Can proceduralization support coping with the unexpected?

NORROS Leena[1], SAVIOJA Paula[1], LIINASUO Marja[1], and WAHLSTRÖM Mikael[1]

1. Human Factors in Complex Systems, VTT Technical Research Centre of Finland, Vuorimiehentie 3, 02044 VTT, Finland (firstname.lastname@vtt.fi)

Abstract: Operations of safety critical industries unquestionably require a diversity of technical and organizational control measures to increase stability and predictability of the complex sociotechnical systems. Nevertheless, experiences from recent severe accidents and results of safety research have questioned the effectiveness of the prevailing safety management strategy that mainly relies on standardization and designed-in defenses. This paper discusses the identified need to balance between stability and flexibility in a concrete safety issue, *i.e.*, proceduralization.

The main research problem of our study is whether procedure guided practice can offer sufficient support for flexibility of operating activity. We shall frame our study with the help of a model that explains different aspects of procedures. We then elaborate how these different aspects were considered empirically in our 3-phase study. In the first study we interviewed 62 main control room operators and asked how they consider procedures to support balancing. In the second study we observed in detail 12 NPP operator crews' activity in a simulated loss-of-coolant accident. In a third study we inquired 5 procedure designers about their conceptions concerning procedure guidance in operator work. Drawing on either interview or behavioral data we analyzed the personnel's stance to the flexibility and stability balancing, and how the conceptions portray in the practices of procedure usage.

Our results demonstrate that the operators are aware of the need for balancing flexibility and stability and consider successful balancing to represent "good" professional action. In actual action many operators, however, tend towards more straightforward following of procedures. Designers also see the capability for balancing stability and flexibility as a key operator competence but describe actual acting simply as procedure-following. According to the documents of the nuclear community, procedure-following is the ideal to be emphasized. The paper will be finished by discussing what new insights our results would provide for developing training of procedure usage and for the design of procedures.

Keyword: procedure guidance; interpretative use of procedures; resilience

1 Introduction

In the aftermath of the Fukushima nuclear disaster, voices have been raised concerning the overall safety philosophy upon which the nuclear industry relies. [1] The basic assumption of the community, that it is possible, by careful and comprehensive pre-planning, to defend the system completely for failures, has argued to be insufficient. As a remedy it has been proposed that the underlying idea of safety as non-existence of failure should be substituted for, or at least completed by another one that focuses on the development of capability for safety. Such a positive conception of safety is what the resilience engineering approach advocates. [2, 3]

In complex work systems extensive I&C systems are required to control processes efficiently and safely. I&C systems also provide automatic safety functions to guarantee safe operations in design-based disturbances and accident situations. Beyond these fundamental defenses also other defenses are created to ensure safety. Among these are rules and regulations, emergency procedures, safety-informed practices and culture, *etc.* The aim of safety defenses is to control the variability of the system and decrease uncertainties of the system.

Yet, cross-domain experience shows that the strategy of increasing safety by creating stability via standardization of the system behavior has probably gone too far: It has been claimed that stability through standardization is either inefficient or harmful for safety [1,6]. These and other authors claim, instead, that both stability and flexibility are needed, and that the key challenge for safety is to be able to manage the co-existing duality of

Received date: September 16, 2014

stability and flexibility [4]. We see that human and organizational factors (HOF) research faces the challenge to identify the capabilities of the human actors and organizations that may support the needed flexibility in operations, but HOF also has to participate in the design of technical and organizational means that may bring stability into the functioning of the sociotechnical system.

Balancing between the required stability and flexibility of complex sociotechnical systems is a global design issue. As Papin [5] has indicated, the balancing must cut across the basic process design, I&C system design, and the design of organization and procedures. It has also been noted that the balancing always takes place within a particular human-technology collaboration paradigm. When the paradigm turns non-functional, *e.g.*, due to inefficiency of system performance or threats to safety, a leap to a new "master coupling" takes place [6]. For example, in order to control the increase of air traffic there is a need to re-consider the roles and responsibilities of air traffic controllers, aero plain pilots and the technological aids like, *e.g.*, the traffic collision avoidance systems (TCAS). Understanding the requirements of future work is clearly a great challenge for HOF if it wants to participate effectively in the design of future sociotechnical systems.

In the current paper we focus on one specific area of safety management in which the need for balancing between stability and flexibility is very pressing, *i.e.*, on procedure usage and design in nuclear power plant operations. What regards the design of organizational rules and operating procedures, general solutions for the whole organization will not work. Instead, different balancing solutions are needed depending on the work demands and task characteristics of the work [7]. Therefore sufficient effort should be devoted to the analysis of the work demands in the connection of procedure design so that decisions concerning the types of procedures, and the level of prescription they assume, could be based on sufficient evidence. The same applies when concepts of operations and tasks are designed in connection with major renewal projects, and when completely new plants and processes are designed.

2 Proceduralization as safety strategy

It would, of course, be against available evidence and very polemic to question the important role of procedures for safe operations of complex high-reliability organizations [2]. Yet, there is a need to address the issue of the efficiency of a safety management strategy that strongly relies on proceduralization. This difficult and sensitive issue has recently been raised by experienced experts of safety management in the various high-reliability domains, *e.g.*, in aviation [8].

We may summarize the current literature concerning procedures as a safety defense by listing the main advantages for proceduralization.
As main advantages of proceduralization we could mention [9]:

- Support for control and coordination of actions and for facilitating communication in action
- Reduction of stress in complex situations by guiding what to do
- Reducing uncertainty of the situation and steering the system or process to safe track in expected situations
- Enabling structured storing of information and facilitating learning

Strong emphasis on the advantages of procedures may, however, hide disadvantages that emerge from un-reflected procedure usage. There are clear doubts concerning procedures that need to be considered:

- Procedures are considered equal with action, *i.e.*, it is considered that action can be described completely in a procedural way, which misunderstanding leads consideration of deviations of this description, and attention is drawn to human error. [10, 11]
- Procedure following is not sufficient for safe operation. Instead competence is always needed for their appropriate use and to enable flexibility that variable, sometimes very un-expected situations require [12].

- A tendency of over-proceduralization of behavior in an organization, *e.g.*, proceduralization of safety management, or of safety culture, has shown to be disadvantageous [13].
- Comprehensive proceduralisation, combined with advanced technical safety defenses, tends to create an illusion of a failure free system. Disturbances or accidents occurring in such a system can only be explained as disobedience of procedures, which needs to be fought against with strict disciplinary means or excessive training or procedure use. As a result a "learning trap" may emerge [13].

We see that in order to successfully balance stability and flexibility in the use, design and implementing procedures, a better understanding of actual procedure usage is needed. We shall provide highlights of our own empirical research at two Finnish NPPs in which we studied operators' own conceptions of the role of procedures in competent process control work, and the actual use of procedures in emergency exercises. We also queried procedure designers' conceptions of the role of procedures. Our main hypothesis was that operators' ways of procedure usage may reveal different solutions to manage the stability and flexibility requirements, and that a successful integration of these two requirements supports capability to act, also in unexpected situations.

3 Approach to study procedure guidance in safety critical work

In the analysis of procedure usage it is necessary to distinguish two different perspectives to procedures [9]: The first perspective has been called the ostensive view to procedures which concerns procedures as physical artefacts that describe the routines. The ostensive view is dominant in work that focuses on procedure design. The second perspective has been called the performative point of view. Here the interest is in the detailed practice of accomplishing the routine.

The distinction between ostensive and performative perspectives is further developed by Grote in her model concerning the relationship between rules and behavioural routines [4]. This model distinguishes three aspects of procedures or routines: rule, routine in principle and routine in practice (see Fig. 1).

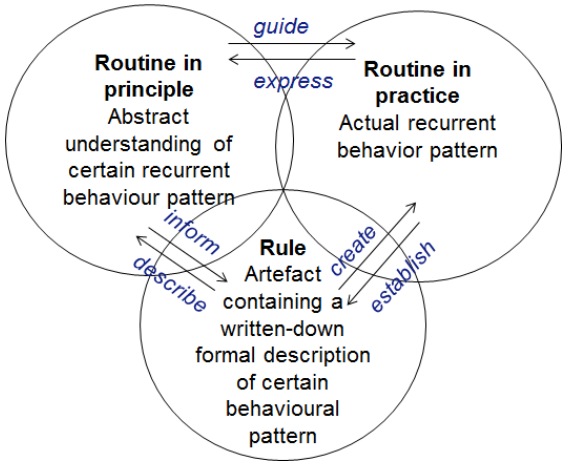

Fig.1 The distinction between rules and behavioral routines in organizations by Grote [4].

According to Grote rules are artefacts containing the written formal specifications for behavior patterns required in predefined situations. The actual behavioral patterns that occur in a more or less regular form and can be observed in real situations are called routines in practice. Grote identifies a third aspect that is relevant in considering routines which she calls routine in principle. This aspect refers to a generic conception or reasoning of the nature of behavior. The model also indicates that the three aspects of routines have impacts on each other: Routines in practice, *e.g.*, as they appear by operators, are guided by operator' conceptions of routines (routines in principle) and the latter express themselves in routines in practice. Rules are used to create actual practices, but actual practices also influence establishing of routines. Rules are also informed of the reasoning and beliefs behind behavior and rules describe these beliefs. What these routines concerning behavior, and they In the above described model we find important that actual behavior (routines in practice) is not considered merely as improvisation or expression of flexibility of human behavior, but the inherent strive for regularity of behavior is also acknowledged. We also consider important the

inclusion of the idea that conceptions of behavior (by operators themselves or also designers) is considered and seen to modulate the actual practice. These ideas correspond very much with our own theorizing of procedure-guided action as will be explained in the next section.

4 Analysis of procedure usage in NPP emergency operations

In this section we introduce our approach to study procedure-guided action in NPP emergency operations. We shall elaborate our theoretical conceptions and the three phases of empirical study by mapping them on the distinctions of different aspects of rules and routines by Grote. This mapping is demonstrated in Fig. 2.

The focus of our work is on the practice of procedure use. Practices are learned meaningful patterns of behavior within which procedures are incorporated as tools that provide possibilities to act. For empirical analysis we have conceptualized practice by three elements that closely correspond with the distinctions made by Grote. These concepts are habit of action, orientation and procedure.

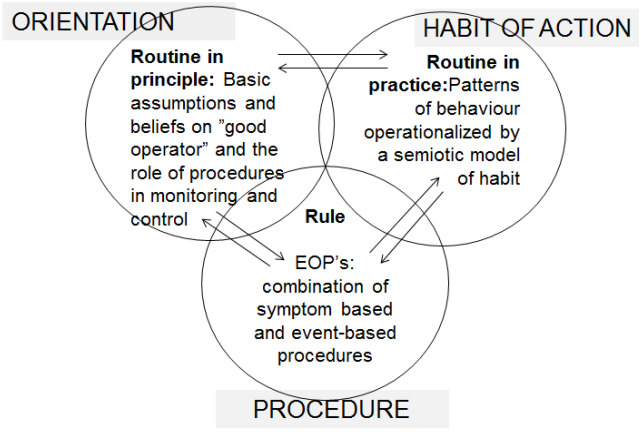

Fig.2. Demonstrating the relationships between the central concepts of our study, *i.e.*, orientation, habit of action, and procedures, with the aid of Grote's model. [4]

The concept of habit of action relates to the actual way of acting in procedure usage and corresponds to Grote's concept of routine in practice. Drawing on the pragmatist tradition, especially Charles. S. Peirce [14], we consider habits of action as patterns of behavior. As patterns they are not seen only recurrent but also reflective routines. We see further that reflection in action is possible through abductive reasoning that is characterized by the constantly on-going action-perception-interpretation cycle, as a result of which habits of action emerge. We exploit the Peircean semiotic model of habit depicted in the next section to identify the structure of habits of action in empirical data (see Fig. 3). Habits of action enable stability and anticipation of environmental events and also a possibility to revise beliefs of, and responses towards the environment.

The second concept we use is orientation. They are generalized beliefs of the nature of action, procedures, process *etc.*. [15] In this case we developed a model of procedure orientation in which we included conceptions of good operator and the role of procedures in monitoring and controlling of the plant. We consider procedure orientation to correspond to Grote's routine in principle.

Finally we used the concept of procedure to indicate to the rule-like tools that the operators are using in controlling the NPP plant. We were especially interested in the analysis of the use of emergency operating procedures (EOP). In our study procedures as written-down formal descriptions of behavior (Grote) were studied by querying about the design rationale of the EOPs as expressed by the procedure designers.

Very crucial for the understanding of the usage of procedures, and for understanding how stability and flexibility may be balanced, is the evaluation bases that was used for differentiating operators' procedure usages. Drawing on Peirce's ideas we consider that Orientations and habits of action, as expressions of the actor' interaction with the environment, may be analyzed with regard to how profoundly actors exploit the abductive reasoning in his/her acting in the environment. According to the theory, habits of action and orientations may be characterized as follows:

- Interpretative: identifying situational particularities, creating hypotheses and expectations and checking outcomes, connecting to and building a whole.

- Confirmative: taking situation as expected by a rule; need to check the outcome of own response not acknowledged.
- Reactive: immediate responding to singular signs, being led by the situation, no clear expectations.

These characteristics need to be contextualized through qualitative data analysis, which also took place during the analysis.

The claim is that the interpretative relationship with the environment, that expresses full exploitation of abductive reasoning, enables development of routines of using procedures within which sufficient flexibility for situational variations is included.

In the next section we shall provide a summary of the results of our three part empirical study. Separate publications are (are going to be) available of the results.

4.1 Operators' orientation to procedure usage

In the study of NPP operators' conceptions of procedure usage we interviewed 62 main control room operators and asked how they consider procedures in their work and how they see procedures to support balancing between stability and flexibility. The operators represented both two NPP's in Finland, so that all the control room operators of the NPP1 were interviewed and half of the operators of the NPP2.The interview questions were:

1. What is the role of procedures in process control?
2. Do such situations exist to which no dedicated procedures exist?
3. Do the procedures determine the course of actions totally in some situations?
4. Are alarms the primary starting point for action?
5. How would you characterise a good operator?

A comprehensive account of the results is given in reference. [16] In this connection only a summary can be given.

We were interested in the overall orientation of the Finnish NPP operators' to procedures, and the potential differences in the orientations between the plants. Hence data of responses to all questions were summarized for both plants, and the difference of distributions between interpretative, confirmative and reactive answers were tested. The result is depicted in Table 1.

Table 1 Overall orientations NPP1 (N=44) and NPP2 (N=18) control room operators.

	NPP1 %	NPP2 %
Interpretative	27	27
Confirmative	41	50
Reactive	32	22

As can be seen the distributions of the plants are very similar and the statistical testing verifies that the two distributions do not differ statistically ($\chi 2= 7.61$, df=2, p=0.472). As the table indicates confirmative orientation is dominant in both plants and interpretative orientation is characterises only less than 1/3 of the operator conceptions.

We pooled the data from both plants and studied whether different indicators constructed of the data would show differences in orientation, and we also broke down these analyses with regard to the operator roles (shift supervisor, reactor operator, and turbine operator). These analyses revealed that some statistically significant differences in orientations appear. The main result is that the interpretative orientation increases by turbine operators when the question deals with procedures in controlling the plant, by reactor operators and shift-supervisors when the question deals with the role of procedures in monitoring the plant, *i.e.* , with regard to issues that are the very core competence of the three roles. The proportion of interpretative conceptions in all roles was highest when the question dealt with considering what a good operator is, and how procedures relate to competence. In other words, operators seemed to esteem interpretativeness as a characteristic of professional competence.

4.2 Operators' habits of action in use of procedures

Our second study dealt with habits of action, *i.e.*, was focused on the actual use of procedures in the control

of the NPP. In this study we focused on the crews of NPP1, all the 12 crews (N=44) participated in the study. We studied a simulated loss of coolant accident (LOCA) in which operators are prescribed to use EOPs to manage the situations. Comprehensive data of operators' behavior was collected and debriefing interviews were accomplished in which the operators could give accounts of their behavior. The analyses of habits of action were accomplished on crew level. A comprehensive report of the study is available in reference [17].

The process control activity of the crews was analyzed in three important episodes of the LOCA: Initial detection of emergency situation and scram; Taking accident identification procedure into use; Taking accident management procedure into use. Using regular analyses of operator behavior sequences we identified differences in procedure usage with regard to following aspects of the work: Information usage; Identification of situation; Dealing with automation; Decision making; Communication; Leadership. Analysis of habits of action was accomplished according to these aspects in all episodes.

Habits of action were analyzed with the Peircean semiotic model which connects three elements of the human-environment interaction cycle, the environment (Object), a sign representing the environment (Sign) and the behavior or model that interprets what is the connection of the sign to the object (Interpretant). The analyses provided understanding of what was the meaning of the observed actions of the crews. The application of this model to the episode 1, *i.e.*, initial detection of emergency situation and scram to indicate a habit of information search is indicated in Fig. 3. Figure 3 portrays the different optional ways the object was considered, and also shows which sign was considered relevant to refer to each object when accomplishing the scram according to the procedure. These optional ways of reacting to the same situation were classified as portraying interpretative, confirmative or reactive relationship to the situation.

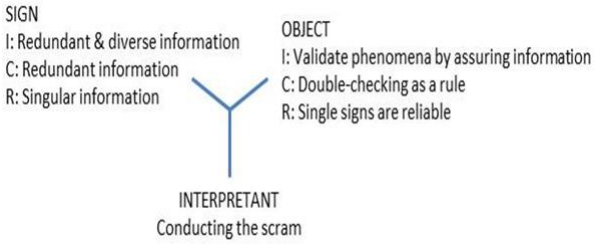

Fig.3. Habit of information usage in episode 1 in LOCA scenario. I=interpretative; C=confirmative; R=reactive relationship.

In Table 2 we provide the results of all crews' habit of information usage, habit of situation interpretation, habit of dealing with automation, and habit of decision making in episode 1. It serves as a demonstration of the results we achieved in this very detailed and comprehensive qualitative analysis of each crews activity. The Table 2 shows that no crew was coherently portraying any one form of habit of action (see color coding of the Table) but that some crews tended to leans towards being interpretative (Crew C), whereas some even towards reactive forms of behaving (Crew L).

When we summarized all results of habit of action analysis it became clear that the proportion interpretative habits was 32.1%, confirmative 40,5 % and reactive 27.4.

The analysis of the habits of action was completed with an analysis of the actual features of behavior that we had considered as indicating of interpretative relationship to the situation and compared them with characteristics considered in the literature [3] to demonstrate system level resilience.

4.3 Procedure as a design object

Our third study focused on the procedures as design objects as comprehended by the procedure designers themselves. This perspective to the procedures was taken to correspond to the perspective Grote defined as rule, *i.e*. procedures as they are formally described. We interviewed five designers who had been involved in the designing of new EOPS for the Plant 1. These procedures were the same that were studied in the simulated LOCA scenario (see the previous section).

Table 2 Habits of information usage, situation interpretation, dealing with automation and decision making of 12 NPP crews in simulated LOCA accident –Episode 1 (black=interpretative, grey=confirmative, white=reactive) .

Crew	Habit of information usage	Habit of situation interpretation	Habit of dealing with automation	Habit of decision making
A	plant protection, pressurizer level	Disturbance	Cue to perform scram	SS
B	emergency cooling, pressurizer level, primary circuit pressure, plant protection	Leakage	Cue to perform scram	SS
C	containment isolation, plant protection coolant flows, pressurizer level, pressurizer level gradient	Mass balance	Realise isolation	SS
D	plant protection, pressurizer level, primary circuit pressure, several trends in PMS	Leakage	Cue to perform scram	procedure
E	alarms, plant protection, pressurizer level	Leakage	Realise isolation	SS
F	pressurizer level, plant protection, emergency cooling, pressurizer level	Leakage	Realise isolation	procedure
G	emergency cooling, plant protection	Leakage	Realise isolation	procedure
H	emergency cooling, primary circuit pressure, containment isolation, plant protection	Disturbance	Ensure isolation actively	procedure
I	emergency cooling, pressurizer level, primary circuit pressure	Mass balance	Cue to perform scram	SS
J	emergency cooling, plant protection	Disturbance	Cue to perform scram	procedure
K	plant protection, alarm info	Leakage	Cue to perform scram	procedure
L	alarms, plant protection signals, primary circuit pressure	Disturbance	Cue to perform scram	SS

We inquired about procedures as the product of the designers' work, and in this connection we also wanted to know how the designers conceptualise procedures as tools in operator work. We used the same set of questions concerning the role of procedures and good operator that was used with the operators.

It must be noted that the results from the designers' interviews deal with procedures as design objects to be used by operators, which view is broader than procedures as artefacts as meant by Grote.

The results of this study have been published in a separate publication. [18] The results demonstrate that the designers' orientations were clearly split. The designers considered the operators work, for which they were designing the procedures, in clearly interpretative terms. However, when the designers were queried about the way procedures should be used, their conceptions were clearly confirmative.

5 Summary of results

The adapted model of Grote introduced earlier should serve as a frame with the help of which we can accomplish a heuristic summary of the results of our analyses procedure-guided activity in the Finnish NPPs (Fig. 4). We may consider that orientations of the operators tend towards interpretative features, as this feature is strongly represented in issues that are critical to the operators own competence, and since they value interpretative features as qualifications of their professional ethos. This conclusion is depicted in Fig. 4 as a black color of the orientation circle. The actual behavior of operators demonstrated about the same percentage of interpretativeness (32,1%) than was the mean of this type of orientations (27 %), but the proportion of confirmative is still quite high in actual action (40,5 %). Hence, we take the overall result to demonstrate confirmative relationship as the dominant feature for habit of action (grey color of the habit of action circle), and we also see that too many operators in reality act more straightforward according to procedures. The designers consider

the balancing capability as a key operator competence but describe actual acting as procedure-following. These results reflect clearly the prevailing conception of the nuclear community, that procedure-following is an ideal that is also emphasized in the documents.

6 Discussion

The title of this paper raises the question whether proceduralization as a safety strategy can support managing the unexpected. The recent safety management literature that we have cited in this paper, and the growing interest in the new safety concepts labelled as resilience engineering, express doubts about the dominant role of proceduralization as a safety strategy of high-hazard organizations. Proceduralization as an expression of predefined defense aimed to stabilize harmful variation in the system is accepted but this stabilizing effect should be balanced by other types of resources. These are labeled as capabilities that support flexibility of the system to adapt even in unexpected situations. It is, however, not very clear what such capabilities are in concrete and how they can be promoted.

Our intention in this paper was to consider how procedure usage is comprehended by NPP operators and procedure designers. We aimed at potentially finding out if these actors themselves have invented ways of using procedures so that procedures would both help in stabilizing difficult situations. And also help in managing the unexpected. Indeed, we consider that we have in the current study been able to identify signs of practices of procedure usage that demonstrate such capabilities, *i.e.*, show signs of supporting resilience of the system.

The resilience-facilitating practices were labeled as interpretative practices for which we have strong theoretical arguments. We have also operationalized the interpretative practices with regard to basic assumptions, *i.e*., orientations, concerning procedures.

What regards to the empirical findings of NPP operators' procedure orientation we see the findings concerning high interpretativeness with regard to conceptions of good operator to speak of professional ethos of NPP operators that demonstrates the "moral sense of safety" which has recently been named as the core of safety culture [19].

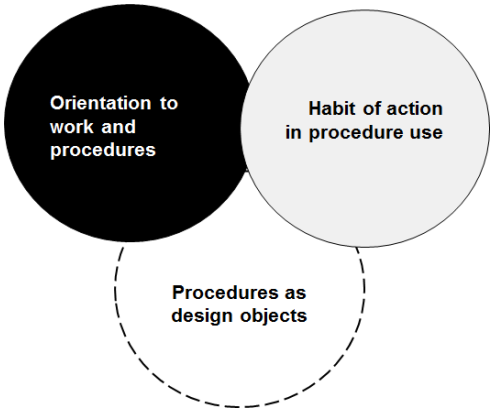

Fig. 4 A heuristic summary of the results of the study on procedure-guided process control in Finnish NPPs. Black=interpretative; Grey=Confirmative. The dashed line indicates that the results from the designers' interviews deal with procedures as design objects to be used by operators, which view is broader than procedures as artefacts meant by Grote. The designer orientations were clearly split between interpretative and confirmative.

The concrete forms of interpretative procedure using practices that we could identify from the data demonstrate that the extremely well-rehearsed procedure-guided emergency handling practices are not necessarily mere repeated routines but routines that are reflected upon in connection to situational demands. Such routines develop in use, and the actors learn from the experience of using them.

We see that our results support the belief that even if normal work, emergency exercises, and unexpected emergency situations put different demands on actors, the way normal work is accomplished has impact on the capability to respond to the unexpected. This is because the interpretative practice supports attention to the specifics in situations, observing outcomes of action, and building a picture of the situation, which all enable finding new solutions, and learning from experience.

Our results demonstrate however, that interpretative practices are not very dominant within the operators, nor among procedure designers. The operator work is supported by excellent technical and organizational defenses that are intended to minimize any variance in the system or in the operator behavior, and this

standardization may easily hide the possibilities of observing the dynamics of the process and the effects of own action on the process. A natural outcome is that the confirmative relationship to the process is considered good and sufficient, signs of interpretativeness even negative. Therefore we see that the characteristics of interpretative practice should be clarified better in the future research, that the training of daily practices should be studied, and such training programs and methods developed that support appropriation of interpretative practices in initial training of operators, in the refresher training and in the emergency exercises. We also see that learning in daily work requires more understanding and emphasis.

Implications to safety management are that the prevailing concept of safety should be elaborated by the idea of developing capability for safety. There is no need to question proceduralization but procedure following and professional competence should not be contradicted as is often done in managerial thinking today. We also see that development of new principles and practices of procedure design are needed. Studies of actual usage of procedures should be accomplished.

References

[1] BOURRIER M., and BIEDER C.: Trapping safety into rules: An introduction, in Trapping safety into rules. How desirable or avoidable is proceduralization, C. Bieder and M. Bourrier, Editors. 2013, Ashgate: Farnham, UK. p. 1-9.

[2] PARIES J.: Resilience and the ability to respond, in Resileince engineering in practice. A guidebook E. Hollnagel, *et al.*, Editors. 2011, Ashgate: Farnham. p. 3-8.

[3] HOLLNAGEL E., *et al.*: eds. Resilience engineering in practice: a guidebook. 2011, Ashgate: Farnham.

[4] GROTE G.: Safety management in different high-risk domains – All the same? Safety Science, 2012(50): p. 1983–1992.

[5] PAPIN B.: Integration of human factors requirements in the design of future plants. in Enlarged Halden Programme Group Meeting. 2002. Storefjell.

[6] AMALBERTI R.: Optimum system safety and optimum system resilience: Agonistic or antagonistic concepts?, in Resilience engineering. Concepts and percepts, E. Hollnagel, D. Woods, and N. Leveson, Editors. 2006, Ashgate: Aldershot. p. 253-271.

[7] SCHULMAN P.: Procedural paradoxes and management of safety, in Trapping safety into rules. How desirable or avoidable is proceduralization, C. Bieder and M. Bourrier, Editors. 2013, Aschgate: Farnham, UK. p. 243-255.

[8] PELEGRIN C.: The never-ending story of proceduralization in aviation, in Trapping safety into rules. How desirable or avoidable is proceduralization, C. Bieder and M. Bourrier, Editors. 2013, Aschgate: Farnham, UK. p. 13-25.

[9] FELDMAN M.S., and PENTLAND B.T.: Re-conceptualizing organizational routines as a source of flexibility and change. Administrative Science Quarterly, 2003. 48: p. 94-118.

[10] SUCHMAN L.A.: Plans and Situated Actions: The Problem of Human-Machine Communication. 1987, New York: cambridge University Press.

[11] DEKKER S.: Failure to adapt or adaptation that fail: contrasting models on procedures and safety Appl. Ergon., 2003. 34(3): p. 233-238.

[12] SAVIOJA P., *et al.*: Identifying resilience in proceduralised accident management activity of NPP operating crews. Safety Science, 2014(68): p. 258-274.

[13] ROSNESS R.: The proceduralization of traffic safety and safety management in the Norwegian Rail Administration: A comparative case study, in Trapping safety into rules. How desirable or avoidable is proceduralization? , C. Bieder and M. Bourrier, Editors. 2013, Ashgate Farnham, UK. p. 173-190.

[14] PEIRCE C.S.: Letters to Lady Welby, in Selected writings of C.C. Peirce, P. Wiener, Editor. 1958, Dover Publications: New York. p. 380-432.

[15] NORROS L.: Acting under Uncertainty. The Core-Task Analysis in Ecological Study of Work. Vol. Publications 546. 2004, Espoo: VTT, Available also http://www.vtt.fi/inf/pdf/publications/2004/P546.pdf

[16] NORROS L., LIINASUO M., and SAVIOJA P.: Operators' orientations to procedure guidance in NPP process control. Cognition, Technology & Work 2014(on-line).

[17] SAVIOJA P., *et al.*: Identifying Resilience in Proceduralised Accident Management Activity of NPP operating crews. Safety Science, 2014. Volume 68(October): p. 258–274.

[18] WAHLSTROM M., *et al.*: Rule-abiders or individual thinkers? Instruction designers' views on NPP operation. Enlarged Halden Programme Group Meeting. 2014. Röros, Norway.

[19] FUCKS I., and DIEN Y.: "No rule - no use"? The effects of over-proceduralization, in Trapping safety into rules. How desirable or avoidable is proceduralization, C. Bieder and M. Bourrier, Editors. 2013, Aschgate: Farnham, UK. p. 27-39.