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Safety and Situation Awareness in Offshore Crews

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Abstract
Much work involved on offshore installations has the capacity to be hazardous, and despite many rules and regulations in place to ensure that accident risk is kept to a minimum, accidents still occur. One factor known in other industries (e.g. aviation) to contribute to the occurrence of accidents is a reduction in the 'situation awareness' (SA) of those concerned. Good SA is essential when work is potentially hazardous, as workers must accurately discern and monitor conditions if they are to reduce accidents. Accident analyses have shown that a team can lose their shared awareness of the situation when it is vital to the safety of their operation. This may be particularly relevant to drill crews given the interactive and hazardous nature of their work. In this way, lack of/reduced SA may be a predictor of the likelihood of an accident occurring.

This paper presents a brief history of SA, an overview of the study, a preliminary review of an accident database, and results from interviews with onshore and offshore oil and gas industry personnel.

Introduction
One factor critical in preventing accidents in everyday life should be maintaining an adequate understanding of the current situation. This is needed in order to perceive the conditions of the environment, and judge the consequences of any actions taken in relation to the safety of the work, in order to avoid adverse events. By having full and correct understanding of the situation, the potential risk involved in an action can more effectively be gauged and in turn minimised, reducing the risk of an accident. However, if the understanding of the situation is impaired, then the ability to predict the outcomes of actions is more flawed, and due to this the risks of an accident occurring are increased. The method by which this understanding of a situation arises is known as Situation Awareness (SA), and the possession and maintenance of good quality SA is fundamental to safe working practice. This is of paramount importance in the offshore oil and gas industry where the work is hazardous and in many cases, complex, thus crews must be able to monitor and understand their environment if they are to keep their accident risk to a minimum.

The theory of SA has been in existence for many years, stemming from research in the aviation industry. In the late 1980's, interest in the area grew and research became more widespread, including domains such as aircraft maintenance, the military, driving, and medicine (Adams, Tenney & Pew[1]; Endsley[2,3]; Shrestha, Prince, Baker & Salas[4]). However, with the exception of one article (Hudson & van der Graaf[5]) and a few industry documents (Shell Exploration and Production[6,7]), the concept has remained relatively uninvestigated in the oil and gas industry, despite its importance and relevance, and remains little understood.

The aim of this paper is to initially establish the domain of SA in the offshore oil and gas industry: to discover how it is regarded, and the main underlying issues involved. Future work (currently being researched as a PhD thesis) aims to fully understand SA in offshore drill crews, with the hope of providing a means of maintaining and improving SA in the crews in an attempt to reduce accident risk.

Situation Awareness: Definition
The theory of situation awareness has been in existence for many years, with references to the concept believed to originate from the pilot community of World War I. Definitions of SA vary greatly, as they are explained in terms of the industry concerned, and as a result, understanding SA has been hampered since there is no one universally accepted and agreed upon definition of the concept (Sarter & Woods[8]).

However, there are two definitions widely cited, the fist of which characterizes SA as *"..the perception of the elements in the environment within a volume of space and time, the comprehension of their meaning, and the projection of their status in the near future"* (Endsley[9]). The other describes SA as *"..the up-to-the minute cognizance required to operate or maintain a system"* (Adams, Tenney & Pew[1]). These definitions are the most widely cited and accepted as appropriate and accurate descriptions of the concept. SA therefore, in simple terms, is the ability to successfully pay attention to and monitor the environment, and essentially 'think ahead of the game' to evaluate the risk of accidents occurring - a vitally important factor in ensuring a safe working environment.

Levels of SA

Endsley's three-level approach (Endsley[2]) is the most popular view of the construct of SA due to its simplicity, while the framework also provides a comprehensive theoretical construct that can easily be applied to a multitude of other domains. Of the model, Level 1 is Perception, Level 2 is Comprehension, and Level 3 is Projection. Each of these will be discussed in more detail.

Level 1 SA: Perception. This is the basal constituent of SA: the perception of the elements in the surrounding environment. Without the correct initial perception of the relevant elements of the environment, it is unlikely that an accurate illustration of the situation would be formed. This increases the likelihood of an error or accident, since the fundamental components on which the later stages of SA are based are of poor quality.

Level 2 SA: Comprehension. This involves the combination, interpretation, storage and retention of the aforementioned information (Endsley[10]) to form a picture of the situation whereby the significance of objects/events are understood (Endsley[2]; Stanton, Chambers & Piggott[11]) – essentially derivation of meaning from the elements perceived. The degree of comprehension that is achieved will vary from person to person, and Endsley[2] maintains that the level attained is an indication of the skill and expertise held by the operator.

Level 3 SA: Projection. The final level is projection, and occurs as a result of the combination of levels one and two. This stage is extremely important, as it means possessing the ability to use information from the environment to predict possible future states and events (Endsley[2,9]; Sarter & Woods[10]). Having the ability to correctly forecast possible future circumstances is vital in allowing the best decision to be made regarding appropriate courses of action, as time is made available to dispel potential discords and formulate a suitable action course to meet goals (Endsley[2,3,9]; Stanton et al[11]).

Attention and SA

In order for SA to be achieved, objects and information in the surrounding environment (i.e. stimuli) must be attended to. When we attend to something, it involves the process of observing the surrounding environment and being made aware of the attentional target's presence and the information that it provides (Styles[12]). Without the ability to do this, level one perception could not be achieved, and accurate SA could not be formed. In addition, we must also be able to concentrate on these stimuli to determine to which ones we should attend. We must concentrate further still in order to continually monitor the surroundings and attend to changing stimuli. It can therefore be seen that attentional processing is intrinsically linked to the theory of SA, but attention is bound by the limits of the working memory (the construct that allows the perceived information to be processed). The fact that attention is limited is a problem, as a person is unable to pay close attention to every single detail of his/her environment. In doing so, critical elements may be missed in the observation/perception stage, leading to an incorrect mental model (the representations of objects, people and tasks that people hold in their minds of the understanding of the various roles and relevance of the items concerned) being formed, and this has been supported by research (Jones & Endsley[13,14]). Possession of a poor or incorrect mental model can increase accident risk as there is no 'template' to guide actions.

Team Situation Awareness

Much of the work on an offshore installation/rig requires teamwork. As the successful attainment of the goal is entirely dependent upon the team collectively working together, then the nature of the situation dictates that the crew must have a mutual understanding of the situation. Thus the team should have a collective SA. This amassed awareness is known as team situation awareness (Bolstad & Endsley[15]; Endsley[2]; Endsley & Robertson[16]; Salas, Prince, Baker & Shrestha[17]; Shrestha et al[4]).

Team SA can be characterized as follows: *"..compatible models of the team's internal and external environment; includes skill in arriving at a common understanding of the situation and applying appropriate task strategies"* (Cannon-Bowers, Tannenbaum, Salas and Volpe[18]). This shared knowledge and understanding can then be called upon in order for the crew to make critical decisions and adapt in order to react to and predict their working environment.

Factors Affecting SA

The main goal of situation awareness is to keep those involved aware of their surrounding environment, reacting to and anticipating events and actions. There are many possible explanations as to why a particular accident has occurred, but it has become apparent that one factor may be a reduction/loss of the SA of those concerned. SA can be reduced by a number of different means, but the most salient in the prevailing literature state these as stress (whereby performance decreases due to the extra pressures imposed on the mental system) from either physical (e.g. noise, vibration, temperature) or psychological (e.g. mental workload, anxiety, confidence) stressors; workload; automation; and the decision-making process.

Errors in SA

Much of the literature suggesting that it is when SA fails that accidents occur, is derived from post-analysis of accident data. By examining the data provided in accident reports, factors can be classified, and SA elements investigated, e.g. misidentification of information, unperceived information, incorrect update of information, and lack of co-ordination/communication between team members (leading to non-communication of required information). Endsley[2] reviewed the literature pertaining to human cognition and information processing, and developed a taxonomy describing the areas in which errors in SA can be classified (see Jones & Endsley[13,14] for more detail). This taxonomy was applied in the analysis of drilling accidents in a database to discover if the cause could be attributed to an error in SA, in an attempt to discover how much of an issue poor SA is in the offshore drilling industry.

Drilling Accident Analyses

Method. A search was performed on a multinational oil company's accident database, seeking information on drilling activity accidents (on fixed installations, mobile rigs and well operations) from the period January-October 2003, revealing 332 incidents in total. Of these, those which were found not to be related to SA errors, or did not provide enough information to identify the error source, were discounted. This left 135 remaining incidents to analyze.

These incidents were analyzed and subsequently classified using the aforementioned taxonomy. If it was found that an error could fall into more than one category, it was classified at the lowest taxonomy level.

Results. Overall, it was found that 66.7% were classified as Level 1 SA errors, 20% were Level 2 errors, and the remaining 13.3% were Level 3 errors.

***Level 1 errors**:* involved the failure to perceive, or the misperception of, information in the environment. Of these errors, the majority were due to a failure to detect the information (e.g. one incident involved a data engineer who did not perceive the initial H_2S readings indicated on the chromatograph). This was followed by the information being unavailable for/obscured from perception, e.g. leak in a pipe obscured by a piece of cloth in front of the equipment.

Level 2 errors: regarded the incorrect assimilation or understanding of the perceived information. Of these errors, the majority were due to a lack of, or incomplete, mental model with which to process the information, i.e. the significance of the perceived information was not fully understood due to not having an appropriate mental model of the event. One example of this occurred during tripping of a drill pipe - the pipe handler (new hand) observed all that was occurring, so perceived information correctly, but turned to the wrong position as he had never carried out the procedure before and was unaware what direction in which to face (i.e. no mental model of the operation).

Level 3 errors: were errors in which the projection of future state of affairs was poor, incorrect, or missing. For example, one incident involved a rig being skidded; lookouts were posted to check for any clash points, and two beams observed. Despite this observation, the rig continued to skid and the subsequent clash was not foreseen.

Discussion. Analysis of the drilling accidents attributable to SA errors discovered that of 135 incidents, the vast majority (66.7%) were due to errors in Level 1 SA (failure to perceive correctly), followed by 20% of errors in Level 2 SA (failure to comprehend correctly), with 13.3% attributable to errors in Level 3 SA. These results are comparable to the distribution pattern of SA errors found in Jones and Endsley's[13,14] research (Errors in SA Level 1 - 76.3%, Level 2 - 20.3 & and Level 3 - 3.4%). This suggests that SA errors in the offshore drilling industry and the frequency of their occurrence are similar to those occurring in aviation, indicating the comparative frequencies of SA error causal factors to be a potentially more generalisable pattern.

Interviews with Drilling Personnel

Once it was discovered that errors in SA were an issue for the drilling industry, interviews were conducted with members of drilling personnel, both onshore and offshore, in an effort to understand more about how the concept of SA is viewed in this field.

Method. Interviews were conducted with 17 drilling personnel of various oil and gas operator and contractor companies. 10 personnel were based onshore in positions as HSE Managers, Operations Managers and Well Engineering Managers), and 7 personnel were based offshore. For logistical purposes, the offshore personnel were interviewed on their installation.

All interviews were informal and of a semi-structured nature. Questions posed included "How is the concept of SA known in the offshore industry"; "What factors can affect the quality of a person's awareness?"; "What are the indicators of reduced awareness?"; "How can reduced awareness be improved?"; and "How is team SA achieved?". Interviewees were given background information to the study, made aware that they could withdraw at any point, that all information gained would remain entirely confidential, that while de-identified quotes may be used, they would not allow for individuals to be identified, and that at no point would the individual's data be released to their company. Permission to record the interview was requested, after which the interview was transcribed, de-identified, and the record erased.

Interview transcripts were then analysed using a grounded theory approach (developed by Glaser & Strauss[19]), which uses qualitative data such as unstructured interview data to construct new theory (Pidgeon & Henwood[20]). This method was employed as no previous research has been done regarding this topic in the drilling industry, and so no assumptions could be made about the data or possible existing relationships within it.

Results. The main themes and concepts from the interviews were extracted and assimilated to understand how SA is seen in the offshore drilling industry. Table 1 lists these findings, by question.

Table 1. Main findings from Interview Analysis

1. How is situation awareness known in the offshore industry?
Safety awareness; positional awareness; safety accountability
2. What factors affect the quality of a person's awareness?
Home/family problems; fatigue; stress; experience; routine tasks/complacency; workload; daydreaming; conflict; job continuity/prospects/motivation; inadequate communication; having a near-miss; weather/seasons
3. What are the indicators of reduced awareness?
Character change; reduction in communication; having to give repeated instructions; reduced work standards, expressionless
4. How can reduced awareness be improved?
Communication: discussion of events; interaction; place them in a different job; alter the work level; remove him from the situation; alter the crew line-up; increase involvement in rig activities; problem solving; training;
5. How is team situation awareness achieved?
Consistency; time; understand their capabilities and traits; experience; increased interaction; planning

Discussion. As Table 1 shows, most questions elicited a number of different answers. However, there was general consensus among all interviewees on these answers, assumed by the frequency of their occurrence (i.e. all interviewees tended to respond with similar answers, indicating general understanding of the concept). The interview findings will be discussed in more detail here. All items will not be discussed, only those most prominent. (Q1 is self-explanatory, so no further details will be given).

Q2. What factors affect the quality of a person's awareness?

Having problems with family/at home was felt to be the most prominent factor that could affect awareness. Being offshore meant personnel had no control over the situation, weighing heavy on their minds, which may distract them from work. Fatigue was most problematic when on short change, as this disrupted sleep patterns. Stress from several areas was also a cited issue – as heavy workload increases; supervisor pressure (to get a job done quickly), and also self-imposed pressure to complete a task by a certain time. While it is widely reported that stress can lead to decrements in performance, the significant impact upon awareness should not be ignored – stress can place increased pressure upon already limited cognitive resources, meaning less available resources for attention and awareness, reducing the overall quality of SA. Experience impacted SA in two ways: new hands felt they required time to adjust to rig surroundings, infrastructure, regulations, etc, and were not as aware until this was done; experienced crew felt less experienced workers impacted their awareness as they had to "look out for them" and compensate for their inadequate levels of SA, meaning attention was divided between their own job and the inexperienced worker. Routine tasks/complacency impacted awareness in that if a task had been done may times beforehand, there was less inclination to focus on it as operations had gone smoothly in the past – this leads to complacency, less attention to the job, and thus reduced awareness.

Q3. What are the indicators of reduced awareness?

All personnel interviewed stated that the most important indication of reduced awareness was a character change in the individual that was not within the norm for them and familiarity with the individual concerned was a key driver in noticing this. Communication was also reduced, whereby the individual did not talk as much as usual, and became more withdrawn. As a supervisor or colleague, having to repeatedly give the same instructions over a relatively short space of time was also felt to be a good indicator, as it was suggested that the person was not paying as much attention as they should. A drop in work standards of a normally productive individual, and blank, glazed expressions were also believed to indicate reduced awareness.

Q4. How can reduced awareness be improved?

Communicating with the individual and having a discussion was believed to be the most important (and instantaneous) method of increasing awareness - this brings to their attention the fact that they were not being as attentive as is appropriate, prompting them back to 'normality'. Also, if the reduced awareness was due to problems weighing on their mind, this provides the opportunity to voice the concerns, 'getting them off his chest', thus alleviating the problem. Interaction was believed to aid awareness by keeping the crews alert and focused. Tasking the individual with a job out of harm's way was perceived as a remedy as this allowed them not to be in harms way (so required less SA), and also gave them time to regain their awareness levels. Reducing workload (if this was the problem area) was felt to have the same effect. If the problem was more severe and a short break with reduced work was ineffective, then removing the individual from the situation entirely and sending them home was felt to be the only option, although rare.

Q5. How is team situation awareness achieved?

Consistency was felt to be the key factor in achieving team SA – by keeping the same crew together over a period of time, this allowed the crew to fully get to know and understand each other, learning how they worked, their roles and capabilities, traits, strengths and weaknesses, eventually leading to a team which automatically knew how each other crew member would react in a given situation due to their detailed knowledge and understanding: *"..an unspoken understanding with everyone working from the same mental plan"* and *"..pulling in the same direction"*.

N.B. While not discussed here, findings from the interviews also fully support the various theoretical components of Endsley's[2] model of SA in dynamic decision making (see Endsley[2] for further details of this model).

Conclusions

The initial accident analysis has shown SA to be an issue for the drilling industry, while indicating possible factors underlying losses to SA, and also the frequency/causes of various types of SA error (failure to detect information being the largest category). The interviews conducted with both onshore and offshore personnel have led to a more detailed understanding of what is a relatively uninvestigated area of the oil and gas industry, and it is anticipated that with further research SA can be more acutely understood not only in the conceptual form, but also to provide companies with guidance regarding effective actions that may help to reduce the risk of accidents in the future.

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