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RULE- AND ROLE-RETREAT: AN EMPIRICAL STUDY OF PROCEDURES AND RESILIENCE

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ABSTRACT:

To manage complex and dynamic socio-technical systems places demands on teams to deal with a range of more and less foreseeable situations. Three groups of participants with different maritime experiences were studied using the same simulation of a ship to better understand the role of generic competencies (e.g. information management, communication and coordination, decision making, and effect control) play in such high-demand situations. Groups with moderate maritime experience were able to balance contextual knowledge with use of generic competencies to successfully manage unexpected and escalating situations. Novices, lacking contextual knowledge, performed less well. Groups with the most maritime expertise remained committed to presumed procedures and roles and did not perform as well as the other two groups. The results suggest that training to operate complex socio-technical systems safely and effectively should go beyond procedures and include development of generic competencies. This could provide operators with better tools to enhance organizational resilience in unexpected and escalating situations.

Keywords: resilience, procedures, emergency management, training, simulation

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INTRODUCTION

Procedures & resilience

Teams managing complex and dynamic systems have to be able to deal with a range of more and less foreseeable situations. In unexpected and escalating situations demands on such abilities can increase rapidly, for example when an operational problem of unknown origin becomes more serious or more intense. A fire aboard a ship could be a relevant example, such as the blaze on the *Scandinavian Star*, a passenger ferry on the route between Oslo and Copenhagen, on 7 April 1990, in which 158 people died when fire broke out and could not be contained until the next day (NOU, 1991). Unexpected and escalating situations create a range of cognitive and coordinative demands. As the tempo of operations rises and becomes more (if not entirely) event-driven, there is more to consider, communicate and coordinate, i.e. more information to process, distribute and act upon (e.g. Woods, Patterson & Roth, 2002). Goals can multiply, diversify and compete more steeply, and risk can increase dramatically.

A common regime in many operational worlds for absorbing those increased demands is proceduralization - the matching of situational symptoms with prepared scripts of coordinated action. Proceduralization is meant not only to help teams accomplish the sorts of actions necessary to further diagnose the situation, reduce uncertainty in it, and deal with its effects. It also supports the prioritization of certain work in the face of time pressure and resource constraints. Proceduralization can also be indivisibly connected with role assignments that govern who does what in dealing with the problem, and who double-checks or follows up the accomplishment or effect of specified actions. Proceduralization has provided operators in complex socio-technical systems with solutions on how to resolve normal and emergency situations and thus increased the reliability of operational activities. In the aviation industry in particular, proceduralization has been regarded as the most important system component to achieve increased operational safety and this has inspired maritime, nuclear and chemical industry as well as recently medicine. Shipping has relatively unthinkingly adopted this practice without reflection on the consequences, often perceived by seafarers as “counteracting the use of common sense, experience, and professional knowledge epitomized in the concept of seamanship” (Knudsen, 2009). Over time proceduralization has become more than an answer of how to increase safety in modern socio-technical systems, it may have become *the* answer.

Scientific management gave the original impetus to the development of procedures as ways of specifying action (see Taylor, 1947). It assumed that order and stability in operational systems can be achieved rationally, mechanistically, and that control is implemented vertically. These strategies persist. For instance, shortly after a fatal shootdown of two US Black Hawk helicopters over Northern Iraq by US fighter jets "higher headquarters in Europe dispatched a sweeping set of rules in documents several inches thick to 'absolutely guarantee' that whatever caused this tragedy would never happen again" (Snook, 2000, p.201). In the maritime regulatory domain, one sees the direct influence of singular accidents in new rules, often to the point where a ship can be identified by name. In many operational worlds, the strong influence of information-processing models on human factors has reinforced the idea of procedures as IF-THEN rule following, where procedural prompts serve as input signals to the human information processor (Wright & McCarthy, 2003). Procedures, however, are inevitably incomplete specifications of action. They contain abstract descriptions of objects and actions that relate only loosely to particular objects and actions that are encountered in the actual situation, and a procedure often requires a whole set of cognitive and coordinative tasks to be executed that the procedure itself cannot specify or call for (Suchman, 1987). Therefore it will remain difficult to construct global and prescriptive rules intended to guarantee certain outcomes of human behavior in complex socio-technical systems. Consequently, an over-reliance on procedures for safe operation may add additional layers of complexity rather than guide action and become part of the problem rather than the solution on to how to resolve a situation. One example is the fatal accident of Swissair 111 that crashed into the Atlantic ocean after that the presence of smoke in the cockpit was responded to promptly by the crew by adhering to the relevant checklist (Transportation Safety Board of Canada, 2003). However, while following established procedures for this situation (aiming at finding the source of the smoke rather than extinguishing any fire or putting the aircraft on safe ground), the fire engulfed the aircraft. In this case following the procedures turned out to be the problem rather than the solution (see Burian & Barshi, 2003).

The literature has recognized the limits and costs of a procedural approach to management of high-demand situations (e.g. Vicente, 1999, ; Snook, 2000, ; Burian & Barshi, 2003, ; Dismukes, Berman & Loukopoulos, 2007), but it has remained relatively mute on the mechanisms that translate that cost into real performance losses. Whereas the literature has shed light on the difficulty of processes of sensemaking in demanding situations that lie beyond procedural reach (Weick, 1993) it has not developed a detailed understanding of those aspects of performance that enhance or debilitate a team's adaptive capacity; its ability to migrate into a different regime for handling high demands. These are situations where novel behaviors can emerge, new and different resources are brought to bear, a regime where the stretched capacities of its constituent members actually open up opportunities for novel initiatives, interactions or role adoptions.

The ability to adapt is one of the key aspects of making a team work as a resilient organization, where resilience is defined as the ability to recognize, absorb and adapt to disruptions that fall outside a system's design base (Woods, 2006). The design base incorporates soft and hard aspects that went into putting the system together (e.g., equipment, people, training, and indeed procedures). The question is whether we can expect this kind of resilience from operators, experts as they may be, who are trained to follow the rules, adhere to checklists, and who have perhaps been professionally indoctrinated to believe that there is a procedure for every occasion.

In this paper we report on a series of empirical studies in which we explored the basis for the kind of adaptive capacity that could enhance organizational resilience in high-demand situations. Previous micro-world experiments (see Dörner, 1996) have illuminated the importance of generic competencies in handling dynamically escalating situations. Based on previous research on team decision making and human behavior, when handling unexpected and escalating events, as well as case studies from various domains, Bergström, Dahlström and Petersen (2008) suggested a theoretical framework to describe such generic competencies. The framework contains the four categories information management, communication and coordination, decision making, and finally effect control.

Here we ask the question whether a gap in such generic competencies can lead to over-proceduralization, over- reliance in role behavior and real operational losses. Without generic competencies to lean on, an increase in demands could actually accelerate rule- and role-retreat: a fall-back into, and an increasing rigidity of, rehearsed roles and rules (procedures). Possession, articulation and rehearsal of generic competencies, in contrast, could enhance a team's resilience in the face of accumulating demands.

The M/S Antwerpen simulation

The M/S Antwerpen simulation is part of a two-day emergency management training course developed at the University of Bamberg in Germany (Strohschneider & Gerdes, 2004). The course consists of first one simulator session, followed by instructions, extensive debriefings and theoretical training on emergency management, and concludes the following day with a second simulation session. However, apart from its training purposes, the simulation can be used as a research tool for providing data on group action and interaction in escalating events.

The simulation is designed for a group of five to seven participants who act as the ship's officers. Each participant takes on a specified role, namely: captain, chief officer, chief and main engineer, chief steward, ship's doctor and navigation officer. Initially each participant is provided with general information which describes the features of the ship as well role specific information. The information emphasizes the conditions for the simulation with extreme clarity, e.g. stresses not to make assumptions about the ship or its status but rather use the information that is available. It is the participants' task to safely navigate the ship through a stormy night in the North Atlantic. Due to the adverse conditions, and because the ship has been poorly maintained, the crew is forced to deal with a number of passenger-related problems and technical failures that towards the end of the simulation result in a state of emergency.

To sail the ship and handle these events, the participants have a wide variety of options and actions available to them. They have control over the technical facilities of the ship, including maintenance and repairs. Furthermore, they are presented with an abundance of information regarding the ship provide by regular printer outputs. By filling out order sheets they direct the crew and give various orders relating to the passengers (including, e.g. sending misbehaving passengers to their cabins, closing or evacuating sections of the ship, and using life boats and rafts to abandon the ship). Participants are not provided with a prescribed list of possible responses. Instead they have to plan and execute actions as a team and deal with the possible consequences and side-effects of their actions. The participants, therefore, find themselves in a dynamically developing situation, one that has a high level of uncertainty. Moreover, they have to deal with all this under the threat of all the conceivable emergencies that come with navigating a poorly maintained ship in bad weather.

The effect of different levels of procedural-experience

In this study, three different types of groups participated in the M/S Antwerpen training program. Each type of group differed in their familiarity with maritime operations. We were interested in the effects of the different levels of knowledge, experience and availability of procedures on concepts regarding team interaction and management of unexpected and escalating situations. Each type of group was represented by three groups of participants which were observed during the M/S Antwerpen training program.

The first type of participants was made up of novices in maritime settings, namely civil aviation student pilots. This type of group had minimal knowledge of maritime concepts, operations, and procedures. The second type of group consisted of maritime students with limited experience of maritime operations. These participants had some professional experience, however, being students, they did not have years of practical firsthand experience with the procedures and practices on large ships. The third group consisted of experienced seafarers, who had multiple years of experience on large ships. This type of group possessed practical expertise in regards to maritime concepts as well as with normal and emergency procedures onboard such ships.

Our main point of interest was whether the availability of procedures would enhance or impair the groups' use of generic competencies and therefore their ability to be resilient. When observing the three groups in order to assess their generic competencies, we categorised statements made and strategies chosen into the four categories information management, communication and coordination, decision making, and effect control (see Bergström, Dahlström & Petersen, 2008).

Regarding the teams' information management-strategies we specifically recorded whether or not the participants: openly stated their personal and group's goals, whether or not these goals were discussed, and whether or not decisions were based upon them. The simulation ensures that the groups are required to find a way to manage the continuous printer outputs. Therefore strategies for receiving and distributing incoming information to the group or its individual members were examined. We were also interested in how the groups would establish strategies, like prioritize incoming information based on the team goals, to cope with the data overload problem.

Secondly we focused our attention on the category communication and coordination; mainly how team members dealt with workload and role definition. We were interested to see to what extent participants shared their tasks and workload (flexible structure), or whether they rigidly remained within the work constraints of their prearranged roles (robust structure). How the groups dealt with the idle time during the simulation was a further area of interest. Idle time refers to the periods during the simulation in which there is hardly any work to do for the group. Idle time, intentionally produced by the simulation, provided the groups with the opportunity to think ahead, reflecting upon team processes, and construct team strategies accordingly, instead of just waiting for the next crisis to come along.

Thirdly we observed and recorded the decision making process, specifically at where the decision making process took place (distributed, hierarchical, etc.). We were interested in observing whether or not group goals were used to build up shared mental models and shared expectations of the problems at hand, and also in how team members shared information about decisions made.

Finally we examined the groups' overall capabilities to step back and on a meta-level analyze, discuss, and adjust their approach and team functioning during the simulation.

It seems that the different levels of (procedural) experience described above give rise to different ways of managing emergencies, in particular unexpected and escalating situations. In analyzing the performance of the groups, we distinguished between the two perspectives of "process" and "outcome". Outcome relates to the quantitative results of the simulation; primarily numbers of injuries and casualties, and damage to the ship. As a performance measure, however, the outcome of the simulation is dependent on the interaction between the participants and the facilitators of the simulation and therefore renders it a less reliable measure of performance. "Process" refers to qualitative aspects of how the group managed situations encountered in the simulator sessions, e.g. the generic competencies outlined above, in relation to accepted and recommended practices for emergency management. Reporting of results are mainly focused on "process".

RESULTS: DESCRIPTIONS OF THE THREE TYPES OF GROUPS' PERFORMANCES DURING THE M/S ANTWERPEN SIMULATION

Group type 1: Civil aviation student pilots

The first type of group, in general, performed poorly in the first simulator session in regards to both process and outcome. Most of these groups lost the ship and barely saved any passengers on their first trips. This began directly with the group getting immersed in the simulation, literally just starting and going wherever events would take them, without any clearly communicated goal or strategy, thus becoming locked in the dynamics of events almost immediately. This was manifested in the group's performance; they soon became overwhelmed by the amount of information they received. At no time did they discuss whether their initial approach of handling the information (printouts that soon formed piles and stacks of paper) was successful or even functional. Actions were almost exclusively reactive, i.e. in response to emerging problems, and normally based on urgency, not priority. Tasks were not shared in the group outside their original role descriptions, which led to a very high workload for some participants while others had few tasks to perform. The group did not monitor, discuss or change the group processes in any way, even when the workload was recognized within the group as becoming impossible to manage.

In the second session this type of groups did better regarding the outcome of the simulation: all groups still lost the ship, however this time they managed to save the majority of the passengers and crew. On a process level, the improvements were even more evident. The group showed great improvements in competencies. Although this improvement is somehow expected due to the participants' experience from the first trip and the subsequent theoretical training on emergency management, it was surprising how these groups were able to successfully transfer this to improved behavior in the second session. Tasks were explicitly distributed and redistributed to manage workload within the group. A role with low workload took the role of moderator, who then was in charge of monitoring the group's processes and dynamics. This meant that the captain was able to maintain an overview of the current situation and focus on issues of priority (rather than of urgency). Measures to ensure effective information sharing were taken, such as attempts at establishing routines for regular briefings and other forms of presenting the current situation of the ship, personnel, and problems to establish a shared mental model of the situation (use of blueprints, whiteboard, log notes etc.). They also followed up on more orders to ensure that they were carried out as intended (i.e. "effect control") and were much more cautious when making assumptions about a situation when there were gaps in their knowledge. The groups took more precautions in regards to various threats and were more proactive during this trip, for example by checking that rescue equipment was operative. The differences between the two sessions, in terms of team processes and generic competencies, are outlined in table 1.

	Session one	Session two
Information handling	▪ No explicit goals ▪ No prioritizing of incoming information ▪ Information overload	▪ Clearer formulation of goals ▪ Captain able to prioritize tasks
Communication and coordination	▪ No assignment of tasks outside role descriptions ▪ Robust rather than flexible environment	▪ Distribution and redistribution of some tasks ▪ Not overruling the predefined roles ▪ Moderator responsible for monitoring group processes and dynamics
Decision-making	▪ No sharing of goals ▪ No sharing of expectations ▪ Little sharing about decisions made	▪ Regular briefings to share information about the latest decisions made ▪ Using blueprints, whiteboards to share information ▪ Clearer orders
Effect control	▪ No following-up on decisions made ▪ No reflections about, or updates of, the tasks assigned to each role	▪ Redistribution of tasks based on the situation ▪ Follow-ups on decisions made and orders given

Table 1. Summary of the established processes to manage the simulation in the groups of type one.

Overall these groups, being student pilots, were hampered by a lack of understanding of maritime concepts which made it challenging for them to extrapolate from available knowledge in order to invent creative solutions for solving the problems they faced. Nevertheless, clever alternatives were devised for a number of problems, e.g. as the general alarm was defective an effective notification was devised for passengers to tell them that they should go to the life boats.

Group type 2: Maritime students

During the first trip, the second type of group performed, in regards to final outcome, moderately better then the first group, however, most groups still lost the ship and the majority of the passengers and the crew. These groups devised creative solutions which were difficult for the first type of group to come up with, since a basic understanding of ships is required to be able to devise such solutions. An example of this was when a group of this second type used a stream anchor to maneuver the ship after a breakdown of the steering engine. However, despite their creative problem solving capabilities, in comparison with the first type of group this type of group only performed marginally better in regards to aspects of process. Similarly to the previous groups, almost all of the second groups' actions were reactive; discussions and action were prompted exclusively by the information that came out of the printer. There was hardly any analysis of the occurred events, revision of current situation and strategies, or discussions on which potential tasks and risks may be ahead of them. There were also no structural solutions to deal with the information overflow.

After reflecting on the first trip and receiving the theoretical training, these groups performed very well in the second trip; saving the ship and its passengers. They were still applying their creative problem solving skills, but proactive thinking was added to that. They questioned their initial approaches to problems, and what became apparent during their second trips was their anticipation of potential problems. Examples of improved effect control were evident in the groups' continuous verification of the results of all their actions. There were numerous examples of proactive actions and planning in regards to potential threats to the safety of the ship. During a large fire all these groups sent people to higher decks, anticipating the spread of the fire. Their ability to foresee contingencies and consequences lead them to react quickly and forcefully. They prioritized effectively and responded in this way to every event that threatened safety. They were able to rank actions, given the situation, and defer the least important of them until a normal status of operation was

	Session one	Session two
Information handling	▪ Everyone's responsibility to handle incoming information ▪ No explicit goal formulations	▪ Clear goals ▪ Prioritizing and ranking potential threats
Communication and coordination	▪ No assignment of tasks outside role descriptions ▪ Robust rather than flexible environment	▪ Resisting confirmation bias ▪ Clear roles, but flexible distribution of tasks
Decision-making	▪ Creative solutions to maritime-related problems ▪ No discussions about potential tasks and risks	▪ Creative solutions to maritime-related problems ▪ Formulation of potential problems guided a distributed decision making processes ▪ Quick reactions to contingencies
Effect control	▪ Hardly any analysis of occurred events ▪ No revision of current situations or strategies	▪ Continuous verification of the results of actions ▪ Dynamically adjusting strategies

Table 2. Summary of the established processes to manage the simulation in the groups of type two.

regained. They were also reluctant to make any sort of assumptions which could not be sustained by facts. They were also able to dynamically adjust their strategies, given the conditions encountered. An example of this was their discovery, prior to any emergency situation, that the instructions did not include specific references to muster stations and the resulting creation of an alternative approach to evacuation. The differences between the two sessions, in terms of team processes and generic competencies, are outlined in table 2.

These groups performed better than the first type of groups mainly because they had contextual knowledge that supported a more effective use of generic competencies. They devised creative solutions based on extrapolations of their nautical knowledge, e.g. reducing roll angle by course change and using auxiliary engines proactively.

Group type 3: Experienced seafarers

This type of group consisted of participants with 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). In the first trip a steep hierarchy of command was quickly established among the participants. This hierarchy seemed comparable to that of real vessels, with the captain being clearly in charge of everything. This hierarchical role division and task distribution worked effectively during this session as it provided structure to both normal tasks and unclear situations. All group members reported to the captain, which resulted in the captain being in control of all goals and problems, and he gave orders accordingly. He then relied on his crew to execute the given orders. The captain and the rest of the group relied heavily on many types of procedures that they would also apply in real-life situations, and these proved useful on most occasions. These procedures, drawn from practical experience, led to the participants checking a number of parameters. This also proved useful as it supported a structured plan for management of emergencies. However, the group did not fully integrate and act on information given to them even though this issue was heavily emphasized in the instructions they had received. This was manifested on many occasions, including a fire where a captain ordered the crew to go to their muster stations and only then it was discovered that these were not specified in the simulation. The participants were however unable to solve this problem by inventing an alternative to the concept of muster stations; instead there were repeated questions about them in the group as well as complaints to the facilitators about the lack of them. Overall the procedures, often unspoken and simply assumed, did not always work as anticipated, because the scenario of the simulation did not match entirely with their expectations based on their previous experiences. As a result the group was not able to advance much beyond their silent consensus on how things "should be". There were also expectations on the behavior of the crew in the simulation which did not prove valid. The amount of expectations and inability to break out of them resulted in unanticipated failures and losses. The hierarchical team structure worked smoothly initially. It did however start to erode as soon as the workload increased; the captain became buried in information and tasks. For example, during a large fire the captain was in charge of both the fire fighting and evacuation of passengers. In practice, this meant that only one of these two tasks could be adequately managed. The final outcome was moderately successful because, based on his experience, the captain decided at an early stage of the emergency that they were not going to be able to fight the fire effectively and therefore he decided to evacuate.

Surprisingly, after the relatively good first trip (keeping in mind the flaws of relying solely on procedures mentioned above) and subsequent training, this group showed only marginal improvement in the second session after receiving the training that the other types of groups received. The group preserved their reliance on roles and procedures that proved less than ideal during the first trip. In many aspects the mistakes during the second session were identical to those committed during the first session. The serial approach to problems used in the first session, which was ineffective at times when the captain was preoccupied, again in the second session lead to standstills until the captain was free to approach the next problem. With the exception of maintenance of machinery, practically no action was executed in parallel. An example of this was seen as the group was attempting to investigate potential water penetration at a time when a bomb threat was received, resulting in a switch of full focus to the bomb threat and a return to the potential water penetration only when the bomb threat had been investigated. By not approaching these two problems in parallel, for which there were more than enough resources available, the lower decks could have been flooded before both problems had been addressed. The group members stayed precisely within the boundaries of their roles and task descriptions (relying on other "roles" to do "their own" tasks). In one case it took a "hero", one of the most experienced group members, a chief engineer, to break out of this structure. During an emergency he stepped out of the hierarchy to suggest to the captain that he should take charge of the evacuation as long as the captain was preoccupied with fire fighting. Due to this initiative, the evacuation was taken care of effectively and again the outcome was relatively successful (although not nearly as successful regarding process as session two for the type 2 groups). The differences between the two sessions, in terms of team processes and generic competencies, are outlined in table 3.

DISCUSSION

Group type 1 & 2 vs. type 3: The limiting effect of procedural experience

Overall, the third type of group did relatively well in terms of group process and outcome. Despite that they did not perform optimally under increasing stress they did have a clear solution to the information flow problem and a clear distribution of

	Session one	Session two
Information handling	▪ All group members reporting to the captain ▪ The captain in control of possible goals	▪ All group members reporting to the captain ▪ The captain in control of possible goals
Communication and coordination	▪ Steep hierarchy ▪ Robust rather than flexible environment	▪ Steep hierarchy ▪ Robust rather than flexible environment
Decision-making	▪ Decisions made by the captain ▪ Reliance on perceived procedures ▪ Not acting on the information given ▪ No information sharing except for reporting to the captain ▪ Tasks not performed in parallel	▪ Decisions made by the captain ▪ The Captain overloaded with tasks ▪ Reliance on perceived procedures ▪ No information sharing except for reporting to the captain ▪ Tasks not performed in parallel
Effect control	▪ Unable to revise the belief in perceived roles and procedures ▪ No revision of roles and tasks ▪ Few follow-ups on orders given	▪ Unable to revise the belief in perceived roles and procedures ▪ Few revisions of roles and tasks ▪ Few follow-ups on orders given

Table 3. Summary of the established processes to manage the simulation in the groups of type three.

tasks, as well as a systematic approach to most of the situations encountered. However, as soon as events developed beyond the "design base" of their procedures, the work structure started to disintegrate rapidly. This did not occur in the other two types of groups – ones that were not as reliant on presupposed procedures. These two groups used the generic competencies and the knowledge they gained from their experiences in the simulation as well as from the training in-between the two scenarios. Furthermore, in contrast to the other two types of groups, the third type of group very rigidly held onto their original hierarchical group structure, even when this proved ineffective. The other groups were able to manage a more dynamic group structure in order to deal with unexpected situations and the different phases of escalation.

Although procedures may prove effective to some degree, as shown by the relative success of the third group during their first trip, as soon as the specific conditions for a procedure did not precisely apply, control was lost and competence degraded. As not all scenarios or situations can be foreseen, relying on procedural knowledge or procedures may not always be enough. However, trained crews tend to react to emergency events with the use of pre-prescribed procedures even when these do not match the problem. In other words, for someone equipped with a hammer all problems will look like nails, and this is where the danger lies. In particular in emergency situations individuals and groups need to be able to review their situation and assess whether their "standard" approach is appropriate (exemplified by the fatal accident of Swissair 111, outlined above).

Relying on procedural knowledge can limit alternatives and may prevent potentially powerful non-presupposed solutions from being considered. This may mean that not even reviewing or reframing of a situation may occur. In short, relying on procedural knowledge can severely limit crews' options to be resilient.

Moreover, armed with the knowledge that they have a procedure for every scenario, the experienced participants (group type 3) felt more secure than the inexperienced groups (group type 1 and 2). This sense of security seemed to cause overconfidence. In the simulation this was manifested by the following: giving non-specific orders, not following up on orders and making unfounded assumptions in many situations. This may be a functional approach in extremely stable and reliable conditions. However, this was not the case in the simulation and is rarely the case in the transportation industry, where crew composition and operational conditions may change frequently and equipment often is used at or close to the limits prescribed by the manufacturer.

Despite long periods of operation during which nothing dangerous ever happens, it is important that operators go to work and are prepared to expect the unexpected (Dekker, 2006). In the simulation sessions, in particular during the second trip, group types 1 and 2 showed caution regarding their situation; institutionalizing effect control, proactively checking the status of equipment (e.g. technical and rescue equipment) and simply contemplating what might go wrong next. Multiple groups of type 1, for example, checked whether all the life-boats were in good condition, whereas the experienced seafarers assumed that they were, based on the claim that such matters are regularly tested (even though they admitted that there has been a number of accidents at sea where rescue equipment has been defective). This summarizes exactly the issues that the experienced crews faced (group type 3); they assumed that things were as they should have been, that situations would proceed as expected or as ordered, and all of this would occur in accordance with procedures. Experience makes people expect certain things regarding quality of equipment, action sequences performed by crews, crew reactions in emergencies, passenger reactions and behavior etc. Procedures create reliability, i.e. expected events. Procedures are in place to fight foreseeable problems, whereas caution, forethought and inspection can give rise to resilience, to the ability to adapt to unexpected and escalating events (see McDonald, 2006).

A point of criticism may be that the experienced crew did not do as well as the other type of groups during the simulation because the simulation did not exactly mirror real world conditions. This is however to some degree the main point that the participants of the simulation were meant to take home; in an emergency situation not everything will go according to plan, e.g. not everybody will report back and not all orders will be carried out (Dahlström, van Winsen, Dekker, & Nyce, 2008). But under those circumstances groups need to find and mobilize resources and competences that will enable them to remain functioning. When procedures limit options they need to be able to find alternative ways to solve problems.

Group 1 vs. group 2: Difference between generic competencies, domain knowledge and procedural knowledge

If relying entirely on procedures is not appropriate, we can argue that having only generic competencies without having any domain specific knowledge (group type 1) may have the same effect. Maritime knowledge should facilitate the generation of solutions to the problems encountered in the simulation. The student pilots (group type 1) were not likely to come up with alternative solutions for navigation at sea. The second group type did have knowledge of maritime concepts in addition to the general competencies learned during the training phase of the program; even when the steering engine broke down they explored actions in order to make the bow of the ship turn into the wind, thereby reducing the dangerous roll angle of the ship. However they were not limited to following established procedures, even when there were explicit procedures available. To argue that even in a simulation appropriate contextual and domain competence "counts" seems self-evident. But this is not the point we wish to make here. What we believe this simulations suggests is that the role generic competencies can play for safety needs to be reconsidered for unexpected and escalating situations.

On a process level, it proved easier for groups with a certain level of domain knowledge (group type 2), as compared to groups with only generic competencies (group type 1), to cooperate. The reason for this lies in the more appropriate match between their common knowledge and the situation. The type 1 groups improved their generic competencies between the two trips and therefore performed more effectively during the second trip. Despite this improvement, it proved harder for these groups to apply their skills in an unfamiliar setting. Moreover, for participants without previous domain-specific knowledge, it proved impossible to step out of their roles, in order to assist or even overrule other roles. The reason for this lays in the role-specific information being the only information on which to base their behavior. With no alternative knowledge to use in these unfamiliar settings they remain "too loyal" to these roles.

There is a fine line that distinguishes the second group's (theoretical) domain knowledge, which enabled them to come up with more creative solutions, from the first group who lacked maritime concepts, and the third group's procedural experience which seemed to limit them to following procedures. The student pilots had no tools with which to deal with a maritime emergency, they had to rely solely on generic knowledge and competencies. The experienced crews relied on tools and procedures they normally used. The maritime students on the other hand were able to look into the toolbox and select an appropriate (but not necessarily prescribed) tool for the situation.

CONCLUSIONS

If operators are to be able to resolve normal and emergency situations, they do need to be trained in established procedures. Many industries, including the maritime, have tended to equate training and education with the acquisition of procedural knowledge. This has led to a regime of control, a discourse, in which every conceivable variation away from normal operation can be "anticipated" or controlled additively by the creation of new or more procedures and rules—a trend that may be larger than the safety-critical situations studied for this paper (see Foucault, 1977). However, the intractability of human action and design compromises inherent in any complex socio-technical system can lead to operational situations which require action and response that extends beyond any set of established procedures no matter how elaborate or detailed. Observations of emergencies in these ship simulations suggest that procedural knowledge or guidance can lead operators in unexpected and escalating situations to act in ways that are irrelevant or detrimental given the situation at hand. The issue here is not whether procedural knowledge be part of any operator's training. It is to suggest that operator training should not be limited to this. Apart from being reliable in the sense of following predetermined procedures, an organization also has to be able to "recognize and adapt to handle unanticipated perturbations that call into question the model of competence, and demand a shift of processes, strategies and coordination" (Woods, 2006, p.22). McDonald (2006) suggests that being able to successfully resolve this apparent contradiction is a characteristic of a resilient organization. While unanticipated, it is industry's strong commitment to and investment in safety and procedure that has left operators less able to respond to unexpected and escalating situations. Next to the training of procedures, operator training needs to stress as well the development of generic competencies that add up to resilience in the face of unexpected and escalating situations. This would provide operators with the tools they need to manage situations that go beyond what can be anticipated. Only then can the kinds of counterproductive rule- and role-retreat behavior observed in these shipboard simulations (and often reported in accident reports) be avoided.

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