Healthy Ecosystems Grants 2 Final Report

Project Title: Factoring in the Human in Offshore Operations: Forces for Scenario Planning
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I. PROJECT SUMMARY (from proposal)

Incident reviews of oil spill events (both large and small) suggest that human error is a contributor to 50% of well control incidents (primarily kicks). Therefore, any work that can reduce this contributor, benefits not only the safety of those on board these rigs but also society at large. “Human error”, or more accurately “systems error” is such a broad term that it fails to tease apart the possible causes, sources, moderators, inhibitors, etc. that affect it. Given the breadth of “human error” and its inherent lack of specificity, its inclusion in scenario development can be understated. The compounding effects of fatigue, owing the nature of the work and working conditions offshore, can further contribute to “human errors”. The objective of the proposed project is to systematically explore different scenarios to determine the fatigue-related variability in operator performances during simulated drilling operations. Both routine and kick-related drilling scenarios will be simulated, using a state of the art drilling simulator, that vary in the degree of task complexity, since these are possible current realities within the offshore drilling environments. Additionally, interviews will be conducted post study to explore methods of fatigue mitigation that are perceived to have a high likelihood of adoption. The proposed work provides a novel approach to quantifying human performance in scenario planning.
Characterizing cognitive performance across shifts, for realistic scenarios, gives planners the ability to create scenarios that are consistent with the capabilities of the people who carry them out, when they are to be carried out. With this information, spill prevention scenarios can more readily reflect the capabilities of workers. The proposed work is also innovative in that it will leverage a state of the art drilling simulator to generate four drilling scenarios for testing that have high ecological validity. Finally, the proposed work seeks to explore, through detailed psychophysiological assessments, the physiological impact of maintaining performance in the difference scenarios. This multidimensional

approach to determining variability in operator performance and identifying the sources of variability (whether sleep loss or task type or complexity) can provide scenario planners with additional information that may help in developing alternative strategies to mitigate or prevent errors. This holistic approach to understanding the fatigue that workers—and specifically drillers—experience offshore is an innovative approach in that it gives the scenario planners a greater level of clarity (that reduces uncertainty) regarding variables that predict, and thus can help prevent, "human error." The proposed study aims to capture critical interactions between the various aspects of the human (i.e., the driller) in optimal and sub-optimal states and the system (i.e., simulation of the oil rig scenarios), and better understand the framework within which potential mitigation strategies can be designed and sustained. Through these efforts, uncertainties in scenario planning can be addressed and, more importantly contained, that would in turn contribute towards reducing the frequency and severity of loss of containment incidents in offshore operations.

II. PROJECT SUMMARY (from final report)

Incident reviews of these types of events (both large and small) suggest that human error is a contributor to 50% of well control incidents (primarily kicks). Given the breadth of "human error" and its inherent lack of specificity, its inclusion in scenario development can be understated. The compounding effects of fatigue, owing the nature of the work and working conditions offshore, can further contribute to human errors. The objective of the project was to systematically explore different offshore drilling scenarios to determine the fatigue-related variability in operator performances during simulated drilling operations.

Both routine and kick-related tripping and drilling scenarios were simulated in a NOV drilling simulator, that varied in the degree of task complexity and criticality, since these are possible current realities within the offshore drilling environments. We conducted a two-study approach. The first study focused on the development and testing offshore scenarios with petroleum engineering students. Several lessons on scenario simulation and measurement parameters and logistics were learned. These were used to refine the scenarios for the second study. In the second study, we tested 12-hour shift-related and cognitive demand factors associated with the refined scenarios (from study 1) over the course of two work shifts (i.e. day shift and night shift). 12 male drillers, having at least 2 years of drilling experience. Measures of task performance and physiological responses (heart rate and heart rate variability) were obtained. While task performance did not differ between shifts and remained comparable across task complexity and criticality, physiological responses were significantly different. Specifically, night shifts were associated with greater physiological load (increased heart rate and decreased temporal heart rate variability).

Additionally, the effect of task complexity and criticality were observed largely in the night than the day shift. These results not only highlight the importance of quantifying operator physiological "cost" of maintaining performance, but also emphasize that the type of tasks performed may interact with shiftwork to increase risk of incidents during well control scenarios. To date, scenario planning have not considered the impact of cognitive loads due to the type of the tasks, and offshore worker fatigue is largely linked to sleep/shift issues. Our study provides fundamental evidence that cognitive stressors can further exacerbate fatigue and influence risks associated with offshore energy systems.

III. PROJECT RESULTS

Accomplishments

The objective of the project was to systematically explore different offshore drilling scenarios to determine the fatigue-related variability in operator performances during simulated complex and critical drilling operations. Both routine and kick-related tripping and drilling scenarios were simulated in a NOV drilling simulator at UT RAPID lab, that varied in the degree of task complexity and criticality, since these are possible current realities within the offshore drilling environments. We conducted a two-study approach. The first study focused on the development and testing offshore scenarios with 12 petroleum engineering students (who had 10+ hrs of simulator trainings) for a day-long offshore simulation study. Study measures included measures of task performance, physiological responses, and situation awareness. We found that complex and critical tasks were associated with lower performance and situation awareness, while physiological responses showed high variability during high-risk well control operations. Several lessons on scenario simulation and measurement parameters and logistics were learned. These were used to refine the scenarios for the second study.

In the second study, we tested 12-hour shift-related and cognitive demand factors associated with the refined scenarios (from study 1) over the course of two work shifts (i.e. day shift and night shift). 12 male drillers, having at least 2 years of drilling experience, participated in this 4-day study (i.e., familiarization, day shift, rest, night shift sessions). Measures of task performance, situation awareness, and physiological responses were obtained. While task performance did not differ between shifts and remained comparable across task complexity and criticality, physiological responses were significantly different. Specifically, night shifts were associated with greater physiological load (increased heart rate and decreased temporal heart rate variability). Additionally, the effect of task complexity and criticality were observed largely in the night than the day shift. Because only one shift was measured for each the day and the night shift, it is reasonable to expect that the increased physiological "cost" of maintaining performance might result in performance decrements when drillers accumulate sleep debt over multiple days. These results not only highlight the importance of quantifying operator physiological "cost" of maintaining performance, but also emphasize that the type of tasks performed may interact with shiftwork to increase risk of incidents during well control scenarios. To date, scenario planning has not considered the impact of cognitive loads due to the type of the tasks, and offshore worker fatigue is largely linked to sleep/shift issues. Our study provides fundamental evidence that cognitive stressors can further exacerbate fatigue and influence risks associated with offshore energy systems.

Implications

Human performance can be influenced by the various interplays of the attributes of person (expertise, stress reactivity, etc.), task (e.g., activities that challenge different modalities, codes, and stages) and environments (stochastic-uncertain, novel, that can affect decision making, situation awareness, or lead to stress or fatigue, etc.). Thus, it is critical that several dimensions of human capabilities and limitations, outside of task performance, be determined to establish human performance envelopes for various system/mission types. Findings from our project support that human performance ≠ task performance. By providing evidence that maintaining task performance is associated with increased physiological load, we demonstrated that human performance = ∫ (task performance + (neurophysiological) cost of maintaining performance). This is an important research finding in the offshore operator performance domain, since most studies target performance metrics.

Several new experimental scenarios and hypotheses have been generated based on the findings obtained that have strong implications for future work for the project team, other researchers, and have practical significance for broader societal impact:

- Quantification of human performance:
    - Human performance during complex and critical well control scenarios need to be assessed using some composite metric, consisting of both task performance and physiological responses.
    - Measuring eye track behavior during these testing would have elucidated to fatigue-related differences since task performance measures were speed/accuracy for tasks conducted over several minutes.
    - Understanding neural processes (through brain imaging) underlying cognitive strategies adopted in the different scenarios, during the day vs the night shifts, would have provided greater insights on how performances were maintained in the more complex, critical task conditions at night.
    - Thus, we plan to develop methods that help establish human performance envelopes (from Dynamic Adaptability Theory, Hancock & Warm, 1989) that would represent the limits within which operator performance is reliable and within system tolerance when considering 1) performance outcomes, 2) physiological zone of adaptability, and 3) subjective (or psychological) zone of adaptability.
- Based on driller's feedback, through interviews post experimentation, future research is warranted testing the effects of fatigue due to sleep/shift and cognitive demands on team cognition and decision making – testing the driller and aux/assistant driller.
- The experimental protocol needs to be extended to multiple day shiftwork testing, as it is hypothesized that performance decrements using task performance metrics will be seen as an effect of sleep debt.

- The results also highlight requirements of measurement systems that offshore safety systems need to consider when developing surveillance and/or mitigation methods to reduce fatigue risks of errors by operators.
- Based on the results, scenario planners can consider the timing, staffing, equipment, user interface, and supervision requirements when performance reliability is at its nadir and when it is at its vertex, within the framework of the existing organizational barriers for adoption and implementation.

Unexpected Results

We expected a larger effect of day versus night shift on performance outcomes - however, we did not find task performance measures to be sensitive to the day/night variables. Several factors could have contributed to this unexpected outcome:

- we only tested one day and one night shift, and performance decrements can be largely seen with accumulation of sleep debt over time (which was out of scope for the study)
- we manipulated scenarios that varied in complexity (number of items to be monitored during drilling and tripping) and criticality (task leading to kicks or loss of circulation, vs none). The NOV simulator may not have full drilling operations capabilities generally found in offshore operations and thus manipulating these scenarios may not have been completely representative of real drilling operations.
- Finally, we only manipulated tasks in isolation that one driller could perform, where as actual drilling operations are team operations, requiring real-time interactions from two, sometimes three, drillers simultaneously. Since our participants were experienced drillers, the cognitive demands may not have been representative of which drillers are used to in the field thereby making it easier for them to perform the tasks.

Project Relevance

The following audiences would be most interested in the results of this project:

- Researchers
- Educators
- For-Profit Private Sector
- Safety practitioners, safety regulatory agencies

The study provides insights on human performance as it relates to safer operations in offshore drilling environments. Several guidelines and recommendations can be informed:

- Development of better measurement systems for risk quantification due to fatigue sources commonly experienced by drillers in offshore work

- Design of fatigue management strategies: engineering (e.g., improved user interfaces to aid in decision making during highly-variable performance windows – night shifts, or during complex or critical tasks) and administrative (e.g., shift schedules, breaks, staffing, etc.)
- Inclusion of human performance considerations during scenario planning
- Training requirements: technical skill-based (developing expertise, improving decision making) and non- essential skills (crew resource management, etc.)
- Guidelines for technology solution vendors (interface design for the cyber chair)

Education and Training

Number of students, postdoctoral scholars, or educational components involved in the project:

- Undergraduate students: 2
- Graduate students: 6
- Postdoctoral scholars: 0
- Other educational components: 0

IV. DATA AND INFORMATION PRODUCTS

This project produced data and information products of the following types:

- Data

DATA

See attached Data Report.

Other Activities to Make Data Discoverable:

We are still in the process of writing a publication for this study. Once we have it drafted, we will append the data repository reference to it so that other researchers can have access to it.
Additionally, any future presentations or news articles/interviews from this study will have the information for data access for the audiences.

V. PUBLIC INTEREST AND COMMUNICATIONS

Most Unique or Innovative Aspect of the Project

The project provides a new approach to human performance in scenario planning. Prior efforts have used research to evaluate work shift durations and rotations. Despite evidence suggesting one shift/rotation process as superior to another when it comes to fatigue management, there is little flexibility in modifying these shift characteristics. Other psychosocial factors often dictate the acceptability of a shift's configuration. The 14-day to 21-day, two-shift tour has become typical for drilling operations in the Gulf of Mexico. Fatigue is expected, the question remains when and for whom the effects will be most prevalent. Characterizing cognitive performance across shifts, for realistic scenarios, gives planners the ability to create scenarios that are consistent with the capabilities of the people who carry them out, when they are to be carried out. With this information, spill prevention scenarios can more readily reflect the capabilities of workers. The work is also innovative in that it will leverage a state of the art drilling simulator to generate four drilling scenarios for testing that have high ecological validity. Finally, the project explored, through detailed psychophysiological assessments, the physiological impact of maintaining performance in the difference scenarios. This multidimensional approach to determining variability in operator performance and identifying the sources of variability (whether sleep loss or task type or complexity) can provide scenario planners with additional information that may help in developing alternative strategies to mitigate or prevent errors. Such psychophysiological assessments would otherwise be not feasible, nor safe, in volatile offshore environments.

Most Exciting or Surprising Thing Learned During the Project

Human performance can be influenced by the various interplays of the attributes of person (expertise, stress reactivity, etc.), task (e.g., activities that challenge different modalities, codes, and stages) and environments (stochastic-uncertain, novel, that can affect decision making, situation awareness, or lead to stress or fatigue, etc.). Thus, it is critical that several dimensions of human capabilities and limitations, outside of task performance, be determined to establish human performance envelopes for various system/mission types. Findings from our project support that human performance ≠ task performance. By providing evidence that maintaining task performance is associated with increased physiological load, we demonstrated that human performance = ∫ (task performance + (neurophysiological) cost of maintaining performance). This is an important research finding in the offshore operator performance domain, since most studies target simple speed/accuracy performance metrics.

Most Important Outcome or Benefit of Project

The study provides insights on human performance as it relates to safer operations in offshore drilling environments. Several guidelines and recommendations can be informed:

- development of better measurement systems for risk quantification due to fatigue sources commonly experienced by drillers in offshore work
- design of fatigue management strategies: engineering (e.g., improved user interfaces to aid in decision making during highly-variable performance windows – night shifts, or during complex or critical tasks) and administrative (e.g., shift schedules, breaks, staffing, etc.)
- inclusion of human performance considerations during scenario planning
- Training requirements: technical skill-based (developing expertise, improving decision making) and non- essential skills (crew resource management, etc.)
- Guidelines for technology solution vendors (interface design for the cyber chair)

Communications, Outreach, and Dissemination Activities of Project

N/A