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Title: Investigating Fatigue in Offshore Drilling: A Qualitative Data Analysis of Interviews

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Abstract: Offshore drilling in the oil and gas industry presents a fast-paced, hazardous work environment that can evoke states of fatigue or tiredness. Interviews were conducted with eleven offshore personnel working in the Gulf of Mexico to gain insight into the day-to-day experience and mitigation of fatigue among offshore workers in the industry. Qualitative data analysis of interviews, conducted using the software MAXQDA 12, resulted in an interview structure that provided an initial code set for categorizing, or coding, the interview transcript data. The coding process, enhanced using visualizations, revealed some themes that highlighted dimensions of fatigue, such as physical and cognitive fatigue, in addition to the more commonly recognized source of fatigue, namely shiftwork. The themes also emphasized potential fatigue mitigation strategies that were either organizational or individual-driven. These include improved coordination around shift work and sleeping arrangements, and contradictions involving a widespread perceived obligation to work past fatigue, despite being encouraged to report symptoms. This study provided fundamental insights on workers' perceptions of fatigue sources, reporting challenges, and adoption of personal mitigation strategies in an offshore rig in the Gulf of Mexico. Additionally, findings obtained here can immediately inform specific organizational opportunities for mitigating fatigue in offshore drilling operations.

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Cover Letter

March 8, 2018

To: Editor, *Journal of Process Safety and Environmental Protection*

Re: Cover Letter

Dear Editor,

I am submitting an original research paper, titled "**Investigating Fatigue in Offshore Drilling: A Qualitative Data Analysis of Interviews**" for consideration in the *Journal of Process Safety and Environmental Protection*.

The contents have not been submitted elsewhere and all authors have reviewed and agreed to the contents. We also declare no conflict of interest in relation to the work submitted.

Regards,

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Title: Investigating Fatigue in Offshore Drilling: A Qualitative Data Analysis of Interviews

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Abstract

Offshore drilling in the oil and gas industry presents a fast-paced, hazardous work environment that can evoke states of fatigue or tiredness. Interviews were conducted with eleven offshore personnel working in the Gulf of Mexico to gain insight into the day-to-day experience and mitigation of fatigue among offshore workers in the industry. Qualitative data analysis of interviews, conducted using the software MAXQDA 12, resulted in an interview structure that provided an initial code set for categorizing, or *coding,* the interview transcript data. The coding process, enhanced using visualizations, revealed some themes that highlighted dimensions of fatigue, such as physical and cognitive fatigue, in addition to the more commonly recognized source of fatigue, namely shiftwork. The themes also emphasized potential fatigue mitigation strategies that were either organizational or individual-driven. These include improved coordination around shift work and sleeping arrangements, and contradictions involving a widespread perceived obligation to work past fatigue, despite being encouraged to report symptoms. This study provided fundamental insights on workers' perceptions of fatigue sources, reporting challenges, and adoption of personal mitigation strategies in an offshore rig in the Gulf of Mexico. Additionally, findings obtained here can immediately inform specific organizational opportunities for mitigating fatigue in offshore drilling operations.

Keywords: Overexertion; shiftwork; physical; cognitive; perception; visualizations

1. Introduction

In multiple industries, fatigue experienced by workers is a risk that has resulted in economic losses estimated at $18 billion per year in the US, with these costs being associated with fatigue-related deaths, injuries, and disrupted productivity (Lerman et al., 2012). Fatigue is generally defined as a physiological state of reduced mental or physical performance capability resulting from sleep loss, circadian phase, and workload (ICAO, 2011). Long shifts and working hours coupled with intense physical and mental workload are particularly problematic for workers in the oil and gas extraction (OGE) industries (e.g., drilling and production). Indeed, fatigue has been associated with a majority of incidents associated with worker safety (Caruso, 2014) and the Chemical Safety Board (CSB) found fatigue as a likely contributing factor in both the BP Texas City Refinery Explosion and the Drilling Rig Explosion and Fire at the Macondo well (CSB, 2007; CSB, 2016). Due to insufficient accident reporting and investigation, exact injury rates associated with fatigue are difficult to estimate (Gordon, 1998). Nevertheless, according to one study, 78% of stakeholders in offshore OGE indicated that fatigue is the most critical perceived risk associated with incident causation (Chan, 2011). Given costs and risks associated with worker fatigue, both OGE industry and related federal agencies have determined that improving safety through fatigue mitigation is one of their top strategic research (to practice) priorities.

One of the challenges with regards to determining methods to decrease fatigue-related risks in OGE is that the current research and practices primarily focus on issues associated with sleep and shiftwork (Parkes, 1994; Rosa, 1995). However, fatigue is a comprehensive construct that includes other elements such as physical and cognitive fatigue (ICAO, 2011; Parkes, 2002; Sutherland and Cooper, 1996a; Sutherland and Cooper, 1996b). Given the physical and cognitive demands on OGE workers, it is imperative that any efforts to mitigate fatigue be comprehensive and address these issues. An additional challenge for developing fatigue mitigation methods for OGE workers is that little is known about the workers' perceptions and experience of fatigue and its management as most of these types of inquiries are conducted internally and not published. Knowledge regarding current fatigue mitigation methods (i.e.,

their effectiveness and barriers towards implementation) is necessary for identifying gaps and possible solutions. An important source of this knowledge is the workers themselves as they often have insights regarding the work environment that are not available to others (King et al., 2004; Merriam and Tisdell, 2016). The few studies that have focused on exploring fatigue among OGE workers mostly use structured surveys (Chen et al., 2001; Mehta et al., 2017). Although helpful, these types of studies do not provide opportunities for workers to express any issues not articulated in the survey itself. Further, current surveys and assessment results are challenging to interpret because they are not designed for the offshore domain. Indeed, Mehta et al. (2017) compared results from OGE workers using several fatigue measurement surveys and found remarkable contradictions in survey responses, indicating the low reliability of these responses and measures. Further, these assessments focus almost exclusively on fatigue related to sleep and shiftwork and thus are not comprehensive given there is little to nothing regarding cognitive and physical fatigue. This indicates that new measures for fatigue for OGE workers is warranted.

Before reliable and valid measures to capture fatigue levels in OGE workers can be created, it is necessary to investigate workers' perceived contributors to fatigue. Effective methods for obtaining this type of information are often qualitative, such as interviews and observations, as these methods provide more opportunity for unexpected insights and discovery (King et al., 2004). This paper describes such an effort and is based on interviews with OGE workers on an ultra-Deepwater drillship in the Gulf of Mexico.

The present study documents the findings from an investigation that was developed to gain further insight into the day-to-day experiences, perceived contributors to fatigue as well as causes, effects, and barriers in addressing and managing fatigue in offshore workers. In order to fully understand the data from the interviews, a grounded theory utilizing a qualitative data analysis software was used. In addition to traditional methods for analyzing the data, a novel approach to visualizing the codes and constructs from the analysis was performed. While used in quantitative studies (Caat et al., 2008) and still in the developing stages of mixed methods studies (Aigner et al., 2012; Knigge and Cope, 2006), visualization

holds strong promise for qualitative studies. When based off the interviews analyzed using grounded theory, visualizations can show connections between constructs that are not initially apparent. While still a relatively new approach, the use of visualizations can greatly aid the analysis of qualitative data by bringing a new view to the data.

2. Methods

Semi-structured interviews were conducted with eleven workers in an offshore drilling facility in the Gulf of Mexico (GOM). After completing the transcriptions of the interviews, a team of two coders performed qualitative data analysis to discover and take away the meaningful information.

2.1 Participants

Data collection took place on an offshore drillship in the GOM during the month of January, which has mild temperatures in the GOM. The drillship was a newer one and each crewmember shared a room that has a bathroom with one other person. Crew had workout room available to them on the ship along with entertainment rooms (TVs, pool, video games, etc.). The ship had internet capability (with limited bandwidth) and ship to shore phones available for communicating with family onshore.
All the 11 workers were male and their average years of experience in the industry were 11 (SD = 10) with an average age of 35 (SD = 8) years. The crew worked 28 days on the ship (a hitch), on 12-hour shifts. There were four possible shift times based on the start time: 12am, 6am, 12pm, and 6pm. Three of the workers had to do a "short change" associated with a swing shift during their hitch. A swing shift is when a worker changes shifts, from day shift to night shift or night shift to day shift. To prevent the workers from having to work 24 hours straight to accommodate this change in schedule, change schedules are implemented, namely short changes and long changes. The long and short changes that were observed during the data collection period were: 1) a complete 24-hr break period between the two shifts (day to night or vice versa (3 workers); and 2) a 6-hr work shift before and after a 6- and a 12-hr break, followed

by the swing shift (3 other workers). An example of a short change would be a worker originally working the 12pm to 12am shift, have the same worker come in at 6am (to start a 6am to 12pm shift). The goal of this practice is to have workers on a day shift when they get off their hitch so they will be more adjusted to a daytime schedule and safer when driving home. The types of jobs performed on the drill ship, worker's shift at the time of study, and whether they did a short change as part of their hitch are listed in Table 1.

Table 1. Workers' jobs, current shift, and whether they did a swing shift or short change during the data collection period.

Position	N	Shift during interview	Swing shift	Short change
Assistant Driller	2	noon - midnight	2	0
Crane Operator	1	noon - midnight	1	0
Drilling position operator	1	6am - 6pm	0	0
Floorhand	3	noon - midnight (2) midnight - noon (1)	3	3
Mechanic	1	6am - 6pm	1	1
Subsea Engineer	1	6am - 6pm	0	0
Tool Pusher	1	6am - 6pm	0	0

2.2 Protocol

Workers were introduced to the study during the morning safety meeting and through ship's medical personnel. Those interested approached the researchers or ship's staff regarding their interest and then they were scheduled for their interview session to occur either right before or after their work-shift for the day. After reviewing and signing the informed consent form, the workers were interviewed using a

semi-structured guide to identify their experiences, attitudes, and mitigation methods around fatigue (see Table 2 for a full listing of the interview questions). The study received approval from the Institutional Review Board (IRB) at authors' affiliated institution.

Table 2. Questions for semi-structured interview

- *How would you define fatigue?*
- *How do you manage your fatigue during ….?*
    - *during a single work day*
    - *during a week*
    - *during a 28 day work shift*
- *Do you worry about people's being fatigued on the ship affecting…*
    - *Your safety? Other's safety?*
    - *Your performance? Other's performance?*
- *Why do you think some people might work even when they know they are too tired to work?*
- *Are you ever asked to report your level of fatigue?*
    - *If so, how is this done? What do you think about being asked this?*
- *If you thought you were too tired to do your work, what would you do?*
- *What kind of fatigue do you typically experience?*
    - *during a single work day*
    - *during a week*
    - *during a 28 day work shift*

After completing the interview, the workers completed several standardized measures regarding fatigue, sleep, and stress and were fitted for sensors that would measure physiological measures throughout their workday. Results from the standardized measures and sensors are beyond the scope of this paper and preliminary findings are reported elsewhere (Mehta et al., 2017).

2.3 Analysis Tool: MAXQDA 12

The qualitative data analysis software, MAXQDA 12, was used for the analysis of the interview transcripts. The software provides a convenient means to organize and visualize findings through the process of coding the interview responses, as well as the ability to write down notes in the form of memos attached to the coded sections for retrospective viewing. "Coding" refers to the process of systemizing and organizing transcript data and from deductive and inductive perspectives.

2.3.1 Deductive Coding

Deductive coding is an analysis technique that develops an initial code list as a start point for the coding process (Miles, 2014). The initial code system was created from the interview questions, with seven parent codes and sub codes associated with each question and probing question, respectively. The coding process involved a team of two coders. Each coder developed the initial code set independently, synchronized their approach, and proceeded to code the eleven interviews separately with periodic checks to establish inter-coder reliability through discussions over data interpretations. This step laid the groundwork for the analysis and comparison of inductive, emerging codes later in the study.

2.3.2 Inductive Coding

The nature of the semi-structured interviews allowed participants the flexibility to express more thoughts than would fit into the fixed, deductive code set. These sentiments were logged via MAXQDA's memo system, and if repetition occurred, a new code would be formed. This process is known as *inductive coding,* and develops codes progressively as patterns or recurring ideas manifest during analysis, hence the iterative process of reexamining data. Inductive coding captures important local factors that would otherwise have been missed, if not included in the initial code scheme because of deductive coding (Miles, 2014). For example, "Sleep", while not included as an interview question, was mentioned by several interviewees in some regard. This and other emerging codes, or themes, were then added to the code system, resulting in the final set. The final set was used to model relationships, interpret findings, and synthesize patterns in the results that follow.

4.0 Results

Seven main codes emerged from the deductive coding process. These were fatigue definition, managing fatigue, effect of team's fatigue on safety, working past fatigue, reporting fatigue, "if too tired…", and types of fatigue. In addition, several sub codes and themes (or inductive codes) emerged from tangential interview responses for some of the main codes (Table 3). Together, these topics form a narrative that identify some opportunities for improving the working conditions contributing to driller fatigue.

Table 3: Results of Inductive and Deductive Code Development

Concepts/Codes	**Sub Codes**	**Inductive Codes / Themes**
Fatigue Definition	- Increased stress - Tiredness/ worn down	
Types of Fatigue		-Cognitive / Mental -Effects of Family -Physical
Managing Fatigue	- Single work day - Week - 28 day shift	-Organizationally imposed -Sleep -Short Change -Channel Fever -Self-initiated -Communicating with family -Exercise
Effect of Team's Fatigue on Safety	- Self - Others'	

4.1 Fatigue Definition

Fatigue was defined very generally by the workers as "tiredness" or, in two cases, "increased stress" (Figure 1). Notably, majority of the workers (7/11) acknowledge both mental and physical aspects of fatigue.

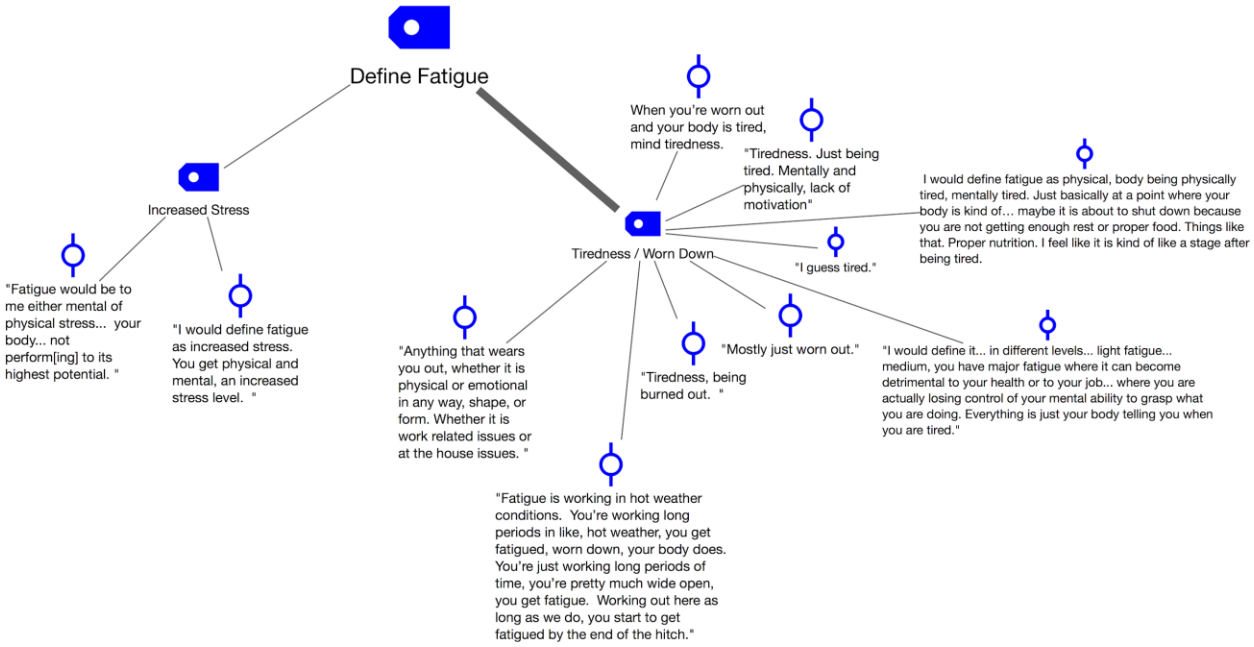

Figure 1: A visualization of fatigue responses. In these responses, the colored tags represent codes and sub codes while the circular nodes represent participants' direct quotes. Line thicknesses represents frequency of responses.

4.2 Types of Fatigue

The workers generally experienced mental or cognitive, physical, or a combination of both fatigue types.

4.2.1 Mental/Cognitive

Several workers (4/11) mentioned that they experience mental or cognitive fatigue more than physical fatigue. This was associated with the job characteristics or roles held by some workers. Those with managerial positions claimed effects of cognitive fatigue, citing their planning, organizing, and supervising of simultaneous activities as tiresome.

"*Cognitive mostly. Then, there are some days that are a little physical, but in my position, it is mainly cognitive, because you are supervising the guys below you making sure they are doing what they are supposed to. And then, planning jobs and stuff like that.*"

"*...sometimes if there are situations where… a lot of activity is happening like if we're doing arrival checks. When we come to a new location to drill, there's a whole set of checklists and more cognitive fatigue that happens...*"

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4.2.2 Family

Workers also expressed thoughts around missing family and associated this with sources of emotional stress and cognitive/mental fatigue. In several cases, talking with family has developed into healthy psychosocial behaviors that offer some relief for perceived mental fatigue, although the limited time for sleeping between shifts remains a challenge.

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"*Well, when you're trying to do a job, most of the time, you've got your family, what your wife's doing, what your kid's doing. Things you miss; birthdays and there's Christmas, New Year's, and we missed it all this year. That wears on your mind a lot so you're more mentally drained.*"

"*...like I said, you've got your family on your mind, you're ready to go home.*"

"*I just try to get as much sleep as possible. I usually try for about seven to eight hours, but sometimes… you stay up… talking to the family members back home, try to as little as possible with the work schedule we work. We get off at midnight, so they are all sleeping, so you can't speak with them there. You have to wake up a little earlier and you might get to call them, but you still want to get as much sleep as possible. It is kind of a double edged sword. You want to try and relive a little fatigue whether it is because you want to talk to your mom and dad/husband/wife/whatever. You have got to lose a little sleep so you can get up early.*"

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4.2.3 Physical

Several workers (4/11) mentioned that they experienced physical fatigue more than mental or cognitive fatigue. This may also be related to the job or role of the participant; those with labor-intensive duties performed claimed physical fatigue over mental fatigue. However, these sentiments were loosely associated with mental exhaustion as well.

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"*…let's say an AD (assistant driller) would have to deal with a driller or numbers... Fatigue on calculating things like that. From my job, I would say that mine would be more physical because I am doing a lot more hands on working, moving things. I think my job would be more physical fatigue that we experience rather than mental fatigue or something like that. I think their job would be maybe more mental. Constantly thinking trying to figure out if they have got the right dip, the right space out. Just different things.*"

"*What type of fatigue? I guess physical fatigue, usually just lack of good sleep for whatever reason, there's things on my mind or just things at home, whatever reason I can't sleep well, then you'll definitely be tired the next day. It's no different when you're at home.*"

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4.3 Reporting Fatigue

The majority (8/11) of workers commented that they are not asked or required to report their fatigue, despite being encouraged to report it at their own discretion. This shift of responsibility to the participant may reinforce the perceived obligation to work past fatigue and potentially withholding information about their fatigue.

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"*They tell us in the meetings, 'If you need to take a break or whatnot and just get some water and cool off' or whatever 'If you feel like you are going down or whatnot.'*"

"*No, nobody ever asks. Of course, when short change comes, you know everybody is tired… if we short change, a driller might only get a couple hours of sleep before he is waking up to go right back out, because he stayed up until two o'clock doing reports or whatever...*"

"*No. You are just expected to come to your shift and do your shift. That is all. Nothing like that you are going to report. Nothing like that!*"

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According to the workers, while vessel once required the reporting of rest and sleep via a "rest period sheet", at some point, this practice ceased.

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"*We used to report quite a few years ago, our sleep; there was a rest period sheet. That was quite a few years ago and that's not done anymore.*"

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4.4 Managing Fatigue

Workers generally mentioned sleeping, taking breaks, drinking water, physical exercise, and eating a good meal as means to manage fatigue. Balancing jobs between perceived physically or mentally demanding work was noted once as a means to offset the fatigue associated with either "types".

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"*... you can balance your jobs to make it to where you can do your physical and then, if you plan your cognitive where you can actually rest from the physical. After that, you sit down and do your paperwork and your computer work. Once you have rested up a little bit, you can get back in and do another physical job or something like that. Then, you have breaks. Stuff like that. Nine and three in a twelve hour*

hitch. It really helps to take a minute…."

Several constructs emerged in relation to managing fatigue, namely: Sleep, Short Change and Channel Fever. A visualization of these observed relationships among some responses is presented in Figure 2 and described below.

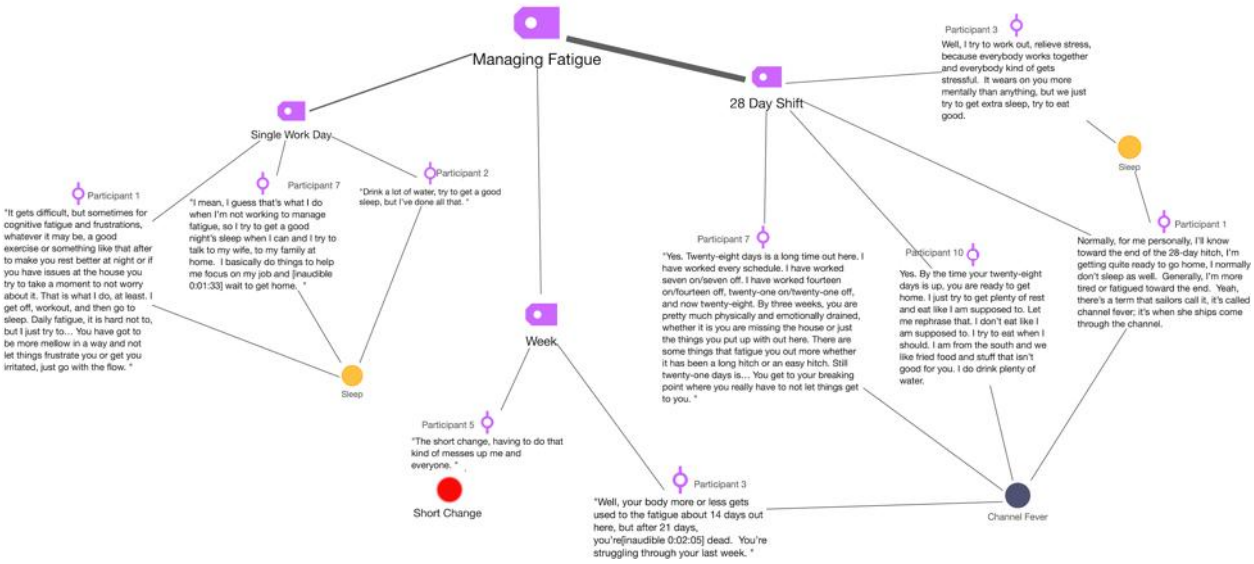

Figure 2: A visualization of some responses to the main code "Managing Fatigue", organized by sub-codes and presented as their relation to emerging themes of "Channel Fever", "Sleep", and "Short Change".

4.4.1 Sleep

Overall, the workers commented that sleep provides the best means to combat fatigue. However, all workers mentioned difficulties in their sleep habits. One immediate opportunity for improving these situations is demonstrated in disturbances between sleep shifts.

"*...good sleep… is very hard on night shifts because people walk off and they just start making noise and don't particularly care if everybody else is woken up... it turns out they mixed up day shift and night shift.*

You have night shift down on one side with a guy on the opposite shift, 12 to 12. Every time I sleep, he comes in…"

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4.4.2 Short Change

All but one worker mentioned short change as a contributor to fatigue. Short change was perceived to have a significant impact on sleep as personnel are required to work extra hours so as to alter from the 12-hour day shift to the 12-hour night shift. This reversal in schedule disrupts the sleep cycle and can take up to three days to recover. One worker commented that this was the most dangerous time for work.

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"*...take for instance crew change dates, we don't plan any major activities for those days because those are our most dangerous days, when you are short changing or something like that. Mostly, in the technical department anyway, we don't try to do any major things planned during that time because of that.*"

"*I talk to everybody. Everybody gets up like that. Everybody on the crew, like, 'Did you sleep good last night?' 'No. No.' It takes a few days. It probably takes two or three days to get back right.*"
"*Your body is used to sleeping those times and then you can't sleep during the short change. You get no sleep and you are back at work. You go back to bed and you wake up. You think about a good night's sleep and you only get two or three hours sleep. You wake up and you have only been asleep two hours.*"

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4.4.3 Channel Fever

Channel fever references a sense of malaise associated with the end of the 28 day shift as the vessel makes its way into the channel. Several workers emphasized mental or physical exhaustion after the 21-day mark (Figure 2).

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"... I normally don't sleep as well. Generally, I'm more tired or fatigued toward the end. Yeah, there's a term that sailors call it, it's called channel fever; it's when she ships come through the channel."

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4.5 "If Too Tired…"

This code sought to understand a worker's course of action in the event that they find themselves too tired to work. Majority (8/11) preferred to communicate their fatigue to a supervisor or teammate if they found themselves in these situations. The workers responded that they were asked to report fatigue in the event they feel too tired to work. However, this contradicts previous findings that the majority of workers also feel obligated to work past fatigue and are not asked to report fatigue. This contradiction is demonstrated in the following quotes.

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"*We have pretty good supervisors and technical superintendent and stuff like that. You can pretty well tell them, "Hey, I am sick. It has really got me down" or something like that. They will adapt to that or cover for you or help you out... You can depend on your boss. Like I said, our technical team is pretty good about grouping together and helping each other out, because you have got the mechanic and then you have got hydraulics. They will drop that and help out the mechanic and while whatever is happening there…and we will jump up and help them wherever they need help if one of them are sick. It is a team effort. But, if you haven't got that team and you are working against each other, it would be difficult.*"

"*I would let it be known that 'I am getting a little sleepy over here' or something, but there is a coffee pot in the back… I would say it would be frowned upon if you went to someone and said, 'Hey, can I go take a nap?' or something. You are expected to do your job out here. There are only two people; you and the guy sleeping. So, if you are not doing it, he is sleeping. We try to manage it the best we can.*"

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4.6 Effect of Team's Fatigue on Safety

After discussing fatigue management techniques, workers were asked to comment on the effect of the group's fatigue on safety. While the workers acknowledged that fatigue will impact performance they insisted that looking after each other is essential for safe operations. However, three workers mentioned difficulties in understanding the extent of fatigue acting on themselves and others.

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"*It is kind of hard to see if somebody is tired. I don't know how you could see fatigue. Unless somebody is like, "I am tired today." If somebody came up to me and said, "Hey, I am really, really tired." I guess...*"

"*It is not that. I just don't think of it. You keep occupied and focused on your own jobs. Obviously, if you see somebody struggling, you see they are getting the shape bent out of it or something like that, you see them physically struggling…they can't handle their stuff.*"

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4.7 Working Past Fatigue

A majority of the workers (9/11) described a notion of feeling obligated to work past the point of fatigue due to job or financial pressure, or for fear of seeming weak. One participant insisted on this being the typical attitude.

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"*Everybody's out here basically just to make money. Nobody's using any sick days, rainout days; it's all – it's work or not work.*"

"*…people want to perform at the highest level. They don't want anyone thinking they are a weak link or what not. That is probably why they work even if they are fatigued.*"

"*They don't want the higher-ups thinking that they're slacking or something.*"

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5. Discussion

Interviews with eleven offshore platform crew in the Gulf of Mexico were conducted to investigate worker fatigue causes and consequences and its safety implications. The results from the qualitative data analysis provide insight that inform opportunities for mitigating fatigue.

5.1 Defining Fatigue

Worker fatigue has been associated with several high-profile incidents in OGE, such as the BP Texas City Explosion (CSB, 2007). Therefore, it is imperative to understand, and subsequently to assess, this critical risk factor. However, operationalizing fatigue in OGE sector is a challenging task. In this sector, research and practice pertaining to assessing and mitigating fatigue have largely focused on performance declines due to sleep deprivation and shift length and duration (Parkes, 1994; Rosa, 1995). Indeed, the Fatigue Risk Management System Recommended Practice 755 (API, 2010), which were developed in response to fatigue-related risks that led to the BP Texas City Explosion, focused on hours of service guidelines associated with varying shift lengths and durations.

In line with previous findings, shiftwork and sleep quality were noted to be top reasons for workers' fatigue levels in this study, which corroborates with the industry's efforts on addressing sleep and shiftwork to mitigate fatigue. The workers noted that a 28-day offshore deployment was too long to safely continue work on the rig. The level of exhaustion was felt the most at around the 21-day mark. This aligns with the findings from the two Chemical Safety Board Investigation reports pertaining to the BP Texas City and Macondo incidents (CSB, 2007; CSB, 2016). Of importance is the theme of short change that emerged from the interview analysis, which workers reported as being a major contributor to sleep quality and fatigue. Short changes are adaptations strategies to mitigate adverse effects of swing shifts. In

swing shifts, workers rotate midway through their offshore deployment (Parkes, 2012; Parkes, et al., 1997; Ross, 2009). However, associated circadian re-adaptation typically takes 3-6 days (Bjorvatn et al., 1998; Lauridsen and Tønnesen, 1990; Parkes, 2012; Parkes, et al., 1997) and studies have reported that adapting to swing shifts are more challenging than adaptation to day shift and/or night shift (Saksvik et al., 2011). The two different short changes observed during the data collection was a complete 24-hr break period between the two shifts (day to night or vice versa; offered to 3 workers) or a 6-hr work shift before and after a 6- and a 12-hr break, followed by the swing shift (offered to 3 other workers). Workers, in general, reported that short change was associated with increased fatigue and that they ensured that major tasks were not scheduled around those days to minimize impact on safety and productivity.

Fatigue is a multifactorial occupational hazard, which can be influenced not only by sleep and shift issues, but also the intensity and duration of the work exposure (Mehta, 2017; Mehta and Agnew, 2012). This was evident by the responses by most the workers interviewed in this study (Figure 1). There was strong consensus that fatigue meant "tiredness", however, the workers recognized that the definition of fatigue (cognitive/mental or physical) varied based on one's work profile and responsibilities. This is a key finding, since it provides a modification to the existing understanding of the sources of fatigue in OGE operations, which to date have omitted the evaluation of the work in determining fatigue levels. In addition to sources that are work-related, the workers also identified emotional psychological factors, such as missing family members during the deployment, contributing to perceptions of fatigue. While some studies have reported work-life balance as psychosocial stressors in offshore OGE work (Chen et al., 2009; Parkes, 2002; Sutherland and Cooper, 1996a; Sutherland and Cooper, 1996b), this is the first investigation that links emotional stress, due to work-family conflicts, to worker fatigue perceptions and thus may have implications for potential fatigue mitigation strategies that are currently not investigated.

5.2 Reporting and Monitoring Fatigue

Several research studies have documented the use of surveys and sleep diaries and objective

measurements, such as actigraphy, to assess fatigue (Mehta et al., 2017; Saksvik et al., 2011). However, there is no evidence of translation of these methods to safety practices in OGE operations. In the present study, workers recollected the use of a "rest period sheet" to document sleep quality and recovery from shift work, however the practice was discontinued for undisclosed reasons. Also, ten out of the eleven workers mentioned that they are not asked to report any fatigue symptoms. Some worker sentiments have already been presented that suggest the organization's resilience, or capacity to adapt in the event of a worker's exhaustion, can compensate for the temporary loss of a team member, which would combat the perceived sense of being the "weak link" that otherwise discourages this behavior. After all, some workers felt as if there is no real solution in the event they are too fatigued to work, and thus they withhold this information. If a simple fatigue assessment tool was utilized, management's implementation of such a mechanism would shift the weight of that decision away from the operators and demonstrate that possible solutions may be presented if fatigue can be reliably assessed.

5.3 Managing Fatigue

5.3.1 Organization-led fatigue management strategies

In general, the most common fatigue management strategy identified by the workers was getting quality sleep. Most the workers recognized the importance of sleep in recovery post work and rest between shifts. To reduce or mitigate the effects of fatigue during the circadian adaptation, and to potentially improve performance during work, brief naps during shift hours have found to be effective (Caldwell et al., 2008; Pallesen et al., 2010). While recognizing this to be an operational constraint in offshore work, designated rest spaces that minimizes environmental noise and light may serve as an alternative. Finally, to reduce the adverse effects of swing shifts on worker health and performance, effective short change strategies need to be researched in robust experiments before they can be utilized as management strategies in offshore environments. Further studies should explore the implications of company policies or resource constraints that may limit the ability to alter shift lengths, opportunities for

sleep, or the amount of personnel on-hand.

In addition to circadian disruption due to shift work, most workers identified that their sleep quality was affected by environmental factors (i.e., ambient noise and shared cabins). Workers in the present study shared cabins with those of a different shift. While this shared strategy enables effective utilization of space, it was identified as a major contributor to disruptive sleep. The industry could improve coordination around shift changes and sleeping arrangements, as well as preserve the quality of sleep for their crew. Steps can be taken to ensure that the sleeping quarters of night and day shift workers are separate and isolated, preventing disturbances from outside sounds and interruptions. Shared accommodation has shown to exacerbate perceptions of extended work schedules and isolated setting in offshore petroleum industry (Shrimpton and Storey, 2001) and in offshore installations (Chen et al., 2001).

As argued earlier, fatigue can be caused by several sources, the task-at-hand itself could contribute significantly to worker fatigue and associated performance decrements. Studies have reliably shown that when individuals are tasked heavily with both physical and cognitive stressors, they fatigue at a quicker pace (Marcora et al., 2009; Mehta and Agnew, 2012; Mehta and Parasuraman, 2014). At the same time, a task consisting of either physical or cognitive stressors, performed for a long duration, can fatigue individuals physically and mentally, due to intense workload or boredom. It is possible that job rotation, particularly rotating between physical and cognitive work, may serve as a plausible solution (Kuijer et al., 2005). This recommendation considers the option that operators tasked with intensive physical tasks can be relieved of the demands in favor of some other role that requires cognitive capacity. Conversely, perhaps those tasked with mentally draining tasks can be rotated to physical tasks, providing a change that combats the mental drain associated with extended periods of attentiveness. However, constraints in job training, roles, and responsibilities in dynamic offshore environments can limit this. Thus, there is a critical need to design engineering controls, such as improved display designs, automation, and power assistance etc., to reduce cognitive and physical demands imposed by the tasks.

5.3.2 Individual-led fatigue management strategies

An important finding of the study was that interview responses alluded to the fact that the greater burden of managing fatigue fell on the workers themselves. In addition to identifying changes that management could make to alleviate some of the fatigue risks, such as shared cabin arrangements and rotating between physical and cognitive work, the workers identified personal strategies they used to manage their fatigue levels. These included taking breaks, drinking water, being physically active, and eating healthy. Additionally, when fatigued, the workers emphasized that lack of alternatives led them to continue working despite recognizing that their cognitive and physical capabilities are being compromised. However, they identified quality sleep as the most effective countermeasure to fatigue. The workers also underscored the importance of looking out for their coworkers for signs of fatigue; however some raised concerns that it was challenging to assess fatigue, particularly by observing others. Overt fatigue indicators, such as verbalizing that one is tired, could not be relied upon due to both the workers' and the organization's attitudes on perceptions of strengths versus weaknesses.

5.4 Study Strengths and Limitations

This study has several strengths and limitations that need to be noted. One of the major strengths of this study is that very few studies have focused on fatigue investigations in offshore platforms in the Gulf of Mexico. Most the existing studies are from work platforms in the North Sea and Australia, with workers from different cultures and in different regulatory environments than the present study. Thus, findings here are novel and relevant to offshore safety in the Gulf of Mexico. Second, this is the first fatigue perception study that focuses on understanding, from a worker's perspective, the sources of fatigue, and current fatigue assessment and management practices in the Gulf of Mexico. Third, the visualizations present a unique look at the qualitative data analysis process as connections and relationships between codes are brought to the forefront. The use of visualizations helps understanding in areas such as fatigue management strategies and how participants defined fatigue through the exposition

of connected codes and descriptive categories. This novel visualization approach will inform future studies on creating and testing empirical methods for further collection of information pertaining to fatigue in the offshore work environment. One major limitation of this study is that perceptions of workers were obtained from one oil rig platform, which may not be generalizable to other companies or offshore applications. While using stratified samples from multiple sites is desirable, this may be challenging due to issues related to access to such hazardous environments. Further, this first effort in documenting worker perceptions on fatigue in the Gulf of Mexico region will provide the foundation for the future studies targeting this topic in this region of the world. Second, the sample size is relatively small. Given that the aim of this investigation was on documenting research and practice challenges associated with offshore worker fatigue, the interview questions (while semi-structured) were focused and targeted, thereby allowing for an in-depth investigation of fatigue within this small sample. In addition, even with such small sample, the findings reached a point of saturation. Finally, while participants were assured anonymity, most qualitative data collection methods (including this study) are prone to Hawthorne Effect where the nature and depth of the responses may become constrained due to fear of breach of anonymity.

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