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Numerical Values for the Environmental Factors' Influence on Surgeons' Technical Performance Decrement: Spherical Fuzzy-SWARA Approach

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Abstract

Background: Surgical practices are critical activities within healthcare systems, and when human error (HE) occurs, the consequences can be irreparable. However, the literature on HE quantification reveals significant gaps in both structural and methodological approaches. This study aimed to suggest a new taxonomy of environmental influencing factors (EIFs) that impact surgeons' technical performance.
Methods: In this cross-sectional study, EIFs related to the operating room were selected by reviewing various literature. Structured expert judgment elicitation was used to validate the EIFs under consideration. The weight and negative impact rate of the EIFs during surgical processes on surgeons were quantified using the spherical fuzzy-SWARA (Step-wise Weight Assessment Ratio Analysis) method and an eleven-point numerical scale, respectively. Questionnaires from expert surgeons were employed to quantify the weight and negative impact rate of the EIFs.
Results: The taxonomy of nine EIFs was validated through individual interviews with surgeons from three regional hospitals. The ranking of the influence of EIFs showed some conflicts regarding weight and negative impact rate. Specifically, climate conditions and music received the highest and lowest grades in both weight and negative impact rates.
Conclusion: The current study offers an original contribution to developing a new taxonomy based on domain-specific knowledge. The proposed EIFs taxonomy illustrates how surgeons' reliability can be degraded qualitatively and quantitatively. Furthermore, the results could enhance patient safety programs in the operating room.

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Introduction

Errors can occur during occupational performances, particularly in high-stakes environments. These errors may have irreparable consequences in settings such as the operating room. Medical error is a deviation from the expected medical care process that can harm patients.[1] Throughout history, numerous disasters have been attributed to human factors. Human error was responsible for nearly 90% of nuclear sector accidents, 80% of chemical industry accidents, 75% of marine industry accidents, and 70% of aviation industry catastrophes.[2]

In 1999, medical errors were responsible for 98,000 deaths in the United States. This number doubled by 2010, reaching 180,000 deaths, while statistics showed a further increase to between 210,000 and 440,000 deaths in 2013. This trend indicates a significant rise in deaths caused by medical errors in recent years.[3] According to another study, between 5% and 10% of patients experience medical errors, which are responsible for more than 7,000 fatalities annually.[4] Human errors can negatively impact equipment performance, system reliability, and safety, potentially leading to financial losses.[5] Published statistics in the United States indicate that between 17 and 29 billion dollars are spent annually due to preventable adverse events that result in patient harm.[6]

The need for more data and information regarding human performance in the literature remains a key challenge in human error management over time.[7] However, human error is recognized as a significant contributor to accidents in many technical and complex sectors.[8] The risk of human error can only be reduced by acknowledging that human errors are rooted in human factors science.[9] Human factors are defined as improving clinical performance through understanding how teamwork, tasks, tools, working conditions, culture, and organization influence human behaviors and skills. This understanding is then applied in clinical settings.[10]

It has been established since the early phases of the human reliability assessment (HRA) approach that two groups of elements—internal and external factors—can impact the technical performance of operators. External factors are related to the environmental conditions in which tasks are performed, while internal factors refer to the psychological and physiological conditions of the operators.[11] In various contexts and HRA techniques, these influencing factors are defined in different ways, such as performance-shaping factors (PSFs),[12] error-producing conditions (EPCs),[13] common performance conditions (CPCs),[14] and influencing factors (IFs).[15]

Using empirical data to gauge the extent to which factors influence the probability of human error occurrence is considered a significant step in the HRA process.[16] The lack of reliable data and extensive research on environmental factors affecting surgeons' technical performance during the surgical process remains a fundamental challenge in HRA within operating rooms.

Given this gap, an adaptation of the environmental influencing factors (EIFs) taxonomy, originally developed for the surgical process, is necessary. The current study aims to propose an EIFs taxonomy specifically for surgical processes and to assess the weight and negative impact rate of EIFs in a surgical context using a domain expert judgment approach.

Methods

Study Design and Participants

The primary objective of this cross-sectional study was to assign numerical values to environmental influencing factors (EIFs) in terms of weight and the probability of their negative impact on surgeons' technical performance. The study was conducted in October and November 2021. Surgeons from three operating departments across three hospitals in Shiraz, Iran, were selected as the target participants.

Data Collection Procedure

Surgeons from the participating hospitals' operating rooms were recruited using a convenience sampling technique. The demographic characteristics of the participating surgeons included age, years of work experience, gender, and specialty.

A three-section questionnaire, combined with in-person interviews and interactive discussions, was used to gather data on surgeons' perceptions regarding the importance and the rate of negative impact of EIFs on their technical performance. The first section of the questionnaire outlined the study's overall purpose and general principles. The second and third sections focused on quantifying the weight and the percentage of negative impacts of the EIFs, respectively.

The study was carried out in four phases. The first phase involved a literature review and identification of potential EIFs present in the operating room. In the second phase, the identified EIFs were validated. The third phase focused on quantifying the weight of each EIF, and the fourth phase was dedicated to quantifying each EIF's negative impact rate.

The Suggested Taxonomy Design of Environmental Influencing Factors (EIFs)

The following environmental influencing factors (EIFs) were identified as relevant in the current study: noise and ambient talk, music, noisy use of social media, verbal interruptions, rude talk, and disrespectful behaviors,[15] Climate conditions, Inappropriate postings/signs, Poor lighting/illumination, Poor workplace layout and configuration,[17] and inappropriate tools.[2]

Variable Selection (EIFS)

The criteria for selecting each EIF in this study were based on the positive opinion (i.e., "yes") of at least 50% of the participating experts (surgeons).[18] Any EIF that received more than 50% agreement from the experts was considered for further investigation. In the scientific literature, there is no universal consensus on the minimum number of experts required for such studies. However, it is generally recommended that this number should be at least six experts.[19]

Quantification of the EIFs Weight

The Step-wise Weight Assessment Ratio Analysis (SWARA) technique, a multiple-criteria decision-making (MCDM) method, was employed to determine the weight of each Environmental Influencing Factor (EIF) based on its negative impact on the technical performance of surgeons during surgical processes in the operating room.[20]

SWARA Technique

The process begins by having experts rank the criteria according to their importance. The most crucial criterion is assigned a score of one. Subsequently, the criteria are ranked based on the average relative importance values. The steps of the SWARA technique are as follows:

Criterion Arrangement

Initially, the criteria should be arranged in order of importance, with the most essential criteria placed at the higher levels and the less important ones at the lower levels.

Comparative Importance of Average Value (Sj)

In this step, the relative importance of each criterion is determined by comparing it to the previous one.

Calculation of the Coefficient (Kj)

The coefficient KjK_jKj is calculated based on the relative importance of each criterion using Equation 1.

Equation 1: *Kj=Sj+1*

Calculation of the Primary Weight of Each Criterion (Qj)

The primary weight of each criterion is calculated using Equation 2. It should be noted that the weight of the first criterion, which is the most important, is considered to be 1.

Equation 2: $$Q_j = \frac{Q_j - 1}{K_j}$$

Calculation of the Final Weight of Each Criterion (Wj)

Equation 3 calculates the final weight of each criterion, which is also considered the normalized weight.

Equation 3: $$W_j = \frac{Q_j}{\sum Q_j}$$

Spherical Fuzzy Sets

Mahmood et al. introduced the first spherical fuzzy set (SFS) in 2018, utilizing the range [0, 1] as the 3D space for graded satisfaction, abstinence, and dissatisfaction.[21] Kutlu and Kahraman,[22] assigned membership, non-membership, and hesitancy degrees to represent the ambiguity of SF values. Along with an explanation of SFS, they also provided a list of spherical distance measurements, arithmetic operations, aggregation operators, and defuzzification procedures.

Definition 1: Spherical fuzzy Z of the universe X is denoted as follows.

$$Z = \left[\left(x\left(\mu_z(x)\ \nu_z(x)\ \pi_z(x)\right)\right) | x \in X\right]$$

$$\mu_z : X \to [0.1].\nu_z : X \to [0.1].\pi_z : X \to [0.1]$$

$$0 \le \left(\mu_z(x)\right)^2 + \left(\nu_z(x)\right)^2 + \left(\pi_z(x)\right)^2 \le 1$$

with ∀x ∈ X, for each x, μ_z for membership, ν_z for non-membership and π_z for hesitancy levels of x to Z.

Definition 2: Suppose $Z1 = [\mu_{z1}\nu_{z1}\pi_{z1}]$ and $Z2 = [\mu_{z2}\nu_{z2}\pi_{z2}]$ are two spherical fuzzy numbers, and k is a constant number greater than 0. The basic mathematical operations of these two spherical fuzzy numbers are as follows:

1. Union Operation

$Z_1 \bigcup Z_2$=[max $[\mu_{z1}, \mu_{z2}]$, min $[\nu_{z1}, \nu_{z2}]$,

$$\min[(1-((\max[\mu_{z1}, \mu_{z2}])^2 + \sqrt{(\min[\nu_{z1}, \nu_{z2}])^2}$$

, max $[\pi_{z1}, \pi_{z2}]$]]

2. Interaction Operation

$Z_1 \bigcap Z$=[min $[\mu_{z1}, \mu_{z2}]$, max $[\nu_{z1}, \nu_{z2}]$,

$$\max[(1-((\min[\mu_{z1}, \mu_{z2}])^2 + \sqrt{(\max[\nu_{z1}, \nu_{z2}])^2},$$

min $[\pi_{z1}, \pi_{z2}]$]]

3. Addition Operation

$$Z1 \oplus Z2 = \left[\frac{\sqrt{(\mu_{z1}^2 + \mu_{z2}^2 - \mu_{z1}^2\mu_{z2}^2)}\nu_{z1}\nu_{z2} *}{\sqrt{(1-\mu_{z2}^2)\pi_{z1} + (1-\mu_{z1}^2)\pi_{z2} - \nu_{z1}\nu_{z1}}}\right]$$

4. Multiplication Operation

$$Z1 \otimes Z2 = \left[\frac{\mu_{z1}\mu_{z2} \cdot \sqrt{(\nu_{z1}^2 + \nu_{z2}^2 + \nu_{z1}^2\nu_{z2}^1)} *}{\sqrt{(1-\nu_{z2}^2)\pi_{z1}^2 + (1-\nu_{z1}^2)\pi_{z2}^2 - \pi_{z1}^2\pi_{z2}^2}}\right]$$

5. Multiplication by k scalar; k > 0

$$kZ = \left[\frac{\sqrt{(1-(1-\mu_z^2)^k)}\nu_z^2 *}{\sqrt{(1-\mu_z^2)^k - (1-\mu_z^2 - \pi_z^2)^k}}\right]$$

6. Power of Z; k > 0

$$Z^k = \mu_z^k\sqrt{(1-(1-\nu_z^2)^k - (1-\nu_z^2-\pi_z^2)^k)}$$

Definition 3: Suppose $Z = \mu_z v_z \pi_z$ In this case, Z represents a spherical fuzzy number. The value of the score and the accuracy function of the Z number is calculated as follows:

$$Score(Z) = (\mu_z - \pi_z)^2 - (v_z - \pi_z)^2$$

$$Accuracy(Z) = \mu_z^2 + v_z^2 + \pi_z^2$$

Note that Z2 is considered greater than Z1 when the following conditions are met:

$i.\, score(Z1) < score(Z2)$ or

$ii.\, score(Z1) = score(Z2)$ and

$Accuracy(Z1) < Accuracy(Z2)$

Definition 4: Spherical weighted arithmetic mean (SWAM) concerning $w = (w_1.w_2 \ldots w_n); w_i \in [0.1]; \sum_{i=1}^{n} w_i = 1$SWAM is defined as follows.

$$SWAM_W(Z1 \ldots Zn) = w_1 Z1 + w_2 Z2 + \cdots + w_n Z = \left[1 - \prod_{i=1}^{n} (1 - \mu_z^2)^{w_i}\right]^{\frac{1}{2}} * \prod_{i=1}^{n} v_z^{w_i} * \left[\prod_{i=1}^{n} (1 - \mu_z^2)^{w_i} - \prod_{i=1}^{n} \times (1 - \mu_z^2) - \pi_z^2)^{w_i}\right]^{\frac{1}{2}}$$

Definition 5: Spherical weighted geometric mean (SWGM) concerning $w = (w_1.w_2 \ldots w_n) w_i \in [0.1]; \sum_{i=1}^{n} w_i = 1$; SWGM is defined as follows.

$$SWGM_W(Z1.\ldots.Zn) = Z1^{w_1} + Z2^{w_2} + \cdots + Zn^{w_n} = \prod_{i=1}^{n} \mu_z^{w_i} * \left[1 - \prod_{i=1}^{n} (1 - v_z^2)^{w_i}\right]^{\frac{1}{2}} * \left[1 - \prod_{i=1}^{n} (1 - v_z^2)^{w_i} - \prod_{i=1}^{n} (1 - v_z^2 - \pi_z^2)^{w_i}\right]^{\frac{1}{2}}$$

Determination of Experts' Weight

The relative weight of expert opinions on each criterion may vary, as expert judgment is influenced by professional position, experience, and education. Therefore, it is essential to rank and weight the experts based on their background.[23] Various approaches have been suggested in the literature for weighing expert opinions, considering factors like education level, professional experience, and other relevant factors.[24, 25] In this study, professional position, age, experience, and education level were considered key factors in calculating the final weight of each expert.

Based on the background of the participating experts, the accumulated score E_k for each expert kth can be calculated using Equation 4, which considers the score ratings provided in Table 1.

E_k=S1 + S2 + S3 + S4   Equation 4

Equation 5 is used to determine the weight of each expert across all participating experts (n).

$$w_E^k = \frac{E_k}{\sum_{n=1}^{n} E_k} \quad \text{Equation 5}$$

Spherical Fuzzy - SWARA

Each final selected environmental factor was ranked based on the experts' evaluations, from the highest to the lowest importance. The steps followed were as outlined below:[26]

Step 1: Determination of $\tilde{S}_j$: A comparison of average values is determined as $\tilde{S}_j$, using linguistic terms as described in Table 2.

Step 2: Determination of the $\tilde{K}_j$: The $\tilde{K}_j$coefficient is calculated as follows:

Table 1: Scores Ratings for Experts' Weighting

Group	Classification	Score
Professional position (S1)	Professor	5
	Associate professor	4
	Engineer	3
	Technician	2
	Worker	1
Age (years) (S2)	≥55	5
	45-54	4
	35-44	3
	25-34	2
	≤24	1
Experience (years) (S3)	≥30	5
	20-29	4
	10-19	3
	6-9	2
	≤5	1
Education Level (S4)	PhD	5
	Master	4
	Bachelor	3
	HND	2
	School level	1

Table 2: Linguistic Terms for Importance Comparison of Each Criterion.[27]

Linguistic terms	(μ, v, π)
Equally Importance (EI)	(0.5, 0.4, 0.4)
Slightly Low Importance (SLI)	(0.4, 0.6, 0.3)
Low Importance (LI)	(0.3, 0.7, 0.2)
Very Low Importance (VLI)	(0.2, 0.8, 0.1)
Absolutely Low Importance (ALI)	(0.1, 0.9, 0.0)

Equation 6:

$$\begin{cases} (0.5; 0.4; 0.4) & j=1 \\ \widetilde{s_j} + (0.5; 0.4; 0.4) & j>1 \end{cases}$$

Step 3: Score of $\widetilde{K_j}$ coefficient: The scores of $\widetilde{K_j}$ is calculated as follows:

Equation 7:

$$SI\ (\widetilde{K_j}) = \sqrt{|100 \times [(\mu_{\widetilde{K_j}} - v_{\widetilde{K_j}})^2 - (\pi_{\widetilde{K_j}} - v_{\widetilde{K_j}})^2]|}$$

Step 4: Primary weight: The Primary weight of each criterion (Q_j) is calculated through the Equation 8**:**

$$\begin{cases} 1 & j=1 \\ \frac{Q_j - 1}{K_j} & j>1 \end{cases}$$

Step 5: Determination of the final weight (W_j): The W_j for each criterion is calculated through Equation 9:

$$W_j = \frac{Q_j}{\sum_{K_j}^{n} Q_j}$$

Quantification of the EIFs Negative Impact Rate

To evaluate the negative impact rate of each EIF, an eleven-point numerical scale (ranging from 0 to 10) was adopted, with thresholds set at 0 and 10. Surgeons were asked how frequently they perceived each EIF to negatively impact their technical performance during the surgical procedures they participated in. The scale was defined as follows:[15]

0: The EIF had no adverse effect on the technical performance of surgeons during any surgical operation.

10: The EIF consistently harmed the technical performance of surgeons during all surgical operations.

Statistical Analysis

Descriptive statistics, including maximum (Max), minimum (Min), mean, and median values, were used to analyze the demographic characteristics of the participants. For the analysis of the EIFs' weights and their influence rates, statistical indicators such as mean, median, standard deviation (SD), maximum (Max), and minimum (Min) were employed. Additionally, a density function of the EIFs was performed to assess their distribution.

Results

Demographic Characteristics

Twelve surgeons from three territory hospitals participated in the study. Eight were male, and four were female. The participants' ages ranged from 33 to 56, with a mean age of 44 and a median age of 42.5. Regarding work experience, the range was from 4 to 12 years, with a mean experience of 7.66 years and a median of 7.5 years.

The surgeons who participated in the survey had diverse specialties: the largest group consisted of obstetrics and gynecology surgeons (n=4), followed by general surgeons (n=3), neurosurgeons (n=2), cardiovascular surgeons (n=1), and orthopedic surgeons (n=2).

Inclusion of Expert Opinion into Variable Selection

The selection of environmental influencing factors (EIFs) for the final assessment was based on the principle that at least 50% of the participating experts must agree on the relevance of each factor.[18] In the questionnaire, the experts were asked to evaluate the variables and their impact on surgeons' technical performance. All participating experts were selected from governmental hospitals.

The responses to the questionnaire were used to evaluate the relevance of each EIF. Factors selected by six or more experts (N≥6) were included in the final assessment. The EIFs that were chosen included: Noise and ambient talk (N=11), Music (N=8), Verbal interruptions (N=10), Rude talk and disrespectful behaviors (N=11), Climate conditions (N=10), Inappropriate postings/signs (N=10), Poor lighting/illumination (N=12), Poor workplace layout and configuration (N=7), and inappropriate tools (N=9). On the other hand, "Noisy use of social media" (N=0) was not considered in the final EIFs taxonomy.

Weight and Impact Rate of the EIFS

Table 3 summarizes the information regarding the experts who participated. Tables 4 and 5 present the descriptive statistics of the SWARA results for EIFs weight quantification and the negative impact rate of the EIFs, respectively.

In Table 4, the importance order indicates the ranking of EIFs based on their adverse effects on surgeons' technical performance during tasks. EIFs ranked 1 and 9 represent those with the most and least significant effects, respectively.

Table 5 illustrates each EIF's negative impact rate. Like the importance order, climate conditions have the most significant negative impact rate, while music has the least. The order of the negative impact rate in Table 5 reflects the extent to which each EIF

Table 3: Experts Profile and Their Associated Weights

Expert ID	Age (years)	Experience (years)	Weight
E1	56	11	0.11
E2	36	5	0.06
E3	41	8	0.08
E4	42	7	0.08
E5	36	5	0.07
E6	52	12	0.1
E7	34	4	0.06
E8	49	10	0.1
E9	53	7	0.1
E10	39	6	0.07
E11	47	9	0.09
E12	43	8	0.08

Table 4: Descriptive Statistics of the Weight of EIFs During Surgical Process

PSFs	Mean (Median)	SD	Max	Min	Importance order
Climate conditions	0.35 (0.401)	0.131	0.466	0.132	1
Inappropriate postings/signs	0.21 (0.23)	0.106	0.444	0.037	2
Verbal interruptions	0.17 (0.106)	0.14	0.43	0.028	3
Poor lighting/illumination	0.113 (0.123)	0.046	0.213	0.061	4
Poor workplace layout and configuration	0.041 (0.042)	0.021	0.091	0.013	5
Noise and ambient talk	0.034 (0.025)	0.028	0.085	0.009	6
Inappropriate tools	0.032 (0.031)	0.02	0.07	0.009	7
Rude talk and disrespectful behaviors	0.03 (0.027)	0.014	0.063	0.011	8
Music	0.02 (0.022)	0.009	0.037	0.006	9

Table 5: Descriptive Statistics of the Negative Impact Rate of EIFs During Surgical Processes

EIFs	Mean (Median)	SD	Max	Min	Impact rate order
Climate conditions	8.259 (9)	2.06	10	1	1
Poor lighting/illumination	8.333 (8)	1.4	10	4	2
Inappropriate postings/signs	8.037 (9)	1.9	10	4	3
Verbal interruptions	7.185 (8)	1.5	10	2	4
Inappropriate tools	5.03 (5)	1.8	9	2	5
Poor workplace layout and configuration	4.851 (5)	2.1	9	1	6
Noise and ambient talk	4.592 (4)	1.7	8	2	7
Rude talk and disrespectful behaviors	3.666 (4)	2.09	7	0	8
Music	3.407 (4)	2.3	8	0	9

negatively influences the technical performance of surgeons, with EIFs ranked 1 and 9 representing the highest and lowest impact rates, respectively.

Probability Density Function of the EIFS

The most probable value for each Environmental Influencing Factor (EIF) was calculated based on the observed values, and the results are illustrated in Figure 1, which describes the probability distribution functions for the EIFs. The most probable *noise and ambient talk* EIF values were 3, 4, and 5. The most probable value for *music and inappropriate postings/signs* was 4. In contrast, *inappropriate tools, rude talk, disrespectful behaviors, and climate conditions* all had a most probable value of 10. *Verbal interruptions* showed the most probable values at 4 and 5. *Poor lighting/illumination* had the most probable values of 8 and 9. Finally, *the Poor workplace layout and configuration* EIF had a broader distribution, with the most probable values being 2, 4, 5, 6, and 7,

Discussion

The primary objective of the current study was to analyze both the weight (strength of effect) and impact rate of various Environmental Influencing Factors (EIFs) on surgeons' technical performance while proposing a new taxonomy that explicitly reflects the influence of environmental factors in operating rooms. One of the key findings of this study is that climate conditions were identified as having the highest weight and negative impact rate compared to other EIFs. In contrast, music, while included in the EIFs taxonomy, demonstrated the least impact in terms of both weight and negative impact rate on surgeons' technical performance. It is important to note that this study was conducted within the context of the Iranian healthcare system, and as such, the findings may not be universally applicable.

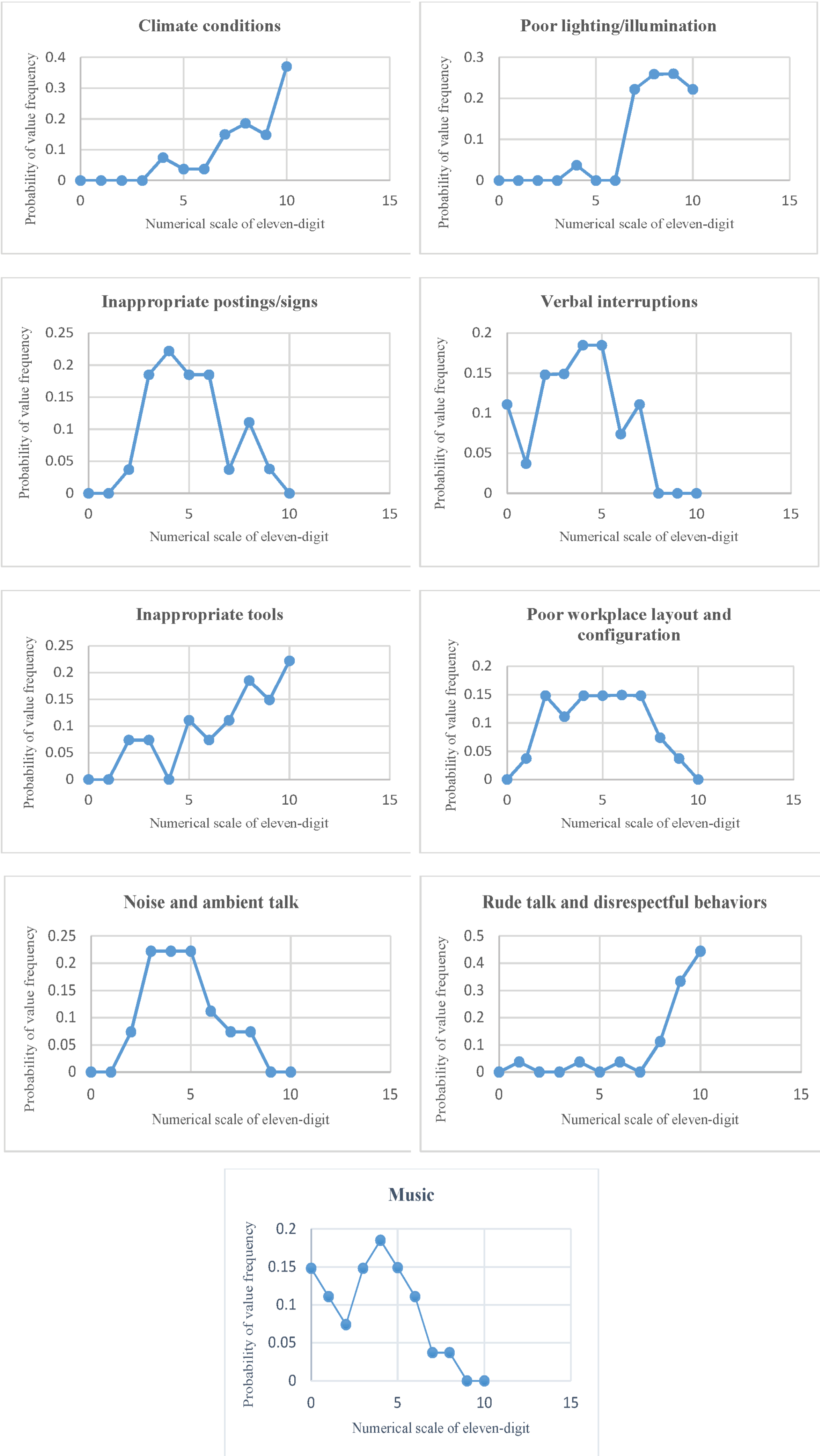

Figure 1: Probability Distributions of the EIFs

Climate conditions were found to have the most significant effect on the occurrence of human error, with a weight of 0.35, and the highest negative impact rate, with a value of 8.7. A similar study in the operating room context also examined the impact of working conditions, categorizing factors such as noise, distraction, temperature, and lighting as subcategories under the working conditions performance shaping factor (PSF). In that study, working conditions were ranked as the fifth most influential factor, with a weight of 0.114, and the eighth in terms of negative impact rate, with a negative influence rate of 5.54.[28]

Following climate conditions, other environmental influencing factors (EIFs) such as lighting/illumination, verbal interruptions, noise and ambient talk, rude talk and disrespectful behaviors, and music were ranked in the subsequent positions regarding their effect on surgeon performance. Lighting/illumination had a weight of 0.21 and a negative impact rate of 8.33, while verbal interruptions had a weight of 0.17 and a negative impact rate of 7.2. Noise and ambient talk were ranked next with a weight of 0.034 and a negative impact rate of 4.6, followed by rude talk and disrespectful behaviors with a weight of 0.03 and a negative impact rate of 3.7. Music, which showed the least impact, had a weight of 0.02 and a negative impact rate of 3.4. These results align with findings from a study in the healthcare context, which reported that distractions caused 43% of medication errors,[29] many of which can stem from similar EIFs such as noise, interruptions, and disrespectful behavior. This suggests that managing and mitigating the impact of these factors can significantly improve patient safety and surgical outcomes.

The failure to provide adequate indicators for coolant levels and the opening of the pilot-operated relief valve were identified as key contributing factors in the Three Mile Island accident.[30] In the current study, the environmental influencing factor (EIF) of inappropriate postings/signs was found to have a significant impact, ranking as the second most influential factor on human error occurrence (with a weight of 0.21) and the third in terms of the negative impact rate (with a negative influence rate of 8.26). Following this, the poor workplace layout EIF ranked fifth in terms of weight and sixth in terms of the negative impact rate, while the configuration and inappropriate tools EIF ranked seventh in terms of weight and fifth in terms of the negative impact rate.

In comparison, a study conducted by Jahangiri et al.[31] identified the machinery or tools category as the most impactful on human error in maintenance tasks, with a weight of 0.056. Similarly, the Human-Machine Interaction (HMI) Performance Shaping Factor (PSF) described by Taherzadeh Chenani et al.[32] overlaps with the factors in the current study related to equipment quality, displayers, annunciators and labeling, and personnel positioning. One more study determined HMI as the eighth most effective PSF (with a weight of 0.067) and the ninth regarding negative impact rate (5.11).[28] The differences in results between the current study and previous research can likely be attributed to variations in the occupational contexts of the studies.

Most human performance influencing factor (PIF) taxonomies are designed for specific contexts and consider diverse components, including environmental, software, hardware, and liveware factors.[33] For example, Kim and Jung,[34] proposed a taxonomy of PIFs for HRA in emergency and accident tasks within nuclear power plants. Their taxonomy is divided into four categories: human, task, system, and environment. The environment category encompasses working environmental factors, team cooperation and communication, and plant policy and safety culture.

In a similar vein, Taherzadeh Chenani et al.[32] developed a context-specific taxonomy for operating rooms, incorporating nine PSFs: available time, threat stress, task complexity, education/training, procedures, working conditions, human-machine interaction, fatigue, and teamwork. These PSFs were recommended for adapting the Standardized Plant Analysis of Risk-Human Reliability Analysis (SPAR-H) technique to surgical processes. The working conditions and human-machine interaction PSFs in their taxonomy align closely with the Environmental Influencing Factors (EIFs) suggested in the present study.

Similarly, Onofrio and Trucco[15] identified three environmental subcategories in the operating room: noise and background talk unrelated to the task, distractions, and safety culture/climate. Their taxonomy overlaps with the EIFs proposed in the current study, which include noise and ambient talk, music, noisy use of social media, verbal interruptions, and poor management of errors and threats to patient safety.

Conclusion

The current research proposed a new context-specific taxonomy of Environmental Influencing Factors (EIFs) tailored to surgical processes. This effort focused on addressing three primary objectives: (1) identifying environmental factors specifically affecting surgeons' technical performance, (2) minimizing the semantic overlap between EIFs, and (3) accurately assessing the weight and negative impact rate of these factors on surgeons' performance.

Following a thorough literature review, a taxonomy comprising nine distinct EIFs was developed. These include noise and ambient talk, music, verbal interruptions, rude talk and disrespectful behaviors, climate conditions, inappropriate postings/signs, poor lighting/illumination, poor workplace layout and configuration, and inappropriate tools. The taxonomy was designed to evaluate the impact of these factors on surgical processes with greater precision.

The study conducted weight quantification and negative impact rate analysis, complemented by a probability density function, to determine the most significant EIFs affecting surgeons' technical performance in the operating room. To validate and expand upon these findings, future research in diverse healthcare departments is recommended. Supplementary studies would provide more comprehensive and reliable data, enhancing the proposed taxonomy's generalizability and applicability across various surgical and clinical environments.

Authors' Contribution

All authors played an integral role in the study. They contributed to the study's design, data collection, analysis, drafting, and subsequent article revision.

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Conflict of Interest: None declared.

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