Stress, fatigue, situation awareness and safety in offshore drilling crews
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1. Introduction

Critical factors in the prevention of industrial accidents include the ability of workers to maintain awareness of the work environment, understand the information it holds, and predict how situations will develop (Jones and Endsley, 2000; Stanton et al., 2001). The term used in industry for this cognitive skill is situation awareness (SA), defined by Endsley (1988, p. 97) 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”.

Cognitive skills such as situation awareness are known to be susceptible to the effects of work-related conditions such as fatigue and stress (Endsley, 1999; Sexton et al., 2000; Tucker et al., 2010) which are common in many high-risk industries, for example in offshore oil and gas exploration, where personnel work on remote installations, often in time-pressured, dangerous conditions (Flin and Slaven, 1996). The recent Deepwater Horizon drilling rig disaster in the Gulf of Mexico which killed 11 men and caused the worst oil spill in US history is testimony to the very hazardous nature of this industry’s activities. Ongoing examination of the causal events indicates failures in situation awareness and risk assessment (Report to the President, 2011). Analysis of earlier drilling industry accidents, such as the Montara blowout in 2009 off Australia (Hayes, 2012), and on the UK Continental Shelf (UKCS) also identified failures to attend to relevant information in the work environment as a common contributory factor (Sneddon et al., 2006).

Drilling activity is a critical and challenging process in hydrocarbon exploration and production, especially for the increasingly hazardous deepwater wells (Skogdalen et al., 2011). Drillers have to maintain control of the well, lead work on the drill floor (sometimes involving heavy, physically demanding work), but also deal with advanced technological equipment and monitoring facilities. They may be based in the drill cabin, using advanced computer systems to provide them with a clear view of the task and real time data logging. The drill crew have to manually handle heavy equipment since the process is not entirely automated. The ‘well’ is drilled into the sub-sea oil reservoir or gas field, which involves carefully positioning the drill bit, collar and drill pipe into the well. This assembly is then attached to the Kelly and rotary table which rotates, lowers and raises the drill pipe in order to carry out drilling activities. Drilling mud is introduced into the centre pipe in order
drill to counterbalance internal pressures and to float the rock cuttings back to the surface where they are extracted from the hole, making the process slippery. Additional sections of drill pipe are added as the well gets deeper forming the ‘drill string’. The drill bit often needs to be replaced due to different rock compositions and in order to do this, the entire drill string has to be removed from the well and the pipes stacked in order to reach the drill bit. This is a hazardous process due to the slippery mud from the cuttings. Once this process has been completed, oil or gas flows up through well by placing a smaller-diameter pipe (tubing) into the casing and a
packer down the outside to form a seal round the tubing. A device
known as a ‘Christmas tree’ is attached at the top of the tubing
allowing the drill crew to control the flow from the well. Due to
the pressures at the depths where hydrocarbons are found,
‘blow-outs’ are possible and are an added risk to the process (Skoge
dalen et al., 2011). Blow-out valves are placed on the seabed in or
der to stabilise the pressure and control the well when necessary
but the potential for a catastrophic situation is very real for the
drill crew.

It is apparent from the description above that SA is a critical is
sue influencing safety in the drilling industry but little research has
been undertaken focusing on SA in this area. In particular, there is
a lack of offshore specific SA models and measures available and
there is also limited evidence of the role of stress and fatigue in
affecting global SA. The current study was designed to first develop
a measure of global SA in offshore drilling crews and secondly to
use it to measure the relationships between stress, fatigue and situ
ation awareness in offshore drilling personnel on the UKCS, and to
determine whether situation awareness (SA) is associated with
safety outcomes such as unsafe behaviour, near misses and acci
dent history.

2. Measuring SA

Several methods for measuring SA have been developed, usually
as a task-based, state characteristic, often using simulators (see
Salmon et al., 2006 for a review). Several of these were considered
for the current study, including the Situation Awareness Rating
Technique (SART) (Taylor, 1990) where after task completion,
respondents rate factors affecting their performance and under
standing to give a global measure of SA. This method was deemed
unsuitable as it measures SA for a specific task, while the aim of
this research was to assess a more global estimate of SA. The Situ
ation Awareness Global Assessment Technique (SAGAT) (Endsley,
1988) is used to assess a participant’s SA when a simulated task is
interrupted. This was also rejected as no drilling simulator facili
ties were available to the researchers at the time this study was
conducted. We appreciate that there have been further develop
ments in SA theoretical underpinnings and measurement in recent
years (see Salmon et al., 2008) however at the time this study was
conducted, this literature was not available for consideration.

We therefore decided to develop a self-report measure which
could be used with workers in the high risk drilling environment
without the presence of an observer, or the interruption of tasks.
This measure was intended to indicate an individual’s level of SA
as a general measure, rather than a transient, task-dependent, state
measure. Individual differences in situation awareness have been
documented (Gugerty and Tirre, 2000) and this is an emerging in
terest, as two trait-based, self-report measures have recently been
developed. The Workplace Cognitive Failures Scale (Wallace
and Chen, 2005) is a 22-item scale developed to assess cognitive
failures in the workplace. The Factors Affecting Situation Aware
ness (FASA) (Banbury et al., 2007) is a measure of a pilot’s acquisi
tion and maintenance of SA. These scales were not available for
consideration during the design stage of the present study but they
could be useful in the future as measures of SA or to provide a
source for testing concurrent validity with the current measure
ment instrument if future work was being conducted in the off
shore drilling sector.

Several general (i.e. not workplace) trait measures of attention
and cognitive disposition were scrutinised, such as the Short
Inventory of Minor Lapses (Reason and Lucas, 1984), the Everyday
Attention Questionnaire (Martin, 1983), and the Mindfulness
Attention Awareness Scale (Brown and Ryan, 2003). They were re
jected because of limited validity and reliability data and/or items
were not appropriate for assessing awareness in a work environ
ment. The Cognitive Failures Questionnaire (CFQ – Broadbent
et al., 1982) was also reviewed. The CFQ provides a robust measure
of everyday attention and lapses but is not work specific and did
not cover issues that would be relevant to a drilling industry situa
tion. It was therefore decided to develop a new trait SA measure
ment technique, the ‘work situation awareness’ (WSA) scale specifically aimed at measuring general awareness of the drilling
work environment, based on an adaptation of the CFQ.

3. Factors affecting SA and attentiveness

There is limited empirical evidence regarding the factors affect
ng general levels of SA: many studies focus only on specific atten
tional processes such as vigilance, and do not consider awareness
in a broader sense. Two workplace-related conditions that have
been more widely reported in the literature as impacting SA are
stress and fatigue.

3.1. Stress and SA

Increasing levels of stress can result in reduced working mem
ory capacity and diminished attention (Hockey, 1986; Hancock
and Szalma, 2008). Stress can result in poor concentration/alertness
due to an overload on the individual’s cognitive resources, and this
can interfere with the primary perception of the situation, causing
inattention to the available information. Consequently, there may
be a narrowing of the individual’s attentional field to incorporate
only a restricted number of core aspects, resulting in peripheral
information receiving little or no attention. While this ‘cognitive
tunnel vision’ (Tversky and Kahneman, 1974) may be a valuable
adaptive strategy in a safety critical environment by preventing
overload, factors outside the central focus of attention may be
those that have most potential to be harmful. Relatively high levels
of occupational stress have been measured in offshore studies,
(Mears and Hope, 2005; Parkes, 1998) and associations between
stress and offshore accident rates have also been established (Suther

3.2. Fatigue, sleep disruption and SA

Fatigue also causes detriments to alertness levels and conse
quently increases the risk of accident involvement (HSE, 2006),
as the cognitive resources required are depleted due to physical
exertion or sleep deprivation (Rosekind et al., 1994). Dawson and
Reid (1997) found that deficits in cognitive processing in individu
als with only moderate sleep deprivation were akin to those expe
rienced when blood alcohol levels are over the legal limit for
driving. The effects of fatigue are to generally decrease the speed
of cognitive processing, and thus increase reaction times, tunnel vi
sion, inattentiveness, and lower vigilance and concentration
(Helmreich et al., 2004). These effects have been reported in the
marine industry (Smith, 2001; Wadsworth et al., 2008), transpor
tation (Fletcher and Dawson, 2001), and power generation
(Ognianova et al., 1998) and have also been reported for the off
shore oil and gas industry as outlined below.

4. The working environment in the offshore drilling industry

Managers in the offshore oil and gas industry report that lack of
care and attention is one of the main causes of accidents (O’Dea
and Flin, 2001). This has particular relevance for drilling personnel, who
are involved in one of the most dangerous activities, running long,
heavy pipes into hydrocarbon reservoirs under the sea bed in a fast
operation. They must be able to continuously monitor and under

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stand the drill floor environment if they are to keep their accident risk to a minimum. Occupational stress is a feature of offshore life, originating from the usual sources, the offshore living environment, helicopter travel, and the interface between job and family (Parkes, 1998; Sutherland and Cooper, 1986, 1996; Sutherland and Flin, 1989). Fatigue and sleep disruption are common. Drilling crews often work 12-h shifts for 14 or more days with no rest days. Many locations work a shift pattern (known as ‘short change’ or ‘mid-hitch roll over’) which involves personnel changing half-way through their stint offshore from day-shift to night-shift or vice versa, disrupting sleeping patterns (Gibbs et al., 2005). Conditions generally tend to be noisy due to machinery. There are high numbers of personnel living and working in a limited area, and personnel also may share an accommodation cabin, which can disturb relaxation time and sleep (Mearns and Hope, 2005).

5. Relationships between performance shaping factors, work SA and accidents

Examining the relationships between performance shaping factors such as stress and fatigue and work SA (WSA) may identify their relative contribution to accident involvement. The relationships being examined in the study are illustrated in Fig. 1 and explained below.

N.B. Only volitional non-compliance was measured, due to the difficulty of measuring non-volitional non-compliance (e.g. forgetting), as by their very nature, individuals may not be aware of them.

Fig. 1 proposes that fatigue and stress will have a detrimental impact upon WSA, and that as a result workers with lower WSA will have more accidents and near-misses, and report more unsafe behaviours, due to their attention and alertness being reduced. It is proposed that WSA is a key part of the explanatory mechanism for why stress and fatigue are related to workplace accidents.

5.1. Hypotheses

As part of the validation process (see above) it was predicted that the Cognitive Failure Questionnaire (CFQ) scores would correlate negatively with WSA scores. The nature of the scoring on the scales means that higher WSA scores represent better SA whereas higher CFQ scores represent more cognitive failures. This validation was conducted before a series of hypotheses were tested.

Hypothesis 1a. Stress will be negatively associated with WSA.

Hypothesis 1b. Sleep disruption will be negatively associated with WSA.

Hypothesis 1c. Fatigue will be negatively associated with WSA.

It is proposed that WSA will have a subsequent effect upon personal safety outcomes such as unsafe behaviour, accidents and near-misses. Wallace and Vodanovich (2003a,b) found that cognitive failures were a predictor of occupational safety behaviour, in that individuals reporting more cognitive failures also reported increased safety non-compliance and more accidents, and Wadsworth et al. (2003) showed that occupational accidents were associated with increased cognitive failures.

Hypothesis 2a. WSA will be negatively associated with unsafe behaviour.

Hypothesis 2b. WSA will be negatively associated with rates of accident involvement.

Hypothesis 2c. WSA will be negatively associated with rates of near-miss occurrence.

It is also proposed from the above that WSA mediates the relationship between performance shaping factors (fatigue, sleep disruption, stress) on unsafe behaviour.

Hypothesis 4. WSA mediates the relationship between the performance shaping factors and unsafe behaviour.

6. Method

6.1. Sample

The sample consisted of drilling personnel \( n = 378 \) based on eight drilling rigs and platforms on the UKCS. All locations were contracted to operate for one multi-national operating company at the time of the survey. A total of 185 (49%) questionnaires returned were viable for analysis. This is an acceptable response rate for this remote sector, and is comparable to that found in other studies (e.g. Mearns et al., 2006). Respondents included all levels within the drilling hierarchy, from roustabout to drilling supervisor. Respondents indicated which age group they belonged to, rather than giving their actual age so that anonymity would not be compromised. The mean age group of respondents was 35–44 years. Of the sample, 77% were employed directly by the drilling company – the remainder were employed by the operating oil company or another contracting company. A total of 44% were supervisors, and 74% had worked at their present location (rig) for 5 years or less. Of the respondents, 66% worked a 2-week trip rotation pattern (2 weeks offshore then 2 weeks leave onshore), 44% worked a rolling shift pattern of one trip of day shift followed by one trip of night shift and 34% had ‘on-call’ duties.

6.2. Procedure

A self-report questionnaire survey was used to collect data on cognitive failures, WSA, stress, sleep disruption, fatigue, unsafe behaviour and accident history. Two modes of distribution were used: personal offshore site visits by one of the research team and (due to logistical limitations for offshore trips), postal distribu-

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Fig. 1. Proposed relationships between fatigue, sleep disruption, stress with WSA and unsafe behaviour, accident/near miss involvement.

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tion. Respondents were given envelopes in which to return the completed questionnaires to the research team. No significant differences were found on any measure between the samples surveyed using the two methods.

6.3. Measures

The questionnaire consisted of five sections: WSA, cognitive failures, fatigue and sleep disruption, safety behaviour, and accident history.

6.3.1. Work SA (WSA)

This scale was developed to measure specific awareness of the work environment on the drilling rig. It was adapted from the Cognitive Failures Questionnaire (Broadbent et al., 1982) and drew on our previous work on situation awareness in drilling, which involved interviews with experienced drillers (Sneddon et al., 2006). It contained 20 items (Appendix A), and was scored on a 5-point scale (0 = very often to 4 = never; i.e. the higher the score, the better the individual’s awareness of the work environment). Items were customised for the offshore drilling environment. They included 5 positively worded statements such as “I take note of objects/events on the rig even if they are not directly related to my work”, “I think ahead of my work to plan for different possible outcomes” and 15 negatively worded (reverse scored) statements “I am easily distracted by my thoughts and feelings”. A final question asked at what time of the shift/rotation respondents felt least aware.

6.3.2. Cognitive failures

The CFQ (Broadbent et al., 1982) was included for validation purposes, as it is an established measure for assessing slips of attention in everyday life. It has been shown to have high internal reliability, i.e. the items group together to measure the same underlying construct (e.g. Larson et al., 1997; Vom Hofe et al., 1998; Wallace, 2004), is well validated with other scales and has been found to be a significant predictor of accidents (Wallace and Vodanovich, 2003a,b). It contains 25 items, with responses indicating how often particular situations indicating failures of attention and cognition have happened to the respondent within the last 6 months, and is answered on a 5-point scale (4 = very often to 0 = never).

6.3.3. Fatigue

To measure levels of fatigue, a scale developed by the Australian Maritime Safety Authority (AMSA; Parker et al., 1998) was selected since it had been developed for a marine environment, similar to that experienced by the offshore oil and gas industry both with regard to the physical environment and the shift patterns. The fatigue scale was modified to make the 13 items more suitable for the offshore work domain. They assessed to what extent boredom, number of days into the trip, working with a crew who are not fully competent, and working a night shift contributed to respondents’ feelings of tiredness, fatigue or decreased alertness. The items were rated on a 5-point scale (ranging from 1 = never to 5 = always).

6.3.4. Sleep disruption

The sleep disruption scale also came from the AMSA set of marine measures and contained 14 items, assessing how often sleep was disrupted offshore (or the onset of sleep delayed). As above these items were listed on a 5-point scale (ranging from 1 = never to 5 = always). For both these scales, a higher score indicated greater sleep disruption and fatigue.

6.3.5. Stress

Standard occupational stress scales were rejected due to their length, or the unsuitability of the items. Instead the measure of stress was derived from offshore stress scales (Parkes, 1998; Sutherland, 1994; Sutherland and Cooper, 1996) into a list of 32 items customised for the drilling industry. The stressors included work overload, threat of job loss, demands of work on private life, and making mistakes. Respondents rated how much stress they perceived from each of the items on a 6-point scale (ranging from 0 = no stress to 5 = extreme stress).

6.3.6. Unsafe behaviour

This measure was the safety behaviour scale of the Offshore Safety Questionnaire (OSQ) (Mearns et al., 1997), which assesses to what extent respondents participate in short-cuts and violating behaviours. It has been used in a number of offshore oil industry studies (e.g. Mearns et al., 2003, 2010) and has acceptable internal reliability. The Cronbach’s alpha of the scale in the current study was 0.88. The 11 items were rated on a 5-point scale (1 = never to 5 = always), modified from the three-point scale used in the OSQ, as this was felt to limit respondents’ answers. Higher scores represented more unsafe behaviour.

6.3.7. History of accidents and near-misses

The final section recorded respondents’ accident history while working offshore. They were asked if they had been involved in an accident at any time in their offshore career; if they had experienced an accident on board the rig within the last 12 months that required a trip to the medic; and if they had experienced a near-miss on board the rig in the last 12 months. Four final items asked for: (a) very brief details of the accident or near-miss; and (b) the time of day/period of trip the accident or near-miss. We acknowledge that the respondents may have been unwilling to report such incidents due to the possibility of reprisal but by assuring confidentiality of the results we hoped that this unwillingness would be counteracted to some extent.

6.4. Analyses

The structure of the WSA was examined with a principal components analysis. To test relationships between stress, fatigue and WSA levels, correlations (Pearson’s Product Moment) and regression analyses were used. The Sobel test was run to test for mediation effects of WSA between stress and safety non-compliance.

7. Results

7.1. Principal components analysis

Principal components analysis (using the Varimax technique, which results in a rotated, orthogonal solution for the matrix) of the WSA scale was conducted, in order to test the factor structure. A loading level of 0.4 was set, as suggested by Field (2005). A four-factor structure (see Table 1) emerged, accounting for 53.6% of the variance. They were labelled as follows: concentration; attention; anticipation and distraction.

7.2. Hypotheses results

The total WSA scale was found to have a Cronbach’s alpha of 0.86, and was highly correlated with the total CFQ ($r = -0.70$, $p < 0.01$), confirming Hypothesis 1 that the scales are measuring similar underlying constructs. The four sub-scales also had alphas ranging from 0.65 to 0.83. It is acknowledged that an alpha of 0.65...
is rather low (Nunnaly, 1978) but given that we were developing a new scale, we believed it was acceptable to retain this scale for current purposes.

Table 2 displays the bivariate correlations between the four extracted factors and the other test variables, while Table 3 shows the accident history of the group. It was found that higher levels of stress had a negative relationship with WSA (Hypothesis 2b), as did higher levels of sleep disruption (Hypothesis 2c) and fatigue (Hypothesis 2d).

Consistent with expectations, lower levels of WSA were significantly related to increased unsafe behaviour in the workplace (Hypothesis 3a), \( r = -.51 \). This could be because the people who admit to having lower WSA are also the people who are willing to admit to non-compliance. Table 3 shows the self-reported frequency of involvement in an accident or near-miss. Hypothesis 3b was supported: those who had previously experienced an accident were found to have significantly lower WSA than those who had never experienced an accident (\( t(166) = -2.33, p < 0.05 \)). In contrast, no support was found for the hypothesis that individuals with lower levels of self-report WSA are more likely to have been involved in a near-miss than those with higher levels, (\( t(158) = -1.44, p = ns \)). This could be due to the fact that the participants did not want to report near misses, although reporting near misses could be seen as less threatening than reporting accidents. Individuals who had experienced an accident had significantly higher unsafe behaviour scores than individuals who had not (\( t(171) = 2.07, p < 0.05 \)).² Those who had experienced a near-miss in the last 12 months reported that they engaged in significantly more unsafe behaviour than those who had not (\( t(163) = 3.76, p < 0.01 \)).

In addition to the above analyses, a linear multiple regression analysis (Field, 2005) was carried out to determine what combination of workplace variables predicted global WSA (see Table 4).

² This calculation used the accident statistics from the item “Accident history at any time in career” rather than “Accident in past 12 months” as only three respondents had actually been involved in an accident in the last 12 months.
Stress was the only factor to make a significant contribution to the model, indicating that those who report higher stress levels also report poorer WSA. The model explains 22% of the variance in the global WSA scores.

Regression analyses for each of the four WSA factors were also conducted (see Table 5). Similar to the regression conducted for global WSA, the only significant predictor was stress, explaining 17%, 5% and 8% of the variance in the WSA factors ‘concentration’, ‘anticipation’ and ‘attention’, respectively (those who report higher stress also report poorer concentration, projection and attention levels). When the variables were entered to predict ‘distraction’, sleep disruption was the only significant predictor, explaining 17% of variance.

Earlier analyses indicated that stress was a significant predictor of unsafe behaviour at work, and so the next step was to test whether WSA was a mediator of the relationship between stress and unsafe behaviour. Baron and Kenny (1986) recommend using the Sobel test (Sobel, 1982) to identify the percentage of the total effect that is mediated, and the ratio of the indirect to the direct effect (see Preacher and Hayes, 2004). A syntax program was downloaded from the internet (http://www.ats.ucla.edu/STAT/spss/faq/mediation.htm). Tables 6 and 7 display the results.

The results show that WSA mediates 47.82% of the relationship between stress and unsafe behaviour, therefore accounting for almost half of the effect.

8. Discussion

Previous studies have demonstrated that cognitive failure is related to workplace safety behaviour and accident occurrence, and this study aimed to discover how different occupational factors inherent to the offshore drilling industry can affect attentiveness, and subsequent accident risk.

Regarding Hypothesis 1, a significant negative association was found between the Cognitive Failures Questionnaire and WSA, indicating that the more mishaps and lapses of attention an individual reported, the less workplace awareness he/she reported. This suggests that the skills required to maintain attention in everyday life are similar to the abilities that control attentiveness in the offshore drilling environment, as it is only the context that changes, and not the mental activities. Reason (1988) suggested that some people are more likely to experience cognitive failures due to their more rigid style of cognitive management and attentional focus. This could be an area for further investigation, particularly in high hazard domains where more flexible styles of cognitive management and attentional focus may be necessary to keep the appropriate perspective on ongoing operations. Such styles could either be selected for or trained for, but only if the WSA scale can be shown to have predictive validity for performance in the drilling sector. The development of more realistic simulators since this study was conducted, provides the opportunity to test the measure in such controlled environments.

Individuals reporting higher levels of stress were found to have poorer WSA. The literature on indicates that stress has a tendency to cause individuals to narrow their field of attention (Endsley, 1995) and can impair cognitive resources by undermining working memory (Hockey, 1986). Higher levels of sleep disruption and fatigue also correlated with decreased WSA. This corroborates Wallace et al.’s (2003) finding that individuals who scored higher on daytime sleepiness also experienced more cognitive failures. Sleep disruption is part of working offshore and these findings suggest that this is detrimental to employees by decreasing their WSA levels. Companies may wish to consider altering the shift patterns that are in place to make them more stable, for example, allow workers to always work a day or night shift rather than switch shift patterns in the middle (split/swing shift), or installing extra sound proofing in cabins to allow personnel to enjoy more undisrupted sleep.

Stress and fatigue were correlated but the multiple regression analysis showed that stress was the only significant predictor of WSA. When the component factors of WSA were examined in more detail, stress was also found to be the only significant predictor for concentration, projection and attention. Although the effect of fatigue appears to have been diminished in these analyses, sleep disruption was still a predictor of ‘distraction’. Wallace et al. (2003) found that scores on the daytime sleepiness scale correlated significantly with their ‘distractions’ factor in samples of undergraduate students and military personnel, thus corroborating the results found in this study.

Table 6
Summary of regression analysis results for WSA between stress and unsafe behaviour.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Regression coefficient</th>
<th>SE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stress and unsafe behaviour</td>
<td>0.08 **</td>
<td>0.14</td>
</tr>
<tr>
<td>Stress and WSA</td>
<td>-0.14 **</td>
<td>0.02</td>
</tr>
<tr>
<td>WSA and stress on unsafe behaviour</td>
<td>-0.26 **</td>
<td>0.05</td>
</tr>
</tbody>
</table>

** p < 0.01.

Table 7
Sobel test results for WSA between stress and unsafe behaviour.

<table>
<thead>
<tr>
<th>Sobel test</th>
<th>Percentage of the total effect that is mediated</th>
<th>Ratio of the indirect to direct effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.76 **</td>
<td>47.82</td>
<td>0.92</td>
</tr>
</tbody>
</table>

** p < 0.01.
The hypothesis that individuals who report poorer WSA will participate more frequently in unsafe work behaviours was supported. In a study on production workers, Wallace and Vodanovich (2003a) also found that cognitive failure scores were positively related to safety non-compliance. Wickens et al. found that driving errors, lapses and violations were predicted by cognitive failure and the loss of SA through use of mobile phones has been found to be associated with traffic violations, e.g. speeding (Kass et al., 2007). These findings suggest that unsafe work behaviours such as taking short-cuts and breaking rules could be due to lapses of attention or awareness, rather than deliberate violations. On the other hand, perhaps those who violate simply do not bother to pay attention. It may be that this is an issue with the projection stage of WSA, in that an individual is more likely to take a short-cut as he/she cannot (or is poor at) predicting the possible negative outcomes of this action. Conversely, those with better quality WSA may be more able to accurately predict what may happen and are more aware of the risks, and so consequently are less likely to carry out the unsafe behaviour.

Support was found for the hypothesis that individuals who had been involved in an accident at some point during their offshore career would have significantly poorer WSA scores. Likewise, Wallace and Vodanovich (2003b) reported that in military electrical workers, cognitive failures were positively correlated with both automobile accidents and workplace accidents. Larson et al. (1997) also found that accidents and scores on the cognitive failures scale were associated. These results confirm the importance of maintaining good quality SA in an attempt to successfully prevent accidents.

There was no support for the hypothesis that individuals with poorer WSA would be more likely to have been involved in a near-miss within the last 12 months. However, this is most likely due to the fact that only 14% of the sample was in this category, and therefore the calculation had very little power. It was found that individuals who had been involved in an accident at any point during their offshore career were significantly more likely to engage in non-compliance at work than their colleagues who had never experienced an accident, as were those who had experienced a near-miss in the last 12-months (compared to those who had not).

8.1. Stress, WSA and safety

The results of a mediation test showed that 48% of the relationship between stress and unsafe behaviour was mediated by WSA, suggesting that WSA is an important construct when investigating workplace safety. High hazard/high reliability organisations should note the results of this and similar studies and either use further validated WSA scales in their selection processes or incorporate SA into their training programmes. It also important to note the impact stress has on human performance and measures to reduce the impact of stress in the workplace should be implemented by all organizations.

8.2. The WSA scale

The principal components analysis of the WSA scale produced a four-factor model (concentration, attention, anticipation and distraction). The CFQ is characterised by three components – perception, memory and motor function (Broadbent et al., 1982) and Wallace and Chen (2005) also identified a three-factor model (memory, attention and action) as the best fit for their Work Cognitive Failures Scale using confirmatory factor analysis. One possible reason for the four factors emerging in the current study is that they are an artefact of the hazardous and fast moving drilling environment. Furthermore, distraction can affect all three stages of perception, comprehension, or anticipation, which could explain why these distractive items clustered into a single factor.

9. Limitations of the study and directions for future research

All results reported in this study are based on self-reported data, so the usual caveats should be applied when considering the implications of the findings. Clearly longitudinal or experimental studies would be required to further test the impact of work factors on SA in personnel in the drilling sector and other high risk industries. Conducting research in the offshore environment brings with it a specific set of challenges including accessing personnel and following up on individuals who are often working as contractors and therefore subject to regular changes in employer and the installation they are working on. Offshore tracking systems (e.g. the VANTAGE system, which records how long and the location where personnel have been working offshore) could facilitate longitudinal studies on the effects of work stress and fatigue on performance in the future.

Other factors to be considered include the work situation at the time of the survey. When the questionnaires were being completed, the operating company to which the drilling companies were contracted had just put their drilling contract out to bid, and a new drilling company had won the tender. Subsequently, there was much unease in the workforce – many staff had already been made redundant, and the remaining personnel did not know whether they were going to be transferred to the new drilling company when they took over the contract in a few months time, or be made redundant. While the researcher was on board, several respondents commented that the current conditions were causing many to feel under more pressure than usual, and therefore the stress levels reported in the questionnaire may not be indicative of the true stress levels of offshore workers in ‘normal’ conditions.

It would be also beneficial to try to gain access to industry records of accident occurrence in order to gain a more objective report on accident frequency, rather than relying solely on self-report methods that may provide an underestimation of the actual number of incidents and accidents.

While the response rate of the study was reasonable for this remote population (49%), the length of the questionnaire may have influenced response rates. While the initial research required the questionnaire to be this length, future work could use a shortened version. As mentioned earlier, Wallace and Chen’s (2005) Work Cognitive Failures Scale (WCFS), assessed cognitive failures in the workplace, while also investigating the associations between WCF and occupational safety. The WCFS was based upon Broadbent et al.’s (1982) Cognitive Failures Questionnaire, and contained items based upon the constructs of memory, attention and action; when factor analysed, this factor structure was found to hold. Similar to the findings reported above regarding WSA and non-compliance, Wallace and Chen (2005) found a significant negative correlation between WCF scores and safety behaviour in production, construction and plant operating personnel (the more WCF reported, the less safety compliant respondents reported themselves to be). Given their evolution from the CFQ, it is not surprising that there was some degree of overlap between the items contained in both the WCFS and the WSA scale, for example, items on daydreaming or distraction. The WCFS appears to be successfully measuring cognitive failures in the workplace, and with further refinement, the WSA scale can measure general workplace attentiveness – comparison of these scales would now be useful.

10. Conclusion

This study has developed a measure of situation awareness (WSA) specifically for use with offshore drilling crews. The WSA scale shows evidence of content, construct and concurrent validity however more work is required to establish discriminant and pre-
dictive validity. This study has shown that higher levels of stress and fatigue are linked to lower levels of WSA, which in turn are indicative of increased participation in unsafe work behaviours, and higher accident risk. These results need to be replicated by testing in drilling simulators or even in longitudinal studies. Social desirability and presentation bias could have affected the results, despite the assurances of anonymity and confidentiality and these biases should be controlled for, for example by using the Marlowe–Crowne Social Desirability Scale (Crowne and Marlowe, 1960). Situation awareness training is not generally used in the oil industry although it is provided in other high risk sectors (aviation, maritime, nuclear). Crew Resource Management (CRM) (Kanki et al., 2010) and in many of these domains, non-technical skills, such as SA, are regularly checked as part of licence revalidation (Flin et al., 2008). Following the Deepwater Horizon accident, the offshore oil and gas industry is beginning to develop CRM syllabi for drill crew and the above results suggest that SA, as well as fatigue and stress management will need to be key components.

Given these findings, and with recent accidents highlighting that offshore drilling crews are employed in one of the most hazardous maritime occupations, it seems justifiable to suggest that offshore companies may also benefit from reviewing their working patterns and conditions to ensure that their impact on cognitive skills is fully understood as part of their risk mitigation strategy.

Acknowledgements

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Appendix A. The work situation awareness (WSA) scale

<table>
<thead>
<tr>
<th>(Circle one number on each line)</th>
<th>Very often</th>
<th>Quite often</th>
<th>Occasionally</th>
<th>Very rarely</th>
<th>Never</th>
</tr>
</thead>
<tbody>
<tr>
<td>I often daydream during work</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>I am easily distracted by background noise</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>I find it easy to remember work instructions</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>My work area is often cluttered or disorganised</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>I am easily distracted by my thoughts or feelings</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>I think ahead of my work to plan for different possible outcomes</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>I ensure I know most rig activities that are ongoing so I can ‘keep an eye’ on things</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>I find it difficult to pay attention to someone, even if I am being spoken to directly</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>I become bored with my work quickly</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>I find it difficult to concentrate for long periods of time</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>I am easily distracted by visual stimulation (e.g., movement)</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>I often find I have carried out work on ‘auto-pilot’, without being aware of it</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>I take note of objects/events on the rig even if they are not immediately related to my work</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>I find it easy to keep track of everything that is going on around me</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>I have trouble getting back into work after an interruption</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>I am not able to keep my mind focused on work and it has a tendency to ‘wander’</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>When I finish reading or being told instructions, I often have to re-read them or ask for them to be repeated as I don’t remember them</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>I often speak or act without thinking</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>I have difficulty paying close attention to details, which often results in careless errors</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>I ‘tune out’ during routine work, or when work is boring</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>

References


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