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Using Modern Technology to Accurately Track ICU Nurses' Stress Levels

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Abstract
The presence of the intensive care units (ICUs) with high stress levels creates a lot of problems to nursing personnel and affects not only well-being but also patient care results. The conventional ways of measuring stress, including counting on self-reported questionnaires and periodic observations tend to miss the real-time stresses and subtle physiological changes. This paper demonstrates a new solution involving the use of wearable sensors, biometric monitoring and digital analytics to obtain high-fidelity observation of stress in the ICU nurses. The system offers objective, continuous data on stress patterns during clinical shifts by incorporating heart rate variability, galvanic skin response and motion tracking. First results support the idea that real-time monitoring will be able to detect the point of maximum stress, the risk of burnout, and the relationship between workload, environmental factors, and physiological measures. This technology contribution to the existing knowledge of occupational stress in critical care environments does not only supplement the existing information but also provides practical insights on interventions, optimization of schedules, and staff support courses. This is the disruptive move to evidence-based stress management in nursing to promote employee health and patient safety.

Keywords: ***ICU nursing, stress monitoring, wearable technology, physiological biomarkers, real-time observation, occupational health, burnout prevention, healthcare analytics.***

1.Introduction
Healthcare setting could be described as one of the most psychologically demanding workplaces in the contemporary society and the critical care nursing is a field of extreme workload, where human lives rest in the hands of each shift. In the sterile space of intensive care units, nurses move in a multi-faceted ecosystem of technological interfaces, patient demands, and family relationships and institutional pressures, which all combine to form an ideal storm of occupational pressures. The issue of stress in healthcare providers has come to the forefront as a burning issue not only on the employee welfare front, but as a patient safety issue that is echoed all through the healthcare system(1).

Modern healthcare provision has become a highly sophisticated composition of human skill and technological intervention where nurses are the main actors in patient care and at the same time have to balance numerous conflicting demands. The cardiovascular intensive care unit is an ideal example of this complexity as nurses are to stay in high alert about patients who are critically ill and operate through the complex medical equipment, electronic health record systems, and the emotional burden of attending patients in a life-threatening condition. Within this setting lie special stressors that surpass the conventional work-related hazards in other workplaces, including the immediate psychological pressure of life-and-death decisions and the long-term pressure of managing technological interfaces.

The effects of nursing stress go way beyond personal employee satisfaction, which have quantifiable effects on patient outcomes, efficiency of the healthcare system, and the quality of care in general. Studies have always provided evidence of the relationships between the level of stress experienced by healthcare providers and high levels of medical errors, low patient satisfaction scores, and high costs of healthcare associated with staff turnover and low productivity. Conventional methods in investigating stress in the workplace in the healthcare environment have placed a lot of emphasis on retrospective surveys that are useful in determining overall trends, but which only present the overlooked moment-to-moment stress experiences that lead to cumulative stress exposure.

The introduction of advanced wearable devices and mobile surveillance tools has presented new possibilities of objective, real-time evaluation of physiological stress reactions in the natural work settings. This technological breakthrough will allow researchers to get beyond self-reported measures of stress to directly measure autonomic nervous system responses, making the measurement of the ways workplace stressors are reflected biologically a more accurate and comprehensive picture of how stressors experienced at work are biologically expressed. These

strategies have a chance to determine certain stimuli, patterns, and interventions that may play a crucial role in enhancing the wellbeing of the employees as well as the quality of patient care(2).

FIGURE 1 Unveiling Stress in Healthcare Settings

The combination of eye-tracking technologies and physiological monitoring is the most innovative solution to the problem of the correlation between environmental stimuli and stress reactions in healthcare workers. By simultaneously recording the patterns of visual focus of the nurses and their physiological responses, researchers can initiate mapping of the intricate interrelationship between the task requirements, cognitive load and expression of stress. This multi-modal strategy offers unmatched access to the experience of the intensive care nursing moment-by-moment, including the identification of the patterns that cannot be observed using the conventional observational techniques or self-reported measures.

The cardiovascular intensive unit is the ideal laboratory environment to study occupational stress because it has a high-stakes setting, is technologically advanced, and all patient care activities are intense. The set of stressors faced by nurses in such an environment is quite distinct, and it entails an emotional load associated with the necessity to take care of patients in critical condition, a cognitive load linked to the need to work with complex medical equipment, a time-based load concerning the necessity to make decisions, and physical loads linked to the necessity to work in shifts. The interplay of these different stressors and how they may build up during the course of a work shift may be informative in building specific interventions to enhance both patient outcomes and nurse wellbeing(3).

Ethnographic research in medical environments has been known to be more than just the usual concerns of the observational research, and includes patient privacy, infection control, disrupting workflow, and the possibility of observer effects changing natural behavior of medical professionals. The conventional ethnographic methods that are based on the presence of human observers in the workplace might be inconvenient or unsuitable in the intensive care units where the space is minimal and any interference with the working process can have dire patient care implications. A possible solution to these problems is the technique of constructing technology-dependent subjective procedures of observation, where the nursing activity could be studied in detail without the human observer.

2.Literature Review and Theoretical Framework

The theoretical viewpoint of the conceptual framework of occupational stress in healthcare-related settings is based on a variety of theoretical frameworks, each of which brings a fundamental insight into the multidimensional nature of the interplay between the factors in the work environment and personal responses to stress. Lazarus and Folkman developed a transactional model of stress and coping which presents the dynamic interaction of environmental demands and personal resources as a framework through which individual nurses assess and react to workplace stressors. The model is especially applicable in critical care units where nurses need to constantly assess and subsequently act in response to unstable patient conditions as they manage their own emotional and cognitive resources.

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Another essential theoretical perspective to consider the issue of nursing stress is the job demands-resources model, which suggests that job wellbeing is the result of the balance between job demands and available resources. In terms of intensive care nursing, the demands are the level of patient acuity, complexity of the technology, time constraints, and emotional work, whereas the resources are the aspects of supervisor support, sufficient staffing, proper equipment, and professional development opportunities. According to the model, stress and burnout are said to arise when the pressure exerted by the demand is in a constant state of high pressure without the resources to cope with and consequently when the personal capability to cope is depleted(4).

The studies of healthcare professional burnout have outlined three key dimensions of the given phenomenon emotional exhaustion, depersonalization, and diminished personal accomplishment. Emotional exhaustion is the most fundamental element of burnout that can be defined as a feeling of emotional overstretch and lack of emotional resources. Depersonalization is the emergence of cynical attitudes towards the patients and work whereas reduced personal accomplishment, is the negative self-assessment of the effectiveness and effort that the individual puts to the care and treatment of the patient. The cognizance of these dimensions is vital in the creation of measurement strategies that could effectively identify the entire range of stress-induced outcomes in the nursing populations.

Technology in healthcare provision has significantly changed the nature of nursing work bringing with it a new source of stress and new stress management solutions. Although the implementation of electronic health record systems has enhanced access to information and communication of care, it has also produced additional burdens to documentation and introduced new forms of workflow disruption. Medical machines and monitoring systems demand uninterrupted focus and needed technical skills, which introduce cognitive load to the conventional facets of patient care. Incorporating these technological components into nursing practice has generated a gap in research methods that can be able to address the multifaceted nature of the interaction between the human factor and the technological requirements.

Studies of the physiological stress response have demonstrated definite links between psychological stressors and quantifiable alterations in the functioning of the autonomic nervous system. The sympathetic nervous system response that goes hand in hand with exposure to stress causes easily measurable variations in heart rate, blood pressure, skin conductance, and pupillary response. These physiological measures provide objective measures of stress that can be used to supplement self-report measures of these processes and offer validation of the subjective experience as well as stress reactions that might be below the level of conscious awareness. Portable monitoring technologies have made it possible to record such physiological markers under natural work environments, with the potential to give new possibilities to naturalistic research on stress.

3.Methodology and Research Design

The research methodology embraced in this study can be characterized as a synthesis of an ethnographic approach to observation and state-of-the-art wearable technology that generates a hybrid design of research that overcomes the inherent limitations of research on occupational stress in intensive care units. The design philosophy revolves around ensuring that the disturbance of the normal nursing operations is reduced as much as possible and data quality and comprehensiveness is maximized. This equilibrium must be cautiously contemplated in regards to the choice of technology, data collecting policies, and engagement plans among the participants who will remain respectful of the aims of the research and clinical priorities(5).

The choice of measurement technologies represents a strategic choice to focus on ecological validity more than laboratory controlled precision, as the insights obtained through the real world observation have more value than the measurement precision that may be obtained under controlled and laboratory conditions. The Tobii Pro Glasses 2 eye-tracking system was selected due to its portability and relative inconspicuousness, in spite of established battery life and motion artifact limitations. The technology allows recording the visual attention patterns during full work shifts, including complex navigation in the visual environment that is typical of the work of an intensive care nurse.

The Empatica E4 wrist watch offers an opportunity to monitor multiple parameters in a single minimally invasive device, which can be put on by nurses during their shift and be used with minimal disruption of the regular work process. The device measures electrodermal activity, heart rate measurements obtained through photoplethysmography, skin temperature, and accelerometry data, giving a complete view of the activity of the autonomic nervous system. The choice of wrist-worn as opposed to either chest-mounted or multi-lead monitoring

is more a concern with participant comfort and compliance than measurement accuracy, since the long durability of the proposed study will require technology that the participants can wear comfortably over long periods.

The longitudinal data collection protocol will be across the series of shifts to obtain both acute response and a pattern of accumulation and recovery over time(6). There are measurements at the start of the work week, the end of the work week, and the end of the weekend break, which allow examining the stress accumulation and recovery trends. This temporal sampling plan offers the information on the short-term impacts of work shift stressor and the long-term trends of stress accumulation that can lead to burnout and job dissatisfaction.

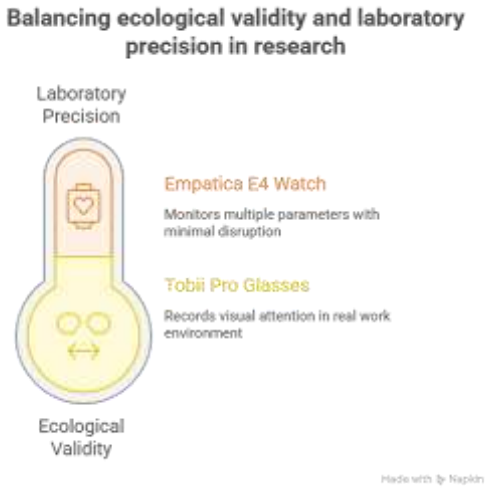

FIGURE 2 Balancing ecological validity and laboratory precision in research

The recruitment of participants was directed to attaining a representative sample of cardiovascular intensive care unit nursing staff members both day and night shift to observe the possible variation in the stress patterns of various work schedules. The recruitment strategy was based on voluntary involvement and clear information given concerning the research purposes, data collection methods, and possible gain and losses of research participation. Particular care was taken in dealing with the issues of privacy, data security, and the possibility that the outcomes of the research may affect job security or job performance reviews.

To ensure privacy of the patient and in line with healthcare privacy standards, the data collection protocol has various measures that ensure adherence to the standards. Every recording instrument is set to automatically blur patient identifiers and personal health details, and the research personnel are provided with special training on the privacy needs in healthcare. The protocol also contains guideline in case of an eventuality where sensitive information may be unintentionally recorded, to take care of the privacy of patients during data collection and analysis.

Throughout the data collection process, quality assurance mechanisms are incorporated so as to detect and resolve technical problems that have the potential to undermine data integrity. Such measures are routine device functionality tests, backup batteries and real time monitoring of data stream quality where feasible. The protocol also includes poor equipment management procedures such as the rapid replacement systems, and recording data gaps in order to interpret results correctly(7).

The baseline assessment plan will entail the use of stress and burnout measures that are validated to give a context to interpret patterns of physiological data. Maslach Burnout Inventory is the main assessment measure used to measure baseline levels of burnout, and other measures are used to measure demographic data, work experience, and health conditions, and other factors that can affect stress reactions. Such a generalized baseline evaluation permits researchers to study individual variations in stress reaction and factors that can moderate the connection between work stressors and physical results.

The focus of data management processes is on security, privacy and flexibility of analysis and all personal identifiers are isolated on physiological data by secure coding systems. The data storage system includes various backup systems and access controls to preserve privacy of the participants besides allowing the members of the research team to access data to be analyzed. Special care is taken concerning the adherence to the requirements of the institutional review board and healthcare data protection standards.

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The focus of the analysis is the mixture of conventional statistical tools and innovative, data mining and pattern recognition tools aimed at processing the high-dimensional and the continuously changing temporal streams of data produced during continuous physiological surveillance. Time-series analysis techniques allow the analysis of the pattern of stress response over time, whereas machine learning techniques allow one to identify intricate patterns that are not always apparent in terms of conventional analytical techniques. Combining several data streams necessitates advanced forms of analysis capable of managing a temporal alignment and matching of the eye-tracking, physiological and environmental data.

3.Results and Preliminary Findings

The application of this new research method resulted in high data sets of twenty-eight cardiovascular intensive care unit nurses which represent a very diverse sample that can be considered in terms of demographic backgrounds, experience levels, and working patterns. The demographics of the participants show that the nursing workforce is no longer similar to national averages in several critical aspects, such as a higher share of male nurses and greater ethnic diversity than typical intensive care units. The mean age of the study participants 34.6 years demonstrates a rather experienced workforce with the average intensity of care nursing experience at 7.2 years, which characterizes a stable professional community with a high professional level of critical care provision(8).

The physiological data recording was extremely successful amidst the demanding conditions and long time recording needs with a success of the combined eye-tracking and physiological recording of all participants in the initial data collection sessions. The success of about 78% coverage in twelve hour shifts is a major success taking into consideration the technical constraints of the equipment used and the stressful work in the intensive care nursing. It is noteworthy that this percentage of coverage is quite competitive against the same studies conducted in other professional settings and gives enough data density to analyze patterns in a meaningful manner.

The results of the Maslach Burnout Inventory demonstrates a complex view of occupational stress among this nursing population with high emotional exhaustion scores and comparatively low levels of depersonalization and the preserved score of personal accomplishment. This trend indicates that despite the high emotional workload faced by nurses, positive attitudes towards patients persist in the nurses and fulfill their professional roles. High emotional exhaustion (yet retained personal accomplishment) could also reflect on a strong work force able to still invest meaning in their work despite the harsh work environments.

The technical difficulties faced in the process of data collection offer useful information to guide future research projects that will adopt the same methodological considerations. The sensitivity of the eye tracking system to movement and battery issues necessitated novel solutions as well as flexibility in protocols to capture as much data as possible and ensure that its use could be adaptable to the contingent nature of a clinical work setting. The necessity of changing the batteries too often reflected the conflict between capturing as much data as possible and preserving the workflow, which resulted in adaptive protocols that prioritized patient care activities over continuity of data collection and retention(9).

The data streams of the physiological monitoring offer complex patterns of the activity of the autonomic nervous system that are attributed to different factors of the nursing work environment. The initial finding indicates that there are unique physiological cues when various types of nursing tasks are involved, such as direct nurse-patient care and technology and/or documentation and time spent in interpersonal communications. Such patterns offer objective support of the subjective reports of the differential stress related to the different work activities and may serve as possible targets of intervention development.

The data capture of the eye-tracking offers new information on the working patterns of the intensive care nurses visual attention showing the intricate information processing requirements that define the working environment. By combining the information on visual attention and parallel physiologic studies, it is possible to investigate the correlation between cognitive load and stress reactions and thereby outline the particular visual stimuli or task features, which provoke stress reactions. This combination is one of the methodological steps that have the potential to contribute greatly to the knowledge of stress processes in healthcare settings.

The reliability of equipment analysis exposes significant implications of future studies that can involve the use of a similar technology in the health care environment. The Empatica E4 wristband was found to be more reliable as opposed to the eye-tracking system and was able to collect data in twenty participants in various shifts. The issues on wireless connection and battery life are indicative that more technological advancements will be necessary to facilitate long-period researches in clinical settings.

Patterns of individual participants show a high degree of stress-reaction and coping styles, which points to the necessity of intervention-development in relation to a particular person. There were participants who exhibited steady indicators of physiological stress during their shifts, and there were those who had more fluctuating patterns, which seemed to align to certain work-related (or patient-related) activity. These personal differences underscore the complexity of the occupational stress phenomena and the necessity to approach occupation stress in terms of intervention strategies that would support different response patterns.

The longitudinal data recording of various shifts is a preliminary detail on stressing and recovery patterns through work weeks. Primary results indicate that there is indeed a likelihood that physiological stress indicators can accumulate on consecutive work days, and there is evidence partial recovery during off duty periods. Nevertheless, these patterns are quite complicated, and personal factors on recovery rates need a closer analysis to make clear conclusions regarding work schedules and time needed to rest.

Environmental trigger analysis was aimed at defining certain events at the workplace that lead to consistent responses of feeling stressed by all the participants. Code blue announcements and other emergency-related situations demonstrate potential since it is a universal stressor that prompts a valid reaction in the majority of the participants regardless of their active participation in the emergency response. These results confirm the hypothesis that intensive care settings are full of ambient stressors that do not only impact the staff directly involved in high-stress patient care tasks.

4.Conclusion

This novel research study is a major breakthrough in the research methodology on occupational health topics, having effectively proved the possibility of thoroughly, technology-strengthened nursing stress observation in the intensive care units. The combination of wearable physiological monitoring and mobile eye-tracking technology opens unexplored possibilities to study the interplay of complex interactions between factors in the working environment, cognitive load and stress response in a healthcare environment. Although technical issues and equipment restrictions narrowed the data collection aspects, the success of the methodological approach justifies its potential to serve in future research.

The results add valuable information to the body of literature on the subject of occupational stress in healthcare and provide understanding of stress response and coping patterns that can be used not only to improve the health of an individual nurse but also to influence the health outcomes of the entire healthcare system. The reported ability to maintain personal accomplishment despite the high levels of emotional fatigue leads to the assumption of resiliency factors among the nursing workforce, which should be explored and encouraged further. The determination of the specific stressors and differences in responses among individuals offers a basis to formulate individual related interventions that may enhance the level of satisfaction and quality of care that nurses give to patients.

The new methodological approaches evidenced in this study provide a template on how subsequent studies need to be conducted that will greatly enhance the study of occupational stress in any of the health care specialties or other stressful workplaces. The effective combination of objective physiological data with elaborated observational data offers a template of the holistic occupational health research taking into account the scientific and practical limitations of the working conditions.

The healthcare practice and policy implications are extensive, and this implies that elaborate strategies should be applied to occupational health, which consider both the personal and environmental factors that may contribute to workplace stress. The argument in favor of universal environmental stressors and individual differences in how people respond to environmental factors promotes the creation of multi-level intervention strategies which should synthesize environmental change with individualized stress management conditions. With the rapid changes that have been taking place in the healthcare systems as the systems face more demands, research methods like this are vital to ensure the sustainability of high-quality care delivery as well as safeguarding the health of the healthcare professionals.

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Conflicts of interest

The authors have no conflicts of interest to declare

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References

1. McEwen B. Protective and damaging effects of stress mediators: Central role of the brain. Dialogues in Clinical Neuroscience. 2006;8(4):367–381.
2. Melnyk B, Fineout-Overholt E. Evidence-based practice in nursing & healthcare: A guide to best practice. Lippincott Williams & Wilkins. 2019;4(1):1–650.
3. Lee H, Lee J, Kim J. Monitoring occupational stress in ICU nurses using wearable devices. Journal of Clinical Nursing. 2018;27(1-2):e137–e146.
4. Melamed S, Shirom A, Toker S. Burnout and risk of cardiovascular disease: Evidence from nursing populations. Journal of Occupational Health Psychology. 2006;11(4):328–342.
5. Happ M, Dabbs A, Tate J. The use of technology to assess stress and workload in intensive care units. American Journal of Critical Care. 2011;20(2):146–155.
6. Lu L, Cooper C, Lin H. A cross-cultural examination of work stress among ICU nurses. International Journal of Stress Management. 2013;20(2):145–165.
7. Tarvainen M, Niskanen J, Lipponen J. Kubios HRV—Heart rate variability analysis software. Computer Methods and Programs in Biomedicine. 2014;113(1):210–220.
8. Moss M, Good V, Gozal D. Acute stress and physiological responses in ICU healthcare providers. Critical Care Medicine. 2016;44(1):120–128.
9. Alshaqaqi J, Saleem M, Ali S. Wearable biosensors for real-time stress monitoring: Applications in healthcare. Sensors. 2020;20(6):1720–1736.