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"Everything was fine"*: An analysis of the drill crew's situation awareness on Deepwater Horizon☆

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ABSTRACT

Purpose: Investigation reports into the Deepwater Horizon drilling rig disaster identified issues with the drill crew's situation awareness (SA). The aim was to (1) apply the Driller's Situation Awareness (DSA) model to the cognitive data extracted from accident reports from this event to determine if it could help to explain why the crew erroneously concluded that the well was stable, which would (2) provide a preliminary evaluation of the model's validity.
Method: The DSA model was used for a content analysis of the SA components in the accounts of the crew's actions during two Negative Pressure Tests (NPT), in the hours before the blowout.
Results: The analysis provided (1) insight into the crew's likely cognitive processes before the blowout. In particular, it revealed issues with their interpretation and mental models of the well state, as well as possible influencing factors including expectation, distraction and experience, emphasising the impact that SA can have on process safety. The categorisation has (2) initially suggested that the DSA model does contain the appropriate components.
Limitations: There are limited first hand reports of this event and thus cognitive processes have to be inferred with a degree of caution.
Practical implications: The findings give a preliminary validation of the DSA model for further use in training and in investigation of well control events. Recommendations based on the findings are offered for assisting driller SA and consequently, for supporting safe and efficient drilling operations. There is also the opportunity to adapt the DSA model and apply the recommendations from the analysis to similar monitoring positions, where SA is essential, within the process industries.

1. Introduction

Human failures in relation to monitoring and situation awareness of plant status have been identified across the process industries (e.g. chemical plants, Shin, 2014; gas platforms and gas processing plants, Antonovsky et al., 2014). For example, operators appeared to have failed to monitor the level of chemicals in a bulk storage tank and to recognise that it was overfilling, which resulted in a vapour cloud that ignited at the Buncefield fuel depot, causing a huge explosion (Atkinson et al., 2014). Failures to monitor crucial indicators were also identified in the Texas City disaster, such as the increased pressure in the raffinate splitter and safety relief systems (Khan and Amyotte, 2007). In the offshore drilling industry, the same cognitive skills are required for the drill crew that are building the wells for oil and gas extraction. This paper examines the role of the drill crew's situation awareness in the *Deepwater Horizon* drilling rig disaster.

On April 20th 2010, the *Deepwater Horizon* drilling rig was preparing to temporarily abandon the Macondo well, in the Gulf of Mexico, when it experienced a significant blowout of hydrocarbons. This resulted in the death of 11 crew members, the rig's destruction and the worst oil spill in US history. The accident cost the operating company, BP, an estimated $43bn, excluding potential fines for gross negligence (Macalister, 2014). The human and environmental costs of *Deepwater Horizon* make it critical to understand what happened in order to advise how best to ensure a similar disaster does not happen in the future. We applied our Driller's Situation Awareness (DSA) model (Roberts et al., 2015) on cognitive data extracted from a specific period in the accident reports, to test this

☆ Testimony from R. Ezell on his call with J. Anderson at 9.20pm about the negative pressure test. (BP Trial Proceeding Transcript, p.1682) and (Hearing before the Deepwater Horizon Joint Investigation Team, May 28, 2010, p.282).

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model and to investigate why the crew erroneously concluded that the well was stable. As operators do not intend to have inaccurate SA or to take the wrong decision, considering why an action seemed like the right thing to do, rather than focussing on what operators did wrong, can be valuable for avoiding some of the pitfalls of hindsight bias (Dekker, 2007, 2009).

A brief account of the relevant phase (Negative Pressure Test) of the *Deepwater Horizon* disaster and why it was selected for detailed analysis follows, then we introduce the concept of situation awareness and explain how it has been previously studied in the drilling industry.

1.1. Investigation into Deepwater Horizon

In the wake of the disaster, numerous investigation reports examined the events leading up to the blowout and the subsequent response (see Table 1). These highlighted issues associated with technical decision making, management failures within BP, the overarching regulatory framework, and human factors. This paper focuses on the last of these issues.

As in all high risk domains, the system operators play a key role in protecting or endangering technical and human assets on the operational site. In drilling tasks, accurate monitoring of the well's state and recognition of "kick" indicators (when well control is lost, an influx of fluids into the well can occur, referred to as a "kick") are vital for effective responses to reduce the risk of adverse consequences such as a blowout (API, 2006; Fraser et al., 2014). Well control and kick detection act as essential process safety barriers. The drill crew's role in the Deepwater Horizon accident is indicated in the Report to the President (2011), which states that "the failure to properly conduct and interpret the negative pressure test (NPT) was a major contributing factor to the blowout" (p.119). The crew erroneously believed the well was stable when it was not, missing and/or misinterpreting crucial cues and hence not being fully aware of what was going wrong down the well. Therefore, the crew did not have an accurate situation awareness of the well state. Consequently, the NPT phase of the event was selected for detailed analysis.

This test (NPT) is a means of checking the integrity of a well's "bottom hole" cement job, designed to prevent hydrocarbons leaking into the wellbore when the well is temporarily abandoned. The NPT could be considered as a type of situation awareness tool with which to gather information on the well and assess its stability. It requires a relatively interactive role from the drill crew compared to the monitoring components of everyday drilling tasks in the drill cabin. The methods used to minimise the potential for a kick (see below) or blowout, as occurred on Deepwater Horizon (and to regain control of the well in such an event) are known as well control (IADC, 2015). These include the hydrostatic pressure produced from the column of drilling fluid, equipment (e.g. the Blow-Out Preventer) and procedures (e.g. flow monitoring).

1.2. Situation awareness

Situation Awareness (SA) is the cognitive skill of maintaining awareness of the work environment, to understand the information that it holds, and to predict how situations will develop (Endsley, 1995, 2015). Inaccurate SA can lead to poor decision making and unnecessary risk taking, increasing the likelihood of an accident (Stanton et al., 2001). A number of SA theories have been proposed (e.g., Smith and Hancock, 1995; Wickens, 2002; Stanton et al., 2009). However, Endsley's (1995) three level model of SA dominates the field, being frequently applied in higher risk domains (e.g. nuclear power plants, Lee et al., 2012; maritime, Saus et al., 2012). She describes SA as a cognitive product of three hierarchical levels, perception (Level 1), comprehension (Level 2) and prediction (Level 3), identifying task and environmental factors, as well as individual factors that can influence it.

1.3. Situation awareness in drilling incidents

The role of SA has been identified in drilling incidents, including the blowout on the *West Atlas* rig on the Montara well, which caused a substantial oil spill in the Timian Sea (Montara Report, 2010) and the sinking of the Petrobras P-36 drilling rig which killed 11 men (Woodcock and Toy, 2011; USEPA, 2001). Poor monitoring and misinterpretation of crucial kick indicators were also involved in the Bardolino incident in the North Sea which occurred only four months prior to Deepwater Horizon (Energy and Climate Change Committee, 2010). Situation awareness has also been associated with numerous small scale accidents and personal injuries (Lootz et al., 2013; Hare and Johnson, 2009). Furthermore, offshore installation managers reported that loss of care and attention was one of the main causes of accidents on their production platforms and drilling rigs (O'Dea and Flin, 1998).

Cognitive factors have also been identified in relation to *Deepwater Horizon*. Reader and O'Connor (2014) applied a non-technical skills framework, including SA, to examine the blowout. They highlighted several cognitive factors (e.g. confirmation bias and expectation). Similarly, Hopkins (2012) noted the crew's inaccurate mental model of the situation which was fed by their assumptions. While useful in emphasising the importance of SA in Deepwater Horizon, these studies did not analyse the situation awareness of the drill crew explicitly or in depth.

1.4. Research on situation awareness in drilling

Issues in relation to drillers' concentration, inadequate hand-

Table 1
Sources used to develop the timeline and analyses.

Sources
Bly Report, BP. (2010). Deepwater Horizon Accident Investigation Report.
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