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**AUTOMATION SYSTEMS AND WORK PROCESS SAFETY:
ASSESSING THE SIGNIFICANCE OF HUMAN AND
ORGANIZATIONAL FACTORS IN OFFSHORE DRILLING
AUTOMATION**

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ABSTRACT

Drilling automation is a rapidly growing area of information technology development. Efforts within automation are being undertaken by numerous and diverse organizations in the oil and gas industry, partly due to a desire for exploitation of marginal and complex fields, and partly in order to increase safety of high risk operations. As offshore drilling occurs in a unique work environment, organizational factors should be emphasized in technology development (and implementation) projects. This paper reports on a study focusing on integration of human and organizational factors in drilling automation. Simulator tests involving automation systems usage and handling of various challenges during drilling operations were performed, and interviews with the test personnel were conducted. The results highlight several important issues related to the interface between work environment and human factors in drilling automation. Examples are fatigue problems due to offshore work-shift arrangements and technology use, and the need for efficient work coordination in an interorganizational environment. Implications for research and practice are discussed.

Keywords: Drilling, automation, organizational factors, human factors, safety, efficiency, work environment.

INTRODUCTION

Offshore drilling operations are becoming more and more complex. Competition for natural resources has motivated companies to explore and produce in more

challenging locations, i.e. deeper, marginal and more complex fields. The trend towards deepwater and subsea operations, and more challenging wells, represents an increase in risk of severe accidents as seen in the Macondo blowout in the Gulf of Mexico in 2010. This development therefore stimulates implementation of new technologies

like real-time advisory systems for the driller, and also automated operations safeguarding against human errors. Automation has thus the potential to provide large improvements in efficiency and safety, but automated aids must be implemented correctly at the workplace [6].

A vast amount of research has been performed on automation systems functionality taking a human-computer interaction perspective (see e.g. [12, 26, 34]). Human factors research has thus identified important relationships between technological features and risk of human error. However, from a safety perspective, development, implementation, and use of automation systems require a holistic approach. That is, focus should not be solely on the technological features and human-computer interaction, but also on work process changes and organizational issues. Integrating these perspectives is necessary for successful implementation of automated aids, including sufficient assessment of safety issues. This may be of particular importance in situations where the work context is challenging and operations involve high risk, like offshore drilling. On this basis, the main objective of this research is to investigate and discuss the significance of human and organizational factors for successful implementation and use of automation systems in offshore drilling.

The paper is organized as follows: First, the theoretical foundation of the research is described, followed by a description of the methodological approach. Then the results are presented and discussed. In doing this, organizational aspects and human factors are presented, and this is followed by a discussion aiming at integrating the two perspectives. The paper concludes with a discussion of theoretical and practical implications, and directions for future research.

THEORETICAL PERSPECTIVES

A holistic approach to automation system usage implies that we need to focus on impacts of technology use on an individual level, but also on group and organizational levels. A combination of perspectives is thus necessary.

Organizational Perspective

Implementation and use of an automation system may disrupt existing work processes and role relations. Work processes, understood as the specific way in which tasks are ordered across time and place, are normally complex, as actions of multiple actors can be combined in many different ways [24]. In this respect, Barley [4] argues that use of information systems has both direct and

indirect effects, as work process changes involve both non-relational and relational elements. The former encompasses all the behaviors that individuals ordinarily perform as role incumbents, while the latter includes interactions, dependencies, and expectations between roles. Because non-relational elements include skills and tasks, it is here that technologies are likely to have their most immediate and direct impact. However, since few tasks are truly independent, the work is likely to influence both the amount and nature of the interaction with others. Technically induced changes in the non-relational aspects of a role are thus likely to alter the role's relational elements.

Altered role relations may at the next step transform the social networks that constitute occupational and organizational structures. According to Barley [4], examination of how technology influences work processes therefore has to involve both relational and organizational aspects. However, it is important to notice that the relationship goes both ways [7]. This means that relational and organizational factors are influenced by information system usage, but they may also very well influence the way in which the systems are applied in a specific organizational setting. Considering the context in which automation systems are applied is therefore important to fully capture the potential efficiency and safety implications.

Individual Perspective

Regarding the relationship between automation systems and operators' role conduct on an individual level, research has emphasized several factors that are of significance for efficiency and safety. Hence, based on previous research, the concepts of trust, vigilance and complacency, workload and situation awareness are emphasized in this study.

Trust

Trust is a central concept in human-machine studies, and research has suggested that trust can affect how people accept and rely on automated aids in the decision-making processes [5]. In particular, trust guides dependence on technology when complexity and unanticipated situations make a complete understanding of the automation impractical [14]. In this respect, research has found that trust in automated aids is significantly influenced by the operator's abilities to perform the task without diagnostic assistance [15]. Research focusing on causes of trust in automation has also shown that it is strongly affected by automation reliability [18, 33]. Automated aids that produce a high number of false alarms may create undertrust in automation, resulting in operators not responding to alarms or other automation alerts [16, 20].

On the other hand, too much trust in automated aids may lead to complacency effects and errors of omission (i.e. operators not taking an appropriate action despite non-automated indications of problems) and commission (i.e. operators following an automated directive that is inappropriate) [23].

Vigilance and Automation-Induced Complacency

Automation-induced complacency can be understood as a conscious or unconscious response of the human operator induced by overtrust in the proper function of an automated system [21]. The phenomenon refers to a decreasing ability to detect automation failures [10, 19], and is one major factor associated with a lack of vigilance in monitoring automation. However, although an attitude of trust in the automated aid can lead to overreliance, this is in itself not sufficient for complacent behavior to occur, but rather represents a potential for complacency. Poor monitoring of automation may arise only when complacency potential occurs jointly with other conditions [22, 27]. In this respect, research has shown that automation-induced complacency is influenced by the amount of tasks that an operator has, and the reliability of the automation system. Regarding the former variable, studies have shown that complacency is more easily detectable in multitask environments where operators are responsible for several functions and have to attend to manual tasks in addition to focusing on the automated aid [21, 22, 32]. When it comes to reliability, research has shown that complacency occurs generally for highly reliable systems in which automated control fails on only a few occasions [21]. Further, detection performance has been shown to be better under variable-reliability than under constant-reliability automation [1]. Studies have also found that access to the “raw” data which the operator can combine with the automation output can improve overall performance [21, 30], and that making the operator accountable for overall performance can reduce complacency [28].

Workload

As discussed above, workload is a central aspect when considering the efficiency and safety of automation systems usage. Several studies have for example shown that workload influences the relationship between automation trust and automation use, more specifically that operators incurring a high workload and task complexity generally exhibit an overreliance on automation in decision making processes (e.g. [5]), which again result in poorer performance [3]. Explanations of these relationships are typically based on arguments that operators can become caught up in attending to particular tasks, or become distracted by other pressing issues, and so do not apportion

adequate time to monitor the situation when under high workload [29]. The effects of workload are thus related to the limitations of humans to be attentive to several tasks simultaneously, and come into play when operators have to reallocate mental resources away from the automation to other tasks that need to be attended to.

Situation Awareness/Understanding

According to Parasuraman and Manzey [21], a performance consequence of selective or less attentive processing of information is loss of situation awareness, which may lead to errors of omission or commission if the automation fails. Situation awareness refers to the operator’s moment-by-moment ability to understand the state of a complex system and its environment [5]. Endsley [9] defines the concept as “the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning and the projection of their status in the near future” (p. 164). This definition underscores that situation awareness involves three levels; 1) perception of signals, 2) interpretation of these signals, and 3) abilities to predict future behavior based on the interpretation. Thus, the concept does not refer to performance or action [31]. In a safety perspective, the projection dimension is of particular importance as it determines the operator’s ability to correctly forecast possible future circumstances and thus enables the formulation of suitable courses of action [29]. The operators’ understanding of system behavior and abilities to predict future behavior will therefore be emphasized in our study.

METHOD

In order to reach the research objective, data concerning both organizational and work process factors, and issues related to operators’ interaction with and perceptions of a drilling automation system were required. Tests in a drilling simulation laboratory designed to support tests of different types of drilling methods, accurate simulation of drilling operations both in normal conditions and with drilling problems [6], were on this basis conducted. The test environment consists of two drilling control stations that are used to operate a virtual drilling rig (Figure 1). It provides a realistic visualization of the drill-floor and derrick in front and on the ceiling of the control stations, and the functionality of the control system is identical to an actual rig operating in the North Sea. Behind the driller’s cabin there is an experimentalist area including several workstations equipped with replicas of the driller’s monitors (Figure 2). This renders possible live monitoring, observation and evaluation of the driller’s actions and decisions [6].



Figure 1: Drilling Control Stations



Figure 2: Experimentalist Area

Based on the functionality of the drilling simulator, a set of 6 test scenarios were designed involving various challenges, varying degrees of task complexity, and decision making requirements. In addition, different configurations of the automation system also provided for variations in degrees of automation. A total of 10 drilling personnel from a drilling contractor participated as test drillers. The tests were conducted over a 5-day period, and 2 test drillers participated for each day of testing. Their offshore work experience varied from 3 to 11 years (as assistant drillers, drillers, toolpushers and other senior drilling personnel), and they were between 29 and 50 years old. Prior to the tests the participants took part in a training program covering all functionalities of the system. During running of the test scenarios there were at all times two research personnel in the rig; one experimentalist and one observer who also communicated with the test drillers when necessary. The test drillers were made aware of all possible events or incidents that could be triggered in the simulator, such as influx, losses, cavings, packoff, stuck pipe, irregular gauge, washout, plugged nozzles, etc. Although the automated safeguards and safety triggers should help prevent most of these events, unknown properties such as unexpected depleted or high pressure zones, stringers, etc., could cause events due to the automation system not knowing about them.

The original test plan involved completion of 60 tests (10 driller * 6 scenarios). However, due to recently performed software modifications in the drilling simulation laboratory, instabilities and poor synchronization between the wellbore simulator and the control system was experienced. Most of these were corrected or avoided during testing, but due to these challenges a limited number of tests were performed for each case (a total of 18 tests). Running of each test scenario lasted for 20-25 minutes, and semi-structured interviews with the participants were conducted immediately after completion of each scenario. These were based on an interview guide covering the theoretical concepts described in the previous section, thus focusing on the participants' perceptions of the automation system and handling of issues and challenges during the tests. A total of 18 test-specific interviews were conducted. In addition, interviews focusing on work processes and organizational factors relevant for implementation and use of automation systems were also conducted with each participant (a total of 10 interviews). All 28 interviews were subsequently transcribed and analyzed.

RESULTS AND DISCUSSION

Organizational Factors

Drilling Crew and the Driller's Role

The position of a driller on an offshore rig is complex. In the interviews, the informants labeled the driller as an "organizer", "node" and "working manager". Being a driller is like being a "communication central", and an important aspect of the job is to distribute relevant information to the relevant/right people. Holding such a role thus implies that the driller needs to have knowledge of what is going on, both with regard to humans and to the equipment on the drill floor. It further implies a significant responsibility regarding work process efficiency and safety. Many activities have to be controlled and administered by the driller, and there is extensive communication with personnel at the deck and the drill floor, and also with support personnel onshore. A consequence of this, as highlighted by the informants, is that there are frequent disturbances of work (e.g. telephone calls) which potentially interrupts the driller's chain of thought and work activities. Daily work can thus be stressful.

Because of the involvement in multiple activities and processes, the driller needs to be good at delegating tasks and be able to use available support functions and personnel. The driller further needs strong abilities to maintain mental focus, receive and interpret input, and initiate actions. The informants also highlight that drilling is a continuous process, and that closing the well or pausing the process in order to make evaluations and assessments is often not an option. Making priorities and provide for work conduct in the correct order during operations is therefore fundamental. This also implies that drillers have to be ahead of operations, meaning that they have to keep focus on current operations while at the same time plan for the next step in the drilling process. Thus, situation awareness is central.

Work Regulations and Control Systems

Drillers have to deal with many different systems, regulations and work practices related to workplace safety and efficiency. The operator companies (holding the production license) have their specific codes of conduct, and require that work is accomplished based on certain rules, guidelines, and work process descriptions. In addition, the drilling contractors (in which most drilling personnel are employed) have their own governing documents and systems. According to the informants, following procedures and complying with work process descriptions is difficult and sometimes impossible. It is further not possible to stay updated on all procedures from both

the operator and the drilling contractor. Regarding the relationship between operator and drilling contractor, the incentive systems may also represent an important issue related to safety. That is, the majority of work is carried out by drilling contractor personnel, but the operator defines key performance indicators (though together with the contractor). In this respect, interview data indicate that an emphasis on speed of work conduct may lead to an increase in perceived workload and stress.

There are also industry standards and public regulations that the workers have to comply with and stay updated on. In general, the informants report that the industry has experienced increased work process bureaucratization, involving a significant increase in the amount of work regulations and systems. The result has been more administrative tasks for the driller, without removal of other tasks. It is further emphasized that a point will be reached where the governance systems become more of a liability than means for increased efficiency and safety. Beyond a certain limit, efforts to be compliant with the systems represent a distraction with regard to maintaining focus on what is going on in the well.

Work shift organization also represents an important issue for consideration. The drilling crew works 12 hours shifts every day for two weeks (followed by 4 weeks off). The data clearly show that work hours can be a challenge as several informants report on concentration problems because of fatigue and sleepiness. This is most often related to work hour changes (i.e. changes from day work to night work). Rotation of work tasks and changes of role functions during shifts are in this respect emphasized as a means to prevent this from being a safety problem (e.g. letting the roughneck do the drilling for a period).

Technological Complexity

To some extent there are differences in tasks and work organization between rigs, especially between floaters and fixed platforms. In addition, differences in equipment and infrastructure on the rigs can also be significant. According to the informants, some rigs have old equipment while others are more up-to-date. The interview data also indicate that badly functioning (or lacking) integration between various systems on the rigs is common, and that attempts at establishing new systems on existing (old) technologies and equipment have had undesirable results.

Several informants report that they have been overriding automation systems that were implemented in order to assist them in daily work, and that they have experienced technologies working contrary to the intentions. This typically occurs when the systems are developed without involvement of the users, and without a careful

consideration of work processes and organizational aspects of offshore drilling. However, they also perceive offshore drilling to be a highly relevant area for work process automation. In this respect, comparisons with the aviation industry are common, which can be illustrated by a quote from one of the informants: "(...) working as a driller is like performing two hundred take-offs and landings per day, and we will probably experience the same challenges as they have". Focusing on issues that research in the aviation industry has addressed when it comes to efficient and safe implementation and use of automation systems therefore seems to be a viable approach.

Human Factors: Perceptions of Drilling Automation

Based on the results of human factor research described earlier, factors investigated during and after the simulator tests were monitoring complacency, workload, situation awareness, and trust.

Monitoring Complacency and Use of Alarms

In general, the system provides signals to the driller that can reduce monitoring complacency. However, the data show that it is important to balance the amount and type of signals based on degrees of significance and urgency. Too many alarms may have counterproductive effects as they may lead to irritation and reduced operator attentiveness. Regarding the system's signals or alarms aiming at directing the driller's attention to specific conditions, the tests thus show that there is a fine line between avoidance of monitoring complacency and risk of automation disuse. Systems applying repetitive alarms calling attention to insignificant information thus reduce the probability of operators being attentive to important information that is communicated, resulting in disuse of automation. Careful considerations regarding the significance of alarms are therefore important.

It was further observed that variation in signals indicating the same thing is important in order to prevent monitoring complacency (e.g. sound variations may trigger attention and direct focus at the screens). This also highlights potential challenges with integrated and remote operations (e.g. use of onshore control rooms in offshore drilling) as the operator might miss important information from other sources than the system.

Workload

The data indicate that use of the system leads to reduced workload compared to manual operations. Freeing of cognitive resources was accomplished as the informants reported that they were able to keep track of a larger amount of relevant issues when running on the lim-

its recommended by the system. Freeing of cognitive resources, however, depends on ease of use of the system. The data clearly indicate a relationship between ease of use and perceived workload. Presentation of important data on two screens instead of one prevented the operators from keeping focus on all necessary elements during the operation, which resulted in an increase of perceived workload. Thus, even though all necessary data are presented, it may be insufficient in a safety perspective, as the ability to exploit the data depends on satisfactory human-computer interaction. The interview data also show that there is a relationship between perceived workload and trust. Operators experienced less workload using the system when they trusted the system limits and thus did not had to focus on tripping speed.

It was further found that use of the system can lead to increased stress and workload if well-functioning communication processes are lacking in unexpected or problematic situations. The feeling of being left to oneself was in this respect highlighted as central to the vulnerability of work process automation. Availability of support personnel and easy access to information when irregularities happen is thus essential in order to avoid stress and hinder the occurrence of potentially dangerous incidents.

Situation Awareness/Understanding

The interview data show that system understanding is fundamental. A lack of understanding of why the system behaves as it does might lead the operator choosing to ignore or not to comply with instructions and guidelines from the system. It is therefore important with training and instructions prior to using the automated aids, and feedback from the system during operations. Further, informants also report that it takes time being accustomed to the system, which is necessary in order for the operator to achieve perceived control and a sufficient level of situation awareness. A lack of system understanding may also result in disregarding of advices from automation systems in situations of multiple and inconsistent signals (i.e. signals from other sources providing contradictory indications compared to the system), thus causing automation disuse.

The data further show that feedback from system to operator might be especially important in systems that are not fully automatic (semi-automatic or advisory systems). In these situations, successful task accomplishment requires well-functioning interaction and collaboration between the system and the operator. Assigning tasks to the operator or computer may depend on situational characteristics, and the total work process (i.e. chain of different tasks) may thus involve mode changes (i.e. changes of states of behavior), which in next instance result in mode

confusion (not knowing what the system is doing). Related to this, the data also indicate that unanticipated lack of responses from the system in situations where the operator provides input that requires a response might lead to mode confusion and/or reduced situation awareness, which again increases the potential for dangerous situations to occur. A situation exemplifying this was the occurrence of uncertainty regarding system behavior when the system failed to respond to input from a driller. The test driller pushed a button (which activates/deactivates a specific function) several times because of a lack of system response. Importance of feedback is thus underlined by the need for operators to know whether their input to the automation system are functioning as intended (i.e. result in the intended system actions).

Trust

As for situation awareness, feedback is also an important determinant of trust and crucial in order to create a solid basis for making decisions. Even in situations where the system is wrong, feedback from the system might be important in creating an informative decision making basis, and can lead to increased trust and confidence in the system. However, this requires training and experience with the system (i.e. learning to know which signals to consider and apply in decision making). Related to this, the history of system use is important. Bad experiences with the system lead to disuse, which may be especially unfortunate in high-risk operations. It was observed that operators did not use the system because of difficulties experienced in previous tests scenarios, and lack of knowledge regarding why the system behaved as it did was in this respect an important aspect. Thus, the importance of feedback from system to operator regarding actions (not) taken is important.

Research has shown that operators of automated aids often have a tendency to follow the advice of the systems, even though it might lead to less optimal work conduct [21]. In line with this, our data show that several operators carried out the activities in compliance with the system limits (tripping speed) even though the limits were set too low. The limits were accepted without consideration of whether they were reasonable, and also when operators knew that the configuration was incorrect. This may be an indication of trust and overreliance in the system, and is in accordance with previous research showing that users have a tendency to ascribe greater power and authority to automated aids than to other sources of advice [8, 21], and that neglect of automation verification constitutes a major source of commission errors [2]. It therefore underlines the importance of providing information to the operator regarding system state and reasons for recom-

mending the particular actions [17], as well as easy access to other information sources that enables or requires the operator to cross-check the relevance of system information to verify the automated aid's recommendation.

Finally, the interview data show that operators experience an ambiguity regarding system use. On the one hand, they believe that the system represents a very useful aid, enabling work conduct and solutions that are not viable without the system. On the other hand, they experience a need for being in control and skepticism towards technological aids in situations with high risks. In this situation, trust in the system is fundamental. However, in accordance with previous research, the data also clearly show that trust-building is time-consuming, while reduction of dependence in the system is not [13, 16]. That is, system failures might result in a long process of regaining trust in the system.

Integration of Perspectives

The results show that both organizational factors and issues concerning human-system interaction are important when evaluating the efficiency and safety of drilling automation systems. They also indicate that these elements are related and should not be treated separately. That is, in order to increase our theoretical understanding and be able to make improvements in practice within this particular field, these elements have to be incorporated in the same discussion. On this basis, we will now discuss important issues related to the relationship between offshore work organization and operators' interaction with the drilling automation system.

A salient issue that can be observed from the interview data is that there are aspects of the work organization that may amplify the risk of fatigue problems when using automation systems. That is, the results indicate that there may be a reciprocal and reinforcing relationship between technology use and offshore work-shift arrangements. Research has shown that the risk of incidents and accidents to occur is related to working hours. For example, Hänecke, Tiedemann, Nachreiner, and Grzech-Šukalo [11] found a significant interaction effect between hours at work and starting time. More specifically, they observed an exponential increasing accident risk beyond the 9th hour at work, and when comparing different starting times, the relative accident risk was found to increase dramatically beyond the 8th hour at work with later starting times. As offshore work involves 12 hours shifts, changes from day to night work, and sometimes long intervals between breaks (3 regular breaks during a work shift), it may thus represent conditions that may trigger the realization of automation complacency potential. That is,

as these work conditions can make it difficult to maintain focus, complacent behavior and possible errors of omission and commission might occur. Work-shift arrangements (and following fatigue issues) should consequently be taken into consideration when problems of automation complacency are discussed and sought to be solved. It should in this respect also be mentioned that studies have found that operators using an automated aid in a state of sleepiness and fatigue performed automation verification more carefully and exhibited less compliant behavior. However, they also showed a decline in secondary task performance and an increased risk of return-to-manual decrements [25].

In addition to work hours, another factor that also influences operators' fatigue and power of concentration is the number (and complexity) of tasks that need to be attended to. Multitasking and high workloads influence the probability of automation-induced complacency and that automation failures are not detected by an operator [21]. As the informants argue that there is an increase in bureaucratization of the driller's work, this is an important factor to consider when assessing the degree to which complacent behavior can occur. In this respect, the reporting of frequent interruptions of work should also be emphasized as interruptions may lead to loss of situation awareness. Combined with use of automation systems that make maintaining an adequate understanding of the situation difficult, this may have unfortunate effects. In this way, work organization (e.g. the driller's current role as a node/organizer) places demands on the amount and type of feedback from the system to the operator that is required in order for the operator to maintain situation awareness and prevent complacent behavior. This is therefore an issue that should be considered in design and configuration of automation systems. It is also important to consider whether (and in case how) implementation and use of drilling automation systems should be accompanied with a restructuring of the tasks of the driller, as well as the overall organization of drilling crew. Likewise, general discussions and evaluations of drillers' tasks and work process organization on the rig should not be accomplished without considering the functioning of relevant technological aids. In this respect, the need for drillers to have backup-solutions in case of automation failures is significant. Both the general work process interviews and the test case interviews showed that well-functioning communication with support personnel and easy access to other data sources (than the automation system) were significant for efficiency and perceived safety in problem-solving situations. The role relations of the operators are on this basis especially important when unexpected situations occur that require unconventional actions.

Regarding work organization, the involvement of multiple organizations in offshore drilling is also an important aspect. As there are several different organizations (operator, drilling contractor and service companies) with their own work process descriptions involved in drilling operations, development of work process descriptions has to be done in an interorganizational perspective. Thorough evaluations of the interfaces between automation system usage and various work process descriptions are thus needed. Because of this interorganizational complexity, implementation of drilling automation systems may also have extensive and sometimes unforeseen ripple effects. Studies of effects and outcomes of system usage should therefore not be limited to a “narrow” human-technology focus, but also throw light on potential alterations of role conduct and role relations in broader parts of the involved organizations.

The need for a holistic perspective is also emphasized by the interrelationship between various technologies on an offshore rig. Efficient and safe functioning of an automation system is often dependent on adequate integration or interaction between different systems and technologies. In this respect, some informants describe a lack of integration between systems, which thus represents an issue that needs to be emphasized in efficiency/safety studies and implementation of drilling automation systems. This is further related to the degree to which operators trust the system, and may thereby affect the potential for automation misuse and disuse to occur. Trust in the system can be reduced even though the automation system works properly and according to the intentions if other related (interconnected) technologies do not work adequately. System trust may in other words depend on adequate functioning of other technologies related to the same work processes. A work process perspective may therefore be required in order to provide an in-depth understanding of the sources to and effects of trust in automation systems.

CONCLUSIONS

In summarizing the results of the study, several work organization aspects of offshore drilling should be emphasized. First, the driller’s role is described as complex, involving a diverse set of tasks and communication with support personnel from several organizations. Frequent disturbances are common. Together with the specific offshore work-shift arrangements, this entails high demands on the driller’s abilities to maintain focus on drilling operations. The involvement of several organizations further entails a high complexity with regards to work procedures, and differences in technological infrastructure

and systems on the rigs are also highlighted as a central issue.

Regarding the operators’ perceptions of the drilling automation system, the study shows that deliberate considerations and discussions of the appropriate amounts of signals are necessary in order for the system to be efficient in reducing monitoring complacency and operator inattentiveness without resulting in automation disuse (disregard of the systems’ alarms and recommendations). It also shows that an increase in use of automated aids (and thus increased level of automation of work process conduct) leads to an increase in the importance of well-functioning communication with support personnel. This is related to operators’ trust in the system, and in this respect the study also provides support of the claim that operators have a tendency to follow advice from automation systems. Well-considered balancing of system feedback and operators’ tendencies toward systematic compliance (automation misuse) with the automated aids is therefore important.

In concluding on the results, we have to point to the interrelationship between the organizational aspects and the drillers’ perceptions of the automation system. Fatigue problems due to monitoring of efficient automation may for example be amplified by work-shift arrangements and the driller’s workload. According to Parasuraman and Manzey [21], complacency and automation bias represent a human performance cost of automation systems characterized by high reliability, high levels of automation, and in high task load situations, and claim that “(...) such costs need to be considered as potentially serious risk factors when evaluating the overall efficiency and safety of human-automation systems.” (p. 403). The results from our study indicate that solutions to such human performance costs of automation systems need to be searched for in the organizational context of the work that is to be done. Accordingly, it is important that future research address how work-shift arrangements may influence automation-induced complacency. The functioning of other technologies related to the same work processes also have to be considered when investigating the effects of automation systems usage. Future research on efficiency and safety of drilling automation systems should also adopt an interorganizational perspective. For example, investigations of issues concerning cultural aspects, business model alterations, and interfaces between work process descriptions are needed when use of automation systems involve personnel from several organizations.

The results of our study have important practical implications. On a general basis, this means that evaluation and implementation of measures aiming at increasing the efficiency and safety of automation system usage have

to be done in light of organizational and work process factors. Aspects of work-shift arrangements (e.g. working hours) and potential fatigue problems should for example be taken into consideration when designing and implementing drilling automation systems. This means that use of technological means aiming at reducing complacency potential (i.e. use of alarms) should be dynamic and easily configurable (emphasizing situational adaptability). Further, development and implementation of automation systems has to take an interorganizational perspective. As use of automation systems may involve design of work processes encompassing several organizations, there may be a significant discrepancy between the “theoretical” and the “practical” functioning of the systems. In this respect, organizational factors like differences in corporate cultures and business model protection have to be considered. A final practical implication of our study concerns the importance of training. Even though experience and practice do not appear to mitigate automation complacency, it is possible that specific experience in automation failures may reduce the extent of the effect [2, 21]. In this respect, the results of our study indicated that experience and training are important when there is room for (and also sometimes need for) overriding of the system. As training involving handling of various automation failures and irregular situations cannot be done in a real setting offshore, simulator training should be included in the implementation process.

Finally, some limitations of the study should be mentioned. As described in the methodological section, software problems experienced during testing resulted in a limited number of completed scenario tests. Although most instabilities were corrected during testing, erroneous behavior of automation system functionalities occurred during the test week. That is, although the scenarios representing the current empirical basis were performed as planned, the test drillers also experienced simulator problems in performing scenarios not reported on in this paper. This may have influenced the participants’ perceptions of the automation system in general. Further testing should therefore be conducted in order to increase the number of tests (and test drillers), but also in order to reduce potential cognitive and behavioral biases of the test drillers.

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