Safer Offshore Energy Systems Grants 2
Final Report

Project Title: Virtual Reality Offshore Operations Training Infrastructure: Enhancing Expert Containment, Decision Making, and Risk Communications
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I. ORIGINAL PROJECT SUMMARY (from proposal)

One of the primary preventable causes of the Macondo blowout tragedy was a cascade of breakdowns in expert decision-making. Unfortunately, typical decision making training programs tend to be ineffective because offshore operations involve complex high-stakes technology-assisted decision making (e.g., classroom training is unrealistic; on the job training is dangerous). The exponential increase in offshore wells means a growing number of decision makers who rely on traditional training methods may be unprepared to manage preventable risks. Accordingly, this project seeks funding to improve process safety and training of expert decision making skills by developing a new world standard in advanced simulation-based offshore decision making assessment and training technologies. In addition, proposal leverages the experience of a multidisciplinary research team with special resources at the University of Oklahoma including:

a. The Nation's leading multimillion dollar Virtual Realty Drilling Simulator (VRDS)
b. Consultants at OU's National Institute for Risk & Resilience
c. Advanced technologies for automated eye-tracking and human performance analysis

If funded, over the next 24 months project team will use product lifecycle management approaches to develop and validate a working testbed prototype module as a foundation for the Offshore Virtual Reality Integrated Simulation of Kicks Training platform (i.e., Offshore Virtual RISKs Training platform). The central deliverable will be a broad set of well control skill training simulations and experimental validation studies, along with vulnerability modeling (e.g., multifactorial modeling of the relations between human factors, biases, and decision making). This proposal also involves establishment of a Technical Advisory Board (TAB), support for graduate student mentoring, and community outreach initiatives including the creation of an interactive educational website with videos and media designed to showcase how the VR technologies supported by this grant will help protect lives, livelihoods, and entire ecologies.

The primary objective of this project is to develop and test integrated scenarios to simulate Loss of Well Control (LWC) incidents on offshore operations. The scenarios will assess the influences of human factors such as effective communication, situation awareness, team working, decision making, reporting, and stress management. The primary deliverable of this project is to develop a validated stand-alone prototype Loss of Well Control (LWC) decision skills training module designed for use with OU's Virtual Realty Drilling Simulator. The broader societal impact of this project is to advance the safety culture by implementing assessment of non-technical skills on offshore operations. If the Oil and Gas industry can make a concerted effort to understand human factors and integrate its concepts into training and operations, significant value can be gained in terms of safety performance and, ultimately, improved efficiency. Oil and Gas operators and training organizations can benefit from project findings to strengthen human factors involvement into their well control training and programs. Furthermore, the data collected in this project can be used by regulatory agencies to implement new regulations to advance the safety culture in the oil and gas operations in the Outer Continental Shelf (OCS).

II. PROJECT SUMMARY (final report)

Offshore drilling operations are complex in nature and include crews consisting of a diverse workforce. An analysis of marine accidents indicates that almost 70% of accidents happen due to human related error; this speaks for the importance of training and evaluation of the crew. The oil-and-gas industry utilizes some of the most expensive simulation-based training, however, these trainings generally lack evaluation for human factors and non-technical skills. This project aimed to develop one of the world's first scientifically-validated immersive simulation-based decision assessment and training systems for offshore well-control. Toward this end, our interdisciplinary team tested and refined system performance by developing predictive and decision analytics using well-established methods from engineering, and cognitive & behavioral sciences. Specifically, our project created several immersive simulation scenarios designed to test and measure cognitive biases, decision vulnerabilities, and teaming processes involved in high-risk oil rig operations using multiple process tracing techniques (e.g., eye-tracking, content analysis, questionnaires, and surveys). Analyses of data collected through integrated decision and eye-tracking studies, predictive decision profiling, and novice-expert experimental comparisons, provided early evidences revealing potential causes of serious vulnerabilities (e.g., mechanistic misunderstandings that biased information search and risk communication), noticeable differences in information-acquisition patterns, and psychological states of minds between novice and experts during routine jobs. These initial findings may help designing an efficient decision vulnerability assessment and human factors training framework via our immersive simulation-based system.

III. PROJECT RESULTS

Accomplishments

The aftermath of the Deepwater Horizon incident in the Gulf of Mexico, revealed a dangerous inadequacy of common science and engineering tools to quantify and control future spills. Further reports of the spill found a deficiency of training framework for human factors and non-technical skills in the offshore drilling operations (U.S. Chemical Safety and Hazard Investigation Board, 2016). Despite the learnings from the Deepwater Horizon, the rate of Loss of Well Control (LWC) incidents in the Gulf of Mexico has remained unchanged and our vulnerability to a similar incident hasn't reduced.

This project was initiated to lay a foundation for a solution to complex human behavior in offshore environments, to explore the complex human factors related issues of offshore drilling operations, and to

get deeper insights into the situational awareness and non-technical skills of the workers for enhanced training infrastructure development.

The University of Oklahoma is home to one of the only Virtual Reality Drilling Simulators (VRDS) that is used for training, research, and study purposes. We proposed this project to contribute in the development of a training infrastructure by transforming the VRDS into one of the most advanced platforms for the integrated study of human factors in well control and loss of containment incidents in offshore operations.

We proposed that new approaches such as creation of novel virtual-reality-based offshore training infrastructure integrated with human factors can help improve process safety. Specifically, this proposal targeted the following sub-topics:

- New approaches, tools, or technologies to integrate human factors into scenario planning to decrease the frequency and severity of loss of containment incidents in offshore operations.
- New approaches, tools, or technologies that use scenario planning to support education and training activities to prevent incidents and improve preparedness for oil-spill containment and or fires and explosions on offshore installations, response, and harm mitigation.

To achieve the project objectives, we designed and conducted two distinct but related series of simulated studies to address the issues of human factors in oil and gas operations. The first series of studies (Experiment-I) were designed for the VRDS and the 2nd series of studies (Experiment-II) were designed for the DrillSim50 drilling simulator.

The VRDS is one of the world's most advanced offshore simulation research facilities. This state-of-the-art simulator facility, donated by the National Oilwell Varco (NOV) company, is housed and managed at the University of Oklahoma.

The DrillSim50 is a class of standard simulator used for the typical drilling training purpose in the industry. The simulator consists of a set of four physical components connected through a pc-based software and can be used to design a range of kick-detection and control scenarios for training. The scenarios designed for this project were team-based (Driller & Supervisor) scenarios; and involved a range of process tracing techniques for performance measurement and situational awareness of the participants. These techniques included eye-tracking, questionnaires, voice logs, pre- & post-test surveys, and a detailed decision-making battery. We have presented these techniques in our article "Situational Awareness Measurement in a Simulation-Based Training Framework for Offshore Well Control Operations" which is submitted for publication (Raza et all., 2018)

As a first step in the process, for both the Experiment-I and II, we developed and validated the scenarios. These scenarios were based on real-time incidents and operations to begin construction of mental decision-making models for both the novice and expert engineers. Furthermore, we designed and validated pre- and post-test surveys to adequately assess the knowledge and skills of the participants.
The pre-test accounted for the core elements for each simulation, such as the importance and behavior of flow-in and-out and drill pipe pressure during kicks (i.e., initial oil well incidences that are most predictive of blowouts). Initial knowledge of oil rig operation was assessed via the newly developed and

psychometrically validated oil-rig knowledge test created by taking twenty Subject Matter Expert selected questions and applying Item Response Theory (IRT)-based analyses to reduce the questionnaire to the best seven questions based on 1) difficulty and 2) discriminability. The participants were not given any detailed description about the actual scenarios. However, verbal information was provided to the participants before simulated scenarios were conducted (such as flow-in, flow-out, penetration rate, pit volume, gas percentage, torque, and drill pipe pressure).

For Experiment-I, while participants completed the simulated scenarios, cognitive processes were measured using eye-trackers and the recording of verbal responses to the displayed data of log readouts on a realistic rig dashboard. Each of the five scenarios for Experiment-I took approximately five minutes. The displays given to participants were validated by digitizing real rig parameter logs via Visual Basic.
The eye trackers were used to track the ocular activity (gaze) of the participants. Post-tests were then probed, via interviews, where each participant was queried for their rationale of actions and for further explanation of their experience during the simulation. Each participant was then given an online post-test to collect their decision-making competencies.

Very similar process tracing techniques were adopted for the Experiment-II on DrillSim50. However, there were distinctive differences. The wearable eye-tracking glasses were used for gaze measurements. This situational awareness was measured through checklists, and questionnaires in addition to the knowledge test surveys, pre- and post-test, and decision-making battery. A freeze technique, where the simulations were stopped temporarily, and all the displays were blanked, was used to assess the situational awareness of the participants using questionnaires. The task related knowledge of the participants was measured via online knowledge tests. These knowledge tests established the knowledge-base of the participants on basic drilling knowledge in two levels, similar to the industry practices for knowledge testing. The scenarios for Experiment-II elapsed an average of 25 minutes.

Human factors such as risk perception, teamwork, communication, risk literacy, stress management, fatigue, resilience, social intelligence were assessed in the online posttest battery. This online battery of surveys included different types of response methodology such as multiple choice, experience sharing, and scaled responses. In the current work, an exploratory factor analysis was done to explore how many correlational factors exist within the knowledge measurement.

Implications

Despite the restressed focus on human related errors in the post Macondo era, advancements in technology, and learnings from the Deepwater Horizon incident, our vulnerability to such a catastrophic incident has not reduced, because the necessary human related non-technical skills training and assessments are not part of the current training modules yet.

The voice-response analysis found difference between the semantic maps which reflected the differences between their cognitive experiences for experts and novices. While the experts generally expressed endorsing, the novices were mostly in the muddled and soliciting states. These important insights may help optimize the human factors and improve performance by predicting & proactively limiting the higher muddled states present at the rig site, while simultaneously generating a feedback for the candidate, too. In real time, such insights can be helpful that the muddled state is proportional to operational time; as a task time goes above the normal time (indicated by the expert completion time)

then an operator may be instructed to destress before continuing the operation or elicit extra help to complete the task. Additionally, maintaining the least degree of muddled state present at the rig site can be crucial during events with critical response time windows like stuck pipe or well control.

Furthermore, these insights could be helpful to improve the safety of the drilling operations as these maybe used to identify the possible human-factors related issues. For example, a follow-up protocol can be established in the field that triggers in situations where communication between co-workers indicates a muddled state, which indicate a confusion in the understanding of the situation by the co-worker. These could be used as a feedback system to resolve the uncertain situation and to improve the overall safety of the procedures in drilling and allied operations. Similar procedures can be adopted for written communication (e.g., emails).

The research also found some preliminary evidences that support the ideas that better kick mitigation performance needs knowledge of the field/current task and confidence calibration (e.g. knowing when to double check and not to assume always correct), that better task related knowledge and confidence are the strong predictors for kick control and mitigation trainings. Given the fact that very little was known for the effectiveness of simulation-based training in the oil & gas industry, these preliminary evidences may help design a better and efficient training framework for offshore drilling that incorporates the training and assessments of human factors and non-technical skills of the workers.

The usability data shows how perceptions can change pre-task to post-task. Using both subjective and objective measures can lead to improved training which in turn may lead to improved situation awareness and performance. All of which can be fine-tuned effectively in a simulation-based environment, further proving it to be an efficient and accessible training tool.

The research has proposed adjustments to the existing training frameworks. One strong future direction of this research is the testing and measurement of the effectiveness of these proposed training frameworks in the industry. In addition, due to the time and budgetary limitations, a few physiological parameters (e.g., mental stress, body fatigue & tiredness, long shift hours, noise levels, individual behaviors, and decision-making biases etc.) could not be included in this research. These lay a direction for future work.

The research utilized multiple process tracing techniques (e.g., content-analysis, eye-tracking, surveys, questionnaires) for enhanced situational awareness measurement in simulation-based learning environment. These concepts have never been used before in the oil and gas training frameworks and may lay a foundation for improved training of offshore workforce. As a result, the research widens the scope of process-tracing and situational-awareness techniques in safety-critical industries and provides important insights for the practitioners to design improved and enhanced modules for training modules.

The results are early evidences as a proof of concept for enhanced learning through simulation-based training in oil and gas drilling operations. The scenario-based learning and training for the oil and gas is sought after in the scientific community advancing research frontier in the oil and gas safer drilling operations, however, very little is known. Especially, eye-tracking techniques and content analysis have never been applied in the oil and gas industry before this project. The developed scenarios, experimental set-up, and results may provide a foundation to advance the scientific frontier in safety science of drilling operations.

The results are especially important for coastal communities as these provide a path towards better training of professionals to minimize the possibilities for the next large spill.

Unexpected Results

Very limited was known on this topic prior to this research project. Most of the findings are first-findings on the topic and therefore, cannot be compared with existing results as a benchmark or to be classified as unexpected. We hypothesized to find differences in understanding, information acquisition patterns, and situational awareness between the novices and experts. The early findings are generally in line with our research hypothesis. However, those differences need to be further explored to establish the cognitive basis for expert performance and decision-making.

Project Relevance

Researchers, educators, local government officials, federal government officials, and the for-profit private sector would be interested in the results of this project.

This research conducted for this project is multi-dimensional and cross-disciplinary, incorporating concepts and theories from petroleum engineering, systems engineering, human factors, psychology, decision science and culminates into a pioneering perspective on the topic in many aspects. The surveys and questionnaires specifically developed for this research have significant scholarship value for other fields as they investigate domain specific knowledge and how it interacts with risky decision-making (e.g., medicine, aviation, and similar high-risk situations). Similarly, the process tracing technologies like eye-tracking and voice logs, which are widely used in other similar high-risk industries, are utilized for the very first time in oil and gas simulation-based training and provide a foundation and opportunity for further research advancements.

A newly developed course entitled “human factors and simulation studies in petroleum engineering” evolved during this research. The class covered new topics not taught in petroleum engineering at the University of Oklahoma or other petroleum engineering programs before. The course includes topics on simulation-based scenario training and human factors analysis of incidents. The course attracted the students at the University of Oklahoma and should be of interest for the educators in larger engineering community.

The findings of this research are of special interest to the state and government officials as these will help evaluate the training requirements for offshore crews and legislations. The petroleum industry spends millions of dollars on the training of the workers. There has been a demand of inclusion of human-factors in the industrial training and evaluation and this research should be of special interest for the for-profit private sector. Some training agencies have already shown their interest in the outcomes of the research and the development of a training framework.

Education and Training

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

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

IV. DATA AND INFORMATION PRODUCTS

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

- Scholarly publications, reports or monographs, workshop summary or conference proceedings
- Websites or data portals

INFORMATION PRODUCTS

Citations for project publications, reports and monographs, and workshop and conference proceedings:

1) Naqvi, S., Raza, M., Ybarra, V., & Salehi, S. (2018). Using Content Analysis through Simulation-Base Training for Offshore Drilling Operations: Implications for Process Safety. Journal of Process Safety and Environmental Protection. Elsevier.
2) Saeed Salehi, Raj Kiran, Jiwon Jeon, Ziho Kang, E.T. Cokely, V. Ybarra. (2018). Developing a crossdisciplinary, scenario-based training approach integrated with eye tracking data collection to enhance situational awareness in offshore oil and gas operations. Journal of Loss Prevention in the Process Industries. Vol 56(PP 78-94)
3) Kang, Z., Jeon, J., Ybarra, V., Salehi., S., and Cokely, E. (2018). Situation awareness assessment through protocol and eye tracking analyses. In Proceedings of the 2018 Institute of Industrial and Systems Engineers (IISE) Annual Conference, May 19-22, Orlando, FL.
4) Kiran, R., Salehi, S., Jeon, J., & Kang, Z. (2018). Real-Time Eye-Tracking System to Evaluate and Enhance Situation Awareness and Process Safety in Drilling Operations. Paper presented at the IADC/SPE, Fort Worth, TX.
5) Salehi, S., Kiran, R., Jeon, J., Kang, Z., Teodoriu, C., & Cokely, E. (2018). Enhancing Situation Awareness and Process Safety in Offshore Drilling Operations: Applications of Eye-Tracking system. Paper presented at the Offshore Technology Conference, Houston TX.
6) Dadmohammadi, Y., Salehi, S., Kiran, R., Jeon, J., Kang, Z., Cokely, E. T., & Ybarra, V. (2017, October 9). Integrating Human Factors into Petroleum Engineering's Curriculum: Essential Training for Students. Society of Petroleum Engineers. doi:10.2118/187241-MS
7) Jeon, J. (2018). Analysis of eye tracking data to measure situational awareness in offshore drilling operations Situation awareness assessment through protocol and eye tracking analyses. M.S. thesis published at the University of Oklahoma, Norman, OK.
8) Ybarra, V., Raza, M., Ghazal, S., Salehi, S., & Cokely, E. (2019). Using Process Tracing and Simulated Scenarios to Validate Oil Well Operator Assessment. 38th International Conference on Ocean, Offshore & Arctic Engineering (OMAE), Glasgow, Scotland, UK June 14-19. (abstract accepted).
9) Salehi, S., Krian, R., Kang, Z., Cokely, E. & Raza, M. (2018). Using Virtual Simulator in Developing an Eye Tracking-Based Framework for Improving Safety in Offshore Operation. Safety. (Submitted, under revision)
10) Naqvi. S., Raza, M., Ybarra, V., Salehi, S. and Kang, Z. (2018, submitted). Process Tracing Through Eye-Tracking in Simulation Based Training to Enhance Expertise in Drilling Operations.
11) Raza, M. A., Cokely, T. E., Salehi, S. (2018). Reverse Cognitive Engineering of Human Performance: Designing a High-Fidelity, Reliable, and Effective Simulation Based Training Program for Oil & Gas Well-Control Operations (in Prep.)
12) Kang, Z., Graham, A., Jeon, J., Salehi., S., and Cokely, E. (2018, manuscript completed). Prediction of Situation Awareness using Visual Scanpaths through Machine Learning: Application in Deepwater Horizon Operation to enable timely intervention and effective communication. To be submitted to IEEE

Presentations:

1) Raza, M., Salehi, S., Ybarra, V., Jeon, J., Tobin, C., Naqvi, S., Bavadiya, V., & Cokely, E. (2018). Expert Decision Making in Offshore Blowout Control: Preliminary Evidences in Simulation Based Training. Poster presentation (accepted), Annual Meeting of Society of Judgement & Decision Making (SJDM), New Orleans, November 17-19
2) Kang, Z. (2017, Oct.) Eye movement data analytics. Presented at the 2nd Human Factors and Ergonomics Chapter Big Meeting at the University of Oklahoma.
3) Ybarra, V.T., Dadmohammadi, Y., Salehi, S., Kang, Z., Allan, J. N., Ramasubramanian, M., & Cokely, E. T. (2017) Integrating Human Factors into Engineering Curriculum: Essential Training for Students. Poster presented at Offshore Technology Conference 2017.
4) Ybarra, V.T., Dadmohammadi, Y., Salehi, S., Kang, Z., Allan, J. N., Ramasubramanian, M., & Cokely, E. T. (2017, April). Drilling down on cognitive processes: Using process tracing with oil well operators. Poster presented at European Group of Process Tracing Studies (EGPROC) 2017.

V. PUBLIC INTEREST

Most Unique or Innovative Aspect of the Project

The risk of catastrophic blowouts is immense in offshore operations. These risks can be mitigated through improving human decision-making performance and our understanding of the human-system interactions in complex environments. One of the most interesting parts of the project is the interdepartmental collaboration and educational connections that we've developed. To more rapidly advance human factors insights in the oil and gas industry, we have integrated methods and insights from allied professionals who have made advances in other complex task environments (e.g., aerospace, software usability, medicine). By borrowing from decision, cognitive, and behavioral sciences, as well as other allied Human Factors disciplines, we gained unique insights into the design and operational aspects relevant to petroleum engineering, building on existing insights of various subject matter expertise. As complex operations require optimization of sociotechnical performance (e.g., human-system collaboration), insights from industrial systems engineering based on eye tracking provide novel approaches for oil and gas operation research. To further understanding and examine human factors, we also drew on cognitive and psychological sciences, as well as behavioral decision sciences, to investigate issues related to mental state, risk evaluation, biases, teaming, culture, and decision making. The psychology team contributed via study design, psychometric test creation, and modeling of cognitive and expert decision processes, and the development of predictive decision analytics that can be used to assess vulnerabilities and the impact of training protocols.

In addition, this project suggested adjustments in the training framework that exists in the industry with a more comprehensive mix of subjective and objective simulation-based assessment systems, which we believe will be the key for future training and resilience development. While subjective assessment tools can quickly reveal potential vulnerability in operational decision-making, the root causes cannot be precisely quantified or tested using a single type of diagnostic tool within a single sample. Past research has heavily relied on either the questionnaire methodology or general surveys. However, this project utilized several strategies to assess the potential vulnerabilities existing in operation that were built upon previous efforts. These strategies (e.g., eye-tracking analysis, voice response analysis, psychometric skill testing, broad decision profile and bias surveys) provided a more integrated and objectively verifiable picture of underlying vulnerabilities and their causes. For example, the eye-tracking analysis provided quantifiable data to assess the situation awareness of the participants, while the voice response analysis provided the subjective measures to create the mental maps of the participant. In

addition, the questionnaire analysis provided insight about the overall understanding of participants of the scenarios. This assessment provided opportunity to quantify the participants' knowledge while the other two measures provide input about the execution proficiency of the participants.

Methods and new technologies, such as the use of uniform scenario protocols and randomized control trials, provide an opportunity to conduct comparative studies on the potential benefits and risks of various decision makers (e.g., precisely compare performance differences of experts and novices, and reverse engineering superior performance to improve and target training for highest yield). Preliminary data from a psychometric skill test (i.e., oil well risk knowledge test) further suggests that even brief tests can be robust and valid predictive indicators of major decision vulnerabilities, and their root causes (e.g., misunderstanding of essential operational facts that bias information search and communication). Real-time mapping of decision vulnerability through process tracing techniques (e.g., eye-tracking, content analysis) with the incorporation of psychometric tests of decision vulnerability in the high-fidelity simulation environment of offshore operations for enhanced situational awareness measurement during the well control situations is the most innovative aspect of this project. Previous research and methodology have been focused on the subjective quantification of participants' performance, revealing potential useful and efficient insights. Here, using measurement tools including data analytics and sophisticated algorithms, research on factors including objective voice response analysis has shown potential to quantify the participants' cognitive behavior objectively. The project revealed some of the first evidence on the causes and consequences of vulnerability of novices, when dealing with realistic high-stakes loss of well control incident indicators. For example, consider one scenario simulation wherein the real time flow-data from one of the well control incidents were displayed. In this task, the participants were asked to track the dynamic data and detect the abnormalities in real time. The response was recorded through eye-tracking and voice recording. The eye-tracking and decision-making data analysis suggested that on one hand the novices easily recognized the primary indicators of the incident yet on other hand they were generally unable to capture the secondary indicator which was critical to contain the incident. The results clearly reveal serious potential vulnerably and possible cause among novices who were nevertheless well-trained in theoretical classroom teaching including applied problem solving and extensive discussions on indicators of kick. Despite this well-designed and essential classroom training, the simulation-based system revealed that students were generally unable to replicate the learning when tested in realistic simulated crisis conditions.

Similarly, the insights gained through semantic maps, and information acquisition patterns of novice and experts provide interesting and unique opportunity to develop protocols for safety enhancements, training & assessment, and display systems.

The pursuit of tying the objective assessment measures with the subjective measures define another innovative aspect of this project. The most challenging part of any training framework is to obtain the results and substantiate those results using converging and trustworthy measures. Having this in mind, the team designed the scenarios in a way that the tests and validation of human factors parameters can be obtained simultaneously (e.g., decision quality triangulation). The experiments included the use of eye-tracking data which is corroborated with the voice-response data, decision data, and may be correlated with independent estimates of expert skill and knowledge. Moreover, in accord with cognitive theory, subjective reports suggest that challenging trainees at technical and non-technical counts simultaneously improves the trainee's understanding of human factors and of their own decision biases. It also provides participants with a more realistic experience upon which to integrate continuing knowledge and skill development during classroom education. Indeed, another analysis tool

implemented was a posttest questionnaire aimed at garnishing realistic feedback, previous experiences, assessing knowledge/skill acquisition, and perceived risk analysis during the task. This helped inform changes in participant performance before and after a single scenario, but also across several scenarios. In accord with best practices in expert performance, the ability to objectively estimate and provide feedback about decision performance tends to robustly improve decision quality and training outcomes.

Most Exciting or Surprising Thing Learned During the Project

The inclusion of cognitive response assessment in combination with the real-time technical problem was the critical part of experimental design. The response of oil and gas professionals and their interest in the projects shown during different conferences and exhibition was unexpected. Even, the single demonstration of the project at OTC 2017 caught the imagination of people from highly successful and reputed companies. Some of the companies' directors and chairmen invited the team members to their private exhibition to discuss the possibility of implementation of technologies in their own training infrastructure. The poster presentation at European Group of Process Tracing Studies in Judgment and Decision Making by the fellow researcher from the team gathered great interest about the project achievements so far. Some of the team members attended the Human Factors and Ergonomics Society Conference where the speech was made regarding the requirement of human factors research in oil and gas industry to defend against catastrophic events. This bolsters the project objectives to improve resiliency of profession in unforeseen events.

Besides that, there are several other exciting components that have been witnessed while execution of this project. The traditional well control training implements the theoretical teaching of the concepts and practice/assessment of defined problems. These problems give the trainees an idea about what they are looking for and how the end result will look like. For instance, the standard training set-up provides data about the parameters to calculate the required mud weight to control the well control problem and the participants must use the standard formulas to calculate it. However, this type of approach doesn't provide participants the opportunity to be proactively involved in any well control activity. The current project provides the participants an open ended problem statement, wherein the participants have to identify the critical aspect of the well controls and respond accordingly. Simultaneously, the cognitive responses of the participants are tracked quantitatively and qualitatively in the real-time which gives opportunity to assess the overall performance and human factors aspects of the participants. For instance, one of the scenarios included the real-time data display of the flow response during Deepwater Horizon operation. The participants were asked to track the data and detect the anomalies in the data in real-time. It was humbling experience to witness the eye-tracking data clearly showed that novices were not able to grasp the secondary indicators despite the classroom training. Similarly, the early evidences regarding the higher decision vulnerability by the over confident supervisors are important takeaways for future well control trainings. If the training is done in traditional set ups, the participants would have passed the test with flying colors as the primary indicator was completely grasped by the participants. This not only shows that the novices lacked on the appreciation of concepts in classroom environment, but their vulnerability is still quite high. Considering the results overall, it will not be wrong to say that given the current status of training framework, the ability to contain the near miss events still exists.

Most Important Outcome or Benefit of Project

The big picture goal of the project relies on laying the foundation for standardizing the training protocols which will affect all the stakeholders: regulatory bodies, academics, students and public. The current dominant industry practice of scenario-based training is vague in terms of a uniform format and inadequate competence markers. There are several contractor companies working in collaboration on a

project and each company has developed their own protocols and training formats. Considering the deep-rooted confidentiality issues among the companies, the non-sharing culture exacerbates the well control situation. This creates a need of standardized universal training which will address the human factors issue holistically. Having this in mind, the training module developed and incorporated in the OU curriculum as Human Factors in Oil and Gas course provided deeper insight about the ways to foster the improved understanding of the students. The case studies for human-factor related industrial accidents conducted as part of the course showed that the students' understanding of dominos effect translating during a course of action has improved. The course has been offered twice so far at OU and attracted a diverse population of undergraduate and graduate students.

Furthermore, this project provided the platform to quantify the professionals' decision-making skills. In each scenario, several critical points were identified which implicates the overall response. For instance, the identification and appreciation of crossover of flow-in and flow-out data provides the insight about the participants' primary understanding of the situation. The eye-tracking fixation count and duration exhibits the situation awareness of the participants at that very moment. Greater counts and higher duration represented significant situation awareness. The voice response corroborates the finding by justifying the confidence level and interpretation skills of the participants. Higher voice response score complemented with higher eye-tracking count and duration presents the trainer an opportunity to make a judgment about the overall cognitive response of the participant. In addition, questionnaire response further validates the inferences from the eye tracking analysis and voice response analysis by establishing the participants' understanding level. The most important outcome of the project is based on scenario execution data analysis. The clear difference between experts and novices indicate that novices were not fully aware of the situation while participating in the scenarios. The similar trends were reflected for voice response analysis and the eye-tracking analyses for novice and experts, where significant differences between the psychological states of mind, and information acquisitions patters were revealed. Hence, the scenario-based training can pinpoint the vulnerabilities in the participants and these can be resolved by addressing their conceptual understanding with validated measures. The knowledge testing confirms the hypothesis of higher ability corresponding to higher probability of getting the questions correct. This confirmation has encouraged to develop a larger set of questionnaires. This developed questionnaire will be reduced to smaller a set of questionnaires which will have predictive ability to quantify/measure different aspects of human factors of petroleum industry professionals.

Information Products Report

InfoProductType	DigitalResourceType	Title	FileName	Creators	PublicationYear	Publisher	RepositoryName	DOIorPersistentURL	DatasetReference
Scholarly Publication		1. Naqvi, S., Raza, M., Ybarra, V., & Salehi, S. (2018). Using Content Analysis through Simulation-Base Training for Offshore Drilling Operations: Implications for Process Safety. *Journal of Process Safety and Environmental Protection* . Elsevier.			2018				
		2. Saeed Salehi, Raj Kiran, Jiwon Jeon, Ziho Kang, E.T. Cokely, V. Ybarra. (2018). Developing a cross-disciplinary, scenario-based training approach integrated with eye tracking data collection to enhance situational awareness in offshore oil and gas operations. Journal of Loss Prevention in the Process Industries. Vol 56(PP 78-94)			2018				
		3. Kang, Z., Jeon, J., Ybarra, V., Salehi., S., and Cokely, E. (2018). Situation awareness assessment through protocol and eye tracking analyses. In Proceedings of the 2018 Institute of Industrial and Systems Engineers (IISE) Annual Conference, May 19-22, Orlando, FL.			2018				
		4. Kiran, R., Salehi, S., Jeon, J., & Kang, Z. (2018). Real-Time Eye-Tracking System to Evaluate and Enhance Situation Awareness and Process Safety in Drilling Operations. Paper presented at the IADC/SPE, Fort Worth, TX.			2018				
		5. Salehi, S., Kiran, R., Jeon, J., Kang, Z., Teodoriu, C., & Cokely, E. (2018). Enhancing Situation Awareness and Process Safety in Offshore Drilling Operations: Applications of Eye-Tracking system. Paper presented at the Offshore Technology Conference, Houston TX.			2018				
		6. Dadmohammadi, Y., Salehi, S., Kiran, R., Jeon, J., Kang, Z., Cokely, E. T., & Ybarra, V. (2017, October 9). Integrating Human Factors into Petroleum Engineering's Curriculum: Essential Training for Students. Society of Petroleum Engineers. doi:10.2118/187241-MS			2017				
		7. Jeon, J. (2018). Analysis of eye tracking data to measure situational awareness in offshore drilling operations Situation awareness assessment through protocol and eye tracking analyses. M.S. thesis published at the University of Oklahoma, Norman, OK.			2018				
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