UNDERSTANDING HUMAN DECISION MAKING DURING CRITICAL INCIDENTS IN DYNAMIC POSITIONING

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Critical incidents in Dynamic Positioning (DP) have potential disastrous consequences. DP operators have to make time-critical decisions in order to rapidly and effectively handle such unexpected incidents. The purpose of this study was to identify characteristics of critical incidents in DP operations and characteristics of decision-making. Semi-structured interviews using the Critical Decision Method were conducted with 13 experienced DP operators. It was found that decision-making in critical incidents in DP are naturalistic and recognition primed. This study contributes to an increased understanding of critical incidents in DP operations and the key decision-making processes in critical DP incidents.

Introduction

Sophisticated automation intends to reduce operator error and enhance efficiency (Parasuraman, Mouloua & Molloy, 1996). Large-scale accidents, such as Chernobyl and Three Mile Island, have primarily been attributed to operator error (Meshkati, 1991), which has been described as an undesired consequence of human automation interaction. The maritime and offshore industry is increasingly becoming dependent on automated vessel station keeping for demanding operations at sea (Fossen, 1994). Critical incidents are events that are unplanned, non-routine but do not end tragically yet have the potential to develop into large scale accidents. The industries use the term “near misses” and have in common the fact that they are recovered throughout the sequence of events. Identifying specific characteristics of critical incidents could reveal important information about how large scale incidents can be prevented.

Automation in the Maritime Domain

In the maritime fields automation has been introduced as a technical aid, taking over the performance of task previously performed by people, with the intention of increasing performance and safety (Parasuraman, et al. 1996). Dynamic Positioning (DP) is an automated system for vessel station keeping. A computer control system automatically maintains a vessel's position and heading by controlling machinery power, propellers and thrusters. Position reference sensors, along with wind sensors, motion sensors and gyro compasses provide input to the computer in order to maintain the vessel's position, making allowances for the size and direction of environmental forces (Sørensen, 2011).

Automation affects humans in their work, the introduction of automated systems imposes new demands on the socio-technical systems, including the human operator (Sarter & Woods, 1995; Øvergård et al., 2008). When new automation is introduced into a system, or when there is an increase in the autonomy of automated systems, developers often assume that adding automation is a simple substitution of a machine activity for human activity (Woods & Sarter, 2000). Empirical data on the relationship of people and technology suggest that this is not the case and that traditional automation has several negative performance and safety consequences associated with the human out-of-the-loop performance problem (Kaber & Endsley, 2004). When a human operator is out of the loop, instances will occur, when he cannot maintain control over the system (Norman, 1990). The need for the operator to be "in the loop" refers to the operator's Situation Awareness (SA). Jentsch et al. (1999) show how the loss of SA can lead to errors in assessments that could result in major accidents by describing how inadequate detection of changes in the position of a hostile aircraft. This may lead to an incorrect understanding of the situation which in turn leads to poor decisions in regards to placement of own aircraft. SA is therefore an important component of sound decision making.

Decision Making in the Maritime Domain

Revisions to the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (the STCW Convention), and its associated Code were adopted in Manila in June 2010. New human factors-related elements where minimum training requirements for maritime officers' decision-making skills as well as resource management were included (IMO, 2011).

The Naturalistic Decision Making (NDM) theory has been proposed to explain real-life decision making, and Zsambok (1997) defines NDM as: "how experienced people, working as individuals or groups in dynamic, uncertain, and often fast paced environments, identify and assess their situation, make decisions and take actions whose consequences are meaningful to them and to the larger organization in which they operate" (p. 5). Klein et al. (1986) identified the following specific features about NMD decision-making. *First*, the fire ground commanders drew on their previous experience to recognize a typical action to take. *Second*, they did not have to find an optimal solution, merely a workable one. *Third*, they mentally simulated the solution to check that it would work.

Klein et al. (1986) proposed the Recognition-Primed Decision-Making (RPDM) model which focuses on situation assessment and explains how an experienced professional can make rapid decisions. Situation assessment in the RPDM model considers understanding of plausible goals, recognition of important contextual cues, the forming of expectations and identification of courses of action as the four most vital aspects (Klein, 1993). Such a situation assessment, including mental simulation, explains how experienced decision makers can identify a reasonable good option as the first one they consider, rather than generating and evaluating a series of alternatives. Expertise has been found to be essential in order to make decisions in uncertain contexts (Kahneman & Klein, 2009). Expertise is characterized by a high ability of skill and/or and knowledge within a domain (Salas et al., 2010). Expertise-based intuition, also called recognition-primed decision-making (Kahneman & Klein, 2009), is the rapid, automatic generation of single decision options, rooted in extensive domain-specific knowledge and the recognition of patterns from past events (Salas, et al., 2010).

The study presented here investigated work situations where DP operations suddenly escalate from a routine situation to a critical incident with potential disastrous outcomes. In all incidents the human operator avoided accidents either by a recovery to normal mode or by aborting the operation. The research employed interviews with experienced DP operators with the aim of addressing one research question - *what characterizes human operator decision-making in critical incidents in DP operations?*

Method

Sampling

Using a purposive sampling strategy to target experienced DP operators, informants were contacted through various channels in Norway (such as DP training centres, maritime educational institutions, drilling companies and shipping companies). Initial contacts with the informants were through e-mail, telephone or personal communication. The inclusion-criteria were a minimum of 5 years seagoing experience and 3 years experience as a fully trained DP operator. A total of 42 candidates were approached of which 13 qualified informants agreed to take part.

Critical Incidents

The informants had to have been on board the vessel at the time of the incident and been actively involved in the incident. Incident recollections that were not personally experienced were excluded from the study. Each informant was interviewed about two critical incidents. Two of the informants provided information about only one incident. Hence the 13 informants provided a total of 24 incident reports for further analysis.

Procedure

Prior to each interview each informant was informed of the purpose of the study, ethical considerations taken, safeguards for their confidentiality and their opportunity to withdraw from the study at any time. If the candidate agreed, an interview session was scheduled and signed consent was collected. A demographic questionnaire was administered before the interview began. The study was - according to Norwegian data protection regulations - reported to and approved by the Norwegian Science Data Services (project number 33042).

Data analysis and reduction

Questions from the Critical Decision Method (Klein et al., 1989) were translated to Norwegian and used in this study. The interviews were analyzed using thematic analysis to find patterns of meaning within the qualitative data. The procedure involved five phases (Braun & Clarke, 2006), familiarizing with the data; initial generation of codes; searching for themes; evaluation of themes and final definition of themes.

Discussion of Results

Demographics

All informants had a nautical education and unlimited DP certificates. Their age ranged from 29 to 69 ($\bar{x}$ = 44,3; σ = 12,1). Seagoing experience ranged from 5 to 40 years ($\bar{x}$ = 20,2; σ = 11,4). Experience as DP operators ranged from 4,5 to 33 years ($\bar{x}$ = 12,9; σ = 8,1). Three informants had experience from one DP vessel type only, while one informant had experience from 8 different DP vessel types. On average was experience from 4,3 DP vessel types (σ = 2,3).

Characteristics of Critical Incidents in Dynamic Positioning

Four themes occurred in all 24 incidents and are considered the main results of the thematic analysis. These categories have been labelled as “Experience and Recognition,” “Situation Awareness,” “Decision Strategy,” and “Human and Automation”. A total of 16 sub-themes contributed to the description of critical incidents.

Experience and Recognition.

The incident accounts presented a picture of the DP operator as action-takers during incidents, assessing the event based on prior experience, recognition and planning within operational limitations in order to avoid serious consequences. In 19 out of 24 incidents the DP operator stated that he used experiences from similar past decisions, thus being indicative of a type of RPDM (Klein, 1993). In the remaining 5 incidents the operators all stated that they were inexperienced with regards to the operation, position on board or vessel at the time of the incident. The informants explained how prior experiences affected incident decision-making and how they collected experiences. The experience-collection can be compared to a mental database of patterns utilized for immediately knowing how to respond to various situations (Lipshitz & Shaul, 1997). Specific patterns were often developed for vessel or operation characteristics and originated not just from real life experiences, but also from training sessions or mental simulation. The DP operators referred to situations where they sat and imagined "what if" incidents and reflected on how to solve and prevent such situations - thus showing that mental simulation *pre factum* can be used as a proactive measure to improve operator response to critical incidents. In all incidents the informants referred to work procedures and emergency procedures as the baseline pattern for performing operations.

Situation Awareness

In critical incidents DP operators are directed by an overarching situation awareness related to the risks involved, and the level of awareness was determined through an assessment process (see *e.g*. Klein et. al, 1986). The findings implied that the situation assessment process was affected by cues, expectancy, problem and goal identification, time limitation, uncertainty and the identification of base events.

Further, sudden changes and continuous updating characterized SA in critical incidents. The DP operators' strove to reach an optimal level of SA through an assessment of the situation. The assessment of the situation involved an overarching evaluation of perceived potential risk and the problem awareness was triggered by a cue, *e.g.* a visual or auditory signal, in the external environment. The findings revealed that all 24 informants defined a goal for their further actions, although they did not fully understand the problem to be acted on.

The DP operators' sense of time in the incidents was also affected. In 19 of the incidents the DP operator did not feel he had adequate time to think. Uncertainty was described as an issue affecting the DP operator in 17 of the incidents. In all of the 24 recollections, the incident brought with it a sudden shift in SA. In situations where the automated system no longer projects the next correct action, the human operator had to take over, yet in order to do so successfully the operator needed a good understanding of the situation. Consequently, the DP operators immediately engaged in an intense evaluation of the situation, producing a recipe for problem solving. In other words the DP operator's SA was determined by the availability of information and the ability to undergo a process of situation assessment quickly enough to make a sound decision.

Decision Strategy

Informants described how decision strategies were formed based on experiences and comprehension of the situation as well as by interacting with automated technical artifacts. In critical incidents DP operator seek compatibility between experience and the actual situation to develop decision strategies. Furthermore, DP operators recognized a limited number of options in decision-making scenarios and therefore employed different decision strategies. Three types of decision strategies were identified from the data analysis: 1) *prescriptive use of a procedure following*, 2) *flexible adaptation of a procedure* or 3) *purposeful violation of procedure*. A process of matching experiences with the ongoing situation usually did not produce a large number of alternative options to the DP operators.

Human & Automation

The findings suggested that the DP operators' role transforms from monitoring to becoming the intervening party during incidents. The DP operator's intervention involved reducing the level of automation during incidents. Furthermore, understanding and knowledge about the DP system affected the DP operators' actions in critical incidents. The DP operator was involved in the recovery of all 24 critical incidents. The DP system was not operational in 7 of the incidents and the DP operator was forced to take over. In 17 of the cases the DP operator chooses to take over control of DP system. Whether or not the DP operators are forced to take over, or choose to, they all do so by manually controlling all or parts of the technical system. One reason for choosing to manually control the DP system was uncertainty and lack of knowledge about how the system would act.

A Model of Decision Making in Critical Incidents

A bow tie model that represents the elements that affect the DP operators' situation assessment during critical incidents is shown in Figure 1. The model links base events (e.g. initiating factors of the incident) to consequences through a sequence of factors that affected DP operators' situation assessment and decision-making. DP operators were able to reason using facts, specific cues and general knowledge to identify base events and predict imminent events and final consequences.

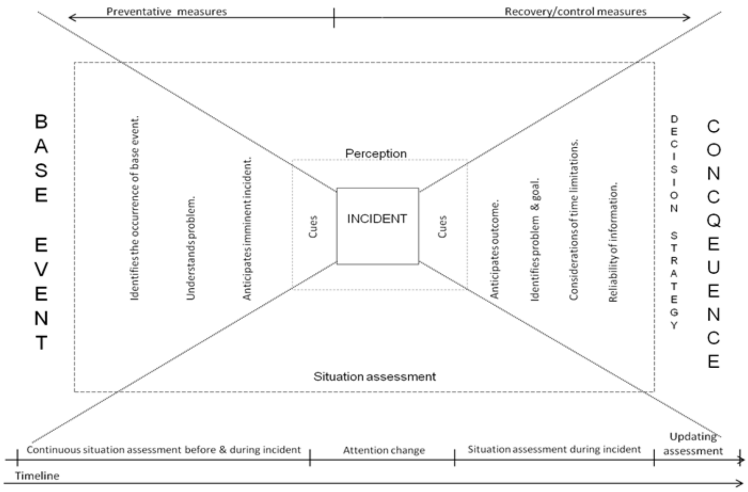

Figure 1: Bow-tie model of characteristics affecting decision-making in DP

The model shows that during an incident the human operator engaged in a cause-consequence assessment. On the left side of the model the operator tried to identify the base event. Being able to identify the base event was helpful for imminent event prediction, assisting the human operator in identification of possible preventive actions, as would be expected in line with the NDM literature (Klein et al., 1989; Klein, 1993). On the right side of the bow-tie model, the DP operator predicted the outcome of the situation through an assessment that was affected by cues, anticipation, identification of problem and goal, consideration of time limitations and the reliability of the information. The assessment assisted the DP operator in finding potential control or recovery actions and formulating a decision strategy.

The model represents all four themes from the thematic analysis that was found to characterise decision-making in critical incidents in DP operations. Experience and Recognition was fundamental in development and maintenance of SA and relevant for the whole cause-consequence assessment. SA in turn influenced the choice of decision strategy. The model shows how SA, Experience and Recognition and Decision Strategy affected how the DP operator handled unexpected incidents involving the automated DP system.

Conclusion

A majority of operators' decision making during critical incidents in DP operations can be characterized by matching information to experience, recognition of salient cues and the creation of a few alternative courses of action - in accordance with the recognition-primed decision making framework (e.g. Klein, 1993). Further, experience and recognition affected the operator's SA that in turn influences decision strategies. The lack of time to react and recover during critical incidents in DP leads to a large extent of highly procedural decision strategies. As an adaptation to the fact that critical incidents impose strict time limitations DP operators often perform mental simulations of imaginary, but potential, future incidents. This mental simulation might allow operators to react faster and more appropriately to critical incidents.

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