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Reviewing Non-Technical Skills & Organizational Learning: A Comparative Analysis of Critical Safety Factors within the UK's High-Risk Industries

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Abstract

Accidents in high-tech organisations are often triggered by a concatenation of human and system anomalies and errors, proving destructive to life, property and the environment. Urgent attention is required to minimize such events by training workers in high-risk organisations and ensuring adequate levels of Non-Technical Skills (NTS) training to counter related risks within the spectrum of their daily tasks. Organisational learning becomes equally relevant when industries are inclined towards becoming learning organisations by encouraging and promoting learning to manage safety. A comparative assessment is drawn by examining current practices in aviation and in the oil and gas sectors. The online survey was used to gather primary data, as well as interviewing 15 safety experts across the three sectors and another 15 safety experts recruited as focus groups to establish if NTS and organisational learning are used in safety management. Our sample comprised health and safety experts from the nuclear (n = 124, 54%), aviation (n = 59, 25%), and oil and gas sectors (n = 49, 21%). Findings revealed that the nuclear sector has not fully and officially acknowledged the use of NTS to train workers. The nuclear sector should look inwardly at how safety is managed since there is limited evidence of formal knowledge or techniques for transferring lessons to staff on NTS, which has proven to be a major critical "ingredient" in safety management in high-risk organisations.

Keywords

Accidents, Human, Organisational-learning, Non-Technical Skills, Nuclear

1. Introduction

There is evidence that failures in the use of Non-Technical Skills (NTS) have contributed to most accidents in the nuclear sector [1] since the Three Mile Island [2] and the Chernobyl accidents in 1979 and 1986, respectively occurred due to lapses in situational awareness by operators [3] [4]. It was further revealed that the Chernobyl accident was worsened due to faulty decision-making [5] and that a lack of training in NTS aggravated the accidents, either directly or indirectly. Overall, lapses were later identified in situational awareness, teamwork, leadership, and communication; since workers did not coordinate or communicate beforehand with safety personnel the procedure that led to the accident [3]. There was a deficiency in terms of attention to safety [6].

In the oil and gas sector, the Deepwater Horizon explosion in 2010 had NTS-related problems as causal factors, as identified by the National Oil Spill Commission [7]. The investigation into Deepwater Horizon described several occasions where there was incorrect situational awareness of the technical process of establishing the oil well. This contributed to the mishap, while decision-making was often influenced by misperceptions of risk. There were reports of poor communication and leadership among crew members on the rig (and with operating companies), and the teamwork never functioned effectively [8]. The Piper Alpha accident in 1988 also featured a lack of communication and decision-making, ultimately leading to the deaths of 167 workers [9].

The aviation sector is not isolated from accidents. However, NTS has been extensively used by the sector to manage safety [1]. Significant efforts have also been made in the aviation sector to ensure that workers are carefully taught the required techniques to fly an aircraft and manage safety [10]. However, until there is improvement in work vigilance, it seems that such lapses will continue to happen since there is a need for a systematic approach to NTS [11].

Public perception of the nuclear power industry has been substantially influenced by high-profile accidents that have led to the release of radioactivity into the environment [12]. Three Mile Island (TMI), Chernobyl, and Fukushima Daiichi (in 2011) are the most prominent accidents that remain fresh in people's minds [13]. The Windscale fire of 1957 is regarded as the worst nuclear accident in the UK, ranked at level 5 in severity according to the International Nuclear and Radiological Event Scale (INES) [14]. In most instances, human error has played either a direct or contributory role in accident causation. Turner [15] hypothesises that accidents are equally triggered by socio-technical causes, mostly arising from human interactions within complex, tightly coupled systems. This view is supported by Gordon [16], who states that all the major accidents in the nuclear power sector have had human factor failures embedded in them.

In the oil and gas sector, the Piper Alpha accident in 1988 and subsequent investigations demonstrated that the safe performance of high-risk industries is reliant on the interaction of organisational, human, technical, social, managerial, and environmental factors [16]. These factors can be important and serve as contributors to incidents that can possibly lead to terrible events. Noticeably, human factors are believed to be the primary cause of many major disasters, such as Three Mile Island, Chernobyl, and Piper Alpha, which have been researched by those concerned with the human contribution to the causes of accidents, such as psychologists, reliability engineers, and human factor specialists [16].

Human factors have been defined as: "The perceptual, mental and physical abilities of people and the connections between individuals in a working environment and the impact of equipment and system design on human performance and the organisational characteristics that influence safety behavior at a workplace" [17]. There is increased awareness in the nuclear power industry of the importance of considering human factors in the design, operation, maintenance, and decommissioning of nuclear power plants (NPP) [17].

The primary human factors known to affect safety practices are organisational, group, and individual. This assertion is supported by a study carried out by the Institute of Nuclear Power Operations [16]. At the organisational level, there are several reasons that could lead to an increase in accidents. These include cost-cutting plans and the level of communication (information disjuncture) that flows among the workforces. At the group level, the associations between workers, individuals, and their supervisors, have the possibility to impact the safety of an installation. Additionally, management's leadership style, supervision, or lack of it, team factors, and cultural characteristics (such as prevalent attitudes to risk) are also reasons that can affect safety [16].

The general approximation is that 80 percent of accidents are credited to human operators and accepted as being another case of "human error" [11]. While humans adhere to inflexible plans, the chances are that accidents will continue to occur [5] [18]. Human error has been classified as a natural, unavoidable, and occasionally probable aspect of human endeavor [11].

It is believed that human error in some form happens at virtually every step in the life and operation of a nuclear power plant [3]; accidents occur when rules are not followed [19]. For instance, the Chernobyl accident is believed to have been a fundamental example of human ineptness in different areas. At Three Mile Island, the human error also contributed to the accident [3] [9]. Similarly, the Fukushima accident showed how a natural disaster (force majeure) such as an earthquake and tsunami, combined to result in the constant power failure and the complete destruction of the heat sink, which further established that the whole process was worsened by human failure [20].

Turner's view of disasters and accidents is that they are a mixture of separate problems originating from both human interactions and technical infrastructures [15]. He coined a specific term to reflect this as a composite of "socio-technical" systems, or human and technological factors combined. Turner highlights the contributory factors that are often nested in the human and technical interface, underlining the incubation of risks in failure events, which can be attributed to managerial, administrative, and political preconditions [15]. Turner's work illustrates how collective failure leads to the incubation of hazardous conditions before a critical incident occurs, without collective awareness, by all concerned, of the hazards that could be mitigated. The stakeholders involved often fail to foresee the full extent of the system's vulnerability and exposure [15]. This leads to a collective "failure of foresight" between managers, system operators, system designers, and policy makers [21].

Nevertheless, humans are not only still involved in the design, testing, maintenance, and operation of complex systems but are vital to the execution of safe and reliable systems being maintained [3]. Therefore, those systems depend on individual competencies, limitations, and behaviors, and thus the quality of instructions and training that everyone receives is important [1] [5] [22].

In the aviation industry, human factors are not exempted [23]; as reliability and structural integrity have improved, the number of accidents originating from engineering failures has also reduced considerably [24]. However, human error is still a major threat to flight safety since it is believed that up to 75% of all aircraft accidents now have a major human factor element [24]. Hence, the main attention of aviation psychology is to reduce human error in all the systems, from the flight deck to the ground staff [23]. Aircraft accidents seldom have a single cause; lapses in NTS still led to the catastrophic end of Concorde F-BTSC, operated by Air France, in 2000 [25].

2. Materials and Methods

2.1. Non-Technical Skills

NTS has been defined and broadly classified into three different categories of skills, as stated in **Table 1** [1].

NTS has on many occasions been seen as the "glue" that keeps together operations and enables safety and efficient management [11]. Even in healthcare, there are additional examples of lapses of NTS, since mistakes in surgery have been linked to failures in communication [26] or in teamwork [27]. Furthermore, within the oil and gas sectors, situational awareness failures have been associated with offshore drilling accidents [28].

Table 1. Non-technical skills (NTS) with allotted categorisations of human-based skills [1].

NTS TYPE	SKILL CATEGORISATION
SITUATIONAL AWARENESS	Cognitive Skill
DECISION-MAKING	Cognitive Skill
COMMUNICATIONS	Interpersonal Skill
TEAMWORK	Interpersonal Skill
LEADERSHIP	Interpersonal Skill
MANAGING STRESS	Personal Resource Skill
COPING WITH FATIGUE	Personal Resource Skill

2.2. Organisational Learning

A good organisational safety climate in which everyone contributes to learning will invariably lead to positive changes, and such investments will encourage the goal of a safer working environment [16]. Organisational learning (OL) becomes paramount, and is defined as a procedure to process, interpret, and respond to internal and external information [29]. It helps to increase knowledge or understanding to influence behavior [30]. Conversely, there is ample evidence that organisations can fail to learn from accidents and critical incidents where cultural conditions and feedback loops are ineffective [31]. Argyris and Schon [32] explain that OL is an organization's gaining of understanding, know-how, techniques, and practices of any kind and by any means [33]. In line with Turner's Failure of Foresight theory and Toft and Reynolds' [31] Systems Failure and Cultural Readjustment Model (SFCRM), it is possible that organisations are not appropriately developed in their organisational learning due to faulty rationalizations [31]; even with the use of accident inquiries, near-miss reporting, and a just culture that facilitates a no-blame reporting model [34]. An important failing in organisational learning happened when personnel at Three Mile Island failed to learn from a similar accident that occurred at the Davis-Besse nuclear power plant in Ottawa County, Ohio of 2002 [35]. Similarly, BP failed to learn from an accident that happened on its oil rig in the Caspian Sea in 2008, before the Deepwater Horizon disaster two years later [36]. 6 Kletz [37] suggests four ways that organisations can learn from past incidents: 1) both recent and older accidents should be described in safety notices and discussed during safety meetings; 2) accident information retrieval and storage systems should be used because they contain useful information; 3) a "black book" containing reports of past accidents with technical incidents that have happened should be compulsorily explained to all newcomers to refresh their memories; and 4) standards and codes of practice should contain notes on accidents which led to the recommendations [22]. The literature demonstrates a range of elements that are critical to maintaining safety and effective infrastructure in critical safety settings. Complex and tightly coupled systems inevitably create challenges for human agents [38]. The need for organisational learning and NTS is a critical matter of preparation. In addition, faulty rationalizations, information disjuncture, and poor cultural mindsets can undermine safety practices and lead to the higher potential for failure events and crisis incubation [33]. Furthermore, operational safety and management is the role of organisational culture and employee behavior [39]; as occupational injuries and accidents occur from failure in communication [40]. In addition, issues such as failure to wear any or the correct personal protective equipment [41]. Khdair, Shamsudin and Subramanim [42] have also identified the need for effective monitoring and control of workers, which is especially important for mitigating what Radell (1992) identifies as "storming" where employees accelerate activities to meet an arbitrary time incentive, at risk of cutting corners. Furthermore, Toft and Reynolds [31] show how Involuntary

Automaticity can lead to failures in recognising errors in systems where menial work undermines verbal checklist techniques because both parties are not fully practicing vigilance, but rather relying on each other's diminished observational state [31]. The above issues are highly relevant and reflective of the greater importance of managing human and organisational behavioral factors; however, these are not designed to be within the scope of this particular research project.

2.3. Questionnaire Design

Questions were designed to be non-leading, and all responses were anonymous. Data was collected using different approaches and targeting individuals in different sectors. Quantitative data collection [43] was based on an online survey hosted on Bristol Online Survey (BOS) as the primary tool [44] to gauge respondents' views on the use of NTS and organisational learning in the UK's nuclear, aviation, and oil and gas sectors. Using online surveys permits first-hand information, supports increased data currency, and is convenient during data collection [45]. Sometimes response rates are low, which affects the sample size [45]. The research also used industry-based focus group discussions (via 15 safety experts) and additional interviews (with 15 safety experts) to test respondents' views on the use of NTS and organisational learning in the workplace for managing safety risks. Participants were asked anonymously for their industry sector, experience, and position, and six sets of questions (indicated in **Table 2**).

2.4. Sample Population and Size

The target population [37] comprised health and safety experts from the nuclear, aviation, and oil and gas sectors within the UK. Respondents from the nuclear sector were recruited from Nuclear Associations and LinkedIn. Social media networks were also used to recruit responses from aviation, and from oil and gas sector experts. Respondents from the three sectors answered the same set of questions in the same predetermined order [46].

Table 2. Six sets of questions administered to the nuclear, aviation, and oil and gas sectors.

Experience and position	
Q1: Which industry do you currently work with?	Q4: Non-technical skills are a strong feature of my organisations practice.
Q2: Have you encountered any of the following within your working environment. [Formally/Informally/Not at all/Don't know] Non-technical Skills, Organisational learning.	Q5: Organisational learning is a strong feature of my organisations practice.
Q3: My Organisation incorporates Non-Technical Skills effectively into training, exercises, and safety practices.	Q6: What type of elements of NTS training have you received in your Organisation?

2.5. Data Collection

Data were collected via an online questionnaire. The survey was conducted anonymously, focusing on industry-specific health and safety experts (managers, operators, and supervisors) in the nuclear and the oil and gas sectors, and pilots, air traffic controllers, health and safety managers, and trainers in the aviation sector. Data received from respondents outside of the UK were not analyzed. Overall, 232 responses were analyzed.

2.6. Data Analysis

SPSS was used to analyze the data collected, with descriptive statistics produced. SPSS is only a tool that is often used to analyze questionnaire data. Kruskal-Wallis (KW) non-parametric one-way ANOVA tests were used to analyze ordinal responses to test if responses from the three different sectors differed significantly. Non-parametric statistics are appropriate for data that are formed in ordinal scales, such as several of the responses to the online questionnaire. The null hypothesis was that there would be no difference between the responses from the three industry sectors. The threshold for statistical significance was taken as $p = 0.05$.

3. Results

The following sections summarize the analysis of responses from the online survey.

1) Q1: Identify the sector you work for. Sector responses are indicated in Figure 1.

a) Q2a: Have you encountered NTS within your working environment? The responses from each sector are given, as percentages, in Figure 2. There were significant differences among the sectors ($p < 0.001$, Table 3). NTS was most common in the aviation sector and least common in oil and gas.

b) Q2b: Have you encountered organisational learning within your working environment? The responses from each sector are given, as percentages, in Figure 3. Responses were not significantly different ($p = 0.538$, Table 4) among the three sectors.

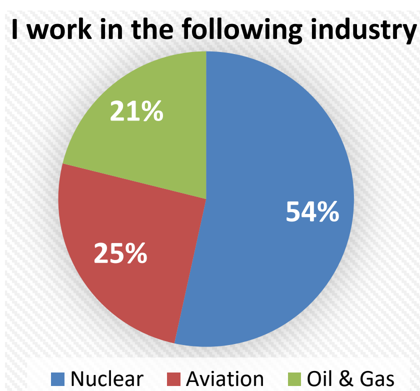

Figure 1. Proportions of respondents from each sector.

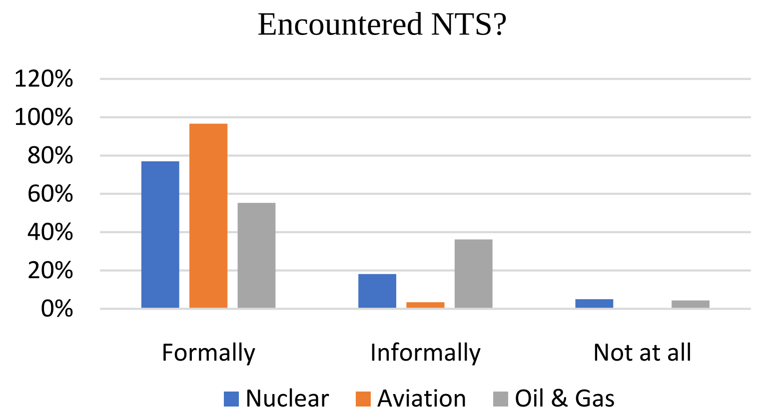

Figure 2. The responses of each sector to the question on their exposure to NTS.

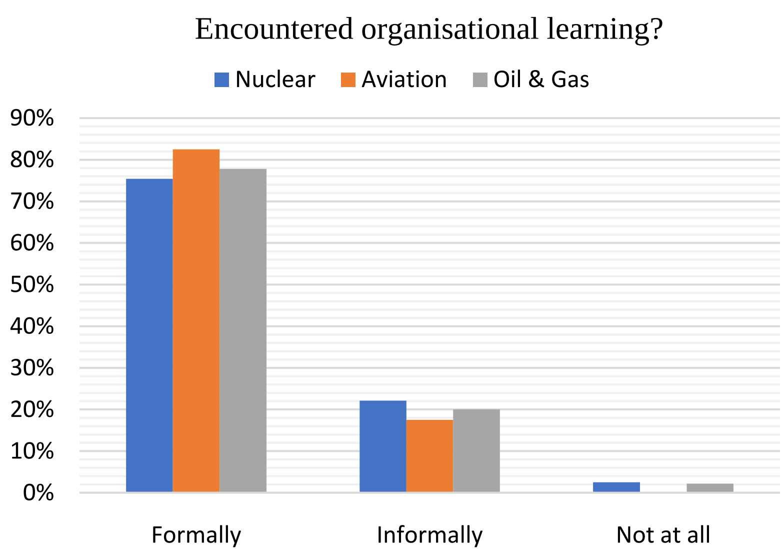

Figure 3. The responses of each sector to the question on their exposure to organisational learning.

Table 3. Responses to the seven elements of NTS in training.

Training Types (Associated with NTS elements)	Formal training (%)			Informal training (%)			No training provided (%)		
	Nuclear	Aviation	Oil & gas	Nuclear	Aviation	Oil & gas	Nuclear	Aviation	Oil & gas
1. Situation Awareness	47	93	54	27	7	30	26	0	15
2. Decision making	44	81	43	31	15	34	24	3	23
3. Communication	56	88	55	29	10	23	15	2	21
4. Teamwork	53	90	50	30	5	35	17	5	15
5. Leadership	61	85	55	20	12	23	19	3	21
6. Managing stress	41	54	40	31	27	23	28	19	36
7. Coping with fatigue	24	69	38	31	20	28	45	12	34

Table 4. Kruskal Wallis tests and means scores for the three sectors.

	Scale	Mean			Kruskal Wallis	
		Nuclear	Aviation	Oil and Gas	H	P
Q2a Non-technical Skills	1 - 3	1.28	1.03	1.53	25.072	<0.001
Q2b Organisational learning	1 - 3	1.27	1.18	1.24	1.239	0.538
Q3 My organisation incorporates NTS effectively into training exercises, and safety practices.	1 - 5	2.09	1.53	2.27	21.359	<0.001
Q4 NTS are a strong feature of my organisation's practice.	1 - 5	2.09	1.73	2.16	8.132	0.017
Q5 Organisational learning is a strong feature of my organisation's practice.	1 - 5	2.09	1.8	2	3.714	0.156
Q6 Situation Awareness (knowing your environment)	1 - 3	1.78	1.07	1.61	36.666	<0.001
Decision Making	1 - 3	1.8	1.22	1.81	25.694	<0.001
Communication	1 - 3	1.58	1.14	1.66	20.234	<0.001
Teamwork	1 - 3	1.64	1.15	1.65	23.81	<0.001
Leadership	1 - 3	1.59	1.19	1.66	13.764	0.001
Managing Stress	1 - 3	1.87	1.64	1.96	4.242	0.12
Coping with fatigue	1 - 3	2.2	1.44	1.96	32.188	<0.001

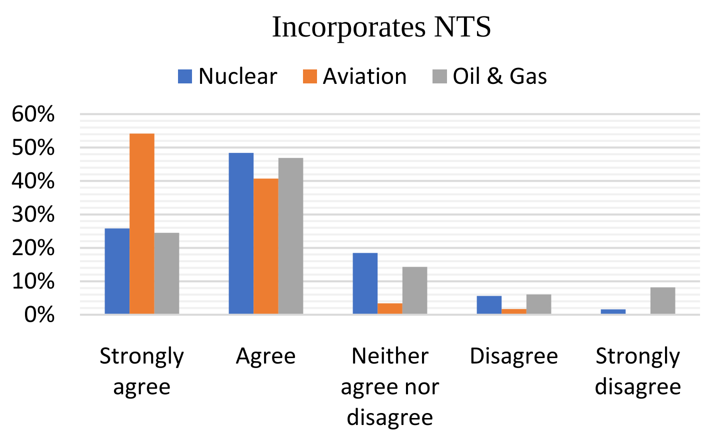

Figure 4. The responses of each sector to the question on incorporating NTS into training.

c) Q3: My organisation incorporates NTS effectively into training, exercises, and safety practices. The responses from each sector are given, as percentages, in Figure 4. There were significant differences among the sectors

d) Q4: Non-technical skills are a strong feature of my organisation's practice. The responses from each sector are given, as percentages, in Figure 5. There were significant differences among the sectors ($p = 0.017$, Table 4). Again, the agreement was strongest in the aviation sector.

e) Q5: Organisational learning is a strong feature of my organisation's practice. The responses from each sector were not significantly different ($p = 0.156$, Table 4) and are shown in Figure 6.

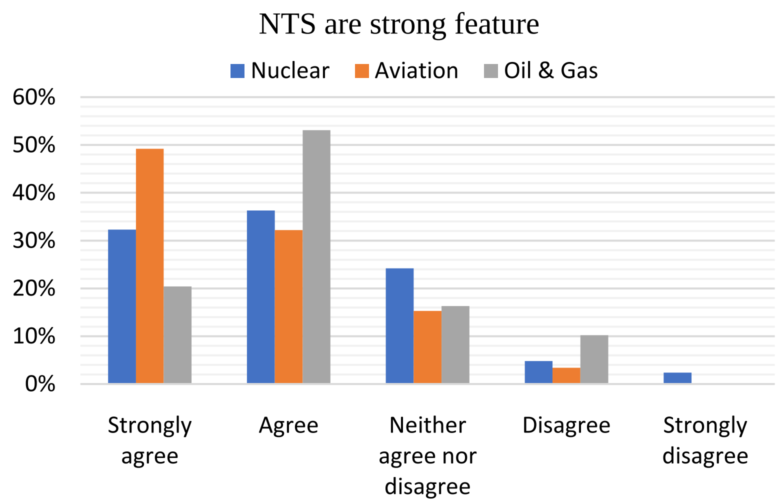

Figure 5. The responses of each sector to the question on NTS as a strong feature in practice.

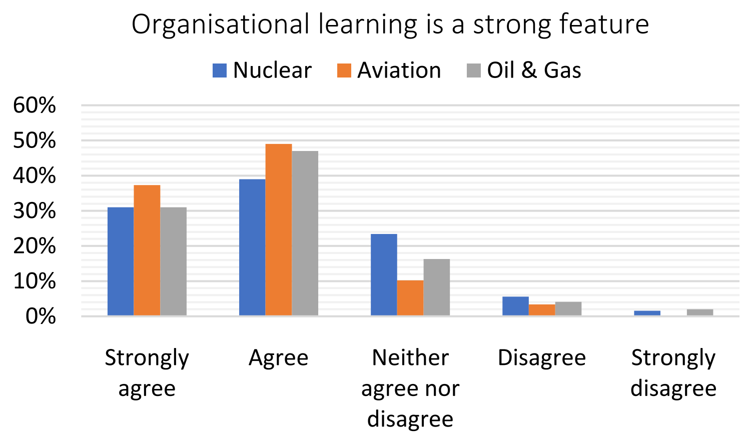

Figure 6. The responses of each sector to the question on organisational learning.

f) Q6: What type of elements of NTS training have you received in your organisation? The responses from the three sectors are shown in Table 3. All of these were significant ($p < 0.001$, Table 4) with the exception of "managing stress" ($p = 0.120$, Table 4). Aviation had the highest level of formal training in each element.

2) Kruskal Wallis tests and Mean Scores A summary of the Kruskal Wallis (KW) tests, together with mean scores, are presented in Table 4. Means are given in preference to medians since the latter may not adequately identify where industry sectors differ.

4. Discussion

The three sectors were asked if they had formally encountered NTS within the working environment. The result confirms that the three sectors have formally encountered NTS within the working environment. However, there is little evidence to show that the nuclear and the oil and gas sectors use NTS in the working environment to manage safety, especially when compared to the aviation sector.

The responses did not always agree with the focus groups across the nuclear and oil and gas sectors. A nuclear participant during one of the focus groups said that NTS is not known as such, instead being referred to as 'soft skills'. In a similar vein, an oil and gas expert noted that some of the NTS elements were used in the industry but not regarded as NTS. Nonetheless, there was a significant difference ($p < 0.001$) between sectors in responses to the question of whether workers have formally encountered NTS within their working environment. The aviation sector had the highest score, followed by the nuclear sector and then the oil and gas sector. Results from the aviation sector agree with the expert view that NTS is better used to manage safety [1].

The three sectors were asked whether they incorporate NTS effectively into training, exercises, and safety practices. The result shows that all three sectors incorporate NTS effectively into training, exercises, and safety practices (see **Figure 4**). Notwithstanding, responses for the nuclear and oil and gas sectors were higher in the "agree" category than the "strongly agree" one. There was a significant difference ($p < 0.001$) among sectors (**Table 4**), with the greatest agreement being in the aviation sector, followed by the nuclear sector, and then the oil and gas sector. The result was confirmed by experts in the nuclear and oil and gas sectors during a focus group discussion, with them noting that NTS had not been incorporated effectively into training, exercise, and safety practices in the way that it is entrenched in the aviation sector.

This research also asked if NTS were a strong feature across the three sectors. There was a significant difference among sectors ($p = 0.017$), with aviation having the highest values. Some respondents in the oil and gas sector admitted, through a comment box provided in the online survey, that the sector is not doing well in the strong use of NTS.

On the use of organisational learning for critical safety management, the findings showed that organisational learning does not differ significantly among the three sectors. During a focus group discussion, participants separately agreed that organisational learning was not a strong feature of the sectors. Furthermore, the results also agree with the literature; most organisations have not fully utilized their learning abilities [35]; since organisations struggle to apply practical methods due to the lack of understandable remedies [47].

NTS Elements

Another crucial aspect of this paper is to determine what type of NTS training the operators in the three sectors have received (**Table 3**. Q6). This incorporates all forms of NTS elements so far identified in the literature [1]. The results show that the aviation sector had the highest responses for situational awareness. The aviation sector results correlate with Flin *et al.* (2008), who state that situational awareness is widely used in the aviation industry to train pilots and crew members as part of the sector's past endeavors on embedding Crew Resource Management (CRM). However, during a focus group discussion, participants in the nuclear and the oil and gas sectors independently noted that situational awareness is not regarded as such but is referred to as observation and monitoring. Perhaps this could be the reason why the responses were different in the nuclear and oil and gas sectors. Familiarity with terminologies may therefore have influenced the respondents and/or focus group participants during the data collection process. However, to counter this known risk, the research did apply accepted definitions of NTS from Flin *et al.* (2008) throughout all data collection stages.

Another cognitive skill gauged here is decision-making. This result proves that decision-making is predominantly used in the aviation sector. However, this does not infer that the nuclear and oil and gas sectors are not adequately making use of decision-making to manage safely. However, one plausible reason the aviation sector had higher responses is that accidents in the aviation sector could occur in a split second if a decision was delayed. On communication skills (interpersonal), the aviation sector had the highest responses, compared to the nuclear and the oil and gas sectors. During a focus group discussion, participants from the aviation sector stated that communication cannot be compromised and has no alternative to managing safety.

Similarly, respondents were asked if teamwork is used across the three sectors. The result shows that actors in all three sectors receive formal training on teamwork to carry out their work successfully, though the aviation sector had higher responses than the nuclear and the oil and gas sectors. The result from the aviation sector confirms one participant's views expressed during an interview conducted by this research. Participants from the aviation sector noted that teamwork, especially in the cockpit, is a prerequisite skill needed in flight safety operations. While on leadership, the result suggests that the three sectors provide formal training to workers. However, the aviation sector had higher responses across the three sectors.

Managing stress is a personal resource skill, and each sector provides formal training to workers on managing stress. However, there was no significant difference ($p = 0.120$) among the three sectors in how they responded to this question.

Formal training on coping with fatigue (personal resource skill) is another NTS element that revealed a significant difference among the three sectors, as shown in **Table 3**, on whether workers had received formal training to manage safety. The responses from the nuclear sector were the lowest among the three sectors, which agrees with the literature that the nuclear sector has not introduced a formal training approach to workers on how to cope with fatigue [48].

There is a need for the nuclear sector to maximize the understanding of NTS since appropriate performance measures are of utmost importance to safety management. These would allow the possibility of more systematic and empirical investigations into nuclear NTS, which would provide a planned assessment tool that could be used in education and training. Furthermore, the nuclear sector should consistently learn and mirror relevant practices from the aviation sector in the use of all NTS elements for safety management.

This leads to organisational learning, which has not become adaptive to personnel concerns in the three industries. This could lead to deficiencies in risk characterisation, and eventually wrong decisions. Learning needs to occur as part of a routine system before, during, and after an incident, with effective counterfactual thinking and a consequential management process. Learning from past incidents and accidents has proven to be helpful, which is needed in the nuclear sectors in the expansion of new knowledge or understanding needed to make crucial decisions.

Human factor issues surrounding safety and accidents in the nuclear, aviation, and oil and gas sectors have been assessed in this paper based on primary data collection processes. However, the fact remains that the nuclear sector should look inwardly at how safety is managed since there is limited evidence of formal knowledge or techniques for transferring lessons to staff on NTS, which has proven to be a major critical "ingredient" in safety management in high-risk organisations. Therefore, it is of utmost importance to consider suggestions made by participants in the nuclear sector that new entrants in the industry should undergo formal NTS training, which is adopted in the aviation sector for pilots and crew members for safe flying.

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Further Research

There is a need for further research to specify the key NTS areas most needed by workers to manage safely and develop measures for assessing components of operators' performance. On organisational learning, further research should focus on whether the UK nuclear sector is a learning organisation. The organisation training manuals and accident report books should be checked to ascertain the root causes of accidents and if they are traceable to a lack of organisational learning culture.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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