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1 **Ergonomics in Design (in press, accepted 11/17)**

2 **Title: Drillers' Cognitive Skills Monitoring task**

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5 **Abstract:** Drilling incidents have emphasised that offshore drillers require a high level of  
6 cognitive skills, including situation awareness and decision making, to maintain safe and  
7 efficient well-control. Whilst there are a number of tools for supporting operators' cognition  
8 available in other high-risk industries, there is not a specific tool for drilling. We developed a  
9 prototype monitoring task simulating drilling scenarios, Drillers' Situation Awareness Task  
10 (DSAT) with drilling experts and piloted with 14 drilling personnel. Preliminary results  
11 suggest that it is viable as a tool for examining drillers' cognition with the potential for  
12 training and formatively assessing cognitive skills in drilling.

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16 authors wish to thank the industrial supervisor, drilling consultants, drillers, assistant drillers,  
17 and all those who added to the project for their contribution. The authors also wish to thank  
18 Mark Wiggins for giving access to the program EXPERTise.

19 **Keywords:** Drilling; Cognitive Skills; Situation Awareness Measurement; Simulated  
20 Computer Tasks; Expertise

22

## INTRODUCTION

23 At 9.45pm on the 20<sup>th</sup> of April 2010, the assistant driller on the Deepwater Horizon drilling rig  
24 in the Gulf of Mexico, calls the supervisor to say that the sub-sea well that had previously been  
25 thought to be stable had now blown out. This meant that there was nothing to stop the hazardous  
26 hydrocarbons from travelling up the pipes that connected the well to the drilling rig. The driller  
27 was trying to regain control by activating the mechanical cutters on the sea bed to stop the  
28 hydrocarbons from travelling up to the rig floor (Chief Counsel's Report, 2011). Four minutes  
29 later, gas which had escaped from the well ignites, causing the first of two explosions on the  
30 rig (see Figure 1). This results in the death of 11 members of the crew, including both the driller  
31 and assistant driller, the rig's destruction and the worst oil spill in US history.



32

33 Figure 1. Deepwater Horizon drilling rig engulfed in flames as fireboats pour water onto the rig.  
34 Courtesy of U.S. Coastguard.

35 In the wake of the disaster, investigations reports identified the drill crew's situation awareness  
36 as contributing to the blowout (Report to the President, 2011; Chief Counsel's Report, 2011).  
37 For example, Roberts, Flin and Cleland (2015a) identified problems such as failing to monitor  
38 the well, misunderstanding of the well state and strong erroneous expectations that the well  
39 was stable. The disaster clearly illustrated that offshore oilfield drillers require high level SA,  
40 particularly during complex tasks such as well control (well control refers to using a hydrostatic  
41 column of drilling fluid to maintain control of the highly pressurised hydrocarbons and other  
42 fluids within the well bore; Roberts, Flin & Cleland, 2016). The skills, associated with Situation  
43 Awareness (SA), are increasingly important given advancements in drilling technology  
44 resulting in more reliance on cognition. SA is the state of knowing what is going on in the  
45 situation and using that understanding to anticipate how it will develop (Endsley, 1995a, b).

46 Recent research has identified the key cognitive skills that expert drillers use to develop and  
47 maintain SA of the well state and surrounding environment (Roberts, Flin & Cleland, 2015b).  
48 Further research into SA in drilling has been identified as vital for offshore safety (e.g. OESI  
49 report, 2016). Measurement and training techniques for operator cognition associated with SA  
50 and Decision Making (DM; e.g. in aviation, Endsley, 1990; Hauss & Eyferth, 2003), have had  
51 limited application in the oil and gas industry despite their potential value.  
52 Our focus for this study is to adapt an existing monitoring task to the new context of offshore  
53 drillers' cognition with the aim of supporting and training these vital skills. It is hoped that this  
54 will have ramifications for safety and performance in not only drilling but similar, high risk,  
55 high reliability domains which involve monitoring.

## 56 **What do drillers do?**

57 In essence, offshore oilfield drillers are responsible for the hazardous task of drilling into the  
58 sea bed, constructing a well bore to gain access to, and extract hydrocarbons (e.g. oil and gas).  
59 As hydrocarbons are highly pressurized with high temperatures, they need to be controlled  
60 using a hydrostatic column of drilling fluids. This complex task is referred to as well control.  
61 In conjunction with the drill crew, including the assistant driller, roughnecks, and tool pusher  
62 (supervisor), the driller controls the majority of the equipment, and subsequently the well, from  
63 the drill cabin.



64  
65 Figure 2. Driller monitors the drilling screens with the drill floor shown in the background.  
66 Courtesy of Maersk Drilling.

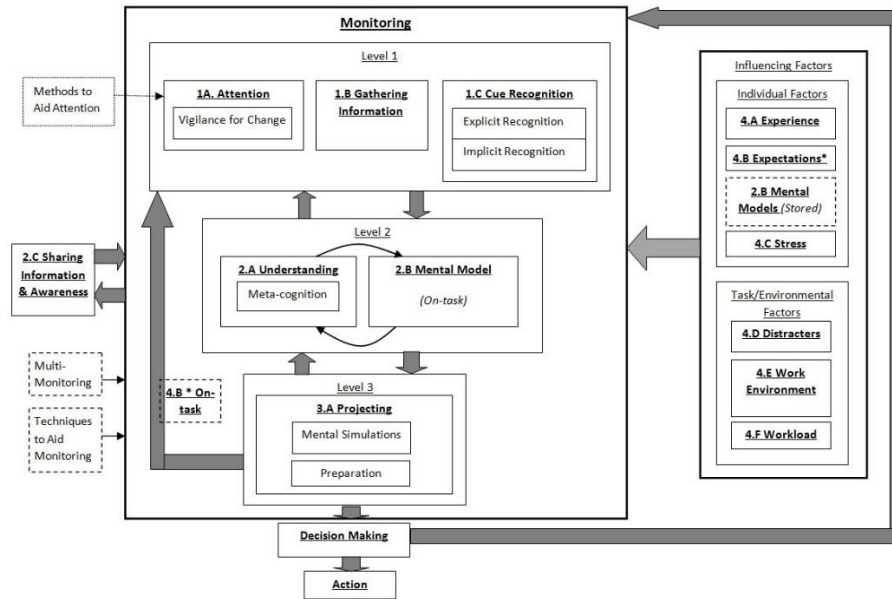
67 On newer generation drilling rigs/cyber rigs, the driller is required to monitor up to eight LCD  
68 screens (displaying information from equipment hundreds of feet below the drill deck), and  
69 multiple CCTV video feeds, navigating between different control panels, as well as keeping an  
70 eye out the window onto the drill floor (for the safety of the crew working with powerful and  
71 heavy equipment) as shown in Figure 2. Thus, the driller has to interact with increasingly  
72 complex technology, requiring high level cognitive skills, principally associated with SA, to  
73 monitor and interpret the significance of the information coming from the well and surrounding  
74 environment.

75 Whilst the drilling industry has recognized the complexity of the drillers' task and the value of  
76 using low fidelity simulations to aid training (Letbetter, 1975), it is only recently that higher  
77 fidelity simulators have been introduced. Material on cognitive skills is being incorporated into  
78 simulation training via teaching non-technical skills (IOGP, 2014a, b) and team training  
79 methods (e.g. tactical decision games, Crichton, Henderson, & Thorogood, 2004), however, to  
80 the authors' knowledge there are no simulation training or measurement tools specifically  
81 designed for drillers' cognitive skills associated with SA.

## 82 **Why do drillers need situation awareness?**

83 Maintaining SA is critical for safe and effective performance in the drilling industry, yet  
84 research is limited with regard to understanding the underlying cognitive skills. Problems with  
85 drillers' SA have been identified, such as difficulties with concentration and interpreting  
86 information (e.g. Sneddon et al., 2006). Roberts et al. (2015a) identified the key cognitive  
87 components required by drillers to develop and maintain SA including: attending to the drilling  
88 screens and recognizing a pattern from available cues, comprehending the significance of cues  
89 to the situation using mental models, expectations and experience, and projecting how the  
90 situation may develop. We used interview and observation data to produce the Drillers' SA  
91 model (see Figure 3), based upon Endsley's (1995a, b) model of SA, in which SA is described  
92 as a cognitive product of three hierarchical levels, cue recognition and perception (Level 1),  
93 comprehension (Level 2) and prediction (Level 3).

94



95

96 Figure 3. The Driller's Situation Awareness model illustrating the key cognitive components  
 97 and associated skills required for developing and maintaining SA for safe well control.

98 The model has been subsequently used to examine drillers' SA in reports of the Deepwater  
 99 Horizon blowout (Roberts, Flin & Cleland, 2015b) and in a cognitive task analysis of kick  
 100 detection (kick detection refers to monitoring changes in readings from the well which may  
 101 indicate that the pressure within the well may exceed the downward hydrostatic pressure,  
 102 potentially resulting in a well control situation; Roberts, Flin & Cleland, 2016). We aimed to  
 103 use the data and DSA model to inform the design of the simulation-based measurement task.

#### 104 **How to measure situation awareness?**

105 A range of methods have been developed to examine expert operator SA (e.g. Loft, Morrell &  
 106 Huff, 2013) including real time probes as they offer a direct and relatively objective  
 107 measurement in which the participant responds to questions during a simulation task (e.g.  
 108 Situation Present Assessment Method; Durso et al., 1998). An alternative but similar computer-  
 109 based method, Expert Intensive Skills Evaluation (EXPERTise; Loveday, Wiggins, Searle,  
 110 Festa & Schell, 2013), has been developed to examine aspects of SA expertise, including cue  
 111 utilisation and pattern recognition (e.g. power control operators, Loveday, Wiggins, Harris,  
 112 O'Hare & Smith, 2013). Similar to real time probes, participants monitor a domain specific  
 113 display (e.g. intensive care unit screen) and respond when they recognise key cues during  
 114 different tasks. In particular, two tasks appeared to be suitable to adapt to examine drillers' SA  
 115 and decision making. One task measured the ability to extract diagnostic cues from the

116 functional work environment (by clicking on an abnormal indicator) and other task measured  
117 the ability (accuracy) to discriminate the usefulness of available information via decision  
118 making.

## 119 **AIM**

120 Our aim was to develop a simulation-based monitoring task that examines drillers' cognitive  
121 skills, including cue recognition, comprehension and anticipation, and decision making.  
122 Firstly, we developed the prototype monitoring task with subject matter experts (Study 1) and  
123 then piloted it with a sample of drilling personnel to test its viability for examining drillers'  
124 cognitive skills (Study 2).

## 125 **STUDY 1 TASK DEVELOPMENT**

126 The authors of EXPERTise generously gave access to an early version (1.0) of their program  
127 to determine if it could be adapted but this proved impractical, so a new program was developed  
128 using the programming platform Delphi 6 (Borland Software Corporation, 2009) with an  
129 experienced programmer (JU). The interface was based on generic drilling parameter screen  
130 images supplied by the sponsoring company.

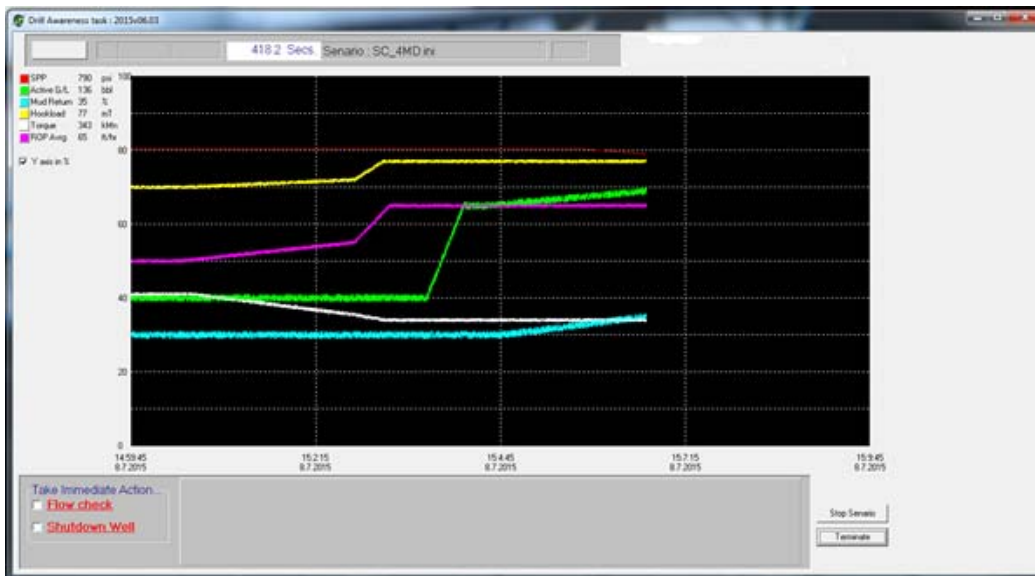
### 131 **Scenarios**

132 Four scenarios plus a practice trial were developed in conjunction with two drilling experts,  
133 both of whom had over 20 years' experience in drilling and were now drilling instructors. In  
134 addition, the sponsor's simulation training well control scenarios and well control incident  
135 reports, technical well control manuals, and a cognitive task analysis were used (Roberts et al.,  
136 2016). Situation awareness requirements (Endsley, 2016; what the participants would need to  
137 know) for key points of each scenario were identified with the drilling instructors. This  
138 included benchmarking data against which to examine the participants' performance (e.g.  
139 minimum cues that needed to be recognised to take the correct decision). The four scenarios  
140 developed were: drilling into a hard formation, drilling into a transition zone, drilling into a  
141 porous formation, and drilling into a hard formation whilst encountering equipment problems.  
142 Additional details on the scenarios, as well as example SA requirements, are in Appendix A.

143 **Task**

144 Participants monitored the simulated drilling parameter screen (See Figure 4 below). In  
145 drilling, cues are predominantly changes in the drilling parameters (e.g. increase in flow rate).  
146 Each line represents a drilling parameter/variable with the dips and peaks representing changes  
147 in that parameter. The reader will notice that these changes often occur in patterns across the  
148 parameters (i.e. one parameter effects another).

149



150

151 Figure 4. Screen shot of the completed scenario 4 running on the DSAT program as displayed  
152 to participants.

153 To indicate that they had recognised a cue, they clicked on the cue's location on the screen.  
154 This acted as a measure of cue recognition in the form of accuracy and latency (time taken to  
155 recognise cue since onset). Indicating recognition of a cue prompts a probe question with a  
156 multiple-choice response. A generic question, based on what the supervisor would typically  
157 ask the driller was used: "What is the current situation?" Four response options were presented,  
158 typically consisting of incorrect, partly correct, a correct level of understanding and the fourth  
159 indicated a higher level of understanding in the form of anticipation, depending on the scenario.  
160 Response scores consisted of: completely wrong = 0; recognising a cue = 1-3 (i.e. minimal  
161 awareness); comprehension of the situation = 4-6; and anticipating how the well state may  
162 progress = 7-9. The score within each category (e.g. 7-9) depends on the pre-determined scoring  
163 of the particular option included in the MCQ, varying with the level of complexity and subtlety



164 of the changes in the scenario (i.e. more complex scenarios required options to have a greater  
165 level of subtlety).

166 Similar to cue recognition, for each scenario there was a comprehension and anticipation  
167 minimum benchmark required needed to take the correct decision.

168 Two decision actions (based on the cognitive task analysis, Roberts et al., 2016) were included  
169 that could be selected at any time: either to flow check or shut in the well, both of which would  
170 terminate the scenario. The accuracy and latency of the choice of these two options was the  
171 performance measure of decision making.

## 172 **Pre-Pilot**

173 After development, these scenarios were piloted on five novices (four postgraduate psychology  
174 students and an individual with experience in the oil industry but not in drilling). We found  
175 that novice participants responded to obvious, sudden cues rather than gradual changes,  
176 generally selecting basic comprehension responses, and none took the correct decisions at the  
177 correct time. Two drilling instructors also completed the task identifying the cues, more  
178 frequently selecting the higher anticipation responses and making the correct decisions quickly  
179 (i.e. small latency responses). This pre-pilot illustrated that the task was functional in that both  
180 novices and experts understood what was required in terms of responses but that it still required  
181 a level of expertise to complete correctly (i.e. the task provided a basic differentiation between  
182 novice and expert).

## 183 **STUDY 2 PILOT STUDY**

184 The aim of study 2 was to pilot the prototype Drillers' Situation Awareness Task (DSAT) to  
185 test its preliminary viability for examining drillers' SA and decision making during four drilling  
186 scenarios.

## 187 **Method**

188 *Procedure.* The DSAT was piloted over a five-week period at two of the sponsor's training  
189 simulation facilities during training courses. Access was negotiated to a sample of drillers from  
190 the same company, attending level three and four, mandatory well control training courses  
191 (through personnel who had previously been involved in the project, i.e. 'snowballing')

192 recruitment (Marshall, 1996)). Ethical approval was granted by the University's Psychology  
193 Ethics Committee.

194 Before starting the task demographic information was gathered: information on age, current  
195 job position, years' in that position and time since last in the driller's chair. This was followed  
196 by the task instructions. At the beginning of each scenario, hand over information was given  
197 (this could later be manipulated for priming). For example, "*You are drilling ahead at 4,450ft.*  
198 *You are not expecting any problems with the formation or equipment*").

199 *Sample.*

200 Drillers completed the DSAT typically in classes of three or four individuals. The sample  
201 (n=14) consisted of three drillers, an assistant driller, two tool pushers, five drilling instructors  
202 and three offshore installation managers from drilling rigs. The age of the participants ranged  
203 between 25 and 55 years (25-35 n=4; 36-45 n=4; 46-55 n=4; 56-65 n=2). More than half of  
204 them had spent time in the driller's chair in the last year (57%) (last month n=5; last 6 months  
205 n= 1; last year n=2; 18 months n=1; last two years n= 1; five years + n=4). The participants  
206 had a mean of 15years' experience in the drilling industry (range 5-30 years, S.D = 8). The  
207 majority had more than 10 years' experience (79%).

208 *Data Analysis.* The responses were analysed using SPSS 21 (IBM, 2012). The analysis  
209 consisted of cue accuracy and latency, comprehension accuracy, and the decision selected and  
210 the time taken (see above).

## 211 **Results**

212 The participants completed the DSAT in an average of 24 minutes (range = 18 - 34 minutes).

213 *Cue Recognition.* The results (see Table 1) showed that on average the participants responded  
214 to three cues (mean= 2.6 SD=1.1) out of a possible 5.5 cues (where two cues (mean=2.1  
215 SD=0.5) were the minimum benchmark) within a mean of 20.9 seconds of the cue appearing  
216 (SD=30.5). This suggests that all participants were able to recognise and respond to sufficient  
217 cues to understand the developing situation.

218 Insert Table 1 approximately here

219 *Comprehension & Anticipation.* On average, the participants scored 17.9 (SD=6.9) out of a  
220 possible 43.8 for the comprehension and anticipation MCQs, where 9 was the minimum

221 benchmark, with a similar score reflected across the scenarios (see Table 1). This suggests that  
222 the participants formed a sufficient understanding and/or anticipated how the scenario may  
223 develop to make a decision.

224 There is a discrepancy between the level 2 and level 3 SA responses (see Table 1). Whilst  
225 participants could be recognising the cues and going directly to anticipation, it is more likely  
226 that they had already understood the situation before selecting the anticipatory MCQ response.

227 *Decision Making.* The results suggest that despite variations in SA, the majority of the  
228 participants made the correct decision for each scenarios (Table 1). In general, the participants  
229 took a decision within a minute of the correct decision point (i.e. benchmark time; see Task  
230 Outline), suggesting that they were responding relatively quickly.

## 231 **DISCUSSION**

232 Considering the importance of drillers' situation awareness and decision making for  
233 maintaining well control, and consequently the safety of not only the drill crew, but also the  
234 drilling rig, it is crucial to have tools that support their cognition. The prototype Drillers'  
235 Situation Awareness Task (DSAT) was developed as a tool for examining drillers' key  
236 cognitive skills associated with situation awareness. Preliminary evaluation suggests that it is  
237 viable as a tool for measuring drillers' cognition using performance measures, in which  
238 participants were able to identify cues (cue recognition accuracy and latency) to develop a  
239 sufficient understanding of the well control situation (comprehension and anticipation  
240 accuracy) so as to take the correct decision (decision making accuracy and latency). These  
241 measures related to Endsley's three key SA cognitive processes, and so those in the DSA  
242 model, of perception and cue recognition (level 1), comprehension and understanding (level 2)  
243 and anticipation (level 3) as well as subsequent decision making. Informal feedback from the  
244 participants supported ecological validity, commenting that task and scenarios seemed realistic  
245 and that the tool would be valuable for training both technical and cognitive skills, particularly  
246 in less experienced drillers or assistant drillers. With further development and evaluation, the  
247 DSAT has the potential to be used as part of training and formatively assessing cognitive skills  
248 in drilling, supporting safe performance (see below).

249 The DSAT adds to the limited existing methods for supporting and training cognition in drilling  
250 which are mainly team class-room based exercises (e.g. non-technical skills training, IOGP,  
251 2014a; tactical decision games, Crichton, Henderson & Thorogood, 2004). The DSAT has been

252 derived from several established techniques (EXPERTise (Loveday, Wiggins, Searle, et al.,  
253 2013) and real-time probes (e.g., Durso et al., 1998). It has the potential to be a relatively  
254 objective measure of SA compared to self-rating techniques (e.g. Taylor, 1990) or observer  
255 rating tools (e.g. Matthews & Beal, 2002), as well as being portable. It does not require  
256 participants to travel to a large, costly training facility.

257 The DSAT is a prototype tool and as such has a number of limitations, possible solutions  
258 through future research are outlined. The MCQ options could be assisting or biasing the  
259 participants' SA by priming their awareness or re-directing their attention (Salmon et al., 2009).  
260 To give a more accurate measure of awareness, the MCQ options could include both  
261 comprehension and anticipation, requiring participants to select as many as they think are  
262 correct.

263 Once further refined, a study could be conducted to evaluate the reliability, sensitivity and  
264 validity of the DSAT, such as was done for the SAGAT (e.g. Endsley & Garland, 2000) as well  
265 as developing benchmarking data for assessments and individualised feedback. This tool could  
266 be further refined to train specific drilling skills as outlined in the DSA model (e.g., significance  
267 of patterns of cues and possible anticipated outcomes), examine influencing factors (e.g.  
268 distractions or expectations) and system changes (e.g. shift patterns, interface design or  
269 procedural change). In addition to applying the DSAT to other monitoring positions within  
270 drilling (e.g. mud logger) and oil and gas (e.g. crane operator). The computer based method  
271 has the potential to be customised for to measure domain specific cognitive skills, such as in  
272 nuclear power control (e.g. control room operators) and health care (e.g. anaesthetists),  
273 particularly for training low frequency, high risk situations. There are also potential  
274 applications for the DSAT to be used in conjunction with crew resource management training,  
275 to evaluate effectiveness of training transferring desired behaviours during routine and  
276 abnormal operation's, or as assessment alternative to large simulations. For example, using the  
277 computer simulation in combination with behavioural markers within drilling (Roberts & Flin,  
278 2016). Employing novel solutions, such as our portable computerised simulation task, is  
279 essential for maintaining safe and effective operations in the current unpredictable, cost cutting  
280 climate.

281

## CONCLUSION

282 A prototype monitoring task simulating well control scenarios, Drillers' Situation Awareness  
283 Task (DSAT), was developed to examine drillers' key cognitive skills associated with situation  
284 awareness, such as cue recognition, comprehension and anticipation, and decision making.  
285 Preliminary results suggest that it is viable as a tool for examining drillers' cognition with the  
286 potential to be used as part of training and formatively assessing cognitive skills in drilling.

287

288

## KEY POINTS

- 289 • The prototype monitoring task simulating drilling scenarios, Drillers' Situation Awareness  
290 Task (DSAT), was developed as a tool for examining drillers' key cognitive skills  
291 associated with situation awareness and decision making.
- 292 • Preliminary evaluation suggest that it is viable as a tool for examining drillers' cognition.
- 293 • There is potential for the tool to be used as part of training and formatively assessing  
294 cognitive skills in drilling, as well as other monitoring positions in high risk industries  
295 supporting, safe performance.

296

297

## REFERENCES

- 298 Borland Software Corporation (2009). Delphi 6 programming platform. Available from [www.borland-](http://www.borland-delphi.software.informer.com)  
299 [delphi.software.informer.com](http://www.borland-delphi.software.informer.com)
- 300 Chief Counsel's Report. (2011). *Macondo; the Gulf Oil Disaster. National Commission on the*  
301 *Deepwater Horizon Oil Spill and Offshore Drilling*. US Government Printing, Washington, DC.
- 302 Crichton, M. T., Henderson, W. G., & Thorogood, J. L. (2004). Command skills for drilling and  
303 completion teams: Managing the unexpected. *In SPE Annual Technical Conference and Exhibition*.  
304 Houston, TX.
- 305 Durso, F.T., Hackworth, C.A., Truitt, T., Crutchfield, J., & Manning, C.A. (1998). Situation awareness  
306 as a predictor of performance in en route air traffic controllers. *Air Traffic Quarterly*, 6, 1–20.
- 307 Endsley, M. R. (1995a). Towards a theory of Situation Awareness in Dynamic Systems. *Human*  
308 *Factors*, 37, 32-64.
- 309 Endsley, M. R. (1995b). Measurement of Situation Awareness in Dynamic Systems. *Human Factors*,  
310 37, 65-84.

- 311 Endsley, M. R. (2016). *Designing for situation awareness: An approach to user-centered design*. CRC  
312 press.
- 313 Endsley, M. R., & Garland, D. J. (2000). (Eds) *Situation Awareness Analysis and Measurement*.  
314 Mahwah, NJ: Lawrence Erlbaum Associates.
- 315 Hauss, Y. & Eyferth, K. (2003). Securing future ATM-concepts' safety by measuring situation  
316 awareness in ATC. *Aerospace Science and Technology*, 7, 417-427.
- 317 IBM (2012). SPSS 21 for Windows. Accessed December 2012 from : [http://www-](http://www-01.ibm.com/software/analytics/spss/products/statistics/)  
318 [01.ibm.com/software/analytics/spss/products/statistics/](http://www-01.ibm.com/software/analytics/spss/products/statistics/)
- 319 IOGP (2014a). Crew Resource Management for Well Operations teams (Report 501). Available from :  
320 <http://www.iogp.org/publications/wells-committee/wocrm-report/>
- 321 IOGP (2014b). Guidelines for implementing Well Operations Crew Resource Management training  
322 (Report 502). Available from : <http://www.iogp.org/pubs/502.pdf>
- 323 Letbetter, S. C. (1975). Kick detection and well control training. In Proceedings of *SPE California*  
324 *Regional Meeting*. Ventura, California. doi:10.2118/5353-MS
- 325 Loft, S., Morrell, D. B., & Huf, S. (2013). Using the situation present assessment method to measure  
326 situation awareness in simulated submarine track management. *International Journal of Human*  
327 *Factors and Ergonomics*, 2(1), 33-48.
- 328 Loveday, T., Wiggins, M. W., Harris, J. M., O'Hare, D., & Smith, N. (2013). An objective approach to  
329 identifying diagnostic expertise among power system controllers. *Human Factors*, 55, 90-107.
- 330 Loveday, T., Wiggins, M. W., Searle, B. J., Festa, M., & Schell, D. (2013). The capability of static and  
331 dynamic features to distinguish competent from genuinely expert practitioners in pediatric diagnosis.  
332 *Human Factors*, 55, 125-137.
- 333 Matthews, M.D., & Beal, S. A. (2002). *Assessing Situation Awareness in Field Training Exercises*. U.S.  
334 *Army Research Institute for the Behavioural and Social Sciences*. Research Report 1795. West Point  
335 Military Academy.
- 336 OESI (2016). Human factors and ergonomics in offshore drilling and production : Implications for  
337 offshore safety. Available from : [http://oesi.tamu.edu/wp-](http://oesi.tamu.edu/wp-content/uploads/Human_Factors_in_Offshore_Oil_and_Gas_final_8_Dec%2016.pdf)  
338 [content/uploads/Human\\_Factors\\_in\\_Offshore\\_Oil\\_and\\_Gas\\_final\\_8\\_Dec%2016.pdf](http://oesi.tamu.edu/wp-content/uploads/Human_Factors_in_Offshore_Oil_and_Gas_final_8_Dec%2016.pdf)
- 339 Report to the President (2011). *National Commission on the Deepwater Horizon Oil Spill and Offshore*  
340 *Drilling*. Washington, DC: US Government Printing.
- 341 Roberts, R. C., & Flin, R. (2016). Behavioural Rating of Drillers' Cognitive Skills. Paper presented at  
342 *SPE International Conference on Health, Safety, Security, Environment, and Social Responsibility*.  
343 Oslo, Norway. Doi: 10.2118/179270-MS
- 344 Roberts, R. C., Flin, R. H., & Cleland, J. (2015a). Staying in the zone: Offshore drillers' situation  
345 awareness. *Human Factors*, 57, 573-590.

- 346 Roberts, R. C., Flin, R. H., & Cleland, J. (2015b). Everything was fine: An analysis of the drill crew's  
347 situation awareness on Deepwater Horizon. *Journal of Loss Prevention in the Process Industries*,  
348 38, 87-100.
- 349 Roberts, R., Flin, R., & Cleland, J. (2016). How to recognise a kick: A cognitive task analysis of drillers'  
350 situation awareness during well operations. *Journal of Loss Prevention in the Process Industries*,  
351 43, 503-513.
- 352 Salmon, P. M., Stanton, N. A., Walker, G. H., Jenkins, D., Ladva, D., Rafferty, L., & Young, M. (2009).  
353 Measuring situation awareness in complex systems: Comparison of measures study. *International*  
354 *Journal of Industrial Ergonomics*, 39, 490-500.
- 355 Sneddon, A., Mearns, K., & Flin, R. H. (2006). Safety and situation awareness in offshore crews.  
356 *Cognition, Technology and Work*, 8, 255–267.
- 357 Stanton, N. A., & Wilson, J. (2001). *Safety and Performance Enhancement in Drilling Operations by*  
358 *Human Factors Intervention (SPEDOHFI)*. HSE Report 264. London : HSE Books.
- 359 Taylor, R.M. (1990). Situational Awareness Rating Technique (SART): The development of a tool for  
360 aircrew systems design. *In Situational Awareness in Aerospace Operations (AGARD-CP-478) (3/1*  
361 *–3/17)*. Neuilly Sur Seine, France: NATO-AGARD.

362

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