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Situation awareness in bridge operations – A study of collisions between attendant vessels and offshore facilities in the North Sea

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ABSTRACT

This study examined accident reports ($n = 23$) for collisions between attendant vessels and offshore facilities on the Norwegian continental shelf during the period of 2001–2011. An initial analysis indicated that the concept of situation awareness (SA) might be useful for providing a more detailed understanding of the processes that lead to collisions. SA is defined as 'being aware of what is happening around you and understanding what that information means to you now and in the future' (Endsley, 2012, p. 13). The first part of the study contains an analysis of accident reports that reveals that the collisions with offshore facilities were preceded by loss of SA on the bridge in 18 of the 23 instances. Three types of SA errors were identified: failure to perceive the situation correctly (Level 1 SA; $n = 13$), failure to comprehend the situation (Level 2 SA; $n = 4$), and failure to project the situation into the future (Level 3 SA; $n = 1$). In the second part of the study, the human, technological and organisational factors described in the accident reports are analysed to evaluate how the factors may have affected the duty officers' awareness of the situation. The results indicate that inadequate operation planning, inadequate bridge design, insufficient training, communication failures and distracting elements were the underlying factors that significantly contributed to the collisions.

1. Introduction

During the period of 2001–2011, a total of 27 collisions were reported between attendant vessels[1] and offshore facilities on the Norwegian continental shelf. At least six of these collisions were deemed to have very high hazard potentials (Kvitrud, 2011; Oltedal, 2012). The catastrophic potential of collisions between attendant vessels and offshore facilities was demonstrated in dramatic fashion by the Mumbai High North accident in July 2005. A multipurpose support vessel lost control and hit several marine risers at the Mumbai High North offshore complex off the west coast of India. The collision caused a gas leak that resulted in a serious fire, and parts of the complex collapsed after approximately two hours. Of the 384 persons who were on board that day, 362 were rescued, and 22 died (Daley, 2013). The objective of this study is to understand the human factors and processes that contributed to the reported collisions on the Norwegian continental shelf to prevent similar events in future. The analysis was based on the assumption that to be effective, bridge crews on attendant vessels must act decisively during stressful, high-risk situations. The analysis also assumed that situation awareness (SA) is a prerequisite for quick and good decisions (Endsley, 1995b). According to Endsley (2012, p. 13), SA can be described as '*being aware of what is happening around you and understanding what that information means to you now and in the future*'. That is, the bridge crew must be able to identify key aspects of the environment accurately, understand the meaning of what they sense, and have a good sense of what can happen. Although we have no data to verify that SA errors contributed to the Mumbai High North accident, the available information strongly suggests that a loss of SA might have been a contributing factor. The weather conditions were unfavourable when the vessel approached the offshore facility on its windward side. Due to technical problems, the approach was initially made in manual mode and, subsequently, in emergency mode, which indicates that the vessel's position was entirely under human control (Daley, 2013). In such conditions, it is particularly important that the bridge crew is attentive and has the ability to assess the situation continuously and act appropriately to avoid severe consequences. Any collision between seagoing vessels and fixed installations, such as bridges and quays, has the

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[1] This term refers to vessels that provide services to offshore installations and includes platform supply vessels (PSVs), anchor-handling vessels, standby vessels and oil tankers. Historical data show that 98% of collisions between vessels and offshore facilities on the Norwegian continental shelf involve attendant vessels (the North West European Area Guidelines, 2009).

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potential for major consequences to human, environmental and economic assets. However, as shown in the Mumbai High North case, collisions with offshore production facilities have notably high hazard potentials. In addition to the risk of injuries and fatalities, damage to hydrocarbon pipes and subsequent ignition and fire may cause severe oil spills and thus represents a threat to marine life and vulnerable ecosystems.

In the current study, we examined 23 of the 27 collisions that occurred in the period from 2001 to 2011 to determine the role of human errors that might have been related to the loss of SA. However, because human error caused by the loss of SA can be perceived as a consequence of the underlying circumstances in an organisation (Reason, 1997), the current study also aimed to identify the human, technological and organisational factors that might have influenced the bridge crews' abilities to achieve and maintain SA as the events unfold. The incidents that we analysed occurred within a petro-maritime context in which various organisations and actors, including both internal actors on board the vessel and external actors (e.g., the offshore facility), interact on a daily basis. However, our primary emphasis was on the bridge operations, and our study is therefore limited to the course of events on the bridge. To provide a frame of reference, we will briefly outline the concept of SA and suggest several factors that might have affected the bridge crews' SA formation.

1.1. The concept of situation awareness

According to Endsley (1995b), SA in bridge operations generally involves three levels of information processing. At the first level (SA Level 1), the duty officer perceives the status and dynamics of the relevant elements in his/her environment. Given that our attention and working memory capacities are limited and selective (Simons, 2000), a typical error at this level would be the missing of critical information. At the second level (SA Level 2), the duty officer will integrate and evaluate the information at hand. He/she is required to understand the perceived information in relation to the relevant goals and objectives. Because our attention and working memory capacities are limited, we rely on information stored in our long-term memory in the form of particular mental models (Endsley, 1995b). A mental model can be understood as '*the mechanisms whereby humans are able to generate descriptions of system purpose and form, explanations of system functioning and observed system states, and predictions of future system states*' (Rouse and Morris, 1986, p. 351). Thus, a typical error at the second level would be a failure to comprehend the situation. The duty officer might misinterpret the information or experience limitations in working memory due to information overload and/or stress (Endsley, 2012). At the third level (SA Level 3), the duty officer uses his/her perception and comprehension of the current situation to estimate what will happen in the near future (Endsley, 1995b). For example, by calculating speed, currents and wind, the duty officer should be able to avoid a collision with an offshore facility by reprogramming the automatic systems.

As proposed by Endsley, the three-level approach focuses on cognitive processes and takes the mind of each individual as the unit of analysis. However, this approach has certain limitations in terms of our understanding of *how* SA is achieved in collaborative systems. In this respect, a more recent perspective on SA provides an alternative manner in which to examine SA. Following from the concept of distributed SA, SA is viewed as a system property in which SA related information is distributed between different agents (both human and non-human) in a collaborative system. In this perspective, the focus of study is on the interactions between the agents comprising the system, and a central aim is to understand how SA-related information is transferred between different agents in day-to-day operations (Salmon et al., 2012). In this manner, the application of a distributed SA perspective may enhance our understanding of the factors that influence SA formation among the bridge crew. Communication is a particularly critical dimension that might be a source of misinformation and thus affect a bridge crew's SA requirements (Kanki, 2010; Patrick and Belton, 2003; Weick et al., 1999). Should a crew member fail to transfer information or communicate information in an ambiguous manner, the bridge crew's SA formation might suffer (Endsley, 1995b). The technological environment of the bridge also provides SA-related information; thus, man–machine interactions are of particular importance on board offshore vessels. The extent to which and how the technology provides the bridge crew with information is therefore a critical dimension in the SA context (Endsley, 2012). It has also been suggested that planning activities aimed at anticipating events might have a positive effect on bridge crews' abilities to achieve SA. High-quality planning should ideally improve the understanding of risk and enable crew members to seek information in advance and plan for various scenarios (Endsley and Robertson, 2000; Flin et al., 2008). Such planning may be particularly important in situations in which the bridge crew has limited time to act to avoid consequences. In addition to highlighting interactions with both humans and the environment, Bolstad et al. (2005) emphasised that the operators' abilities are a central component in the formation of SA in collaborative systems. From this perspective, emphasis should be placed on factors such as training regimes, including how the shipping companies ensure that the bridge crew has sufficient knowledge to understand what they sense.

The loss of SA is frequently seen as an important contributing factor to accidents in various industries, such as the aviation (Endsley, 1995a; Jones and Endsley, 1996) and maritime industries (Barnett et al., 2006; Grech et al., 2002). An accident analysis from the offshore drilling industry indicates that the loss of SA is a significant antecedent of human error. Of the 135 cases that were associated with a loss of SA, 67% were attributable to a lack of perception of critical information (SA level 1), 20% were attributed to a failure to comprehend the situation (SA level 2), and 13% were attributed to an inability to project the situation into the near future (SA level 3) (Sneddon et al., 2006). To the best of our knowledge, no previous studies have examined the significance of the loss of SA during bridge operations on board offshore vessels.

1.2. International standards and industry guidelines

Several international standards and guidelines have been developed to support seafarers and help them operate safely at sea. The oldest such standard is the International Convention for the Safety of Life at Sea that was developed by the International Maritime Organization as a response to the Titanic disaster. This convention was adopted in 1914 and was most recently revised in 2011. The main objective of this convention is to specify minimum standards for the construction of and equipment on board vessels. Of particular significance in the SA context is the principle that bridge design and the design of navigational systems and equipment should enable the bridge crew to have convenient and continuous access to essential information that is provided in a clear and unambiguous manner (International Maritime Organization, 2012). Furthermore, following a series of major accidents at sea in the early 1990s, the International Maritime Organization began to develop new regulations that account for human factors (Gholamreza and Wolff, 2008). This update included a new revision of the Standard for Training, Certification and Watch-Keeping for Seafarers (International Maritime Organization, 2011) that incorporated new minimum requirements for the training and competence of seafarers and thus aimed to increase the knowledge and skills of seafarers worldwide. This update also included a