ahead at high-level goals. Therefore in the strategic mode "the dominant features of the current situation, including demand characteristics of information and interfaces, therefore have less influence on the choice of action" (p. 147).

Method

A mid-fidelity ship bridge-simulator was used to evaluate team coordination processes in unexpected and escalating situations. A within-group design was used with the participants working as one team situated in the same room. The independent variables were domain expertise and experience from crisis management operations. The dependent variable to be analyzed was team coordination in the simulated environment. Outlined below is an overview of participants, the materials, and the procedure used for the data collection and analysis.

Participants

This study was performed by allowing teams manage unexpected and escalating situations in a simulated environment. The participants in this study interacted interdependently in the simulated scenarios with the overall common goal to take a cruise vessel safely from one location to another.

According to Woods (1992) the research concerning people working in complex and dynamic systems "must use a different subject population than the typical subject of psychology experiments – either experienced, domain knowledgeable practitioners, people who are similar to this group […] or people who contrast practitioners on some important dimension". Varying the level of expertise in simulated scenarios has also been practiced by Dörner (1996) and Schraagen (1997). In order to study different team coordination processes in unexpected and escalating situations participants were selected based on two criterions: domain expertise and crisis management experience.

Table 1. Participants

Team	*Domain expertise*	*Crisis management experience*	*Number of teams*
Maritime crisis management instructors	Yes	Yes	Two
Professional seafarers	Yes	Some	One
Maritime students	Yes	No	Four
Civilian crisis managers	No	Yes	Four
Air Traffic Control students	No	No	One
Pilot students	No	No	Four

The maritime crisis management instructors were Swedish instructors of *Bridge Resource Management,* courses in which maritime professionals are taught roles and procedures on the bridge, communication strategies, leadership, and situational awareness. The maritime crisis management instructors also taught specific crisis management strategies.

The professional seafarer-participants were recruited from a course held at the World Maritime University. They had different national backgrounds and had first hand practical experience in direct relation to their roles in the simulation (the Captain, Chief Officer and Chief Engineer all had experience in these respective professional roles). Their crisis management experience was limited to their experience of on-board emergency drills.

The maritime students were students at the Swedish university Chalmers, studying on a four year undergraduate program to become maritime captains. They had no previous crisis management experience.

The civilian crisis managers were Swedish Fire Safety Engineers (with a B.Sc. in Fire Safety Engineering) half way through a one-year program to become incident commanders in rescue service operations. Apart from operative work on accident sites they were also trained to be able to handle staff positions in large-scale emergencies.

The teams of air traffic control students and the pilot students were similar in that none of the participants had maritime experience or any previous crisis management experience. These participants had all gone through tests involving problem solving and multi tasking to be accepted to the respective program.

Materials

For the data collections a mid-fidelity ship-bridge simulation was utilised. Fidelity refers to how closely a simulation imitates reality, essentially how naturalistic it is. Fidelity does not necessarily reflect the level or degree of technology. The simulation used was complex but not photorealistic or three-dimensional. However, all the structural and the major technical aspects of the ship were included in the simulation in an effort to approximate real maritime conditions as closely as possible. For example, conditions like passengers, sea, weather, and other traffic were also included in the simulation. All 193 of the ship's crew members and 300 passengers were simulated individually, using a coarse human-factor model (Strohschneider & Gerdes, 2004). The simulation provided data to the participants in the form of computer printouts. There was no visualization of the simulation beyond blueprints and maps.

The simulation sessions were conducted in rooms equipped with a table for the participants to gather around (however moving around was not at all prohibited), magnetic white-boards (with magnets), and a flipchart.

Procedure

Simulation sessions were performed with teams of between five and seven participants acting in different roles as the crew on the bridge of a passenger cruise vessel caught in a stormy night on the Atlantic Ocean (see Strohschneider & Gerdes, 2004; Bergström, Dahlström & Petersen, 2008). The roles (e.g. Captain, Chief Officer, Chief Steward, Chief Engineer, etc.) were outlined in printed descriptions of the overall responsibilities of each role. The participants themselves allocated the roles within their team. During the simulation the participants experienced different types of events which demanded their intervention to prevent their already difficult situation from escalating beyond their control.

The simulation program was run on a laptop by two facilitators. The facilitators entered crew orders into the simulation program. All orders from the crew to the facilitators had to be written on paper order forms. Information from the simulation to the participants regarding ship status was provided by printouts, which were printed once every minute. Most of this information was of the type to be expected on a ship bridge (course, speed, weather conditions, radar, etc.). The crew could receive additional information, also in the form of printouts, such as incoming messages (e.g. from the vessel's shipping company, maritime radio communications, and signal traffic from other vessels in the vicinity), as well as messages from within the ship (e.g. alarms from systems, technical messages from engineers and passenger complaints). The design of the simulation program ensured that the simulated events adhered to the principles of escalation as described by Woods and Patterson (2003).

Each team went through two simulation sessions lasting for an average of three hours each. The program was a two-day program with one simulation session each day. After the first session long debriefing sessions were held focusing on the participants' own reflections on their performance. Between the sessions the facilitators also led discussions about different aspects on management of unexpected and escalating situations, with much focus on the participants' experiences from the first session.

Data analysis

The simulation sessions and the debriefing sessions were video recorded. A qualitative method was used to analyze team coordination in escalating situations, by applying the requirements for successful team coordination as formulated (and further outlined above) by Klein et al. (2005). Performance outcome was analyzed by using the control modes *scrambled, opportunistic, tactical* and *strategic* as described by Hollnagel and Woods (2005) (also outlined above). The analysis was focused on the coordination processes which the teams used to maintain an optimal level of control, particularly during the high workload experienced. The following questions were used in the first phase of this analysis: How did the participants make their respective actions *interpredictable* to the other participants, how did they form a *common ground* (what constituted the ground and in what way was it made common?), and how were they able to *direct* and adapt their processes to the dynamics of an escalating situation? In performing this analysis guidance in the form of coordination process indicators adapted from research on team coordination were applied, i.e. information processing tactics and strategies, the use of hierarchical structures, rigidity of team roles and extent of explicit or implicit goal formulations and overall management approaches for the teams (Dörner, 1996; Strohschneider & Gerdes, 2004; Hollnagel & Woods, 2005). The differences observed between teams when applying these indicators on the team coordination and decision making then lead to the formulation and labeling of different coordination strategies for the teams.

The second phase of the analysis focused on the way in which the observed coordination strategies enabled the teams to maintain a level of control as close to strategic as possible, specifically at moments where the scenarios were designed to force a transition of the control mode they were currently in. In the debriefing after the simulation sessions the participants' accounts of their perceived level of control in escalating situations were explored by using a structured discussion and this was also video recorded.

Results from simulated escalating situations

In the analysis of the observed coordination processes these were qualitatively organised into four categories: the process which demand all members to be updated on all available data, the process based on hierarchy, the rigid process, and the proactive process.

Coordination process one

– Determined and destined to make the "fully informed decision"

The teams consisting of civilian crisis managers tended to establish a coordination process that was focused on making a fully informed decision, in consensus. In terms of coordination the *common ground* in these teams seemed to be based on a strategy of constantly updating all team members with the latest incoming information from the simulation. This strategy appeared to make all actions *interpredictable* since all team members were updated on all actions to be taken, and the agreements on actions became the strategy used for *directing* the coordination process. However, when the data load increased these teams suffered from the coordination costs that were caused by this strategy of "total" coordination.

During times of lower workload the role structures in these teams seemed stable, but when the situation gradually started to escalate the desire to update all members with all information, and have all members involved in making decisions, caused disruptions to the role structure as well as to interaction between team members. The process was no longer focused on *directing* because the data load simply did not allow any proactive behaviour, or even consideration of actions and consequences, when the team coordination was focused on updating all team members with all incoming information. The data overload problem that the teams experienced was of the first kind described by Woods et al. (2002): the clutter problem, with too much data to process in the time available to be able to make semantic meaning and decisions, but also of the third kind: the inability to determine what incoming data was significant for the task at hand. The control mode in which the teams found themselves was a *scrambled* one, close to a trial-and-error strategy. Rather than trying to refocus on how to create structures and processes to solve problems based on an assessment of their significance, these teams ended up focusing on what to do to solve current problems based on their urgency.

After the simulation, the participants expressed a frustration over their loss of control over the on-board situation and suggested several improvements for their next simulation session (clearer goals, more distributing of information among the team members than a constant updating of all members). The following quotes were recorded during debriefing sessions following simulations with civilian crisis managers:

> There were no division of responsibilities. Everyone worked with everything.
>
> We became really event-driven and reactive.
>
> We did not follow-up our actions.

All these teams also improved their coordination processes within next session. However, when the situations again started to escalate, they had difficulties in establishing other processes than to update all team members with all the latest information, once again slowing down the decision making process rather than finding ways to speed it up.

Coordination process two – The fully informed team leader

The teams with the most maritime experience tended to use a coordination strategy in which the assigned team leader (the Captain) was clearly and fully responsible for making the decisions on the bridge. The *common ground* in these teams relied upon their maritime knowledge and the maritime procedures (even though it was explicitly stated by the facilitators of the simulation not to take any such procedures for granted in this scenario). The teams did not agree on how to respond to different kinds of situations, but instead relied on the Captain's ability to make the best decisions in every upcoming situation. In that sense the way to establish *common ground* was not by making each member's actions *interpredictable* to the others other than relying on the different team members to support the Captain with all information that would be needed to make all decisions. The Captain was in that sense responsible for *directing* the entire process of managing different situations onboard the ship.

As the situation onboard the vessel escalated the Captain got more and more overloaded, but never delegated any specific tasks, other than letting someone hand over the printouts to him (rather than picking them up himself from the printer). No one of the team members offered to support the captain or even asked or prompted the captain in regards to delegation of tasks. When the Captain ended up in the situation of managing a fire fighting operation as well as an evacuation, there was a team member who proposed that he could help by managing one of the tasks and then report back about his progress to the Captain. This seemed to be what was needed to finally break the rigidity of the role structure and to allow the Captain to let go of struggling with managing both situations himself.

Another team used a rather distributed process until the situation started to escalate. Then the captain took over the responsibility of making all decisions onboard the ship by announcing that the situation was developing in such a serious manner that decisions were now made by the captain alone. This strategy immediately seemed to halt the ongoing process of several coordinated actions being carried out to manage the escalation. Now all actions had to be coordinated and managed by one single member of the team who was not able to keep up with the incoming data load.

If the information sharing-process is based on distributing data to the highest level in the hierarchical decision making system this level is also likely to be overloaded with data as well as with demands for decisions to be made, while lower levels of the hierarchy may not be able to get an overview of the situation which would allow them to support the higher levels in their decision making.

Constantly updating the team leader with all data needed to make all important decisions will, in an escalating situation, most likely slow down the decision making process, even if the data presented to the team leader is relevant for the specific situation. The data overload problem facing the team leader becomes one of the second type described by Woods et al. (2002): a workload bottleneck. There are simply too many decisions to make in the time available to keep up with the rapid escalation of the scenario. The reliance on real or imagined procedures and routines suggests that these teams aimed at applying a *tactical* control mode (Hollnagel & Woods, 2005). However the inability to apply such predefined procedures in the escalating situations had the teams degraded to a control mode being at best *opportunistic* (ibid) with limited planning or anticipating due to the inability of the team leader to keep up with the workload of the rapidly escalating situation.

After the first escalation scenario the professional seafarers critiqued the simulation for not replicating the reality in a credible way emphasizing that if only the simulation would have adhered to the “real” procedures of a ship they would have stayed in control. This is a natural response to the feeling of having failed in the professional domain. However the purpose and design of the simulation is aimed at creating escalating situations that cannot be managed using prescriptive procedures and demand adaption beyond such strategies (an argument further outlined in Bergström et al. (2009); Stachowski, Kaplan & Waller (2009)).

Coordination process three – Strictly adhering to predefined roles and tasks

Teams that found themselves in an unknown situation, lacking *common ground* on how to manage a ship bridge (like the pilot students) often reacted by using a rigid coordination process. This process was characterised by a principle of responsibility; that all members of the team were to handle their specific responsibilities and nothing else.

> That’s not my task. I am Chief Steward. My responsibility is passenger comfort. [Pilot student during a simulation session]

The *directability*-problem (in the rigid process) was solved by making sure that all members of the team received the data related to their predefined tasks and responsibilities. The team members made few attempts to brief each other about decisions which had been made or on any other areas of concern, making their actions hard to *predict* for their teammates. The teams distributed fragments of what could have created a common understanding of the developing situation, but they did not establish strategies to define and understand interrelationships among these fragments.

The role of the Captain in these teams was often to distribute the incoming information to the other team members. This absence of an information sharing-process (rather an information distribution strategy) made the rigid teams lack an overall understanding of the status of the operation. The result was often a late, and uncoordinated, response to the escalating events. At several sessions participants with the role of ship engineers worked harder and harder, ordering machines to be repaired, without recognizing the fact that the entire deck where the engine room was situated was gradually being destroyed by a large fire.

> I actually did not know that the fire had spread to the engine room [Civilian crisis manager playing the role of Chief Engineer, during a debriefing session]

Each participant used a *tactical* control mode (Hollnagel & Woods, 2005), adhering to their predefined tasks. However the lack of coordination made the teams respond in a rather *opportunistic* way (ibid) when the escalating situations demanded actions taken outside of their predefined tasks and responsibilities.

> We lost track of the situation. We did not use the strategies that we teach for crisis management situations. [Maritime crisis management instructor during a debriefing session]

The teams adapting this rigid coordination process rarely made any revisions of their decisions and actions, did not update their understanding of their tasks or and did not perform any process-oriented discussions (i.e. used no tools that could adapt the team to the nature of the dynamically changing situation). To have rigid task descriptions which were not adapted to the dynamics of the situation often gave a low priority to incoming data which could not be addressed to a specific member of the team, sometimes resulting in the loss of vital information. The simulation used is designed to provide different participants with different levels of workload. Teams that used this rigid coordination process seldom recognized that some participants were working extremely hard while others were not. This difference in workload was often not recognized by the team members until after the simulation, during the debriefing session. Then the participants recognized how their lack of an effective information-sharing process precipitated the loss of control when the situation escalated.

> We did not use our resources well. Some worked really hard and some did not have much to do at all. [Civilian crisis manager during a debriefing session]

However these teams were likely to establish a much more successful process during the second simulation session, using a more proactive coordination process (see below).

Coordination process four – Proactive management of unexpected and escalating situations

Some teams (mainly the maritime students and the air traffic control students) adapted a strategy where team members were given clearly defined (and agreed upon) roles and assigned responsibilities. In one simulation session the assigned team leader refused to let the team consider any incoming data until they had completed a presentation of their roles and their assigned areas of responsibility. These teams put a lot of effort in briefing each other about their respective roles and tasks. The team leader in such groups was not responsible for receiving and distributing incoming data, nor for making operative decisions. Rather the team leader role was to overview and monitor the coordination process and to *direct* it by suggesting updates of the team goals based on information shared by the other team members. Knowing about the roles of others facilitated the information-sharing process as well as the process of reformulating team roles when adapting to the dynamics of the situation.

The efforts by these teams in briefing all team members of every ones' respective role and tasks, and in regularly updating each other on revised goals and the latest decisions made, proved to be a successful efforts to keep the coordination process *interpredictable.* This made it possible for the team members to be aware of other team member's goals, needs and priorities. The constant and explicit updates of goals seemed to function as a successful strategy to establish *common ground* based on which the participants made their respective actions *interpredictable* to their team members, even as the situation escalated.

> I feel I had a clear view of what everyone was doing and that we based our work on the same goals and priorities. [Air traffic control student, playing the role of Captain, during a debriefing session]

The proactive coordination process was often characterised by a distributed decision making process in which the team members made decisions concerning their respective areas of responsibility. These teams established an information sharing process in which one member was responsible for sorting and distributed incoming information to the different team members. The team leader also stepped in to re-distribute or re-formulate areas of responsibility and could detect and take action to ease the work load of overloaded team members. In this way the coordination strategy was rigid, just as type three described above, but also flexible by adapting it to the dynamic nature of the escalating situations. By distributing the decision making the proactive teams avoided data overload as a workload bottleneck, as described by Woods et al. (2002).

Teams characterised by such a distributed decision making process regularly gathered for briefing sessions to update each other about the latest decisions made and reformulate the team goals based on the development of the situation. In such briefings expectations about possible developments were also shared helping the team to be "ahead" of the developing situation. Information sharing was also eased by the help of making information, essential for other members, visible on whiteboards, charts and blueprints. The decision on what information to share was based on the understanding of the other participants' roles, goals and needs, rather than simply sharing as much information as possible.

The successfully proactive teams used the shared and explicit goals to form a *common ground*. This supported them in sorting the significant pieces of data based on the context, thereby focusing their workload on tasks based on their significance rather than their urgency. In this way the proactive teams avoided the data overload problem; not being able to detect the significant pieces in an intense data stream. The response to the escalating situations (which were designed to trigger a change from higher to lower control mode), by the proactive teams was characterized by a *tactical* control approach in which they applied strategies which they had agreed upon beforehand (e.g. sending crew to investigate indications of fire or evacuate passengers to specific locations in emergency situations). However as the situation escalated even further the proactive teams' coordination strategies made them able to respond *strategically* (Hollnagel & Woods, 2005) by acting proactively on their expectations of the development of the situations (e.g. regarding how a fire would spread, what course to turn into, and where to move the passengers next).

The proactive teams did not wait for more data to clear any ambiguities of the situation status before making decisions. Rather they made decisions that made sense to them given the information that they had and then adjusted the decisions as additional information was received.

> In our training we are taught the importance of taking action and then follow up the actions taken and if necessary make corrections. That I thought we did well. [Air traffic control student during a debriefing session]

The proactive coordination process was often observed at the second simulation session. The maritime students were often early in establishing such a process. They expressed how they were able to use their maritime knowledge in a beneficial way at the same time as they did not rely on preconceived ideas on how the "real world" should work. The air traffic control students also established a successful proactive process. They expressed that they felt that the second simulation session was less demanding in terms of the number of events that they needed to handle. In fact the second scenario is more demanding in terms of number of events (30% more than in the first scenario) and the events are of more ambiguous nature than those in the first scenario.

Teams in which the coordination process was characterised by a distributed decision making process, based on shared goals and regular information sharing efforts, were often able to maintain a proactive coordination strategy of the escalating situations. They avoided all three kinds of data overload, as described by Woods et al. (2002) and could therefore manage the dynamics of the situation in a more efficient way than the groups that rather solved problems after than before they had occurred.

Discussion

In an ideal world the scientist would be expected to approach the observed nature (here the nature of human interaction in complex and dynamic situations) with no fixed conclusions, but instead have the conclusions shaped by the observed events (Rosnow & Rosenthal, 2002). However scientists as Kuhn (1962) and Giddens (1984) point out that even the scientist is constituted in a particular context that itself offers a particular set of constructs, methods and techniques. The observations presented in this paper were in that sense not shaped only by the observed events but constructed in a theoretically selected way in which the theories of escalation, data overload, coordination and control guided what observations that, to the scientist, would count as data.

The data from the team simulations of escalating situations indicate that efforts to update all actors with all incoming data is likely to result in the actors getting caught in data overload with little ability to maintain a high level of control in unexpected and escalating situations. Too much effort put into sharing all available information seemed to lead the teams into refining pictures of history rather than predictions and expectations, a *paralysis by analysis* instead of a willingness to make decisions and then adjust them with additional decisions. This conclusion is supported by Stachowski et al. (2009) who stated that effective crews engage in “less complex interaction, exhibiting patterns that encompassed fewer behaviours (e.g. verbal statements), involved fewer actors, and incorporated less back-and-forth communication” (p.1541) as well as by Kerstholt’s (1993) studies on information processing and decision making. However the other side of the coin is the rigid coordination strategy (strategy three above), with the principle of responsibility hindering necessary coordination activities.

For teams to successfully cope with a high data load in an escalating situation there need to be processes to sort and prioritize rather than present all available, data. In this experiment teams that established proactive coordination processes all coped with the data availability paradox (see above) by constantly adapting the process (redistributing tasks, reformulating areas of responsibility) by the use of higher level agreed-upon goals, as a basis for a distributed decision making process, rather than having all team members processing the same data set. The strategy of sharing all incoming information does not seem to fulfil the three requirements for successful coordination; *interpredictability, common ground,* and *directability.* The results presented here suggest that *common ground* in unexpected and escalating situations implies constant negotiations and updates of goals and tasks as the dynamic situation unfolds. The process of over-viewing, negotiating and updating goals and tasks is in itself a strategy for *directing* the management process in the joint activity. Updating each other with the latest decisions made, priorities and goals is also a proactive approach to making the different actors’ actions *predictable* to the other actors. These are all mechanisms that need to be adhered to when designing any system for information sharing in multi-actor response systems.

The four coordination process labels that are outlined above are not static or absolute. Several teams were able to establish a more proactive coordination process as the two sessions unfolded, a learning tendency that has been shown to last when participants (from a non-maritime background) that have gone through the training program later showed improved abilities to manage escalating situations in their own domain (Bergström, Dahlström & Petersen, 2008). Neither do we claim that the observed processes are a complete set. These processes were triggered by selecting participants based on different levels of domain expertise and experience from crisis management. A selection of other independent variables could render in a different set of team performance observations.

The scalability of these results needs further investigation. It could be argued that the data collections from team-level simulations are not valid in a discussion about decision making distributed not between team members but between organisations and actors that are geographically separated. However such sub-organisations will also involve people acting as team members and it is of great importance that such teams function as efficient elements in the crisis management system. All such teams are to coordinate their actions by sorting, prioritising and distributing information to actors in order to make decisions. Such teams needs training in coordinating their actions and cannot be supposed to simply respond in an efficient way just because they have access to a lot of data. In large-scale crisis management operations the management process is rather distributed among actors in a decentralized network than controlled by a commanding staff (Brehmer, 2008), similar to the proactive teams characterised by a distributed decision making process.

The background of the teams most likely played a role in determining which decision strategy that was most likely to be applied. That was also the reason for having participants from several domains and with different background in crisis management. Professional seafarers often applied a hierarchical approach. Civilian crisis managers were keen on applying a coordination process with a constant sharing of all available data, while operators from environments in which rapid and dynamic decision making is emphasised in the training (e.g. air traffic controllers) were more likely to apply a proactive approach at an earlier stage of the simulation program.

The field of teamwork evaluation needs further method development. Based on the research outlined here we suggest that there are great possibilities to use the theoretical base of joint cognitive activity as described by Hollnagel and Woods (2005) to further develop protocols for evaluating team coordination and control. Such methods would need to include structured ways to map coordination activity and shifts of control modes by bringing in the multiple accounts of those involved (team members and observers). Such methods would be useful when evaluating the effects of training programs, introduction of new technology, and for pure research purposes (e.g. when analysing differences between teams from different backgrounds in managing escalating situations).

Concluding Remarks

The results presented in this paper shows that a broad set of theoretical concepts need to be applied to illuminate the actual demands that escalating situations pose on people's data processing capacities and processes. Tools for information sharing in a crisis management system must go beyond a presentation of all available data to all involved actors. The results also show that when the cognitive work in a team is focused on continuous sharing of as much data as possible this can trap decision makers in a reactive behaviour during escalation. This is a focus that contradicts the prevailing view, which focuses on methods to collect increasingly larger amounts of data, integrate these into systems and display present them in ever more advanced presentation systems. The results of this study suggest that applying the theoretical base of joint cognitive activity is a promising way to establish a contrasting view of what makes teams establish, maintain, and regain control in escalating situations.

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