International Journal of Applied Technology & Leadership
ISSN 2720-5215
Volume 1, Issue 6, July 2022
ijatl@org

ATTENTION, CONCENTRATION, AND FATIGUE IN SPACE OPERATIONS ENVIRONMENTS

David G. I. Heinrich

Capitol Technology University

Ian McAndrew, PhD

Capitol Technology University

Jeremy Pretty, PhD

Capitol Technology University

Abstract

An online human factors research survey was distributed among a sample population of 59 remote operations professionals to gather data about stress and complacency as part of a larger research project. Previous research gathered information about the current applications and theory of human-computer interaction technologies within satellite operations literature. Subsequently, this study seeks to determine if attention, concentration, and fatigue-related issues experienced by satellite operations professionals are attributable to working dynamic shift work patterns. The researchers concluded that space operations centers typically employ college-educated, highly trained individuals who are able to operate within a team setting. Whether a crew size is large or small, in relation to the number of assets on orbit: space operations professionals contend with elevated noise levels, task saturation, inadequate procedures, and strict rules, which may decrease concentration and increase potential occupational fatigue-related issues.

Index Terms— Attention, Concentration, Fatigue

Introduction

This study is the second part of a larger body of work revolving around mitigating complacency-induced human error in remote operations environments. Previous work focused on the current applications and theories on human factors considerations in satellite operations human-computer interaction technologies [1]. Heinrich, McAndrew, and Pretty highlighted a need for more literature detailing actionable lessons learned to help mitigate human error in remote operations [1]. They concluded, “developers of complex remotely operated systems must consider the tendency of the HITL [human-in-the-loop] to seek comfort in complacency. Developers must strive to ensure automation and autonomy do not increase the risk of human error” [1, pp. 36-37]. Attention, concentration, and fatigue have been linked to complacency [2]. Remote operations-center configuration and layout schemas attempt to reduce operator interaction through automation and autonomy to mitigate human error but may increase the potential for complacency-induced errors [3]. This qualitative research aims to increase the body of knowledge in remote operations by analyzing data gathered via a comprehensive online human factors survey of remote operations professionals.

Crews working in remote operations often contend with various shift patterns, which have been shown to lead to sleep and circadian rhythm disorders [4]. Shift work has been associated with an increased prevalence of shift work sleep disorder (SWSD), mental health issues, poor diet, and the potential for an increased risk of certain cancers [5]-[8]. Risks from SWSD and potential corresponding health issues may exacerbate stress placed on shift workers in remote operations environments, potentially increasing the risk of complacency-induced errors [1], [9], [10]. Multiple studies have highlighted the effects of SWSD on night-shift nurses resulting from inadequate and poor sleep hygiene. Only 6.3% of night-shift nurses manage to obtain restful sleep, and the consequences of nursing fatigue have resulted in a two-fold increase in medication administration errors [11], [12]. According to Muzio et al., “Nurses working night-shifts and rotating shifts struggle more to stay awake during their work activities, and they are twice as likely to make errors, compared to nurses working day/evening shifts” [11, p. 4518].

Fatigue has been shown to decrease attention or situational awareness (SA) [13]. In the aviation, medical, and maritime sectors, SA has been well documented where instances of task saturation or task fixation have been cited as a contributory factor during mishap investigations [14]-[16]. According to Endsley, SA has three hierarchical concepts: “perception of the elements in the environment,” “comprehension of the current situation,” and a “projection of future status” [17, pp. 13-14]. An operator’s understanding of their environment is key to knowing where to focus their attention when maintaining control of their system. Understanding the current situation is critical to making the best decision given the circumstances presented [13] because the operator’s understanding of the entire picture aids in an informed anticipation of expected outcomes [17].

Methodology

Due to the ongoing COVID-19 pandemic, human factors research was conducted virtually via an anonymous online survey, fully chaperoned by Capitol Technology University. An institutional review board was approved prior to the commencement of the research. A Google Forms survey consisting of 58 questions was distributed via social media platforms and E-mail for approximately two weeks between October and November 2021. The author’s public LinkedIn network enabled the survey to be distributed to a large population of potential respondents. The survey targeted adults working in remote operations for at least six months within the last five years. The survey was advertised with a specific target audience of remote operations professionals: satellite, remotely piloted aircraft, air traffic control, and launch operations. Seventy-seven total participants responded to the survey. Some of the initial survey respondents were unable to complete the survey because their length of experience was not long enough, or they did not possess the recency of experience necessary to continue the survey. The space operations community mainly represented the sample size of participants.

The questionnaire opened with five qualifying questions to gauge each participant's professional background. If any of the qualifying questions were answered "No," the participant was automatically redirected to exit the survey. If all five qualifying questions were answered with "Yes," the participant was allowed to take the complete survey. Fifty-nine participants answered "Yes" to all qualifying questions. Survey topics consisted of multiple-choice and 5-point Likert scale questions covering the participant's background and experience in the following areas: training, work-life, shift work, attention and boredom, fatigue, automation, alarm management, human-computer interaction, and lessons learned. Multiple-choice questions were used to gather objective data, while Likert scale questions were used to gather data on subjective topics. Descriptive statistics were used to analyze the data to draw conclusions. This paper will focus on the shift work, work-life, attention and boredom, and fatigue results of the survey.

Demographics

The results of the demographics portion of the study are presented in Table I. The age range of the 59 participants at the time of their last remote operations employment was between 18 and over 41-years old, with 61% aged between 18 and 30 years old. Sex and gender were not considered in this study. The majority of the participants (86.4%) held a Baccalaureate degree or higher at the time of remote operations employment, indicating an educated subset of the population. Most workers (67.8%) had worked in remote operations between 2 and 6 years, and 13.6% had worked in the field for nine or more years. Military technical training was completed by 88.1% of those surveyed to qualify to work in remote operations, and 88.2% became fully qualified by attending training for 12 months or less. Satellite operations professionals accounted for 79.7% surveyed. Overall, those surveyed served in various remote operations professions: satellite operations (79.7%), other (13.6%), uncrewed aerial operations (3.4%), missile crew operations (1.7%), and launch operations (1.7%). Those who worked in their job from 2 to 4-years accounted for 39%, with 13.6% working over 9-years in their field.

Table 1: Demographics (N=59)

Age (Years)	Frequency	Percentage	Cumulative
18-25	18	30.51	18
26-30	18	30.51	36
31-35	11	18.64	47
36-40	10	16.95	57
>40	2	3.39	59
Education Level	Frequency	Percentage	Cumulative

High-school or equivalent	2	3.39%	2
Some college	4	6.78%	6
Associates (2-year degree)	2	3.39%	8
Baccalaureate (4-year degree)	31	52.54%	39
Master’s or higher	20	33.90%	59
Remote Operations Experience (Years)	**Frequency**	**%**	**Cumulative**
< 2	5	8.47%	5
2 to 4	23	38.98%	28
4 to 6	17	28.81%	45
7 to 9	6	10.17%	51
> 9	8	13.56%	59
Participant’s Job	**Frequency**	**%**	**Cumulative**
Satellite Operator	47	79.66%	47
U.S. Air Force Missileer	1	1.69%	48
Launch Mission Operator	1	1.69%	49
Uncrewed Aerial Vehicle Operator	2	3.39%	51
Other (not specified)	8	13.56%	59

Work-life and shift work

Table II reflects the results of the work-life portion of the survey. Work-life questions were asked to gather information about the typical amount of assets operated during a standard shift and how many operators are typically assigned on a shift. These questions were used to understand how overwhelmed an operator could become due to the workload while on shift. The majority (45.8%) of remote operations professionals answered they operated between 6-10 assets while on shift. Furthermore, a combined total of 61% were responsible for between 1-10 assets, and 62.7% of those surveyed have been on a crew with six or fewer operators. Finally, only 13.6% answered they had never felt overwhelmed while on shift, while the rest of those surveyed answered that they had felt overwhelmed at some point (86.4%). Reasons for feeling overwhelmed are presented in Chart 1 in the analysis section below.

Table II. Work-life (N=59)

How many assets were you responsible for during your shift?	Frequency	Percentage	Cumulative
1-5	9	15.25	9
6-10	27	45.76	36
11-15	7	11.86	43
16-20	3	5.08	46
21-25	1	1.68	47
>25	12	20.34	59
How many people were assigned to your operations crew?	Frequency	Percentage	Cumulative
1-3	5	8.57	5
4-6	32	54.24	37
7-9	10	16.95	47
>10	12	20.34	59
I have felt overwhelmed while on shift.	Frequency	Percentage	Cumulative
Never	8	13.56	8
Rarely	21	35.59	29
Sometimes	25	42.37	54
Often	5	8.47	59
All the time	0	0.00	59

Table III shows the results of the shift work questionnaire, which started with a qualifying question to gauge if the participant had experience with shift work outside the typical “Day-shift” time range of 8 a.m. to 4 p.m. If the respondent answered “No,” they were directed to the next set of questions. Two respondents answered “No”; thus, only 57 professionals were surveyed in the “Shift Work” section. A significant portion of remote operations professionals surveyed (89.5%) indicated they have had to contend with dynamic shift patterns while working on shift. Questions were asked about typical shift work timeframes, which indicated multiple timeframes used in remote operations. “Other (not specified)” was selected by 35%, but there were no follow-up opportunities to elaborate. Additionally, the survey asked how many days per week the operator worked, with 80.7% indicating having worked five or fewer days per week while the remaining 19.3% answered they had worked over six or more days per week while on shift.

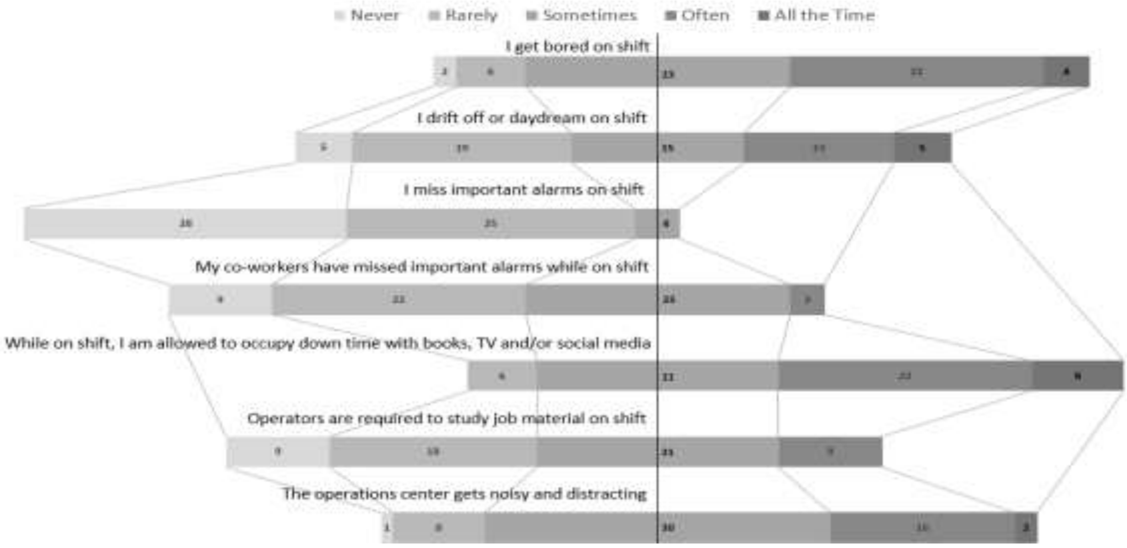
Table III. Shift Work (N=57)

How stable was your shift pattern?	Frequency	Percentage	Cumulative
Unstable	12	21.05	12
Changed often	25	43.86	37
Sometimes changed	9	15.79	46
Rarely changed	5	8.77	51
Very stable	6	10.53	57
What work shift timeframe best describes the shift you typically worked?	**Frequency**	**Percentage**	**Cumulative**
Day-shift--8 a.m. to 4 p.m.	11	19.30	11
Evening Shift--4 p.m.-12 a.m.	6	10.53	17
Night-shift--12 a.m. -8 a.m.	6	10.53	23
12-hour Day-shift 8 a.m.-8 p.m.	7	12.28	30
12-hour Night-shift--8 p.m.-8 a.m.	6	10.53	36
24hr or longer shift	1	1.75	37
Other (not specifed)	20	35.09	57
How many days per week did you work?	**Frequency**	**Percentage**	**Cumulative**
3 days	4	7.02	4
4 days	19	33.33	23
5 days	23	40.35	46
6 days	9	15.79	55
7 days	2	3.51	57

Attention and concentration

Fig. 1 reflects the results of the attention and concentration portion of the study, using a 5-point Likert scale. This section sought to gather information about the level of attention and concentration exhibited by remote operations professionals. Deficient attention and concentration due to drifting off or daydreaming were experienced by 91% of participants while on shift. About 50% admitted having missed critical alarms on shift, while 84% indicated a co-worker had missed critical alarms at some point while on shift. Furthermore, 100% answered they were allowed (at some frequency) to occupy downtime with books, television, and social media, while 84.2% responded they were required to study job-related materials when the operations tempo permitted. The last question in the Attention and Concentration section found that 98.3% have had to contend with a noisy and distracting operations environment.

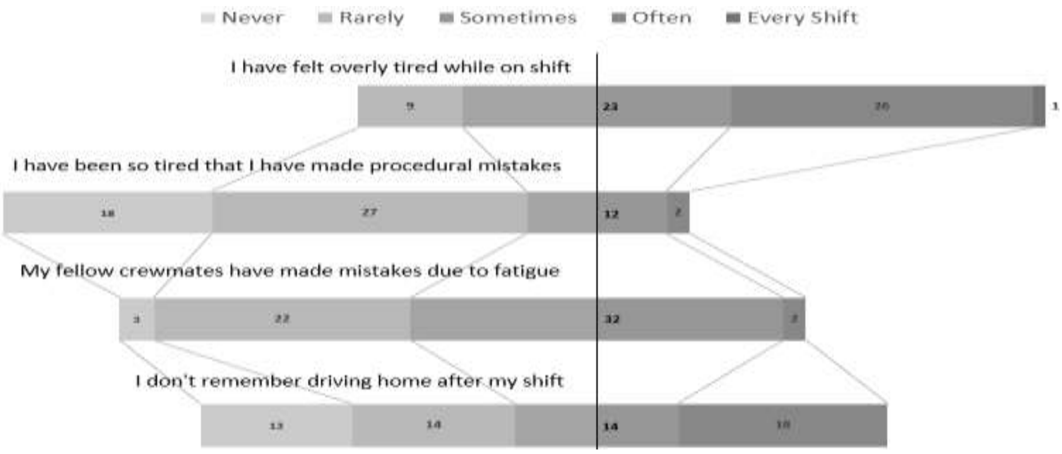
Fig. 1. Results of the Attention and Concentration section



Fatigue

Fig. 2 indicates the results of the fatigue portion of the survey using a 5-point Likert scale. Everyone surveyed answered they had felt overly tired while on shift, even if just “rarely,” yet 30.5% indicated they had never been so tired that they made procedural mistakes. The remaining 69.5% indicated they had made a mistake due to fatigue, while 96.6% indicated their fellow crewmates had made a mistake due to fatigue on shift. The last question in the fatigue section asked if they had failed to remember driving home after a shift which resulted in a random distribution of responses. Every participant indicated they had felt so tired that they did not remember their drive home. None of the questions elicited a “Never” response about fatigue while on shift which is explained more in the analysis section.

Fig. 2. Results of the Fatigue section of the survey.

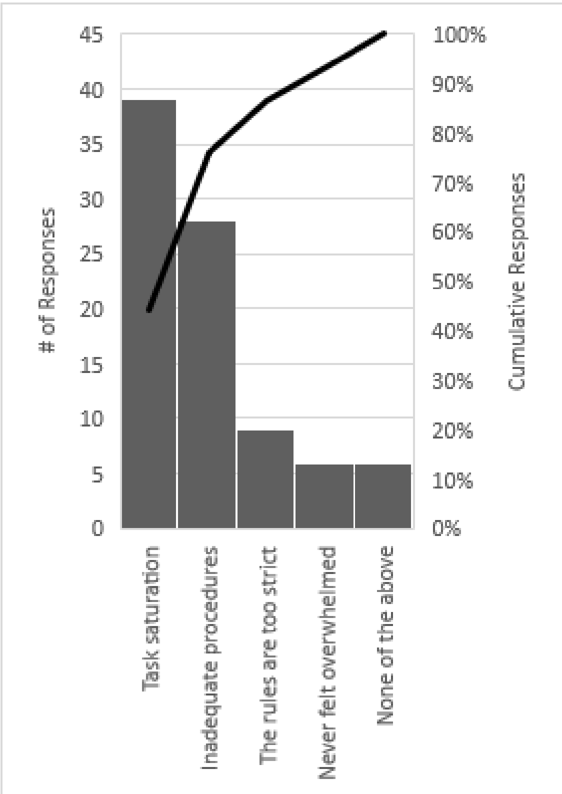


Analysis

Attention and concentration were shown to be limited for shift work operators. The data suggests those who work and occupy their time with books, television, and social media may suffer from decreased attention and concentration. Additionally, poor alarm management may be attributed to a lack of attention. The information gathered points to operations environments as overly distracting, leading to further degraded attention and concentration issues while on shift. The work-life survey pointed to a correlation between the instability of shift patterns and an overall sense of feeling overwhelmed. Being overwhelmed may stem from rules, procedures, and task saturation. Everyone who felt overwhelmed, at some point, also answered they had worked outside regular day-shift hours. Fifty-two (88.1%) people answered they felt overwhelmed while on shift, and forty-seven (90.4%) indicated they had worked erratic shift patterns.

This research points to satellite operations as being a potentially cognitively overwhelming profession. Forty-two of the fifty-two satellite operators (80.8%) indicated they felt overwhelmed at some point during a shift. Only six people (10.2%) indicated they had never felt overwhelmed while on shift. Reasons for feeling overwhelmed are presented in Fig. 3. Task saturation and inadequate procedures were the principal reasons someone indicated they felt overwhelmed while on shift. Twenty of the thirty-nine "Task saturation" responses were combined with "Inadequate procedures," indicating that there may be a correlation between procedures, task saturation, and feeling overwhelmed while on shift outside the hours of 8 a.m. to 5 p.m.

Fig. 3. Reasons for feeling overwhelmed while on shift



Feeling overwhelmed may also be correlated to fatigue. Everyone surveyed had felt overly tired at some point while on shift. Fatigue and feelings of being overwhelmed were experienced in most survey participants. Working shift patterns, dealing with task saturation, and contending with inadequate procedures may add to the risk of fatigue and associated fatigue-related errors. While the question "I don't remember driving home after my shift" was asked to understand just how tired operators were at the end of their shift. The answers presented pointed to a random distribution which could be attributed to a "default mode" or "autopilot role" while driving [18]. The "autopilot role" theory suggests that driving home every day becomes engrained in our brains, leading to the ability to make "automated, fast, and accurate responses" when driving home without remembering what happened, regardless of fatigue [18, p. 12821].

Limitations

There were some limitations associated with this study that should be addressed. In the demographics portion of the study, 6 of the 59 (10.2%) answered "Other" when responding to the question "What job did you work in remote operations," but they were not permitted to elaborate on what kind of job they worked. Furthermore, for the question "When working in remote operations, have you ever worked outside the hours of 8 a.m. to 5 p.m.?" two participants indicated they had never worked outside regular day shift hours and were subsequently directed to the fatigue portion of the survey, which bypassed the two participants past the attention and boredom section.

Discussion

Most participants responded that they felt overwhelmed at some point while on shift due to task saturation, inadequate procedures, and strict rules. Task saturation has been cited as one of the three main mental workload states within human factors, with the remaining two states classified as "mental underload, and adequate load" [19, p. 2]. Cognitive workload research by McKendrick et al. found that different people working on the same task or group of tasks will undergo different levels of cognitive stress depending on the conditions in which the task(s) is encountered in relation to an individual's specific abilities [19]. A study by the United States Army highlighted task saturation experienced within Patriot Engagement Control Station crews and found crew resource management (CRM) to be an effective mitigation technique against task saturation [20]. Furthermore, CRM has been shown to be a critical mitigation method in the prevention of human factors errors within team environments throughout the medical and aviation industry [1], [20]-[22]. As detailed in the literature, employment of practical CRM training may prove necessary and worthwhile to mitigate task saturation issues experienced by the participants within this specific study and operators within the space operations community at large [1], [20]-[22].

Inadequate procedures and strict rules were highlighted as the second and third most common reasons for one to feel overwhelmed while on shift. Researchers in the aviation sector found non-adherence to procedures to be the second most common human factors issue, only behind SA [23]. As seen in the aviation industry, satellite operations crew members who find inadequate procedures challenging may decide to deviate or disregard specific instructions, increasing the risk to the mission or spacecraft [23]-[24]. Furthermore, the Aerospace Corporation's Space Systems Engineering Database, spanning from the 1950s to 1999, attributed 37% of all human error to procedures [25]-[26]. Arnheim found the need for better adherence to procedures and better overall procedure development to mitigate potential future human error in spacecraft operations [25]-[26]. Procedure developers should keep previous research in mind when creating SOC procedures to ensure they are adequate and easily followed.

Attention and concentration were highlighted to cause operations crew members to miss alarms while on shift. Gross et al. found SA to be one of the top five CRM topics in their meta-analysis of healthcare literature spanning 1,037 medical publications [27]. CRM training modeled off advancements within the aviation industry, among other methods, have been developed in the healthcare sector to mitigate attention, concentration, and SA deficiencies [1], [27]-[29]. CRM and sound leadership methods should be employed within satellite operations centers to mitigate the risk of attention and concentration concerns. Additionally, while 98.3% responded that they had to contend with noisy environments while on shift, robust CRM training and implementation may be the key to keeping the operations environment at appropriate noise and attention levels.

Everyone surveyed experienced fatigue; however, 30.5% stated they had never been so tired that they made a mistake while on shift. Night shift workers are overwhelmingly at risk of fatigue-related issues, including shift work sleep disorder and circadian rhythm dysfunction [9], [30]. Circadian rhythm dysfunction has been attributed to wakeful fatigue and related health issues among shift workers in multiple industries: including aviation, healthcare, and transportation [1], [9], [31]. Fatigue has been attributed as a causal factor in many human error-related incidents, notably the Chernobyl nuclear reactor meltdown, the Space Shuttle Challenger disaster, and the Exxon Valdez oil spill [10]. While it may be impossible to mitigate all shift-related fatigue, increased CRM and vigilance may be the best remedy to keep personnel focused and clear of human error while working outside of day shift hours.

Conclusion

This research sought to determine if dynamic shift work patterns negatively contribute to the attention, concentration, and fatigue-related human factors experienced by satellite operations professionals. The majority of those studied were satellite operators who indicated shift work outside of day shift hours might create increased fatigue and concentration risks within satellite operations centers. Members of larger operations crews produced similar responses to those who worked in smaller crews in their responses about feeling overwhelmed, leading the researchers to conclude that simply adding members to operations teams may not be a viable solution to remedy the overall problem. Furthermore, increased fatigue and concentration issues may be due to heightened circadian rhythm dysfunction, frustration with inadequate procedures, work area distractions, and task saturation. The researchers recommend developers focus on decreasing task saturation through increased employment of CRM techniques, increased initial development emphasis toward creating more robust training programs, and creating procedures with the operator in mind. Lessons learned from comparable sectors on shift work, task saturation, and procedure development must be leveraged during the acquisitions development phase before they manifest into real-world mission-impacting problems.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Mr. Heinrich conducted the research, analyzed the data, and authored the paper. I. McAndrew and J. Pretty provided expert oversight and edited the paper. All authors approved this final version.

Acknowledgment

Mr. Heinrich would like to dedicate this journal article to his wife, Samantha, and kids for their unwavering support in his academic and professional pursuits. Additionally, he would like to thank his parents, Catharina, and Terry Johnson, for imparting an education-first mentality and providing unconditional support. Mr. Heinrich would also like to thank Dr. Ian McAndrew and Dr. Jeremy Pretty for guiding him on his academic journey. Finally, he would like to pay tribute to his father, who is no longer with us: You are missed.

References

[1] D. G. I. Heinrich, I. McAndrew, and J. Pretty, “Human factors considerations in satellite operations human-computer interaction technologies: A review of current applications and theory,” *Int. J. Manag. Inf. Technol.*, vol. 13, no. 03, pp. 23–43, 2021.

[2] A. T. Pope and E. H. Bogart, “Identification of hazardous awareness states in monitoring environments,” in *SAE Technical Paper Series*, 1992.

[3] J. Domeinski, R. Wagner, M. Schöbel, and D. Manzey, “Human redundancy in automation monitoring: Effects of social loafing and social compensation,” *Proc. Hum. Factors Ergon. Soc. Annu. Meet.*, vol. 51, no. 10, pp. 587–591, 2007.

[4] J. K. Lilie, “Shift work and circadian rhythm disorders,” *Sleep Psychiatry*, pp. 112–119, 2004.

[5] D. A. Kalmbach, V. Pillai, P. Cheng, J. T. Arnedt, and C. L. Drake, “Shift work disorder, depression, and anxiety in the transition to rotating shifts: the role of sleep reactivity,” *Sleep Med.*, vol. 16, no. 12, pp. 1532–1538, 2015.

[6] W. A. A. Khan, R. Conduit, G. A. Kennedy, and M. L. Jackson, “The relationship between shift-work, sleep, and mental health among paramedics in Australia,” *Sleep Health*, vol. 6, no. 3, pp. 330–337, 2020.

[7] Y. Lee, W. Lee, and H.-R. Kim, “A longitudinal study of the relationship between shift work and prostate-specific antigen in healthy male workers,” *Int. J. Environ. Res. Public Health*, vol. 18, no. 14, p. 7458, 2021.

[8] F. Su, D. Huang, H. Wang, and Z. Yang, “Associations of shift work and night work with risk of all-cause, cardiovascular and cancer mortality: a meta-analysis of cohort studies,” *Sleep Med.*, vol. 86, pp. 90–98, 2021.

[9] K. Mizuno *et al.*, “Sleep patterns among shift-working flight controllers of the International Space Station: an observational study on the JAXA Flight Control Team,” *J. Physiol. Anthropol.*, vol. 35, no. 1, p. 19, 2016.

[10] P. A. Burgess, “Optimal shift duration and sequence: recommended approach for short-term emergency response activations for public health and emergency management,” *Am. J. Public Health*, vol. 97 Suppl 1, no. Supplement_1, pp. S88-92, 2007.

[11] D. Muzio *et al.*, “Can nurses’ shift work jeopardize the patient safety? A systematic review,” *Eur Rev Med Pharmacol Sci*, vol. 23, no. 10, pp. 4507–4519, 2019.

[12] D. R. Gold *et al.*, “Rotating shift work, sleep, and accidents related to sleepiness in hospital nurses,” *Am J Public Health*, vol. 82, pp. 1011–1014, 1992.

[13] A. R. Gaines, M. B. Morris, and G. Gunzelmann, “Fatigue-related aviation mishaps,” *Aerosp. Med. Hum. Perform.*, vol. 91, no. 5, pp. 440–447, 2020.

[14] P. Husemann, P. B. Ladkin, J. Sanders, and J. Stuphorn, “A WBA of the royal majesty accident,” *Uni-bielefeld.de*, 2003. [Online]. Available: http://www.rvs.uni-bielefeld.de/research/WBA/RoyalMajesty.pdf. [Accessed: 21-Feb-2022].

[15] A. Hobbs and R. J. Shively, “Human factor challenges of remotely piloted aircraft,” *NASA.gov*, 2014. [Online]. Available: http://https://humansystems.arc.nasa.gov/publications/hobbs_eaap.pdf. [Accessed: 26-Feb-2022].

[16] M. Rall *et al.*, “The ‘10-seconds-for-10-minutes principle’: Why things go wrong and stopping them getting worse,” vol. 51, pp. 2313–2616, 2008.

[17] M. R. Endsley, *Situational Awareness*. London, England: Ashgate Publishing, 2011.

[18] D. Vatansever, D. K. Menon, and E. A. Stamatakis, “Default mode contributions to automated information processing,” *Proc. Natl. Acad. Sci. U. S. A.*, vol. 114, no. 48, pp. 12821–12826, 2017.

[19] R. McKendrick, B. Feest, A. Harwood, and B. Falcone, “Theories and methods for labeling cognitive workload: Classification and transfer learning,” *Front. Hum. Neurosci.*, vol. 13, p. 295, 2019.

[20] F. Powers *et al.*, “Mitigating task saturation for patriot engagement control station crews: Research product development and evaluation,” *DTIC.mil*, 2019. [Online]. Available: https://apps.dtic.mil/sti/pdfs/AD1077719.pdf. [Accessed: 21-Apr-2022].

[21] N. Pattni, C. Arzola, A. Malavade, S. Varmani, L. Krimus, and Z. Friedman, “Challenging authority and speaking up in the operating room environment: a narrative synthesis,” *Br. J. Anaesth.*, vol. 122, no. 2, pp. 233–244, 2019.

[22] A. W. Calhoun, M. C. Boone, M. B. Porter, and K. H. Miller, “Using simulation to address hierarchy-related errors in medical practice,” *Perm. J.*, vol. 18, no. 2, pp. 14–20, Spring 2014.

[23] H. Kharoufah, J. Murray, G. Baxter, and G. Wild, “A review of human factors causations in commercial air transport accidents and incidents: From to 2000–2016,” *Prog. Aerosp. Sci.*, vol. 99, pp. 1–13, 2018.

[24] J. Ford, R. Henderson, and D. O’Hare, “Barriers to intra-aircraft communication and safety: The perspective of the flight attendants,” *Int. J. Aviat. Psychol.*, vol. 23, no. 4, pp. 368–387, 2013.

[25] B. L. Arnheim, “Ground induced anomalies occurring due to human error,” The Aerospace Corporation, ID No. 99-5474.82.15., Dec. 1999.

[26] W. P. Marshak, T. J. Adam, and D. L. Monk, “Space Review Study: Human Factors Engineering’s Role in Unmanned Space Operations,” *Feb.* 2000.

[27] B. Gross *et al.*, “Crew resource management training in healthcare: a systematic review of intervention design, training conditions and evaluation,” *BMJ Open*, vol. 9, no. 2, p. e025247, 2019.

[28] E. Salas, K. A. Wilson, C. S. Burke, D. C. Wightman, and W. R. Howse, "A checklist for crew resource management training, " Ergon," *Ergon. Des*, vol. 14, no. 2, pp. 6–15, 2006.

[29] E. Salas, K. A. Wilson, C. S. Burke, D. C. Wightman, and W. R. Howse, "Crew resource management training research, practice, and lessons learned," *Rev. Hum. Factors Ergon.*, vol. 2, no. 1, pp. 35–73, 2006.

[30] T. Åkerstedt, "Sleepiness as a consequence of shift work," *Sleep*, vol. 11, no. 1, pp. 17–34, 1988.

[31] G. Shigenaka, "Twenty-five years after the Exxon Valdez Oil Spill: NOAA's Scientific Support, Monitoring, and Research," *NOAA*, 2014.

