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ORIGINAL RESEARCH

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

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OCCUPATIONAL APPLICATIONS Interviews were conducted with offshore operators in the oil and gas industry in order to gain insight into their experiences of fatigue and associated mitigation strategies. These interviews indicated that effective mitigation methods and techniques originate from both the organization and the worker. Current industry practices and potential recommendations to manage worker fatigue in the oil and gas operations are provided. These practices and recommendations include improving sleep quality through effective sleep-cabin arrangements, reducing physical and cognitive workload through improved work/tool/environment designs, and facilitating periodic fatigue monitoring.

TECHNICAL ABSTRACT ***Background:*** Offshore drilling in the oil and gas industry presents a fast-paced, hazardous work environment that can evoke states of fatigue or tiredness. ***Purpose:*** To gain insight into the day-to-day experience and mitigation of fatigue among workers in this industry. ***Methods:*** Interviews were conducted with eleven offshore personnel working on an offshore rig in the Gulf of Mexico. Qualitative data analysis of interview transcripts provided an initial code set for categorizing the data. ***Results:*** The coding process, enhanced using visualizations, revealed some themes that highlighted dimensions of fatigue, such as physical and cognitive aspects, in addition to the more commonly recognized source of fatigue, namely shiftwork. These themes also emphasized potential fatigue mitigation strategies that were either organizationally or individually driven. Such strategies include needs for improved coordination around shift work schedules and sleeping arrangements, and a widespread perceived obligation to work past fatigue, despite being encouraged to report symptoms. ***Conclusions:*** These results provided a better understanding of worker perceptions of fatigue sources, reporting challenges, and adoption of personal mitigation strategies among oil and gas workers. These results can also inform specific organizational opportunities for mitigating fatigue in offshore drilling operations. Potential strategies that encourage periodic fatigue monitoring, improve sleep quality, and reduce work-related physical and cognitive overload should be examined for effective adoption in this industry.

KEYWORDS Overexertion; shiftwork; physical; cognitive; perception; visualizations

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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, 2016). Because of 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 the costs and risks associated with worker fatigue, both the 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 to decreasing fatigue-related risks in OGE, however, is that current research and practice focus almost exclusively 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; Marcora et al. 2009; Mehta & Parasuraman 2014; Parkes, 2002; Sutherland & Cooper, 1996a, 1996b). Given the physical and cognitive demands on OGE workers (Mehta et al., 2018), it is imperative that any efforts to mitigate fatigue be comprehensive and address these issues. An additional challenge to developing fatigue mitigation methods for OGE workers is that little is known about these workers' perceptions and experiences of fatigue or its management, as most inquiries have been conducted internally and were not published. Knowledge regarding current fatigue mitigation methods (i.e., their effectiveness and barriers toward implementation) is necessary for identifying gaps and developing 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, Cassell, & Symon, 2004; Merriam & Tisdell, 2016). The few studies that have focused on exploring fatigue among OGE workers mostly used structured surveys (Chen, Wong, & Yu, 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, existing surveys and assessment results are challenging to interpret, because they were 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, and as noted earlier, these assessments focus almost exclusively on fatigue related to sleep and shiftwork, and thus are not comprehensive given there is little attention to cognitive and physical fatigue. These limitations indicate that new measures of fatigue among OGE workers is warranted.

Before reliable and valid measures can be created to capture fatigue levels in OGE workers, 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 designed to better understand the day-to-day experiences; perceived contributors to fatigue; as well as causes, effects, and barriers in addressing and managing fatigue, among offshore workers. To best understand the data obtained from the interviews, a grounded theory approach utilizing qualitative data analysis software was used. In addition to traditional methods for analyzing such data, a novel approach was taken to visualizing the codes and constructs derived from the analysis. While used in quantitative studies (Caat, Lorist, Bezdan, Roerdink, & Maurits, 2008) and to some extent in mixed-methods studies (Aigner, Rind, & Hoffmann, 2012; Knigge & Cope, 2006), visualization

holds strong promise for interpreting results of qualitative studies. When based on interviews analyzed using grounded theory, visualizations can show connections between constructs that are not initially apparent.

2. METHODS

2.1. Participants

Data collection took place on an offshore drillship in the Gulf of Mexico during the month of January, during which there were mild temperatures. The drillship was a newer one, and each crewmember shared a room that has a bathroom with one other person. Crew had a 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 communications.

A total of 11 workers participated, all of whom were male; mean years of experience in the OGE industry was 11 ($SD = 10$, MIN = 2, MAX = 36) and the mean age was 35 ($SD = 8$, MIN = 23, MAX = 55) years. The crew worked 28 days on the ship (a hitch), on 12-hour shifts. There were four possible shifts that differed in start times: 0000 (midnight), 0600, 1200 (noon), and 1800. Some of the workers had to do swing shifts during their hitches, whereas others had to do "short changes" associated these with swing shifts during their hitches. (Note that swing shift is when a worker changes shifts, from day shift to night shift, or from 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) long change: a complete 24-hr break period between the two shifts (day to night or vice versa); and (2) short change: a 6-hr break after the regular work shift, followed by a 6-hr work shift, then a 12-hr break followed by the swing shift. Table 1 summarizes the difference in work schedule for those who: (1) work a regular shift without a swing ($n = 4$); (2) those who have a swing shift and a long change ($n = 3$); and (3) those who have a swing shift with a short change ($n = 4$). Typically, 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. Not all workers did a swing shift during their hitch, and not all workers who did a swing shift did a short change. Table 2 summarizes the types of jobs performed on the drill ship, the workers' shift at the time of study, and whether the workers did a short change as part of their hitch.

TABLE 1. Descriptions of the three types of shifts observed

Shift times	Regular shift	Swing shift with long change	Swing shift with short change
1200–1800	Working	Working	Working
1800–0000			
0000–0600	Resting	Resting	Resting
0600–1200			Working
1200–1800	Working	Resting	Resting
1800–0000			
0000–0600	Resting	Working	Working
0600–1200			
1200–1800	Working	Resting	Resting
1800–0000			
0000–0600	Resting	Working	Working
0600–1200			

TABLE 2. Worker job profiles, shift time at the time of interview, 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	1200–0000	2	n/a
Crane operator	1	1200–0000	1	n/a
Drilling position operator	1	0600–1800	n/a	n/a
Floorhand/ roughneck/ roustabout	4	1200–0000 (3) 0000–1200 (1)	3	3
Mechanic	1	0600–1800	1	1
Subsea engineer	1	0600–1800	n/a	n/a
Tool pusher	1	0600–1800	n/a	n/a

Since not all workers did a swing during their hitch, the numbers in columns regarding swing shift and short change will not add up to the total number of participants ($n = 11$).

2.2. Protocol

Workers were introduced to the study during a morning safety meeting and through medical personnel on the ship. Those interested approached the researchers or ship staff regarding to participate. Since the interviews addressed workers' overall experiences with fatigue (not the fatigue associated with a current or immediate past shift), participants were scheduled for their

TABLE 3. Questions used in semi-structured interviews

- *How would you define fatigue?*
- *How do you manage your fatigue ….?*
  - *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*

interview session to occur either right before or after their work shift for the day. After reviewing and signing an informed consent form, the workers were interviewed using a semi-structured guide to identify their experiences, attitudes, and mitigation methods around fatigue (see Table 3 for a full listing of the interview questions). The study protocols were approved by the Texas A&M Institutional Review Board.

After the interview, the workers were asked to complete several standardized surveys regarding fatigue, sleep, and stress, and they were then fitted with sensors to measure physiological measures throughout their workday. Results from the standardized surveys 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

Qualitative data analysis software, MAXQDA 12 Plus (VERBI Software, 2016), was used to analyze the interview transcripts. This software provides a convenient means to organize 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 (see Sasangohar, Peres, Williams, Smith, & Mannan, 2018 for a detailed analysis using MAXQDA). "Coding" refers to the process of systemizing and organizing transcript data, from deductive and inductive perspectives. After completing the transcriptions of the interviews, MAXQDA coding was performed by one experienced coder. The codes were discussed in depth with an additional experienced coder, and negotiated consensus was used to finalize the codes.

Deductive coding is an analysis technique that develops an initial code list as a starting point for the coding process (Miles, Huberman, & Saldana, 2014). The initial code system was created here from the interview questions, with seven parent codes and subcodes associated with each question and probing question, respectively (Table 3). 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 11 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 done subsequently.

The nature of the semi-structured interviews allowed participants the flexibility to express more thoughts than would fit into the fixed, deductive code set. During the coding process, these sentiments were logged via MAXQDA's memo system, and if repetitions occurred, a new code would be formed. This process is known as *inductive coding,* and allows for codes to be developed 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 with deductive coding exclusively (Miles et al., 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. This final set of themes was used to model relationships, interpret findings, and synthesize patterns in the results that follow.

3. 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 subcodes and themes (or inductive codes) emerged from the participants' responses associated with the main codes. Finally, several themes emerged as part of the inductive coding process,

TABLE 4. **Results of inductive and deductive code development**

Deductive codes		Inductive codes
Concepts/codes	Subcodes	Themes
Fatigue definition	• Increased stress • Tiredness/ worn down	
Types of fatigue		• Cognitive/Mental • Effects of family • Physical
Reporting fatigue	• Reporting tools • Working past fatigue	
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 fatigue on safety	• Self • Others	

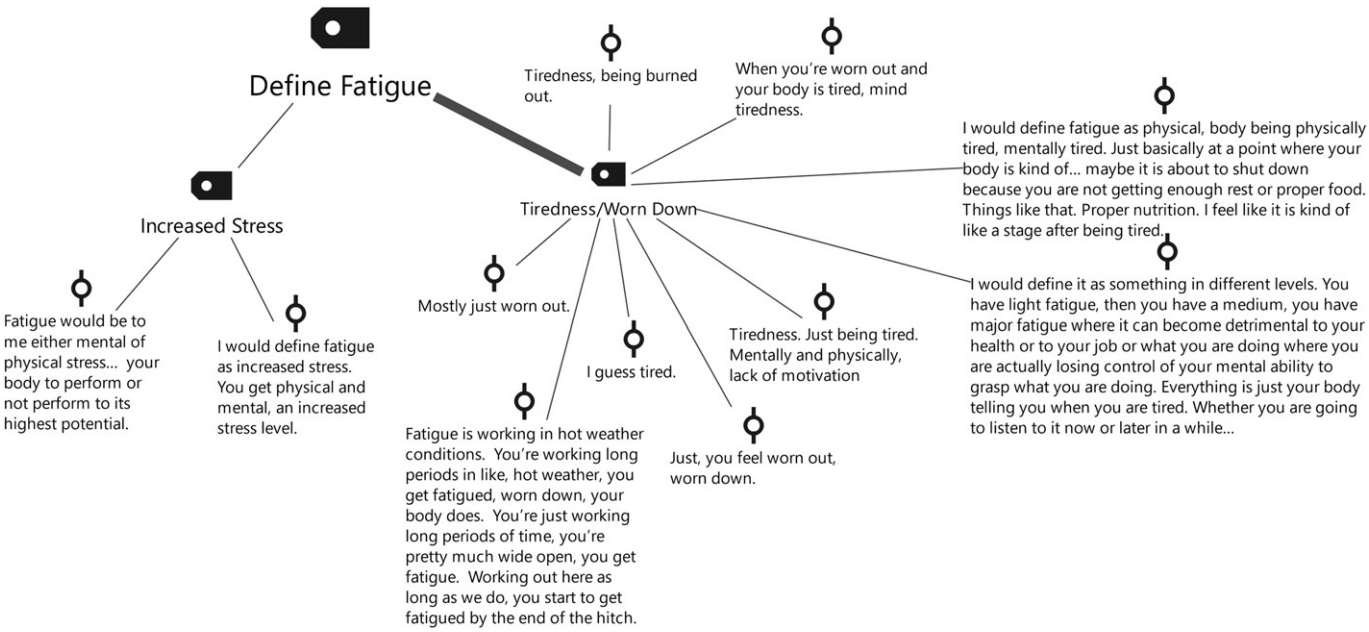

FIGURE 1. **A visualization of fatigue responses. In these responses, the tags represent codes and subcodes, while the circular nodes represent direct quotes of participant responses. Line thicknesses are associated with the frequency of responses.**

and those are listed along with the deductive codes in Table 4. The inductive codes identified were associated specifically with one of two concepts: types of fatigue and managing fatigue. The inductive codes associated with managing fatigue were further broken down into those that were organizationally imposed (i.e., imposed by those running drill ship) and those initiated by the workers themselves (self-initiated). Summaries of the participants' responses that describe each of the code identified are provided below, for each of the seven main codes, along with several narratives of the working conditions contributing to workers' fatigue in the offshore domain.

3.1. Fatigue Definition

Fatigue was defined very generally by the workers as "tiredness" or, in two cases, "increased stress" (Fig. 1).

Notably, a majority of the workers (7/11) acknowledge both mental and physical aspects of fatigue.

3.2. Types of Fatigue

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

> When we come to a new location to drill, there's a whole set of checklists and more cognitive fatigue that happens …

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

> 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.

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.

> … 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 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.

3.3. 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 assignment of responsibility to the participant may establish a perceived obligation to work past fatigue and potentially withhold information about their fatigue.

> 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 …

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

> 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.

This code also sought to understand a worker's course of action in the event that they find themselves too tired to work. A 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 responses described above, specifically that the majority of workers also felt obligated to work past fatigue and were not asked to report fatigue. This contradiction is demonstrated in the following quotes.

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…

I would let it be known that 'I am getting a little sleepy over here' or something … 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.

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.

… 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.

3.4. 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."

… 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. … Nine and three in a twelve hour hitch.

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 Fig. 2.

3.5. 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 (in sleeping cabins). You have night shift down on one side (of the cabin) with a guy on the opposite shift, 12 to 12. Every time I sleep, he comes in…

3.6. 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, since 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 require up to three days for recovery. One worker commented that this was the most dangerous time for work.

… 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.

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.

3.7. Channel Fever

Channel fever references a sense of malaise associated with the end of the hitch as the vessel returns to port. Several workers emphasized mental or physical exhaustion after the 21-day mark (Fig. 2).

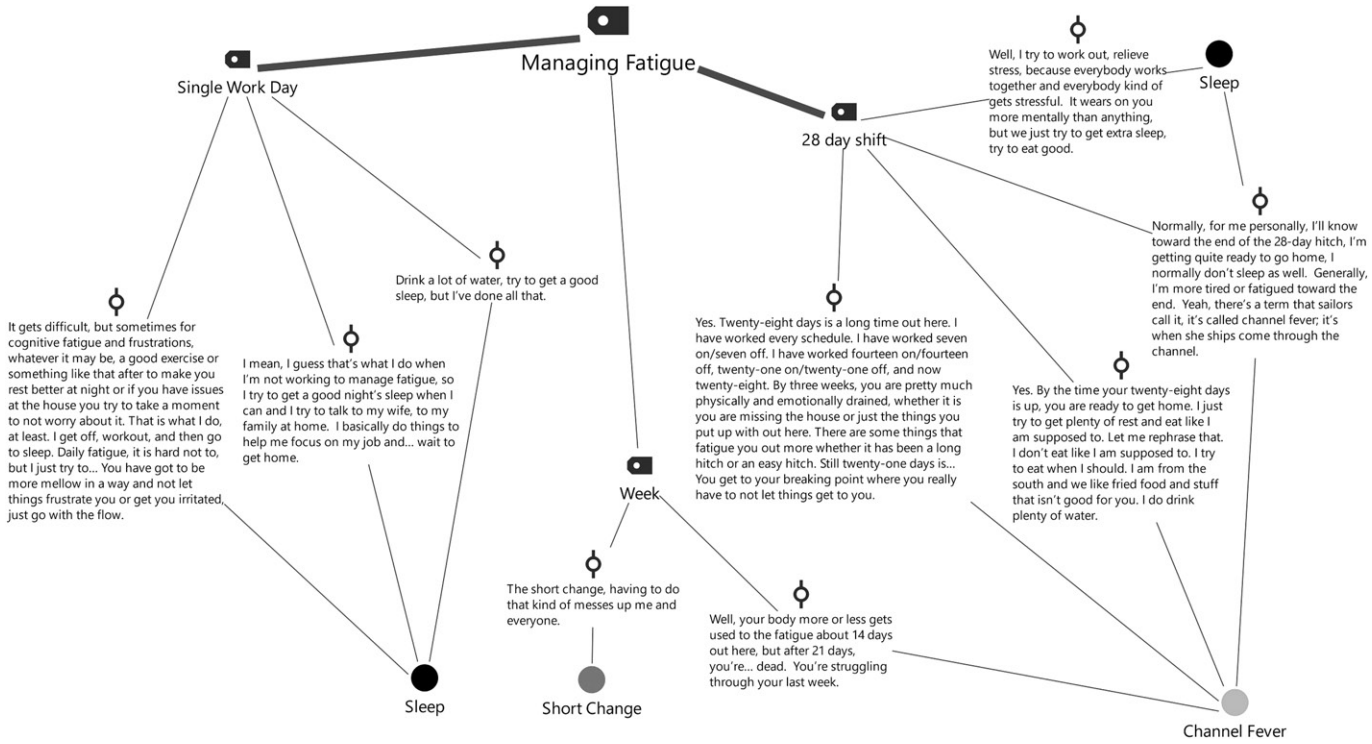

FIGURE 2. **A visualization of some responses to the main code "Managing Fatigue," organized by subcodes and presented in relation to emerging themes of "Channel Fever," "Sleep," and "Short Change."**

> … 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.

3.8. Effect of Team 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.

> 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 …

> 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.

4. DISCUSSION

The purpose of this study was to document the experiences and perceptions of the causes and consequences of fatigue among offshore OGE workers. The main findings of the interviews include: (1) an expanded definition of fatigue from the workers that address physical and cognitive demands, in addition to sleep and shift challenges associated with OGE work; (2) worker concerns on utilizing short changes as an adaptation strategy to swing shifts; (3) lack of offshore fatigue assessments/reporting; and (4) fatigue management strategies are largely initiated by individual workers despite the potential for simple and feasible organization-initiated strategies.

4.1. Defining Fatigue

In line with previous findings, shiftwork and sleep quality were noted here to be top reasons for fatigue levels, which is also consistent with efforts in this industry addressing sleep and shiftwork to mitigate fatigue. First,

the workers noted that a 28-day offshore deployment was too long to safely continue work on the rig and that the level of exhaustion was felt the most at around the 21-day mark. This aligns with findings from the two CSB Investigation reports pertaining to the BP Texas City and Macondo incidents (CSB, 2007, 2016), as well as the hours of service guidelines recommended in the Fatigue Risk Management System Recommended Practice 755 (FRMS RP 755; API, 2010). Second, workers reported that short changes were associated with increased fatigue. This was an interesting finding, as short changes are typical adaptation strategies (Bjorvatn, Kecklund, & Akerstedt, 1998; Lauridsen & Tønnesen, 1990; Parkes, 2012; Parkes, Clark, & Payne-Cook, 1997) used to mitigate adverse effects of swing shifts (Parkes, 2012; Parkes et al., 1997; Ross, 2009). The workers noted that major tasks were not scheduled around the short change periods 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 & Agnew, 2012), as was evident in the responses provided by most of the workers interviewed in this study (Fig. 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 an evaluation of the work in determining fatigue levels. In addition to sources that are work-related, the workers also identified emotional and psychological factors, such as missing family members during the deployment, as contributing to perceptions of fatigue. While some studies have reported managing work-life balance as a psychosocial stressor in offshore OGE work (Chen, Wong, & Yu, 2009; Parkes, 2002; Sutherland & Cooper, 1996a, 1996b), this is the first investigation that links emotional stress, due to work-family conflicts, to worker fatigue perceptions, and which thus may have implications for potential fatigue mitigation strategies that are not being investigated.

4.2. Reporting and Monitoring Fatigue

Several studies have used surveys, sleep diaries, and objective measurements to assess fatigue (Saksvik et al., 2011). However, there is no evidence of the 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, 10 of the 11 workers mentioned that they were not asked to report any fatigue symptoms. Some workers indicated that they refrain from reporting fatigue or taking breaks, to avoid being considered as the "weakest link." Others indicated that they withheld reporting fatigue symptoms due to the lack of practical fatigue management solutions available or offered. Thus, if reliable and practical fatigue assessment practices were available, management implementation of such evaluations would shift the weight of that decision away from the workers.

4.3. Managing Fatigue

Originally, it was expected that methods for managing fatigue would differ based on the period of time over which the fatigue was being managed: immediate (day), short term (week), and long term (28 days or hitch). This expectation was based on the constructs associated with how people recover from fatigue and how fatigue can impact people over time (Parkes, 2012). Interestingly, during the interviews participants did not indicate that there were specific methods for managing fatigue that differed by periods of time, but instead that all of their fatigue management strategies were immediate to them (i.e., they were either doing them or not). Instead, the strategies were categorized as either initiated by the organization or by the workers themselves (Fig. 3). These strategies, specifically self- versus organization-initiated, provide a clearer understanding of how workers experience fatigue and engage in monitoring and managing their fatigue levels.

4.3.1. Organization-Controlled Fatigue Management Strategies

In general, the most common fatigue management strategy identified by the workers was getting quality sleep. Most 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 been found effective (Caldwell, Caldwell, & Schmidt, 2008;

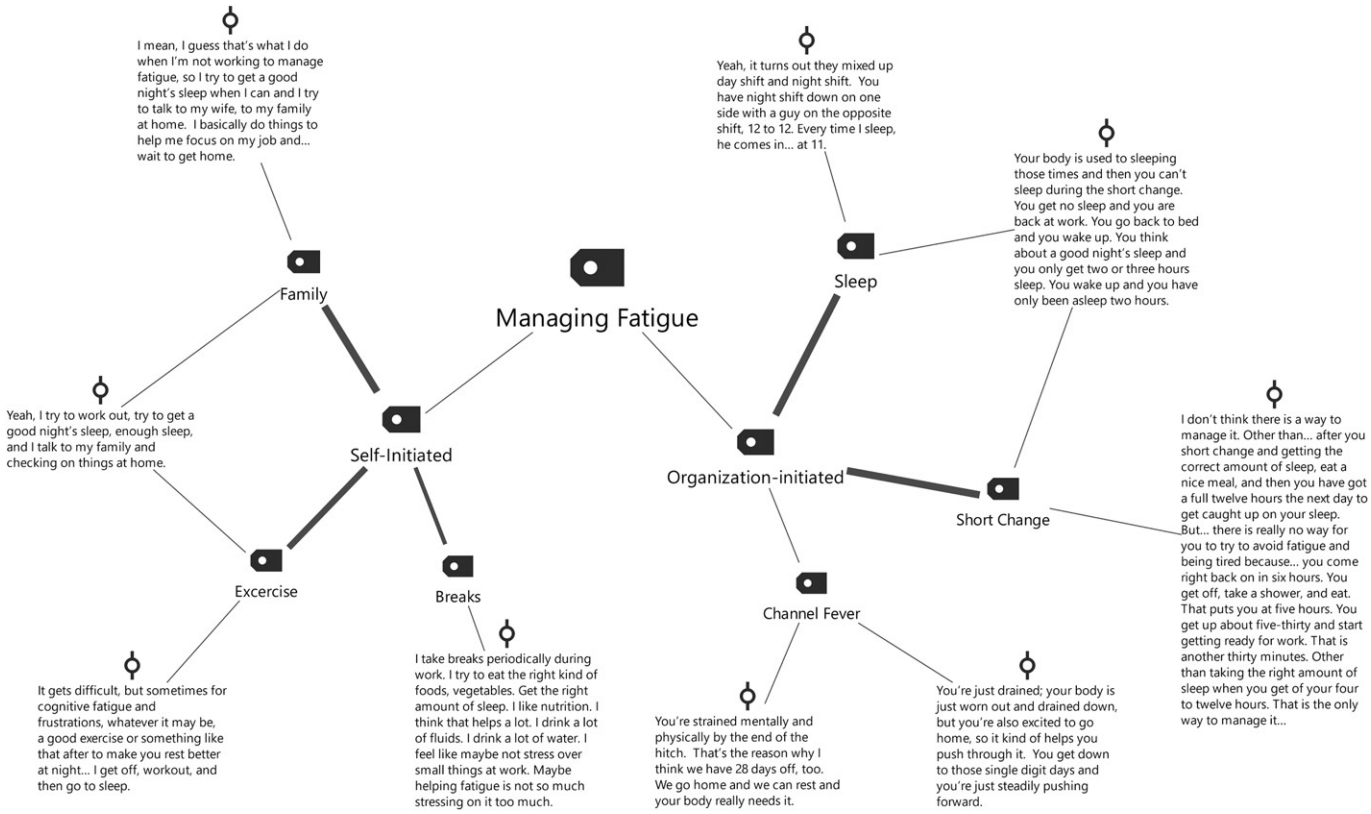

FIGURE 3. **A visualization depicting the inductive categorization of strategies used for fatigue management. Several subcodes were merged into two different categories: self-initiated and organization-initiated. The visualized quotes are selective (not exhaustive). Line thickness indicates the extent of evidence (i.e., thicker lines represent greater degree of qualitative evidence associated with the code).**

Pallesen et al., 2010). While recognizing this to be an operational constraint in offshore work, designated rest spaces that minimize 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.

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 in a different shift. While this shared strategy enables effective utilization of space, it was identified as a major contributor to disruptive sleep. Shared accommodation has been shown to exacerbate perceptions of extended work schedules and isolated setting in offshore petroleum industry (Shrimpton & Storey, 2001) and in offshore installations (Chen et al., 2001). The OGE industry should consider methods to improve coordination around shift changes and sleeping arrangements, as well as preserve the quality of sleep for their crew. For example, efforts could be taken to ensure that the sleeping quarters of night and day shift workers are separated and isolated, preventing disturbances from outside sounds and interruptions.

As argued earlier, fatigue can be caused by several sources, with the task-at-hand itself contributing significantly to worker fatigue and associated performance declines, such as decrements in alertness, vigilance, and situation awareness (Mehta et al., 2018). Thus, there is a critical need to design engineering controls, such as improved display designs, automation, and power assistance, to reduce fatigue due to cognitive and physical task demands.

4.3.2. Individual-Led Fatigue Management Strategies

An important finding of the current study is that interviewees 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, the workers emphasized that a lack of alternatives led them to continue working when fatigued, 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 individual's strengths versus weaknesses.

4.4. Study Strengths and Limitations

This study has several strengths and limitations that need to be noted. One of the major strengths is that very few studies have focused on investigating fatigue in offshore platforms in the Gulf of Mexico. Most existing studies were done on work platforms in the North Sea and Australia, with workers from different cultures and in different regulatory environments than the present study. In addition, this is the first study of fatigue perception that focused on understanding, from a worker's perspective, the sources of fatigue, and current fatigue assessment and management practices in the Gulf of Mexico.

One of the novel methodological contributions of this work was a visualization of the coding process (Figs. 1–3). These visualizations offer a unique presentation of the qualitative data analysis process as connections and relationships between codes are brought to the forefront. For example, while Fig. 2 illustrates the development of three inductive codes (i.e., channel fever, short change, sleep) from the available evidence, Fig. 3 provides information about an additional iteration where these codes are further categorized as self-initiated and organization-initiated fatigue management strategies.

One major limitation of this study is that worker perceptions were obtained from only 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. Second, the current sample size was relatively small. Given that the aim 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. Despite the small sample, though, the findings reached a point of saturation. Finally, while participants were assured anonymity, nature and depth of the responses provided may have been constrained due to a fear of breach of anonymity.

5. CONCLUSIONS AND RECOMMENDATIONS

The current findings emphasize the role that physical and cognitive (and/or mental) demands play when defining the various sources of perceived fatigue, and highlight that fatigue management strategies are largely individual-initiated, despite the potential for simple and feasible organization-initiated strategies. Based on the worker perceptions reported here, potential strategies for organizations to address fatigue mitigation and management in offshore oil platforms are formulated below. Future work is warranted to refine these strategies, develop specific interventions, and test their applicability and effectiveness in offshore oil and gas operations.

- Improving sleep quality—e.g., reducing length of stay at the rig, coordinating cabin arrangements with shift changes, and developing better understanding, and subsequently better solutions, for adaption strategies with swing shifts
- Reducing work demands—e.g., improved human factors and ergonomics considerations, such as improved displays for drillers and automation for repetitive manual work
- Integrating fatigue monitoring and reporting practices into existing safety culture strategies—e.g., surveys, checklists

DISCLOSURE OF POTENTIAL CONFLICT OF INTEREST

The authors report no conflict of interest in relation to the work submitted.

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