RECOGNITION AND ANALYSIS OF HUMAN FACTORS AND NON-TECHNICAL SKILLS USING THE FUNCTIONAL RESONANCE ANALYSIS METHOD - FRAM

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***Abstract**: This study presents a Human Factors and non-technical skills recognition and analysis in the operations activities of an offshore drilling platform, using the FRAM (Functional Resonance Analysis Method) to build a model of how the work is done by the drillers. The observations on board and the discussion together with the drillers provided the information and data necessary for the construction of the model and other conclusions. A specific form of presentation of the FRAM for the drillers was developed, seeking to create a bond of empathy and trust, promoting an adequate way of describing how the work is actually done, recognizing and analyzing the most relevant Human Factors and non-technical skills.*

Keywords: *FRAM; Human Factors; non-technical skills; offshore; oil rig.*

***Resumo**: Este estudo apresenta o reconhecimento e análise dos Fatores Humanos e habilidades não-técnicas presentes nas atividades de perfuração de uma plataforma de petróleo offshore, utilizando o FRAM (Functional Resonance Analysis Method) para a construção de um modelo de como o trabalho é realizado pelos operadores. As observações a bordo e as discussões em conjunto com os operadores forneceram os dados e as informações necessários para a construção do modelo e demais conclusões. Foi desenvolvido uma forma específica de apresentação do FRAM para os operadores, buscando criar um elo de empatia e confiança para promover uma adequada forma de retratar o trabalho que é realmente feito, reconhecendo e analisando os Fatores Humanos e habilidades não-técnicas mais relevantes.*

Palavras-chave: *FRAM; Fatores Humanos; Habilidades não-técnicas; offshore; plataforma de perfuração.*

1 INTRODUCTION

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The Nuclear, Mineral Coal, Hydroelectric and Oil & Gas (O&G) industries are important segments for the whole Society, as it produces the primary energy necessary for the most diverse human activities, from simple cooking of meals to production steel and state-of-the-art pharmaceuticals or technology. However, despite this huge importance, these industries carries some hazardous for the workers, communities and the environment and when that hazardous are not adequately recognized, or controlled, or mitigated, the consequences can affect not only the workers involved in the production activities, but also the surrounding communities, the entire environment, with its consequences reverberating for years and years, as was the case of the Bhopal accident in India in 1984 (Labib, 2015). Particularly the O&G segment, there is some logistics issues that arises the oil as the main energy used by Society – so far, vehicles cannot run by coal or nuclear energy. Moreover, the electric cars are still under validation, especially because there are some batteries issues still being solved and these hi-tech cars is limited for developed countries or specific technology development centers. On this scenario, the O&G industry is under certain pressure to provide the most utilized energy in the world, which can be translated in a trade-off between safety and production, instead of merge those two words in the same sense, it means, safety production, no matter how much pressure can occur. In a world of constant development and innovation, it is necessary to look forward for tools and methodologies that can deal with the complexity of new technologies, the growing demand of energy and the vicissitudes of human beings, providing the necessary resilience and efficiency for this safety production.

1.1 DRILLING ACTIVITIES

The O&G industry is formed by different areas, ranging from studies of geological models in urban and rural geological outcrops, passing through oil & gas production onshore and offshore, and the production of petroleum derivatives required for all other industrial segments of the Society. In a systemic way, this industry can be divided in three main areas: upstream, where oil & gas exploration and production (E&P) activities are organized; in midstream, where the activities of transportation of petroleum and its derivatives are concentrated; and, finally, the downstream, where there is actually the transformation of oil into derivatives such as gasoil, kerosene, naphtha, gasoline, ethylene, n-butane, among others (Hyne, 2012). Specifically, in the E&P segment, the drilling and construction of offshore oil wells emerges as one of the most dangerous of all, because it involves a series of high process parameters, technological complexity, intrinsic sea hazards and the interaction of several workers performing tasks in the same workplace. According to Haavik (2013), one characteristics of offshore drilling operations is the large number of workers involved. The number of professionals and consequently the division of the work in the operations floors has increased steadily in parallel with technological development. There are various professionals which various specialization on the workplace, and although the specialization and division of work is highly necessary to accomplish complicated and intricated tasks, it also creates challenges and complexities of meshing together these tasks and preventing the interfaces between them from affecting the work negatively. Analyzing this scenario, with potential high risks involved, requires something that is not simple and linear, but rather something nonlinear and capable of recognizing the existing complexities. In this sense, FRAM (Functional Resonance Analysis Method) seems to be the most adequate methodology for such peculiarities and complexities.

1.2 DRILLING HAZARDOUS AND SAFETY

According to Biedron & Evans (2016), offshore drilling operations, known also as oil rigs, create various forms of pollution that have considerable negative effects on marine and other wildlife. These include drilling muds, brine wastes, deck runoff water and flowline and pipeline hydrocarbon leaks – crude oil and natural gas. Catastrophic spills and blowouts are also a threat from offshore drilling operations. These operations also pose a threat to human health, especially to oil platform workers themselves.

Oil rigs may also attract seabirds at night due to their lighting and flaring and because fish aggregate near them. Its mortality has been associated with physical collisions with these vessels, as well as incineration by the flare and oil from leaks (Haney, Geiger, & Short, 2014). This process of flaring involves the burning of fossil fuels which produces the emission of various pollutants. These emissions contribute to Earth climate impacts as it is a potent warmer both in the atmosphere and when deposited on shore. According to NOAA (2017), offshore drilling activities is suspected of contributing to elevated levels of mercury in Gulf of Mexico sea life.

In this scenario of high risk and consequences in oil rigs, it is necessary to develop ways to keep drilling, production and operations in a safety and sustainable way. The search for energy is something that all nations, whether developed or not, are constantly looking for their growth, maintenance and protection (Yergin, 2012). Taking into account all the primary energies in the world, crude oil and natural gas are still the most sought after because it has an excellent cost-benefit, logistic differentials and great possibility of transformation - whether for direct burning, plastics, polymers, pharmaceuticals, chemical products, food and state-of-the-art biomedical technologies.

2 THE FRAM - FUNCTIONAL RESONANCE ANALYSIS METHOD

The Functional Resonance Analysis Method is a methodology to analyze and describe the nature of daily labor activities. Due this methodological structure, it can analyze past events of complex system, such as an accident investigation, as well as possible future events, as a risk assessment of an offshore drilling platform. For a professional who has never seen the graphical representation of a FRAM model, this methodology may seem relatively complex, which it is not. In fact, the analysis promoted by this methodology is not an algorithmic process, but rather the gradual development of a mutual understanding among a team of experts working together. It's a kind of complex discussion about the complex relationships of complex socio-technical systems but done in a simple way. This methodology is based on four principles (Hollnagel, 2012b) :

- Equivalence of failures and successes.
- Principle of approximate adjustments.
- Principle of emergence.
- Functional resonance.

The graphic representation of a function is a hexagon, where there is, basically, one output and five inputs for each potential function. Each vertex of this hexagon is, in fact, the determination of one of the six aspects of the FRAM methodology function: Time, Control, Output, Resource, Precondition and Input. It is important to notice that the capital letters, begging each aspect observed, marks its difference from an ordinary input or output of a simple flow chart; they are the aspects that form the FRAM model and determined by its methodology as the connections between functions.

In this study, the FRAM methodology will be applied, initially, to understand how the work is done inside of the drilling unit, during the performing of the drilling activities, once in this place – drilling unit – also called doghouse, most part of the drilling actions are taken by the driller – the worker responsible for drill the well hole itself. Once this preliminary recognition is done, the next step is to identify the relevant Human Factors of this activity, recognizing how non-technical skills are also part of the work performed.

3 MODELLING THE FRAM FOR THE DRILLING UNIT

The modelling of a FRAM model for the drilling activities performed by the operator inside of the doghouse – the driller – began by the understanding of how the work is done. To achieve that, it was necessary to be on board and see, analyze and experience that work, which was relatively effortless. However, in the phase where the drillers would be interviewed and the contact between the researchers and them would be closer, there was a lot of reluctance and disengagement on the part of the drillers, which was treated in a unique way, creating a new way to see the FRAM.

3.1 UNDERSTANDING THE DRILLER ACTIVITIES

As mentioned, the engagement of drillers for participation in research was a barrier, which was adequately addressed, as will be demonstrated further. However, before this happened, only one of the drillers accepted to participate in the studies, assisting in the construction of what he called the "driller workflow", being represented in Figure 1.

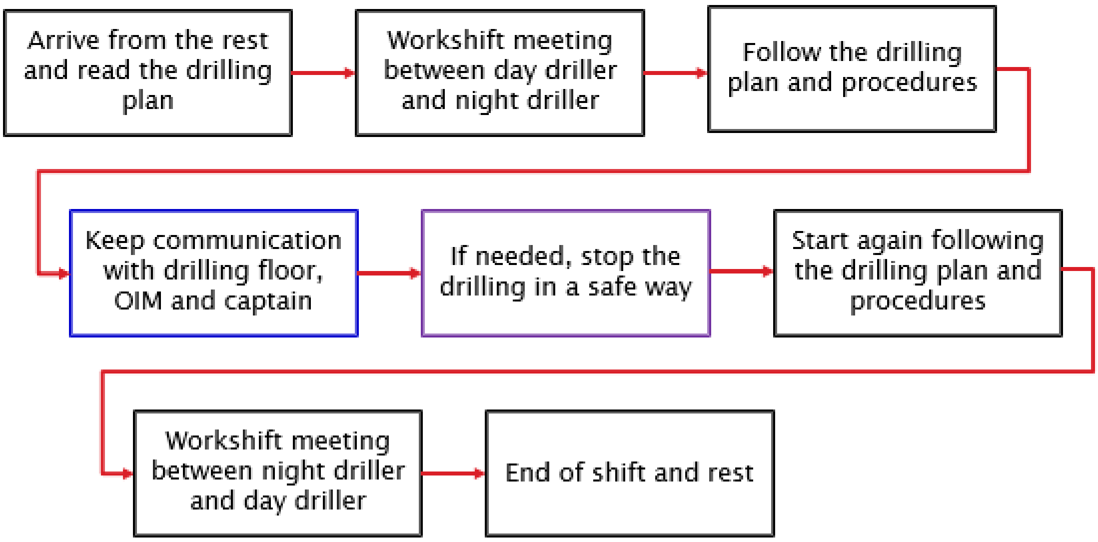

Figure 1 - The "driller workflow" presented by a driller.

Source: Author (2019)

The linear thinking, even for complex socio-technical system like drilling operations, it is the common sense for most workers. Most people, in general, tend to think linearly even when they are performing extremely complex tasks; it is a form of comprehension that translates the complex into the elementary, giving simple answers to things that are, in fact, complex (Hollnagel, 2012a). Taking this linear information from Figure 1, and placing it within the context of how the work is actually done, makes the FRAM modeling show how complex this work is, and also how important issues cannot be seen clearly, which is the case of non-technical skills showed by some FRAM functions.

3.2 BUILDING TRUST AND CREATING A BOND

In the first moment, the engagement of drillers for participation in research was a barrier and only one of them – a total of six – agreed to participated. So, how deal with that? According with Kennedy & Schweitzer (2018), create a trust bond between workers is not easy, and when not properly addressed in a research, can make it ruin, generate invalid data, or mask important results. It has been argued that work contexts are more effective when trust is established. Healthcare, education, and business has a large amount of literature from the perspectives of those who are growing trust on what led them to increase their trust in a person of authority (Griffith & Johnson, 2019). Aiming to grow a trust bond between the researchers and the drillers, a first step taken was a workshop of FRAM, showing what is the methodology, and how it can help their work. The first impressions and words when an example of FRAM was shown was confusion, brain model, real mass, complex, and even “spaghetti noodles”.

Faced with this second barrier, it was necessary to create something simple, but objective and useful, that could effectively improve the understanding of the methodology for the drillers. What's more, something that shows FRAM is something that has come to help, something positive, that will not disrupt the work, but rather help, be a friend. In this context, and using the Portuguese language as a basis, rises the FRAMigo, as shown in Figure 2.

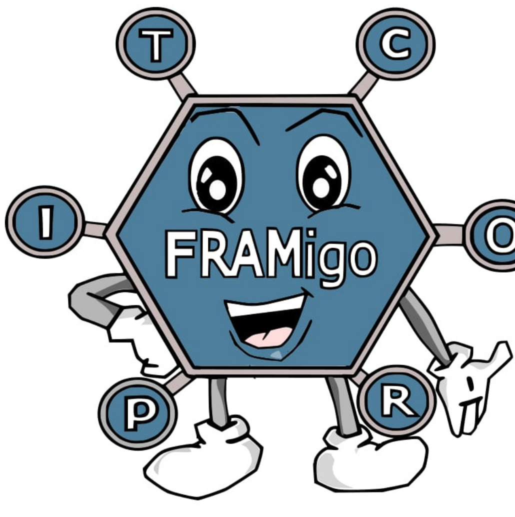

Figure 2 - The FRAMigo.
Source: Author (2019)

Almost immediately FRAMigo creates an empathy between researches and drillers, forming a trust bond where the information flowed efficiently, profusely and concisely, aiding the entire process of recognition of how drilling activities are done by the driller inside of the doghouse. All eight drillers contributed with applicable and real information, allowing the modeling of a FRAM consistent with their activities, showing their complexities and relevant issues related to Human Factors.

3.3 BUILDING THE FRAM MODEL

The FRAM aims to model complex systems looking at their functional aspects rather than their physical structure, defining dynamic interactions among functions and modelling performance variability, which represents the source for both failures and successes. The FRAM allows thus a systemic representation of the system, in order to assess how variability might propagate through the system, potentially generating emerging risks (Patriarca, Del Pinto, Di Gravio, & Constantino, 2018). Based on that, and taking into account all the relevant information of how the real work is done by the drillers, it was possible to build a FRAM model with 19 functions, being of these 5 background functions and 14 foreground functions, as the functions are defined by the methodology (Hollnagel, Hounsgaard, & Colligan, 2014). This FRAM model for drilling activities inside of the doghouse is presented in Figure 3.

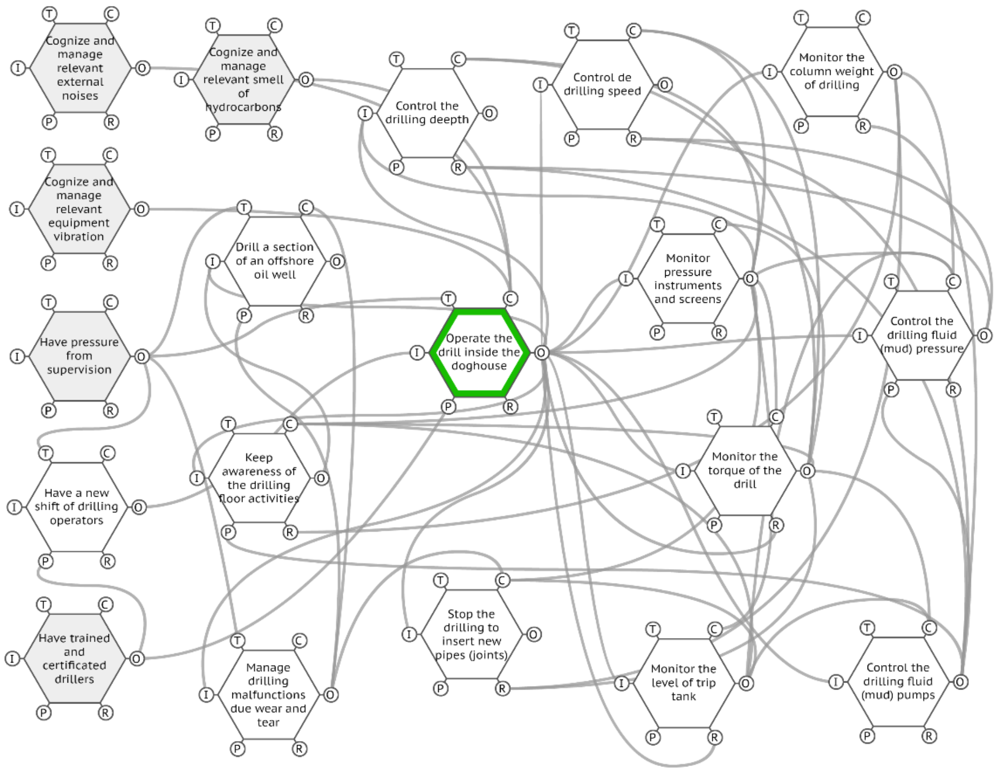

Figure 3 - FRAM for drilling activities inside of the doghouse.

Source: Author (2019)

The 14 foreground functions of this model were not analyzed in terms of Output variability, once the main reason of the research is to identify the functions itself, focusing on its peculiarities, the relevant Human Factors and non-technical skills that may appears. These 14 foreground functions are:

- Operate the drill inside the doghouse;
- Control the drilling depth;
- Control de drilling speed;
- Control the drilling fluid (mud) pressure;
- Drill a section of an offshore oil well;
- Monitor pressure instruments and screens;
- Monitor the column weight of drilling;
- Stop the drilling to insert new pipes (joints);
- Keep awareness of the drilling floor activities;
- Control the drilling fluid (mud) pumps;
- Monitor the level of trip tank;
- Monitor the torque of the drill;
- Have a new shift of drilling operators;
- Manage drilling malfunctions due wear and tear.

In the other hand, the 5 background functions, which by definition does not have Output variability (Hollnagel, 2012b), were defined as:

- Cognize and manage relevant external noises;
- Cognize and manage relevant equipment vibration;
- Cognize and manage relevant smell of hydrocarbons;
- Have pressure from supervision;
- Have trained and certificated drillers.

Those foreground and background functions are the graphic representation by FRAM of how their work is done, presenting the important couplings and relations between the workers, technical system and the organization, and consequently the relevant Human Factors of this working scenario.

4 DISCUSSIONS AND RESULTS OF THE FRAM BUILT

Starting from the premise that the analysis of the FRAM model would not be focused on its Output variability, but rather on the functions that emerged and how these are coupled, a study of this nature was developed, seeking to understand the Human Factors and non-technical skills that can arise. It is important to notice that this is not a deterministic study, but rather comprehensive and preliminary, seeking to identify the most relevant Human Factors and non-technical skills of the observed activity.

4.1 RECOGNITION OF HUMANS FACTORS

Human Factors, as denotes Cacciabue (2010), is a set of conditions and relations that in different and dynamics ways may affect the human performance, including their performance when executing labor activities. Is not something fixed, however the basis of Human Factors knowledge necessarily passes through the analysis and understanding of relations and concepts, that are:

a) individual characteristics and performances, including physical attributes, physiological and psychological issues;
b) communications, supervision, and checks with other persons, in the immediate surroundings of the human being;
c) actual working instrumentation, equipment, and any supporting material which may utilized to carry out a task;
d) all aspects associated with the socio-technical environment interacting with the human being, including physical working context, task environment, and company management; and
e) all indirect or non-tangible issues affecting humans at work, such as training, procedures.

Based on that, and considering the FRAM model built, it is possible to see that the Output of the function “Operate the drill inside the doghouse” is coupled to 12 others functions, which basically poses this function coupled with all other functions of the model. Besides that, is a human function, as defined by the methodology (Hollnagel & Goteman, 2004), and plays an important role in the system, as defined by its couplings. As can be seen here, this entire system is under a human control and influence, and subject to the relations and concepts defined by Cacciabue (2010), which shows the Output of the function “Operate the drill inside the doghouse” as the most relevant Humans Factors of the system. In the Figure 4 is presented this function with its 12 couplings.

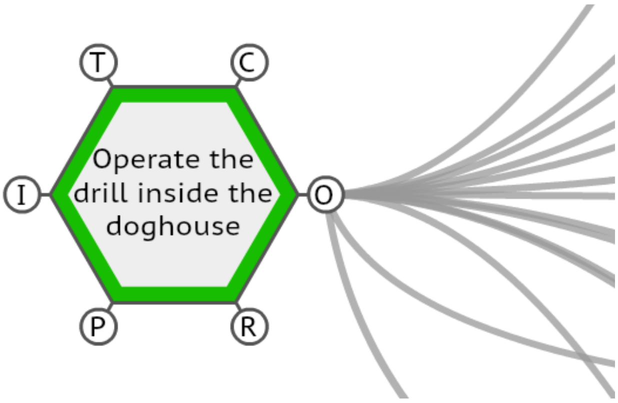

Figure 4 - The function “Operate the drill inside the doghouse”.

Source: Author (2019)

In this way, these 12 different Outputs, although they are different from each other and make different couplings with other distinct functions, are in fact the most relevant Human Factors of this scenario and interact among themselves, further enriching this analysis and understanding. Those 12 different Outputs are:

- Operating the drilling speed;
- Operating the drilling depth;
- Operating the drilling pressure fluid;
- Monitoring of pressure instruments and screens;
- Monitoring of column weight of drilling;
- Stopping the drilling to insert new pipes (joints);
- Operating of drilling fluid (mud) pumps;
- Monitoring of the torque of the drill;
- Monitoring of the trip tank;
- Drilling a section of an offshore oil well;
- Management of drilling malfunctions due wear and tear;
- Awareness of the drilling floor activities.

One of the most relevant factors, which emerges precisely from the interactions among the others, is precisely the "division of attention" that the driller must manage in order to maintain observation, control and management of several drilling parameters, such as such as depth, touch and speed. Other crucial factor that was evidenced on board, during the observation period of the research, was the communication skills that the driller must have to keep awareness of the situations and information that happens in the workflow. As pointed by França (2014), Communication is the most relevant of the Human Factors related to production operations in FPSO platforms. In the observations of the research, on board of an offshore drilling platform, Communication came out as well as one of the relevant Human Factors, but in this case related to drilling activities. In the situations observed on board, few elements showed how the human variability is the trade-off between the work that must have be done and the condition where, or how, it will happens, namely:

- The radio communication, under intense noise from the drilling floor, had three, four, and even five ways of confirmation, to ensure that the correct message was passed;
- Once some of the drillers are non-native English speakers, and they have to communicate in English with other crews, they had developed small nicknames for tools, activities and situation, e.g. dp for drillpipes;
- The non-verbal, especially between the doghouse and the drill floor, is intense and significant, having been observed several moments of "silence", where much of the communication was summarized to these signs;
- When some communication equipment fails, for instance the radio, other ways to do that is pursuit by the drillers, instead of simply stop the work, partially or completely. In addition, even when no communication at all happens, the drillers keeps the activity, using other ways to ensure that it is safe to proceed, without the formal communication required.

Although this posture seems unsafe, inadequate, or even wrong, this is precisely what characterizes the natural variability of the workers performance in their interaction with the complex socio-technical systems, especially which there are high risks, and rewards, involved. This trade-off between efficiency and thoroughness is also what characterizes the ETTO principle (Hollnagel, 2009), where the worker, daily basis in his work activities, has to equalize between being extremely productive - efficiency - or extremely safe - thoroughness. In the observations on board, it was verified that the drillers naturally make this transition, having postures that are more conservative when the communication presents flaws, or acting more productively when communication is full and effective.

The ETTO principle states that people make trade-offs (i.e. sacrifices) between efficiency and thoroughness demands under conditions of limited resources and environmental uncertainty. Efficiency is defined as minimizing the amount of resources used to achieve work outcomes, while thoroughness involves ensuring that all necessary conditions have been met for the successful completion of tasks (Xiao, Sanderson, Clayton, & Venkatesh, 2010). In this sense, unsafe, inadequate, or even wrong postures, as the driller did, are a special case of performance variability and that by understanding what makes performance variability successful, in a wider range of situations, from minimum to maximum of risk.

4.2 RECOGNITION OF NON-TECHNICAL SKILLS

Non-technical skills, according to ARPANSA (2017), are interpersonal skills which refers to communication skills, leadership skills, team-work skills, decision-making skills and situation-awareness skills. They do not include the technical skills required to get the job done e.g. the technical skill or know-how to operate a machine or conduct a certain operation, which is provided by proper training and work profile, however non-technical skills complement these technical skill & know-how making them more efficient and effective.

Particularly talking about situation-awareness skills, it was evidenced on board, and through the FRAM model, that this non-technical skills is extremely present in the work of the drillers and, although not registered in any procedure or standard, it is something required for the performance of the drilling functions. One of the interviewed drillers, of Brazilian nationality, but high great experience in oil rigs outside Brazil, pointed out that: "- It is necessary to feel the rig, to hear the rig, to talk with it... do you understand me? The rig and I are connected... if it is not so, you cannot do the work...". Listening to this report, the importance of non-technical skills in the drillers work routine becomes widely evident. And in fact, by analyzing the built FRAM model, it is noticed that the functions "Cognize and manage relevant external noises", "Cognize and manage relevant equipment vibration", "Cognize and manage relevant smell of hydrocarbons" and "Keep awareness of the drilling floor activities". These non-technical skills functions related to the driller's senses are presented in Figure 5.

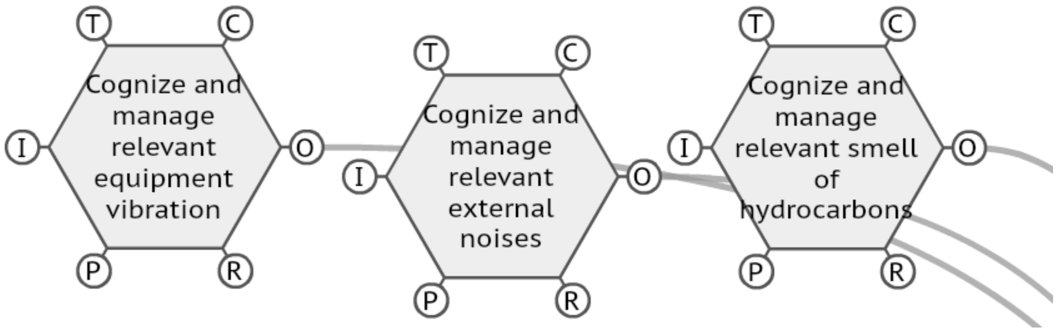

Figure 5 - Non-technical skills functions related to the driller's senses.

Source: Author (2019)

In a more systemic analysis, can be seen an integrality between Human Factors, non-technical skills and the health of the driller; if this professional is sick, for example, with a flu, their senses may interpret mistaken signs and, if there is not a confident and effective communication among workers, the driller will omit this condition, for example by fear or insecurity from leadership, and nourish a chain of events that may lead to an accident. In this context, another important function from FRAM model shows the importance of leadership: “Have pressure from supervision”, which reflects the importance of the non-technical skills communication skills, leadership skills and team-work skills to deal with situations where there is hierarchical pressure to get the job done on time. In fact, for Lustgarten (2012), the pressure of BP's supervision on Deepwater Horizon drilling teams was one of the determining factors that contributed to this tragic accident.

Another relevant report on board, from another driller, of North American nationality, was that he avoided an accident when he felt a “lightness” in the drill...: “- I was descending the drillpipes, and then suddenly I felt the drill lighter, but running... Then I thought: This drill can be like that... I think it is better take this away from the hole... When I pulled the drillpipe and the drill came out, it was sheared! Half of it in the hole! If I had continued... It was going to be f... s…!!!” Analyzing this report, it is possible to realize that the sensitivity, the perception, the situation awareness of the driller made a difference and directly contributed to safety, avoiding a major accident, because the drillpipes could lock and cause the collapse of the entire drilling table, or, on a larger scale, the well abandonment or fatalities.

The situation awareness is one of the most relevant non-technical skills highlighted by Flin, O’ Connor, & Crichton (2016), and can be explained simply as ‘knowing what is going on around you’. It is the perception of the elements in the labor environment, including not only what is around the workers, but also what they are doing. In the mentioned report, the driller had situation awareness that something what was not correct, even not knowing exactly what was going on. Unsure, but being perceptive, he removed the drillpipes and discovered the broken drill, a very high-risk situation, where if he ignored his situation awareness, could cause a major accident.

Analyzing all these data, it is noticed that the non-technical skills of the drillers play an important role for the execution of a productive work, as well as promote the safety in the oil rig. And in fact, for offshore workers, according to O’ Connor & Flin (2003), non-technical skills and safety attitudes, when understood and applied, can prevent or mitigate the effects of fails whether instigated by technology, organization, workers, system, or the interaction between them. In offshore oil drilling, based on the onboard observations, the importance of the non-technical skills was evident, as they make a difference in perceiving risks, situations and signals that potentially demonstrate the possibility of loss of control. In fact, on board, the drillers posture, behavior, enhances productivity and safety in the drilling activities, by using their non-technical skills to enhance their performance.

5 CONCLUSIONS

The offshore drilling activities experienced and observed on board by the researchers are, undoubtedly, one of the most dangerous work activities in society. The isolation, the extreme weather conditions, and the operating of heavy machinery for hours at a time can all take its toll, both physically and mentally. Also, the constant presence of hydrocarbons traces – crude oil or natural gas, machinery lubricants, sea water and drilling fluid maintain an oily, dirty and hazardous work environment, that can not only affect workers' health but also cause a small fire or large explosions. In this chaotic and noisy scenario, the recognition of the Human Factors and non-technical skills that can make this workplace safe and avoid accident is indispensable. Although it is indispensable, it isn't an easy task, and to do so, this study take FRAM methodology to develop this recognition and understanding. The first contact with the onboard teams did not have the expected result, due probably to the closed operational culture, the lack of understanding of the FRAM methodology and the natural fear of information sharing. Seeking to understand and overcome this difficulty and using the FRAM methodology itself as a bond between the drillers and the researchers, a new element of communication facilitation was created, and it was called FRAMigo, a way to show FRAM as something simple, but at the same time able to deal with the variability and complexities of offshore drilling. The connection promoted by FRAMigo helped to understand how the real work is done, noticing the variability of drillers' performances. The FRAM model, once created empathy between drillers and researchers, developed a rich and effective exchange of information, where relevant Human Factors such as "Awareness of the drilling floor activities", have not only been recognized but also understood in terms of importance for safe work. In addition, recognition of important non-technical skills, such as feel the vibration and smell of hydrocarbons, were crucial to show that such skills, even though not prescribed in standards or procedures, are essential for drillers to perform their work productively and safely, dynamically managing the any changes or disturbances that may arise. From a wider perspective, this study showed that, despite what accident investigation reports may say, people, workers, especially in the drilling units, are the real safety element, promoting, in a dynamic and often intuitive way, protective barriers against adversity that may occur in such a hazardous work environment as the oil rigs. As observed, the drillers behavior enhances safety in the drilling activities, by using their non-technical skills to enhance their work performance, showing that their performance variability is not only what makes the work happens, but also what adds safety to offshore oil drilling activities.

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